Working paper No. 3 (b) (2000)

PRELMINARY OPTIONS FOR METHODOLOGIES TO APPLY ADJUSTMENTS UNDER ARTICLE 5.2 OF THE KYOTO PROTOCOL

Fuel combustion activities

Breakdown of aggregated fuel data, estimating CO_2 emissions from per capita emissions, CH_4 and N_2O emissions from fuel combustion

Expert report

prepared for the

UNFCCC secretariat

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1.0 Introduction

This report deals with inventory adjustments for CO_2, CH_4 and N_2O emissions from fuel combustion activities. The issues relating to CO_2 and CH_4/N_2O are fairly different. Therefore, it is appropriate to treat them separately. This section is divided into two parts. The first introduces the concepts relating to CO_2 estimation and the second to CH_4 and N_2O estimation.

1.1 Adjustments relating to CO_2 emission

In most Annex B countries (New Zealand being a notable exception), CO_2 emission from Fuel Combustion activities constitutes over 80% of the National Emissions. Technical estimates for CO_2 emission therefore must provide values having low errors. Countries for which good energy data are available from international sources like the IEA and the UN, the issue is one of organizing the data into the IPCC format for inventory calculations. The accuracy of the technical estimates thus obtained will be determined by the quality of data from the international sources. In this project, the procedure of constructing an inventory from IEA sources has been dealt with in a separate report. The resultant inventory has been given the name “Carbon Balance Inventory”, a term which will be used throughout this report to refer to that inventory. The Carbon Balance Inventory has the same structure as an Energy Balance. The CO_2 emissions from all fuels for the different energy consuming categories are readily obtained from it if energy data from which the Carbon Balance Inventory is constructed is sufficiently disaggregated. In some cases, IEA and/or UN data is incomplete to the extent that the Common Reporting Format (CRF) Table 7A cannot be completed. In other cases, the only data available are aggregated fuel data or the reference approach inventory. The method envisaged to tackle the problem of disaggregating each fuel into the consuming sectors, uses the allocation obtained for each fuel from the Energy Balance of all Annex B countries lumped together. For fuels used for electricity generation and residential activities some more criteria should be satisfied to minimize misallocation. It is clear that if a country’s distribution of each fuel into the various sectors is not similar to that of Annex B total, misallocation will result. Fortunately, CO_2 emission is not very technology dependent, and in terms of the total CO_2 emission from Fuel Combustion, the error will be insignificant.

The worst-case scenario of data gaps is the case where a country has no (or imperfect) energy data. A THEORETICAL exercise is carried out to explore the possibility of making a technical estimate of CO_2 emission for a country without the use of energy data. This is indeed a challenging task because CO_2 emission is dependent on a large number of parameters. The problem can be appreciated from the case of Sweden and the USA. Sweden has a per capita income comparable to that of the USA, but its per capita energy consumption is approximately one-third that of the USA. A large number of parameters must be considered to get a meaningful result. The proposed method, which is based on average per capita CO_2 emissions with population as a driver, takes into account 9 parameters. Since per capita emissions can vary a lot, the average of all Annex B countries cannot be used to get a technical estimate of CO_2 emissions. Therefore, countries having similar per capita emission need to be grouped together to create “clusters” from which a country’s per capita emission can be determined.

1.2 Adjustments relating to CH_4 and N_2O emissions

The emissions of CH_4, N_2O and CH_4+N_2O from fuel combustion activities as a percentage of Fuel Combustion Emissions are shown in Figures 1.1 to 1.3 for 35 Annex B countries for the year 1990. The emissions of CH_4+N_2O from fuel combustion activities as a percentage of National Emissions is shown in Figure 1.4. Appendix A gives the data used to construct Figures 1.1 to 1.4. As can be seen, the emissions of these two gases constitute on the average 2.2% of the Fuel Combustion Emissions and 1.8% of the National Emissions. Therefore, the emissions of these two gases do not constitute a significant category. However, for a few countries, these emissions can go up to 5% of the Fuel Combustion Emissions. For those cases, it does become significant, because the Kyoto Protocol deals with emission reductions comparable to this value. An analysis of Figures 1.1 and 1.2 will reveal that approximately one-third of the countries have reported emissions that are within ±25% of the average, while one-third are above this band and one-third are below the band. Using the kind of averages shown in Figures 1.1 and 1.2 for the IPCC/CRF Table 7A categories, a simple methodology can be developed for estimating CH_4 and N_2O emissions from CO_2 emission. An interesting conclusion that can be drawn from Figures 1.1 to 1.4 is that, unless a country suspects that its emissions are significantly different from the averages shown in Figures 1.1 and 1.2, there is very little merit in investing a lot of effort in developing country-specific emission factors and/or to acquire highly disaggregated activity data required for estimating the emissions of these gases. Significantly higher or lower than the average emissions are important for the UNFCCC because those are precisely the cases, which will require careful evaluation. This is not to imply that parties that are close to the average are beyond scrutiny because parties whose emissions are significantly higher or lower may opt for Tier I default emission factors, which are no better than the averages of Annex B countries, to suit their needs of overestimating or underestimating their emissions. Therefore, the requirement to report emissions using county specific emission factors, which have been determined from good measurements, must remain a high priority.

2.0 CO_2 Emission estimates from the breakdown of aggregated fuel data

2.1 General comments about the method

This method is based on the assumption that at least aggregated data on fuels are available from international sources (IEA or UN) or from the country itself. Depending on the disaggregation of the available data, a CO_2 inventory satisfying the requirements of IPCC/CRF Table 7A, may or may not be possible. This method is applicable to the case where one or more gaps exist in one or more fuels, but the total consumption of all fuels are known individually. Therefore, this method can be used to fill data gaps in the Carbon Balance Inventory. More appropriately, this method can be used to get a breakdown of each fuel into the IPCC/CRF Table 7A categories from aggregated fuel data. This will allow the CO_2, CH_4 and N_2O emissions from the different sectors to be obtained using the Tier I default emission factors, or the Tier II default emission factors, provided that country specific data on technologies can be collected (typical technologies for each sector or sub-sector may be assumed and used). This method can also be used to get a sectoral breakdown of fuels from the reference approach inventory, but in that case the average output fuel mix from the country's refineries will be required, and that must be procured from the country concerned. This information is required to split up crude oil into the different petroleum fractions. Refinery outputs are standard data, and can be obtained for any country in a reliable manner.

Figure 1.1 CH_4 Emission as a percentage of Fuel Combustion Emission

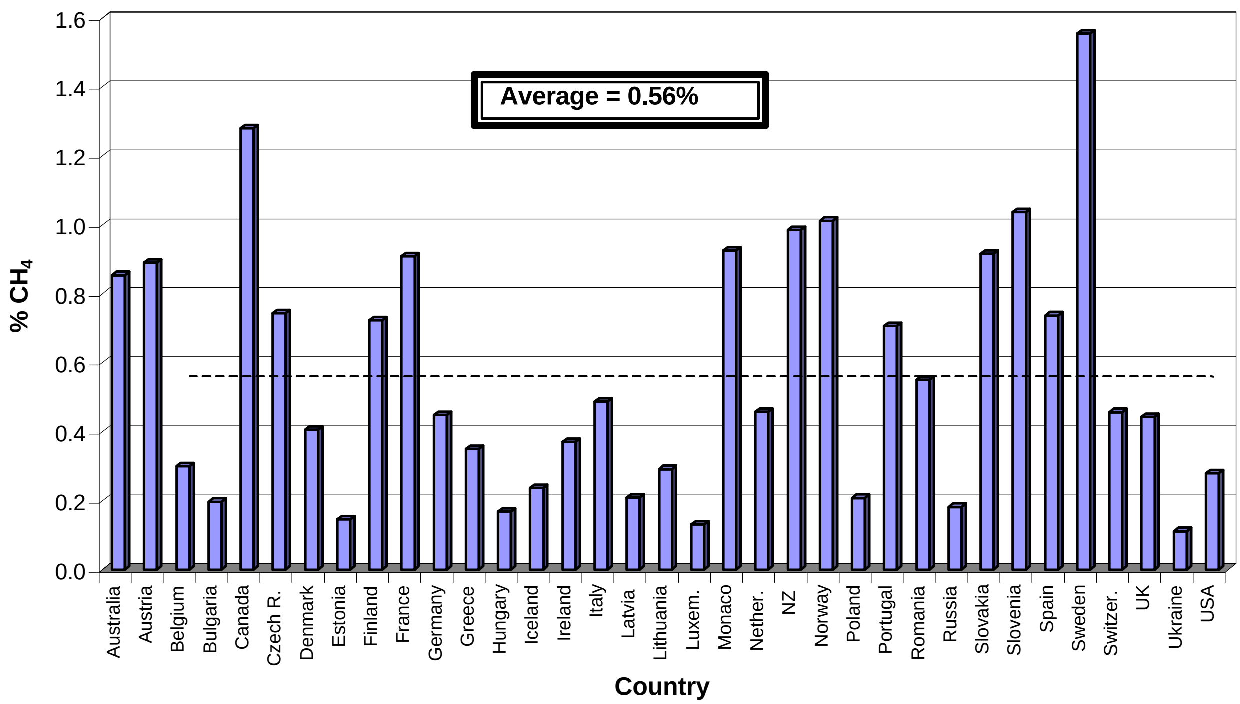


Figure 1.2 N_2O Emission as a percentage of Fuel Combustion Emission

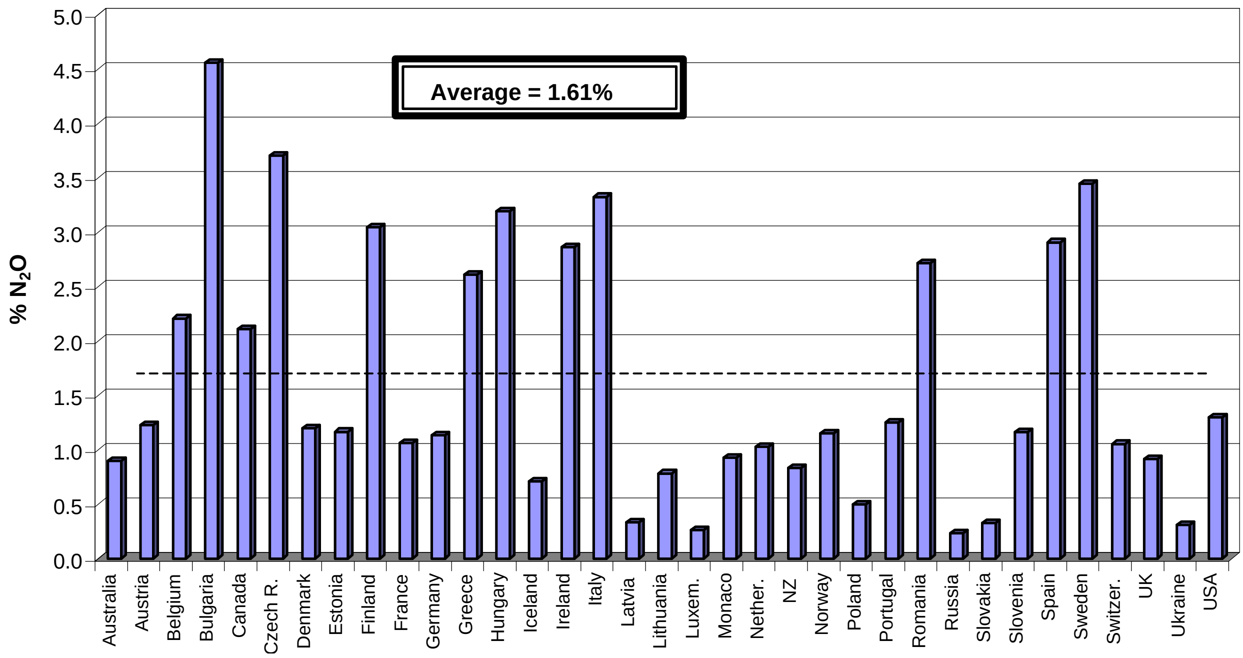


Figure 1.3 (CH_4+N_2O) Emission as a percentage of Fuel Combustion Emission

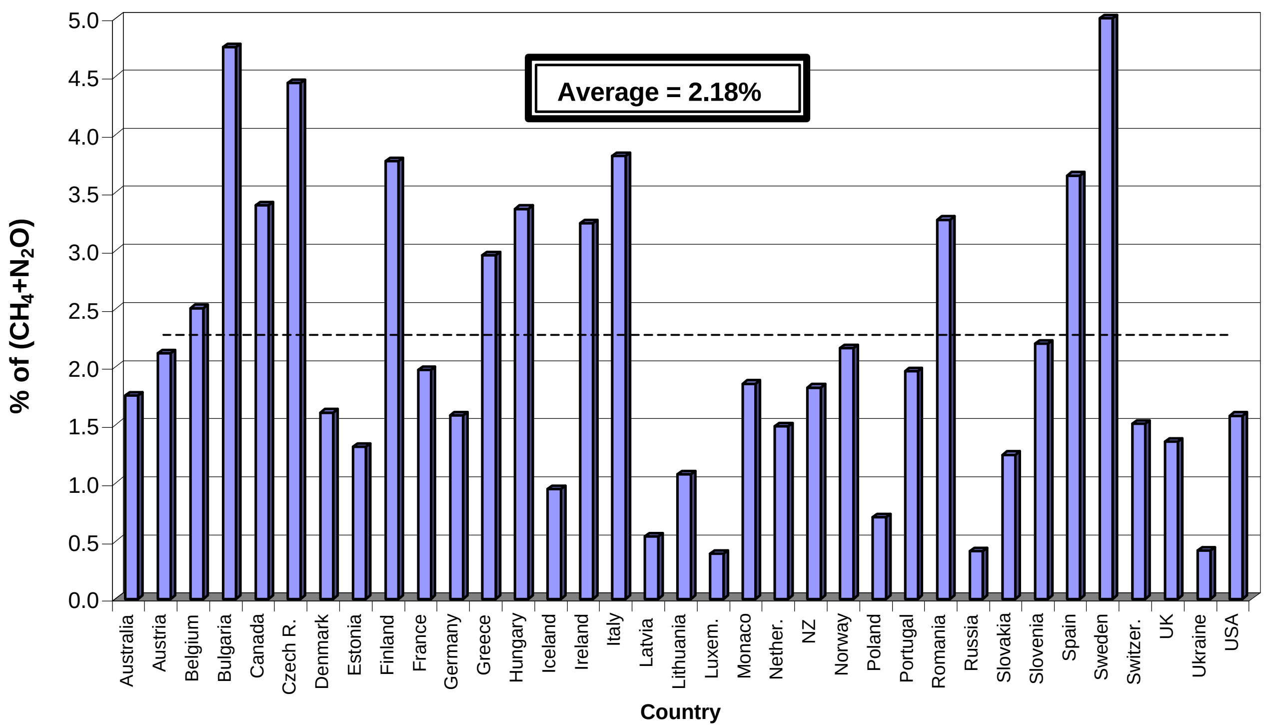
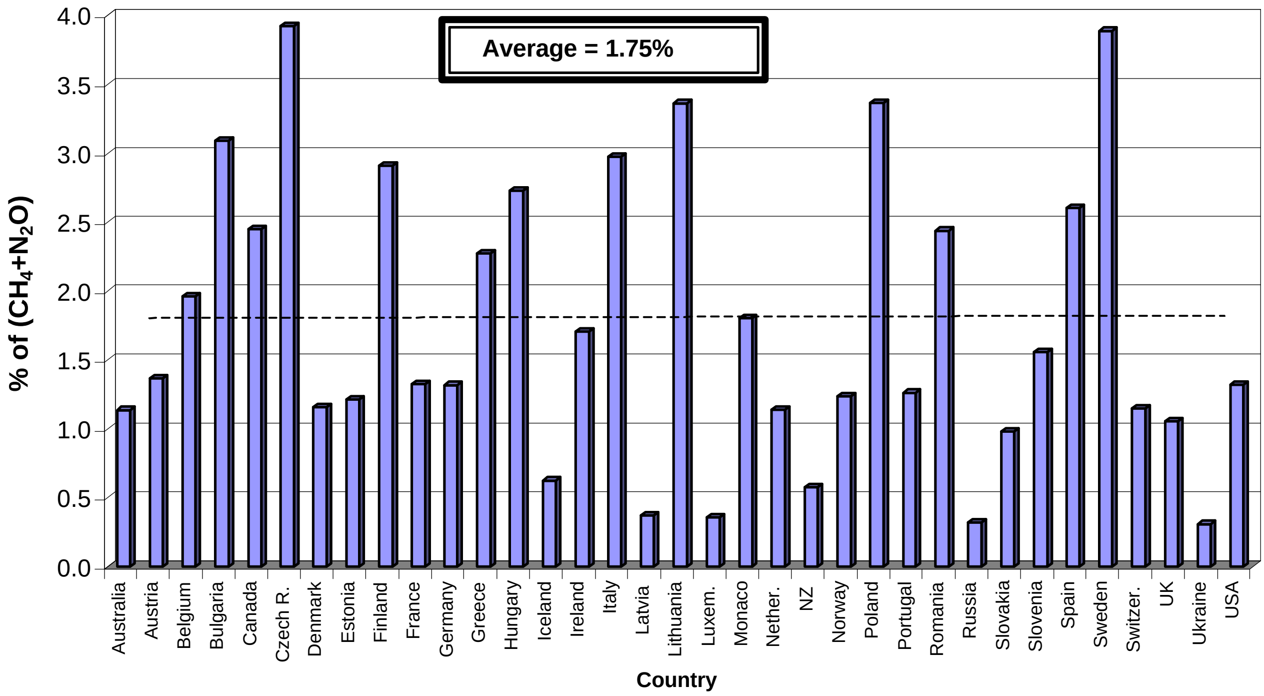


Figure 1.4 (CH_4+N_2O) Emission from Fuel Combustion as a percentage of National Emission



2.2 The Methodology to disaggregate fuel data into consuming sectors

Fundamental to this method is the allocation of 4 fuels (Gas/Diesel Oil, Residual Fuel Oil, Coal and Natural Gas) to the different categories of IPCC/CRF Table 7A by using the consumption pattern of these fuels from the Annex B total. Appendix B shows the breakdown into the consuming sub-sectors of the total consumption of the 4 fuels in 35 Annex B countries. The data in Appendix B has been used to construct Table 2.2, which shows the percentage distribution of the 4 fuels into the consuming sub-sectors. The other fuels are allocated in a simple manner to the predominant use category. The method is executed using the following steps.

Step 1. Allocate all fuels, other than Gas/Diesel Oil, Residual Fuel Oil, Coal and Natural Gas, into the predominant use category shown in Table 2.1. For jet kerosene, the amount used as international aviation bunkers should be deducted.

Table 2.1 Allocation of some fuels into their predominant use category

FUEL	Predominant Use Category
Gasoline	Road Transport
Jet Kerosene	Aviation
Other Kerosene	Residential
LPG	Residential
Ethane	Chemical Industries Feedstock
Naphtha	Chemical Industries Feedstock
Bitumen	Non-Energy Use
Lubricants	Transport Sector Non-Energy Use
BKB and Patent Fuel	Residential
Other Oils	Manufacturing Industries or Other
Other Solid Fuels	Manufacturing Industries or Other
Other Gaseous Fuels	Manufacturing Industries or Other

Step 2. Allocate Gas/Diesel Oil according to Table 2.2. Allocate Residual Fuel Oil, Coal, and Natural Gas according to Table 2.2 as a first trial. It is assumed that international marine bunkers, non-energy and industrial process uses of these fuels have been deducted.

Table 2.2 Distribution of 4 fuels into different sectors according to Annex B countries' total

	Coal	Gas/Diesel Oil	Residual Fuel Oil	Natural Gas
Energy Industries	86.2%	2.6%	64.8%	47.7%
Manufacturing Industries	7.2%	12.2%	24.6%	25.0%
Transport	0.1%	50.0%	2.2%	1.5%
Other Sectors				
Commercial	1.7%	8.6%	4.8%	7.8%
Residential	3.6%	14.2%	2.0%	16.6%
Agriculture	0.3%	10.6%	0.9%	0.5%
Other	0.9%	1.8%	0.7%	0.9%

Step 3. If a country uses both coal and natural gas, then the share of each fuel for electricity generation should be determined from the country. The information should be used to modify the allocation obtained from Step 2. As required all categories should be adjusted ensuring that the relative ratios between the other categories are maintained.

Step 4. By using an average electricity generation efficiency of say 35% (this value, preferably for each fuel, should be obtained from the country), the amount of electricity generated from the fuels allocated to the Energy Sector should be calculated and compared to the actual electricity generated from fossil fuels, the data for which will need to be procured either from the country or from international sources. If the calculated electricity generated do not match the actual electricity generated, then some adjustments would be required. The most probable cause of a mismatch would be that too much or too little fuel has been allocated to the Manufacturing Industries Sector. Adjust the Manufacturing Industries fuel

allocated to achieve balance between calculated and actual electricity generated. If no data for electricity generated are available, then the allocation obtained in Step 2 for natural gas, coal and residual fuel oil should be retained. In many cases, especially if data gaps in the Carbon Balance Inventory are being filled up, the complete information on all fuels used for electricity generation would be available. If the country concerned has other significant energy industries, the energy consumed by those industries should be deducted before computing the electricity generated. The information about other energy industries are usually available in the IEA Energy Balance. Otherwise the UN database should be consulted or the information procured from the country. If no acceptable estimate is available, the following default deductions from the three fuels allocated in Step 2 to the Energy Industries Sector should be performed: Coal – 21%, Residual Fuel Oil – 15% and Natural Gas – 33%.

Step 5. The residential fuel allocation should be conform to the Annex B average or similar country per capita residential energy consumption. Any required adjustment should performed with the allocated fuel for the Manufacturing Industries Sector. Care should be exercised in determining the proportion of electricity use, which competes with fuel use. Ideally this should be confirmed from the country concerned. An expert judgement estimate from the country can eliminate a lot of uncertainly.

2.3 Limitations of the method

The method described above will yield good results only if the sectoral fuel distribution is similar to that shown in Table 2.2. There will be many instances, when this will not be so. For example, in many countries nearly 100% of the diesel is used in the transport sector. Then there are countries, which have large coal use in the Manufacturing Industries Sector, whereas Table 2.2 indicates only 7.2% use in that sector. In such cases, however, country experts would be able to detect quite easily the non-applicability of the Table 2.2 distribution. In extreme cases, it may be better to use fuel distribution from similar countries instead of Annex B average distribution. However, there is no easy way for a non-country expert to know which countries are similar in terms of the distribution of specific fuels into consuming sub-sectors. Since there will be countries for which one or more fuel's distribution into sectors will show significant deviation from that shown in Table 2.2, the person performing the adjustment should be aware of the limitations. It should always be possible to get rough estimates of fuel distribution for the sectors shown in Table 2.2 from the country concerned. This would lessen the uncertainly in the adjustment process. Despite the limitations, the typical distribution shown in Table 2.2 can be used for most countries because data from large number of countries have been used to construct it.

The complete fuel distribution considered in this method depends on two categories of fuels – those listed in Table 2.1 and those in Table 2.2. The applicability of the fuel distribution into sectors shown in Table 2.2 has been discussed above. If all the steps outlined in the preceding section are followed carefully and completely, misallocation will be minimized. With regard to the fuels shown in Table 2.1, it may be mentioned that, in many countries these fuels can constitute 30% or more of the total fuels. These fuels would in all probability, get allocated correctly because there exists only one overwhelmingly predominant (usually > 90%) use for these fuels. It can therefore be assumed that 80% or more of the total fuels should get allocated correctly. There is considerable merit in the proposed methodology because the

chances are that only one or two fuels in one or two categories will be misallocated. The methodology is acceptable from the point of view of inventory adjustments.

Examples to illustrate the methodology have not been provided because of the following two reasons:

1. The full procedure even for one country will be extremely involved and lengthy and will also require considerable amount of country information;
2. The choice of the country will determine the error. If a country is chosen, which fits the data presented in Table 2.2, the errors will be minimal, but there will be countries whose fuel distribution into sectors will show large divergence.

3.0 Estimating CO_2 Emission from Per Capita CO_2 Emission

3.1 Parameters affecting CO_2 emission

As mentioned in the Introduction, this is a THEORETICAL exercise to predict the CO_2 emission from fuel combustion activities without using energy data. The conceptual basis of the method, which uses average per capita CO_2 emission to generate an estimate for CO_2 emission for a country, has been presented earlier. Table 3.1 shows the per capita CO_2 emissions for 35 Annex B countries. As can be seen, the values vary from 4.19 for Portugal to 28.42 for Luxembourg, with a large gap between the second largest value (19.5 for USA) and the largest. It is obvious that if an average is computed, the standard deviation (or the errors) will be large. The average per capita CO_2 emission for the 35 countries is 10.02. Using the average per capita emissions, if the CO_2 emissions for the 35 countries were computed, errors varying between 1.5% and 139% will result as can be seen from Table 3.1. The average error is greater than 40%, and for only 7 countries the errors are less than 15%. It is therefore clear that emission estimates made using the average per capita CO_2 emission of all Annex B countries are for most practical purposes useless. The only way meaningful estimates can be obtained is by grouping countries into “clusters” using small ranges of the per capita CO_2 emission values. This introduces the problem of placing a country into the correct group. The process of assigning a group to a country is indeed a challenging task. A method is devised to achieve this by considering a set of parameters, which define the energy consuming characteristics of a country. A number of parameters including the energy consuming habits of the population influence the energy consumption in a country. Care has been taken to avoid suggesting direct energy parameters, like per capita electricity consumption, because it is assumed that data to determine the values for such parameters do not exist or are unreliable. If such data do exist, then this whole exercise becomes a trivial one. The parameters identified as having significant effect on the CO_2 emission from a country are listed in Table 3.2. Brief descriptions of the parameters follow.

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Table 3.1 Groups of Countries Based on Specified Ranges of Per Capita CO_2 Emission

35 Annex B Countries

		Error, %
Australia	15.41	-35.0
Austria	7.68	30.4
Belgium	10.95	-8.5
Bulgaria	8.43	18.8
Canada	15.42	-35.1
Croatia	3.94	154.2
Czech	13.83	-27.6
Denmark	10.30	-2.8
Estonia	17.97	-44.3
Finland	10.90	-8.1
France	6.67	50.2
Germany	12.37	-19.0
Greece	7.11	40.9
Hungary	6.53	53.4
Iceland	8.71	15.0
Ireland	9.48	5.6
Italy	7.19	39.3
Japan	8.59	16.6
Latvia	6.48	54.6
Lithuania	6.38	57.0
Luxembourg	28.42	-64.8
Netherlands	10.79	-7.2
Norway	7.02	42.7
NZ	7.63	31.3
Poland	9.16	9.3
Portugal	4.19	139.0
Romania	7.21	38.9
Russia	14.71	-31.9
Slovenia	6.37	57.2
Spain	5.53	81.1
Sweden	6.15	62.8
Switzerland	6.51	53.8
UK	10.17	-1.5
Ukraine	12.83	-21.9
USA	19.50	-48.6
Average per capita CO_2	**10.02**	

GROUP

		Error, %
Austria	7.68	-10.9
France	6.67	2.6
Greece	7.11	-3.8
Hungary	6.53	4.8
Italy	7.19	-4.9
NZ	7.63	-10.3
Norway	7.02	-2.6
Romania	7.21	-5.1
Sweden	6.15	11.2
Switzerland	6.51	5.1
Latvia	6.48	5.6
Lithuania	6.38	7.2
Slovenia	6.37	7.4
Average per capita CO_2	**6.84**	

Countries not included in the groupings

Croatia	3.94
Portugal	4.19
Spain	5.53
Estonia	17.97
USA	19.5
Luxembourg	28.42

GROUP

		Error, %
Belgium	10.95	-11.0
Bulgaria	8.43	15.6
Denmark	10.30	-5.4
Finland	10.90	-10.6
Iceland	8.71	11.9
Ireland	9.48	2.8
Japan	8.59	13.5
Netherlands	10.79	-9.7
Poland	9.16	6.4
UK	10.17	-4.1
Average per capita CO_2	**9.75**	

GROUP

		Error, %
Australia	15.41	-8.5
Canada	15.42	-8.6
Czech	13.83	1.9
Germany	12.37	13.9
Russia	14.71	-4.2
Ukraine	12.83	9.9
Average per capita CO_2	**14.10**	

NOTES

1. The data have been taken from the IEA database
2. The per capita CO_2 emissions are in metric tons (mt)
3. The data are for the year 1990
4. Monaco is included in France.
5. Liechtenstein is included in Switzerland
6. Czech is Czech Republic and Slovakia
7. Error = (Average – Actual)/Actual x 100

Population Density. This is defined as population divided by area and is the number of people per square kilometers. This is an indirect parameter and its effect comes into play only when per capita income is high and the parameter's value is very low. In low population density countries to maintain the full range of economic activities, large amount of energy is required. Infrastructure and energy requirement for sparse population will invariably be high. Similar situation may also arise for high population density countries, which have extremely low population (around 1 million).

Per Capita Income. This is also known as GDP per capita, and is defined as the Gross Domestic Product divided by the population. This is an extremely popular parameter and is widely used to correlate various economic activities. There exists a strong direct relationship between energy consumption and GDP per capita, so much so that an allied parameter, energy intensity of the economy, defined as commercial energy consumption divided by the GDP is widely used by energy analysts to characterize the energy consumption of an economy. Unfortunately, the relationship is not linear and wide variations prevail. The reason for the non-linearity is the structure of the economy. Emphasis on the industry sector in an economy will cause large energy consumption. The following example (World Development Report, 1996) brings out this point clearly. In the year 1994, the difference in per capita income between India and Bangladesh was 1.5 times (India – US$ 320, Bangladesh – US$ 220), whereas the difference in per capita energy consumption was 3.7 times (India – 243 kgoe, Bangladesh – 65 kgoe).

Proportion of industry in the GDP. The structure of the economy, or GDP, determines to a great extent the energy consumption of a country. Compared to the industry sector, the service and agriculture sectors need much less energy, and in many cases are capable of producing the same level of GDP output. In the last two decades, most OECD countries' economies have been shifting away from industry and moving towards services.

Industry Structure. This plays a big role in determining the energy consumption in a country. Thus, if a country has a high proportion of energy intensive industries (mining, aluminum and steel production, petrochemicals, and shipbuilding) as opposed to low energy consuming industries (textile, leather, and electronic goods manufacturing), its energy consumption will be high. Equally important is the absolute size of the industry sector.

Energy Efficiency. The concept of useful energy is extremely helpful in understanding energy efficiency. The amount of useful energy is determined by the energy services derived by using a given amount of energy. For example, to produce a given amount of light, measured in lumens, different devices will require different amounts of energy. Historically, low or subsidized energy prices and the need to save on capital investment for plants and machinery have contributed to low energy efficiency in many countries around the world. Energy efficiency is an extremely important parameter, because, for the same energy service, energy consumption of different devices can vary three times or more. The issue of energy wastage also falls under the purview of energy efficiency or useful energy. This parameter is undoubtedly the most important parameter and is the key to high or low per capita emissions. Its effect is so great that it can cause a low per capita income country to have a high per capita emission, and a high per capita income country to have a low per capita emission.

Energy Prices. It is axiomatic that low energy prices will encourage high energy consumption. High energy consumption in countries, where energy prices are low or subsidized, and energy conservation in countries, where energy prices are high, are both fairly common occurrences. The high gasoline prices in Western Europe have contributed to noteworthy energy conservation in the transport sector, and at the same time low gasoline prices in North America have contributed to large energy consumption in the transport sector.

Renewables (hydro) and Nuclear. The extent of renewables (hydro) and nuclear energy in the energy mix directly influences CO_2 emissions. If the proportion of renewables (hydro) and nuclear energy in the energy mix are high, CO_2 emission will be low.

Coal vs. Natural Gas. CO_2 emission is a strong function of the primary fuels used. Natural Gas emits approximately half the amount of CO_2 as does coal for the same heat output. Countries, which have a large proportion of natural gas in their energy mix, will emit less CO_2, and those using a lot of coal will emit more CO_2.

Climate – hot or cold country. Energy for space heating in all sectors in cold countries can be a significant item in the total energy consumption. This parameter becomes all the more important when it gets coupled to the issue of energy efficiency. If thermal insulation is poor in the residential and commercial sectors, as is common in many countries, substantial amount of energy may be required for space heating.

Special considerations. There are special considerations that may be taken into account. An important one is the electricity trade. Thus, countries, which import electricity will have a lower, and countries, which export electricity, will have a higher, per capita CO_2 emission. If no special considerations can be identified for a country, it is suggested to use this parameter to strengthen the assessment for any one of the 9 parameters, which is dominant.

The parameters listed in Table 3.2 and described above are not very difficult to ascertain for any country. Some parameters like population density, energy prices, extent of hydro/nuclear energy in the energy mix, coal vs. natural gas and climate can be known quite accurately for any country, while parameters like per capita income, proportion of industry in the GDP, industry structure and energy efficiency are slightly difficult to ascertain. The effect of the parameters on CO_2 emissions for one state of the parameters are given in Table 3.2. It must be appreciated that these parameters will display a whole range of states from say very high to very low. For the restricted analysis being performed here only two to three states are being considered. Table 3.2 can be used to evaluate a country’s energy consuming potential, and the evaluation result can be used to develop a rating for the country.

Table 3.2 Parameters and their effects on CO_2 emission

PARAMETER	State	Effect on per capita CO_2 emissions
Population Density	Very Low	Increase
Per Capita Income	Low	Decrease
Proportion of industry in GDP	High	Increase
Industry Structure	Energy Intensive	Increase
Energy Efficiency (useful energy)	Low	Increase
Energy prices	Low	Increase
Renewables (hydro) and nuclear	High	Decrease
Coal vs. Natural Gas	Natural Gas	Decrease
Climate – hot or cold	Hot	Decrease

3.2 Groups or "clusters" of countries having similar per capita CO_2 emission

A critical analysis of the data in Table 3.1 suggests that meaningful groupings can only be obtained if extreme values at both ends were not considered. Thus, Croatia, Portugal and Spain at the lower end, and Estonia, USA and Luxembourg at the higher end have been left out of the groupings. Between the values 6 and 16, three groups or clusters are suggested as shown in Table 3.3.

Table 3.3 Groups of countries having per capita CO_2 emission within specified range

Group No.	Per Capita CO_2 range	Number of Countries	Countries
I	6 to less than 8	13	Austria, France, Greece, Hungary, Italy, NZ, Norway, Romania, Sweden, Switzerland, Latvia, Lithuania, Slovenia
II	8 to less than 11	10	Belgium, Bulgaria, Denmark, Finland, Iceland, Ireland, Japan, Netherlands, Poland, UK
III	11 to less than 16	6	Australia, Canada, Czech, Germany, Russia, Ukraine

The boundaries of the groups have been chosen in such a way that even if a country's emission falls at a boundary, the error would be acceptable. In Table 3.1, the average for each group has been computed from the actual per capita emission values of the countries rather than the values for the boundaries. An analysis of the groupings reveals the following facts.

i. The low per capita emission group is the predominant one with one-third of all the Annex B countries falling into it. Low per capita income (compared to OECD members) countries, which do not have high concentration of energy intensive industries and/or are not riddled with large energy inefficiencies across all sectors, are logically located in this group. The high per capita income countries in this group are those which have very high efficiency standards and/or have a lower concentration of energy-intensive industries. New Zealand is located in this group due to its unique characteristics, which is the large share of the agriculture sector in its GDP. The effect of one dominant parameter is evident in the case of France, which might have been located in Group II because of its large

industrial base, but is located in Group I because of the large proportion of nuclear energy in the energy mix.

ii. All European OECD countries, except for Germany, fall either in Group I or II. That Germany is the only exception is easily explained by the facts that it has a large energy intensive industrial base and that it recently merged with East Germany. OECD countries are at the lower end of the spectrum because of the high level of energy efficiency and the high energy prices. European OECD countries are densely populated, and their populations reside mainly in urban centers, which require far less energy than vast thinly populated rural settlements.

iii. The countries whose economies are in transition span the full range from Group I to III. Countries like Russia, Ukraine and Czech will naturally be located in the higher numbered groups because of historical reasons. These countries have large number of energy intensive industries, which are also very energy inefficient. Countries, which have low per capita income, are located in Group I because per capita GDP is one of the dominant drivers for CO_2 emissions. The countries among these which have higher level of industrialization and/or have inefficient energy consumption in some sectors, including the residential sector, like Bulgaria and Poland are located in Group II.

iv. Group III has 3 OECD member countries and 3 countries whose economies are in transition. The two non-European OECD member countries (Canada and Australia) are sparsely populated vast countries.

3.3 Determining the group or “cluster” for a country

The process of assigning a group to a country requires expert judgement. However, in many cases a commonsense evaluation will be sufficient. Country experts will have a good idea of the effect of the parameters shown in Table 3.2, and therefore, should be consulted. Often they will know that their country’s emission is similar to a country in one of the three groups, thus grossly simplifying the process. The process becomes easier if the country, whose emission is being determined, is compared to the countries in each group. It is noteworthy that Group III is a very special group comprising of only 6 countries, all of which have clearly distinguishing characteristics of high energy consumption. Therefore, unless a county possesses obviously distinguishing features of high emissions, the country should be located in Group II. Similarly, if a county is an obvious low emitter, it should be in Group I. For most countries, the choice would be between Group I and Group II. The real difficulties arise with countries, which fall close to the boundary between Group I and II. In Table 3.1 such countries are Austria, New Zealand (NZ), Bulgaria and Japan. A formalized process for assigning a country to a group is suggested below.

Step 1. Determine the state and its effect on each of the 9 parameters as suggested in Table 3.2 for the country whose emission is to be determined. Most parameters can "Increase", "Decrease" or have “No Effect” on emissions. For Population Density, the evaluation should be either "Increase" or "No Effect". Similarly, for Hydro and Nuclear the evaluation should be either “Decrease” or “No Effect”

Step 2. If the number of "Increase" and "Decrease" are equal, the country should be assigned to Group II. If the number of "Increase" is many more than "Decrease", Group III should be assigned. If "Decrease" is greater than "Increase", Group I should be assigned

Step 3. Compare the country's situation to that of the other countries in the assigned group by critically reassessing the parameters. This is important for cases where the number of "Increase" and "Decrease" exceed each other by 1. The intensity of the states should be analyzed. For example, the parameter Energy Efficiency may be "Strong Increase", while Industry Structure is a "Mild Decrease"

Step 4. For borderline cases, make certain that the parameters, which very strongly influence emissions, like Energy Efficiency and Industry Structure have been assigned due weightage

Step 5. If Steps 3 and 4 indicate a possible incorrect group assignment, the per capita emission for the country should be taken as the value of the boundary between the group assigned in Step 2 and the higher or lower group, as appropriate

3.4 Errors and Examples

The averages for the three groups identified in Table 3.3 are shown in Table 3.1. The average for Groups I, II and III are 6.84, 9.75 and 14.1 respectively. Using the average of a group, if the per capita CO_2 emissions for the members of that group are calculated, the resulting errors would range between 1.9% and 13.4%, which is a much more acceptable error range than that obtained without considering clusters. Table 3.1 shows the errors that would result if group averages were used for the 29 countries included in the groups. If the correct cluster can be identified for a country then a technical estimate will not have an error greater than 15%. It should be noted that the discussion in several places has referred to per capita emission and not the emission from the country. There should be no confusion that the difference between the two is only a multiplying factor, i.e., the population.

A few cases are presented in Table 3.4 to illustrate the workings of the methodology.

Table 3.4 Use of parameters to identify a group for a country[1]

Parameters	**Austria**	**Germany**	**Finland**	**Hungary**
Population Density	-	-	Increase	-
Per Capita Income	Increase	Increase	Increase	Decrease
Proportion of industry in GDP	Increase	Increase	-	-
Industry Structure	-	Increase	-	-
Energy Efficiency	Decrease	Increase[2]	Decrease	-
Energy Prices	Decrease	Decrease	Decrease	Increase
Hydro and Nuclear	Decrease	Decrease	Decrease	Decrease
Coal/Natural Gas	Decrease	Increase	-	Decrease
Climate – hot or cold	Increase	Increase	Increase	Increase
Assigned Group Þ	**I**	**III**	**II**	**I**

1. This is ILLUSTRATIVE. The consultant does not have enough knowledge about the countries to claim that the assessments are correct
2. This is due to the re-unification of East and West Germany

3.5 Refinement Process

A refinement of the crude estimate is possible within each group. The two reasons why a refinement is desirable are:

i. A country could be placed in the wrong group. This would result in excessive error;
ii. A much superior estimate, probably having an error less than 5%, is possible by the refinement process.

The refinement process envisaged would locate a country's per capita emission within the boundaries of the group using a cumulative score of the parameters. For example, if a country is located in Group I, its emission without refinement would be determined by the average for that group (which is 6.84) multiplied by the population. If the country's true emission were close to one of the boundaries, an error close to 15% would result. By assigning numerical values to the different states (from very high to very low) of the parameters, a cumulative score can be determined for a country. If the highest possible value of the cumulative score is say 100 (corresponding to high emissions) and the lowest 0, then the score for a country will determine what its emission value will be. Thus, if the score is 10, then for Group I, a value close to 6 (6.2 to be precise) would be assigned. Since the scoring would be done by comparing the given country to the other countries in the group, a country which has been assigned an incorrect group, would through the refinement process get located very close to the boundary of its correct group. For the case where a country has been located in the correct group, the refinement process would yield an estimate with a lower error.

As may be appreciated, the refinement process described above would require a considerable amount of information about the country. In addition, the person performing the exercise would introduce a fair bit of subjectivity. The limited scope of this project does not allow the development of the refinement process.

4.0 CH_4 and N_2O emission estimates for Fuel Combustion categories in Common Reporting Format Table 7A

Two methodologies are proposed for estimating CH_4 and N_2O emissions from Fuel Combustion. The first method estimates emissions of these gases from Annex B averages by linking the emissions to CO_2 emission, and the second, which is more accurate, estimates emissions from the data of fuel use in the various sectors. The next two sections present the two methodologies.

4.1 CH_4 and N_2O emission estimates by linking to CO_2 emission

The methodology proposed here, whereby CH_4 and N_2O emissions are calculated as a percentage of CO_2 emission, is a purely statistical one. There is no fundamental basis to this methodology because CH_4 and N_2O emissions are not in any way dependent on CO_2 emission. The method is based on the expectation, barring any country specific factors causing large deviations, that emissions of CH_4 and N_2O may maintain certain ratios to CO_2 emission. This expectation arises from the following two main factors.

(i) Energy consuming devices are usually standardized equipment

(ii) Within a country the effects on the average of high emitting and low emitting sources would cancel each other out

It is obvious, however, that the factors stated above do not apply to all countries. Thus, there are countries that have non-standard equipment and/or have a preponderance of equipment, which are either high or low emitters. In addition, the extent of emission control technology existent in a country will have a significant effect on the emissions of CH_4 and N_2O, especially of CH_4. Despite these limitations, this methodology is a good one because of the following reasons:

(i) Country specific emission factors for CH_4 and N_2O are very scarce;
(ii) Tier I default emissions factors, which many countries use, are in essence averages of many typical technologies;
(iii) The adjustment procedure applies only to countries which are unable to estimate the emissions in a reliable manner.

Fundamental to this methodology are the average CH_4/CO_2 and N_2O/CO_2 emission ratios for the five IPCC/CRF Table 7A categories (Energy Industries, Manufacturing Industries, Transport, Other Sectors and Other). These average ratios can be obtained from the reported inventories of the Annex B parties. Appendix C presents the emissions of CO_2, CH_4 and N_2O along with the CH_4/ CO_2 and N_2O/ CO_2 ratios for the various IPCC/CRF categories for fuel combustion reported by 35 Annex B parties for the year 1990. A better appreciation of the ratios in Appendix C can be obtained from Figures 4.1 and 4.2, which are for the Transport Sector. The y-axis values in these figures are CH_4 and N_2O emissions divided by CO_2 emission multiplied by 100. It is instructive to note that

(i) Most countries' reported emissions are lower than the average
(ii) Only a few countries have reported emissions higher than the average but the higher emissions are significantly higher
(iii) The significantly higher emission countries, except for Estonia, are all OECD member countries

Since OECD member countries are expected to possess excellent emission measurement facilities/capabilities, there is little reason to doubt these values. In fact, the reason for the deviations is probably that these countries have used country specific emission factors. An important issue here is of course the kind of technology that is predominant in any country. If one studies the emission factors for Utility Boilers in Table 1-15 of the IPCC Guidelines (Reference Manual), one would note that bituminous fluidized bed combustors produce nearly two orders of magnitude higher N_2O emissions than standard combustion equipment. Countries whose reported emissions are close to the average, have probably used either Tier I or Tier II default emission factors. As a matter of good practice, parties should explain or UNFCCC should find out the reasons behind significantly higher or significantly lower than the average (reported in this work) emissions.

The methodology for estimating CH_4 and N_2O emissions from Annex B averages requires that all CO_2 entries in IPCC/CRF Table 7A be available. If these are not available, then one of the three procedures must be initiated

(i) If IEA or UN data exists for the country, a Carbon Balance Inventory can be completed

Figure 4.1 CH_4 Emission as a percentage of CO_2 Emission for Transport

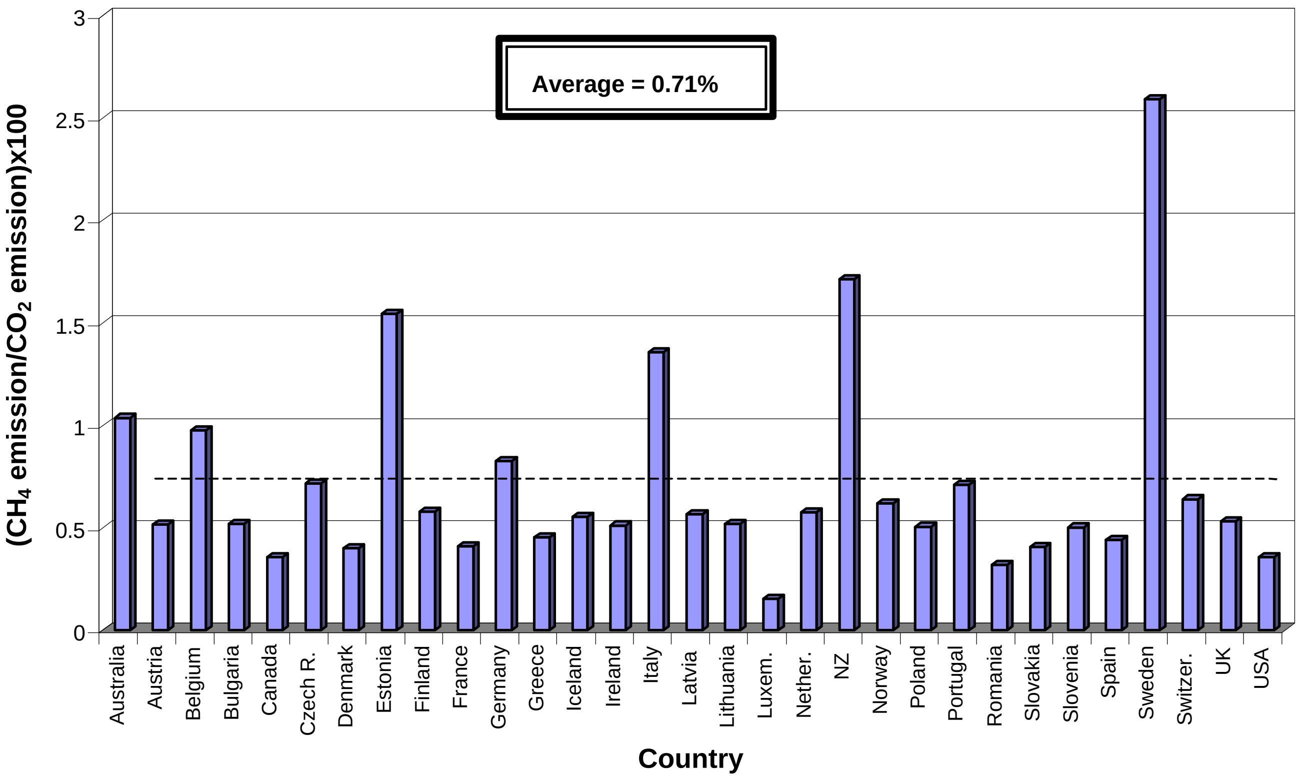
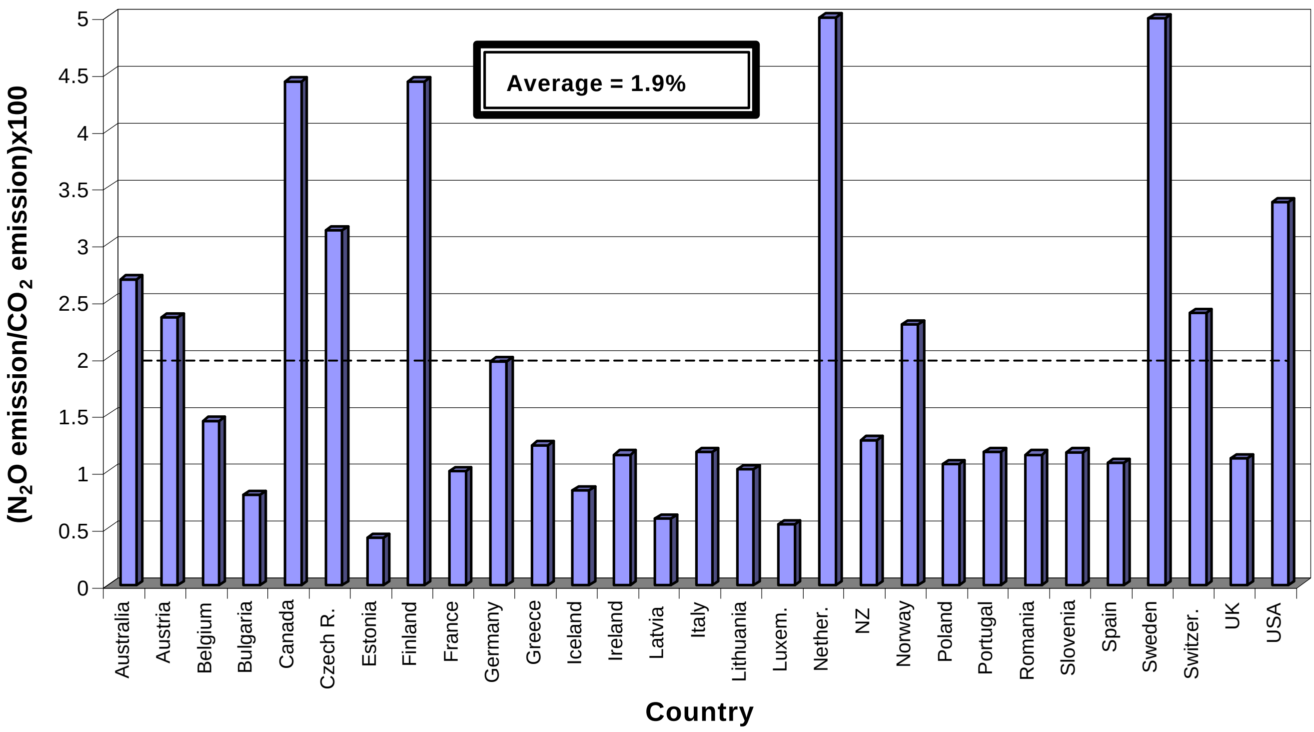


Figure 4.2 N_2O Emission as a percentage of CO_2 Emission for Transport



(ii) Aggregated fuel data obtained from any reliable source, including from the country, can be disaggregated by the method described in section 2.0

(iii) Reference approach data along with the country's refineries' output fuel mix data can be disaggregated by the method described in section 2.0

All the three procedures would yield the desired data to use the methodology. The CH_4 and N_2O emissions for each of the economic activity category in IPCC/CRF Table 7A is estimated by multiplying the CO_2 emissions by the CH_4/CO_2 and N_2O/CO_2 ratios given in Table 4.1, which has been constructed from the data shown in Appendix C. The values shown in Table 4.1 are the averages of the values in the appropriate column of Appendix C.

Table 4.1 Annex B Countries' average CH_4/CO_2 and N_2O/CO_2 ratios

IPCC/CRF Table 7A Categories	(CH_4/CO_2)x100	(N_2O/CO_2)x100
Energy Industries	0.1208	1.6197
Manufacturing Industries And Construction	0.2079	1.5033
Transport	0.7066	1.9024
Other Sectors	2.1625	2.6258
Other	1.4511	2.8320

Errors and Limitations

To appreciate the errors that would result if this method were used, it is instructive to look at Figures 4.1 and 4.2. In these figures, the average emission, which is used by the method, is indicated by a dotted line. The difference between the value for each country and the average is defined as the error, which is visually appreciated from Figures 4.1 and 4.2 as the difference between the heights of each bar and the dotted line. Thus, if this method is used to estimate CH_4 emission, the error for Germany would be negligible and those for Sweden and Luxembourg would be the highest. The estimates would be less than one-third for Sweden and more than three times for Luxembourg.

4.2 CH_4 and N_2O emission estimates from fuel data

If fuel data for each the IPCC/CRF Table 7A or more disaggregated categories are available, as will be if one of the three procedures listed in the immediately preceding section is completed, then finding CH_4 and N_2O emissions is a trivial exercise. In fact, it would make little sense to use the method described in section 4.1 to estimate emissions if data for all fuels consumed in the IPCC/CRF Table 7A categories are known. The method in section 4.1 is intended for the case where CO_2 emission values exist but data for all fuels don't.

If a complete Carbon Balance Inventory can be constructed from IEA (or UN) data, then CH_4 and N_2O emission estimates can be made using Tier I default emission factors, or Tier II default emission factors by assuming typical technologies for each category and/or fuel. If the Carbon Balance Inventory has data gaps, then those will need to be filled up by the method described in section 2.0 before estimating CH_4 and N_2O emissions.

If only aggregated fuel data or reference approach inventory is available CH_4 and N_2O emissions estimate can still be made, but to do that, the procedure described in section 2.0 should be used first to disaggregate the data into the IPCC/CRF Table 7A categories.

Errors and Limitations

There are two sources of errors in this method. The first source of error is the energy data from which emissions are being calculated. If fuel data used in the method were inaccurate, emission estimates would naturally be in error. These errors would be similar in magnitude to the errors presented for CO_2 emission in the report on Carbon Balance Inventory. The second source of error are the default emission factors. However, this should be viewed more as a weakness of the estimate rather than an error. This is because inventory adjustments are being proposed only for cases where there are no or very weak energy data. The errors that the use of default emission factors would introduce will be very similar to those discussed in the preceding section. The reason for this is the fact that default emission factors are in essence averages of many other emission factors of typical technologies in a sector. Without the knowledge of specific technologies in any county, good CH_4 and N_2O estimates cannot be made because unlike CO_2 emission, which is dependent on the carbon content of fuel, CH_4 and N_2O emissions are technology and emission control dependent. Thus, the CH_4 and N_2O emissions can vary by a factor of 10 or more. Tier I default emission factors will never be able to predict, for example, the very high emissions of Sweden or very low emissions of Luxembourg (Figures 4.1 and 4.2). Tier II default emission factors with the knowledge of technologies prevalent in a country (including emission control) will give better estimates, but the true emissions can only be determined by good measurements.

Conclusions and Recommendations

The following are the conclusions and recommendations of the report.

1. The inventory adjustment process, if executed by a team of experts without the participation of the party involved, should only be applied as a last resort because the very nature of a technical estimate implies that a certain amount of error, which cannot be

quantified satisfactorily, must be endured. A technical estimate should be generated and inserted into an inventory only if a party is unable to provide a country estimate. An estimate made by a country expert is always desirable, because the large amount of country information required for generating a technical estimate with low uncertainly would not be available to an expert applying adjustments. In the event that an adjustment does become essential, it is recommended that it be performed through a consultative process.

2. Aggregated fuel data can be disaggregated into the consuming sectors to at least the categories indicated in IPCC/CRF Table 7A by the methodology outlined in section 2.0. The aggregated data can come from several sources, namely, the Carbon Balance Inventory, the reference approach inventory or from the country. Before embarking on the adjustment process, an effort should be made to see if the missing data could be obtained from the country concerned through suitably designed questionnaire or from the UN database. The method proposed here is based on allocating each fuel to the different consuming sub-sectors from the allocation of Annex B total for that fuel. The use of Annex B average can result in misallocation of certain fuels for some countries. Nevertheless, the methodology is still acceptable because unlike CH_4 and N_2O emissions, CO_2 emission is not technology dependent. It is worth emphasizing at this point that for CO_2 emission alone the sectoral approach is not justified, and that a properly completed reference approach remains the most robust method for calculating CO_2 emission. Misallocation does have implications for CH_4 and N_2O emissions but is marginal if only Tier 1 emission factors are employed. The effect is much more pronounced for CH_4 especially for the residential and energy industries sectors. It is therefore emphasized that the allocation of fuel to the different consuming sub-sectors be confirmed from the country concerned. Country energy experts may be able to provide a breakdown using expert judgement, which will be far superior to the distribution obtained from the aggregate of all Annex B countries.

3. For a country, which has no or imperfect energy data, the methodology proposed in section 3.0, which generates a technical estimate of CO_2 emission for a country using the average per capita CO_2 emission with population as a driver, can be used. The method only gives meaningful estimates if groups or "clusters" from Annex B countries are used to calculate the average per capita CO_2 emission. The process of placing a country in one of the suggested groups requires evaluation of 9 parameters for a given country. This exercise may introduce certain amount of subjectivity to the process. The methodology requires a considerable amount of in-depth information about the country, which can be procured by either a questionnaire sent to the country's energy experts or by engaging energy consultants. Even if the country is successfully placed in the correct group, errors up to 15% may result. This error can be reduced by a refinement process, which has only been outlined in the report but not detailed.

4. In section 4.2 a simple methodology has been given which allows CH_4 and N_2O emissions in IPCC/CRF Table 7A to be estimated. In submitted inventories, if CH_4 and N_2O emission values are missing from the IPCC/CRF Table 7A, this methodology can be invoked. The methodology performs the estimation by linking the emissions of CH_4 and N_2O to CO_2 emission. The reported emissions of CO_2, CH_4 and N_2O by Annex B countries have been used for the purpose of developing average CH_4/CO_2 and N_2O/CO_2

ratios. The technical estimates obtained by this methodology are acceptable because for most countries the combined CH_4 and N_2O emissions are approximately 2.2% of the Fuel Combustion total and 1.8% of the National total. A 100% error in the estimation of these gases will result in less than 1.8% error in the National total. A word of caution however is that large uncertainties (by a factor of 2) are associated with these gases. An additional acceptability of these technical estimates comes from the fact that many countries use default emission factors for these gases, which are no better than the technical estimates. In countries, where emissions of these gases are much lower or higher than the average, the onus is on the country concerned to submit a high quality inventory.

5. If disaggregated fuel data are available, or can be generated from aggregated data using the method described in section 2.0, CH_4 and N_2O emission estimates can be made using default emission factors. Since the Carbon Balance Inventory provides detailed breakdown of fuels, this method for CH_4 and N_2O emissions can be taken to the sub-sector level, i.e., categories 1A1 to 1A5. However, there is little merit in it if information on the technologies for consuming the particular fuel in the sub-sectors are not available. In any case, one should go beyond the IPCC/CRF Table 7A categories for the transport sector because the CH_4 emission factors for jet kerosene, gasoline and diesel are very different. Since the inventory adjustment process will only be invoked for countries, which do not have good activity and/or emission factor data to complete the inventory, this method will yield technical estimates which are completely acceptable provided of course the Carbon Balance Inventory is complete and correct to the level of disaggregation desired for CH_4 and N_2O estimation.

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APPENDIX A

CH_4 and N_2O Emission from Fuel Combustion Activities as a Percentage of Total Fuel Combustion (TFC) and National Total (NT) Emissions

	CO_2	CH_4	N_2O	TFC	NT	CH_4+N_2O	$(CH_4/TFC)x100$	$(N_2O/TFC)x100$	$((CH_4+N_2O)/TFC)x100$	$((CH_4+N_2O)/NT)x100$
Australia	262623	2282	2393	267298	410796	4675	0.8537	0.8953	1.7490	1.1380
Austria	46620	424	584	47628	73727	1008	0.8902	1.2262	2.1164	1.3672
Belgium	105919	326	2396	108641	138943	2722	0.3001	2.2054	2.5055	1.9591
Bulgaria	76484	158	3658	80300	123432	3816	0.1968	4.5554	4.7522	3.0916
Canada	412000	5460	8990	426450	590550	14450	1.2803	2.1081	3.3884	2.4469
Czech Rep.	160073	1245	6200	167518	189837	7445	0.7432	3.7011	4.4443	3.9218
Denmark	50898	210	620	51728	71658	830	0.4060	1.1986	1.6045	1.1583
Estonia	37184	55	439	37678	40719	494	0.1460	1.1651	1.3111	1.2132
Finland	53900	405	1705	56010	72486	2110	0.7231	3.0441	3.7672	2.9109
France	364315	3376	3953	371643	553576	7329	0.9084	1.0637	1.9721	1.3239
Germany	986832	4492	11346	1002671	1201117	15838	0.4480	1.1316	1.5796	1.3186
Greece	77256	279	2077	79612	103797	2356	0.3504	2.6089	2.9594	2.2698
Hungary	68105	118	2248	70470	86628	2366	0.1674	3.1900	3.3575	2.7312
Iceland	1674	4	12	1690	2571	16	0.2367	0.7101	0.9467	0.6223
Ireland	29038	111	859	30008	56861	970	0.3699	2.8626	3.2325	1.7059
Italy	400047	2027	13826	415900	532890	15853	0.4874	3.3244	3.8117	2.9749
Latvia	24209	51	81	24341	35669	132	0.2095	0.3328	0.5423	0.3701
Lithuania	37332	110	295	37737	12044	405	0.2915	0.7817	1.0732	3.3627
Luxembourg	12133	16	32	12181	13448	48	0.1314	0.2627	0.3941	0.3569
Monaco	106	1	1	108	111	2	0.9259	0.9259	1.8519	1.8018
Netherlands	157530	731	1643	159904	208307	2374	0.4571	1.0275	1.4846	1.1397
New Zealand	22240	223	189	22652	71889	412	0.9845	0.8344	1.8188	0.5731
Norway	26403	273	310	26986	47129	583	1.0116	1.1487	2.1604	1.2370
Poland	371433	777	1860	374070	78372	2637	0.2077	0.4972	0.7049	3.3647
Portugal	43281	312	552	44145	68442	864	0.7068	1.2504	1.9572	1.2624
Romania	165382	941	4640	170962	229105	5581	0.5504	2.7141	3.2645	2.4360
Russia	2298900	4200	5394	2308494	2998767	9594	0.1819	0.2337	0.4156	0.3199
Slovakia	56585	525	186	57296	72496	711	0.9163	0.3246	1.2409	0.9807
Slovenia	13294	141	158	13594	19212	299	1.0372	1.1623	2.1995	1.5563
Spain	207592	1588	6261	215441	301431	7849	0.7371	2.9061	3.6432	2.6039
Sweden	51328	840	1860	54028	69467	2700	1.5547	3.4427	4.9974	3.8867
Switzerland	40330	187	431	40948	53749	618	0.4567	1.0526	1.5092	1.1498
UK	558091	2507	5165	565763	726642	7672	0.4431	0.9129	1.3560	1.0558
Ukraine	672075	752	2077	674904	919220	2829	0.1114	0.3077	0.4192	0.3078
USA	4866000	13776	64170	4943946	5902990	77946	0.2786	1.2980	1.5766	1.3204
							19.7012	56.4064	76.1076	61.2395
					AVERAGE	→	0.5629	1.6116	2.1745	1.7497

Notes
1. Data are from the UNFCCC database
2. All emissions are in Gg of CO_2 equivalent for the year 1990
3. Japan is not included because of negative entries and Liechtenstein is not included because there are no data for CH_4 and N_2O emissions

APPENDIX B

Consumption of Coal, Gas/Diesel Oil, Residual Fuel Oil and Natural Gas in the different sectors for all Annex b countries*

in ktoe

	Coal	Gas/Diesel Oil	Residual Fuel Oil	Natural Gas
Energy Industries	1107827	13817	205187	601259
Manufacturing Industries	92966	66327	77821	314814
Transport	748	270244	7109	18984
Other Sectors				
Commercial	21897	46483	15217	97996
Residential	46672	76910	6367	209731
Agriculture	3840	57149	2818	6311
Other	11710	9760	2199	11749

* This table has been constructed by the consultant from IEA database. The details of the construction are as follows.

1. From the OECD total for the 4 fuels the data for the following countries were subtracted - Korea, Mexico and Turkey
2. The data for the following countries were added to the OECD total after the above deductions – Bulgaria, Estonia, Latvia, Lithuania, Romania, , Russia, Slovakia, Slovenia and Ukraine
3. Thus, the following countries' data were not included – Croatia, Liechtenstein and Monaco

APPENDIX C

CO_2, CH_4, N_2O Emissions from Fuel Combustion Activities and CH_4/CO_2 and N_2O/CO_2 Ratios for the 5 IPCC CRF Table 7A Categories

	Energy Industries					Manufacturing Industries				
	CO_2	CH_4	N_2O	$CH_4/CO2$	N_2O/CO_2	CO_2	CH_4	N_2O	CH_4/CO_2	N_2O/CO_2
Australia	141807	40	437	0.000282	0.003082	47363	34	229	0.0718	0.4835
Austria	12363	3	43	0.000243	0.003478	7432	10	32	0.1346	0.4306
Belgium	28140	6	657	0.000213	0.023348	31027	29	598	0.0935	1.9274
Bulgaria	49249	61	3503	0.001239	0.071128	9086	4		0.0440	
Canada	141000	34	837	0.000241	0.005936	54700	36	496	0.0658	0.9068
Czech R.	94090	149	3813	0.001584	0.040525	23104	25	775	0.1082	3.3544
Denmark	25865	21	310	0.000812	0.011985	5776	21		0.3636	
Estonia	28461	1	1	0.000035	0.000035	2897	1		0.0345	
Finland	18400	25	372	0.001359	0.020217	14100	40	372	0.2837	2.6383
France	65495	46	561	0.000702	0.008566	82266	92	856	0.1118	1.0405
Germany	412896	168	4433	0.000407	0.010736	196457	261	1860	0.1329	0.9468
Greece	43658	4	837	0.000092	0.019172	9820	34	465	0.3462	4.7352
Hungary	29746					7893				
Iceland	4					243				
Ireland	10863		428		0.039400	5431	4	136	0.0737	2.5041
Italy	148445	105	6169	0.000707	0.041557	78117	170	2945	0.2176	3.7700
Latvia	9530	11	22	0.001154	0.002308	2683	2	6	0.0745	0.2236
Lithuania	16425	15	112	0.000913	0.006819	5396	9	43	0.1668	0.7969
Luxem.	1883	0	2		0.001062	6353	1	11	0.0157	0.1731
Monaco	37	0	1		0.027027					
Nether.	51040	63	155	0.001234	0.003037	41400	84	31	0.2029	0.0749
NZ	6040	6	10	0.000993	0.001656	4710	9	38	0.1911	0.8068
Norway	7396	42		0.005679		3043				
Poland	236582	189	930	0.000799	0.003931	49820	315	310	0.6323	0.6222
Portugal	17015	27	78	0.001587	0.004584	7225	33	56	0.4567	0.7751
Romania	74856	129	2699	0.001723	0.036056	49585	73	599	0.1472	1.2080
Slovakia	11970		62		0.005180	25398	42	62	0.1654	0.2441
Slovenia	6483	18	16	0.002776	0.002468	2488	4		0.1608	
Spain	75184	260	3166	0.003458	0.042110	47971	125	1612	0.2606	3.3604
Sweden	8849	21	310	0.002373	0.035032	13050	105	620	0.8046	4.7510
Switzer.	963	1	2	0.001038	0.002077	5406	7	8	0.1295	0.1480
UK	229316	162	2099	0.000706	0.009153	94757	246	1100	0.2596	1.1609
USA	1748400	483	7440	0.000276	0.004255	1052500	2940	5270	0.2793	0.5007
Average				0.001208	0.016197	Average			0.2079	1.5033

	Transport					Other Sectors				
	CO_2	CH_4	N_2O	CH_4/CO_2	N_2O/CO_2	CO_2	CH_4	N_2O	CH_4/CO_2	N_2O/CO_2
Australia	59596	617	1600	0.01035	0.026847	12178	1588	115	0.13040	0.00944
Austria	13569	70	319	0.00516	0.023509	13256	340	190	0.02565	0.01433
Belgium	19964	195	288	0.00977	0.014426	26262	90	856	0.00343	0.03259
Bulgaria	11756	61	93	0.00519	0.007911	5378	4	62	0.00074	0.01153
Canada	147000	525	6510	0.00357	0.044286	69900	4830	992	0.06910	0.01419
Czech R.	7959	57	248	0.00716	0.031160	35948	1016	1364	0.02826	0.03794
Denmark	10474	42		0.00401		8664	126		0.01454	
Estonia	2656	41	11	0.01544	0.004142	3169	12	427	0.00379	0.13474
Finland	11900	69	527	0.00580	0.044286	7300	237	217	0.03247	0.02973
France	122566	500	1228	0.00408	0.010019	93987	2738	1308	0.02913	0.01392
Germany	162281	1338	3193	0.00824	0.019676	203439	2684	1860	0.01319	0.00914
Greece	15170	69	186	0.00455	0.012261	8168	172	620	0.02106	0.07591
Hungary	8208					20877				
Iceland	721	4	6	0.00555	0.008322	704	2	6	0.00284	0.00852
Ireland	4885	25	56	0.00512	0.011464	7859	81	239	0.01031	0.03041
Italy	95521	1296	1116	0.01357	0.011683	76805	449	3596	0.00585	0.04682
Latvia	5829	33	34	0.00566	0.005833	6142	5	22	0.00081	0.00358
Lithuania	5791	30	59	0.00518	0.010188	6810	47	53	0.00690	0.00778
Luxem.	2625	4	14	0.00152	0.005333	1272	12	6	0.00943	0.00472
Monaco	39	0	0			29	0	0		
Nether.	28560	164	1426	0.00574	0.049930	35400	342	31	0.00966	0.00088
NZ	8645	148	110	0.01712	0.012724	2733	58	27	0.02122	0.00988
Norway	13533	84	310	0.00621	0.022907	2431	147		0.06047	
Poland	29103	147	310	0.00505	0.010652	55749	126	310	0.00226	0.00556
Portugal	14060	100	164	0.00711	0.011664	4468	149	254	0.03335	0.05685
Romania	9417	30	108	0.00319	0.011469	29081	232	977	0.00798	0.03360
Slovakia	5168	21		0.00406		13813	357	62	0.02585	0.00449
Slovenia	3179	16	37	0.00503	0.011639	1144	22	105	0.01923	0.09178
Spain	58260	257	627	0.00441	0.010762	26177	946	856	0.03614	0.03270
Sweden	18650	483	930	0.02590	0.049866	10672	210	310	0.01968	0.02905
Switzer.	14668	94	351	0.00641	0.023930	18322	78	59	0.00426	0.00322
UK	116721	620	1300	0.00531	0.011138	112032	1475	600	0.01317	0.00536
USA	1482400	5292	49910	0.00357	0.033668	549200	5061	1550	0.00922	0.00282
Average	Average			0.00707	0.019024	Average			0.02162	0.02626

	Other				
	CO_2	CH_4	N_2O	CH_4/CO_2	N_2O/
Australia	1680	3	6	0.00179	0.00
Austria					
Belgium	526				
Bulgaria	1015		31		0.03
Canada					
Czech R.					
Denmark	119				
Estonia					
Finland	2200	34	217	0.01545	0.09
France					
Germany	11760	42		0.00357	
Greece	440				
Hungary	1381	118		0.08545	
Iceland	2				
Ireland		81			
Italy	1159	4		0.00345	
Latvia	25				
Lithuania	2910	9	28	0.00309	0.00
Luxem.					
Monaco					
Nether.	1100				
NZ	113	3	4	0.02655	0.03
Norway					
Poland	179				
Portugal	512	4	3	0.00781	0.00
Romania	2443	8	130	0.00327	0.05
Slovakia	234				
Slovenia					
Spain					
Sweden	107				
Switzer.	972	8	9	0.00823	0.00
UK	5265	5	65	0.00095	0.01
USA	33500				
Average	Average			0.01451	0.02

Notes
1. Data are from the UNFCCC database
2. All emissions are in Gg of CO_2 equivalent for the year 1990.
3. Japan is not included because of negative entries, Liechtenstein, Russia and Ukraine are not included because there are no data for CH_4 and N_2O emissions.