

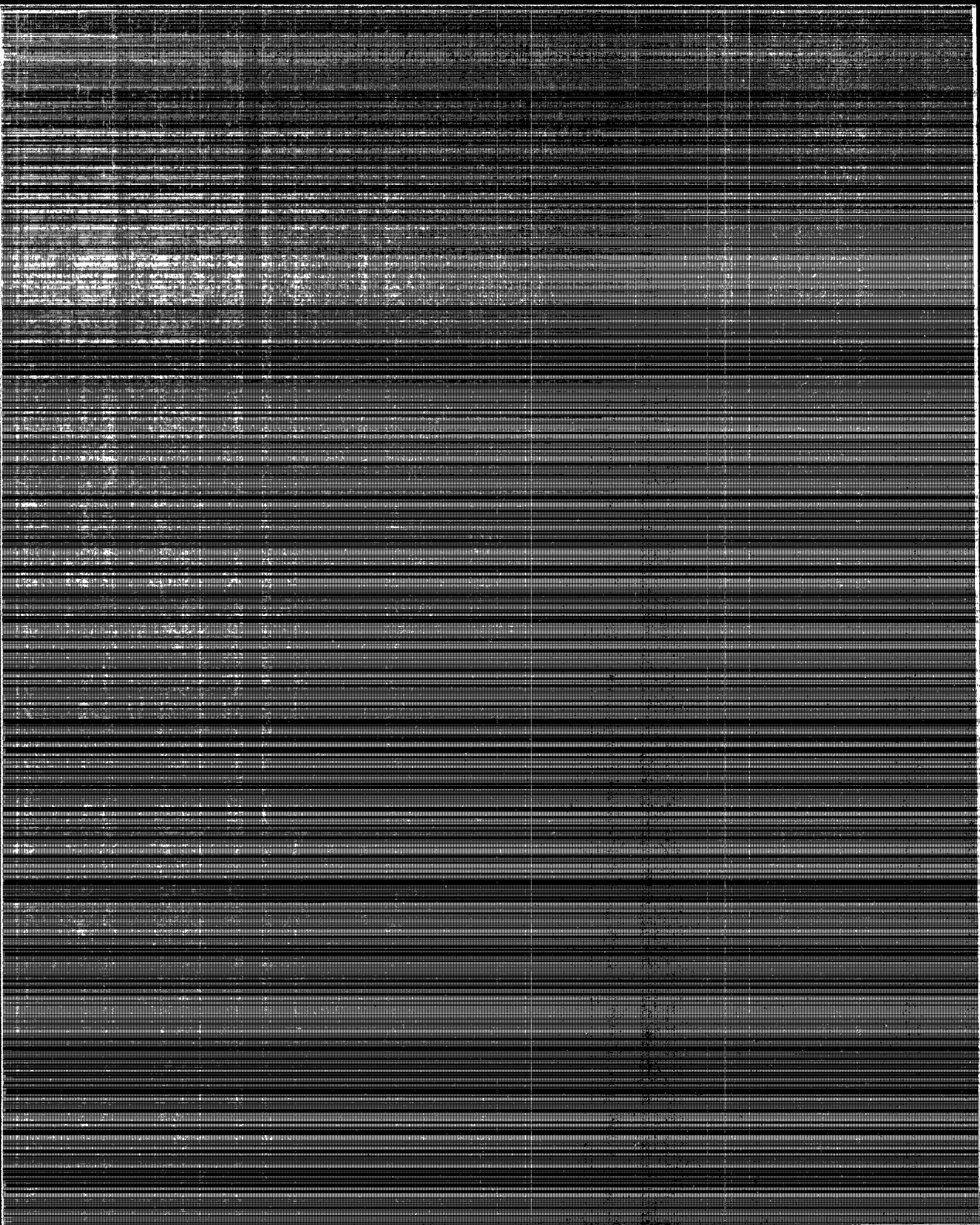


Greenhouse Gas Inventory Workbook

Final Draft



IPCC Draft Guidelines for National
Greenhouse Gas Inventories



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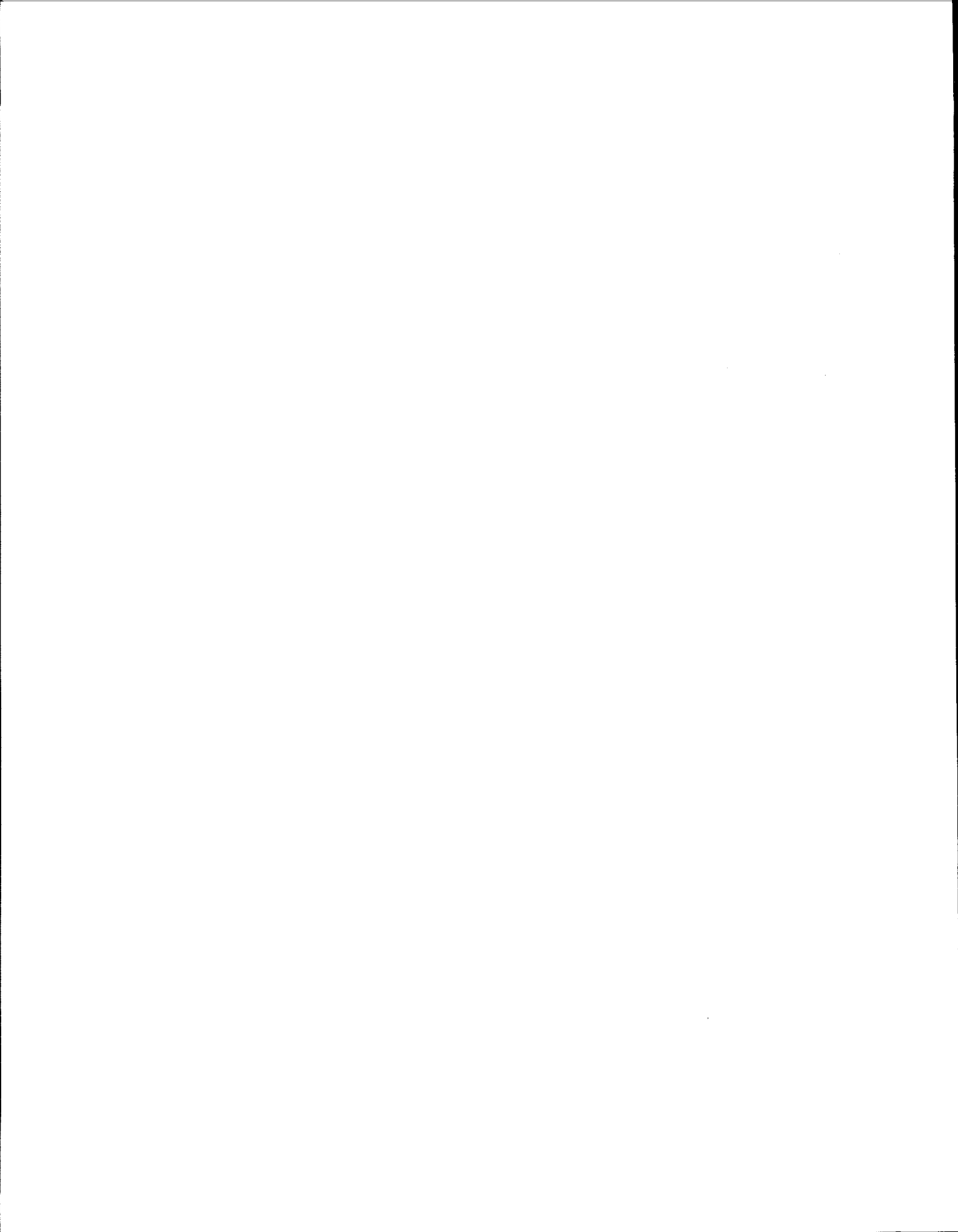
As a result of the review process this draft is expected to undergo amendment and correction before being presented for approval by IPCC WGI in September 1994 and by IPCC plenary in November 1994.

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WORKBOOK CORRIGENDA

page Introduction.18, Table entitled "4 Agriculture" - heading for savanna burning should be "4F" instead of "5F"

page 1.7, Table 1-1, edit 4th row of table to read:

10 ³ t	Multiply by the conversion factor, 41,868 GJ/10 ³ t, to convert to GJ
-------------------	--

In margin under "Conversion Factors" edit as follows:

Replace: Default conversion factors for oil and coal products for many countries are provided separately.

With: Default conversion factors for oil and coal products for many countries are provided in Vol. 3, Reference Manual.

page 1.8, Table 1-3 change emission factors for lignite, sub-bituminous coal and solid biomass as follows:

lignite	27.6
sub-bituminous coal	26.2

solid biomass	29.9
---------------	------

page 1.10, alter Table 1-4 as follows:

Table 1-4 FRACTION OF CARBON OXIDISED	
Coal	0.98*
Oil and oil products	0.99
Gas	0.995
*This figure is a global average but varies for different types of coal, and can be as low as 0.90	

page 1.12, in section entitled "Optional Worksheet 1-2", change title as follows:

Replace: Unprocessed Biomass Burned.....

With: Traditional Biomass Burned.....

page 1.14, in section "Worksheet 1-3", change title as follows:

Replace: Unprocessed Biomass Burned.....

With: Traditional Biomass Burned.....

page 1.15, in Table 1-6 change values in row labelled "General Biomass" and "Agricultural Residues" as foll

Fuel Type	CH ₄	CO	N ₂ O	NO _x
General Biomass	0.010 (0.007-0.013)	0.060 (0.04-0.08)	0.007 (0.005-0.009)	0.121 (0.094-0.148)

Agricultural Residues	0.005 (0.003-0.007)			
-----------------------	---------------------	--	--	--

Step 3, part 2, edit first line as follows:

Replace: For each fuel type, multiply Biomass Burned.....

With: For each fuel type, multiply Total Carbon Released.....

Step 4, part 1, edit as follows:

Replace: Default ratios are given in Table 1-5.

With: Default ratios are given in Table 1-6.

page 1.16

Step 5, edit title as follows:

Replace: Estimating Emissions of Nitrogen and Nitrous Oxide

With: Estimating Emissions of Nitrogen as Nitrous Oxide

Step 6, edit title as follows:

Replace: Estimating Emissions of Nitrogen and Nitrogen Oxides

With: Estimating Emissions of Nitrogen as Nitrogen Oxides

page 1.18, below equation at end - units for CH₄ Emissions delete "(tonnes)" and insert "(Gg)"

page 1.19

Step 1, part 1, edit as follows:

Replace: Enter the amount of coal produced by each type of mining activity, in tonnes, in column A.

With: Enter the amount of coal produced by each type of mining activity, in millions of tonnes, in column A.

Step 1, part 3, line 2:

Replace: ... to give methane emission (in cubic meters)

With: ... to give methane emission (in millions of cubic meters)

Step 2, part 2, line 1:

Replace: Multiply the Methane Emissions in m³.....

With: Multiply the Methane Emissions in 10⁶ m³.....

Table 1-7 - the table should be edited as follows:

Table 1-7 HIGH AND LOW EMISSION FACTORS FOR MINING ACTIVITIES (m ³ /tonne)		
	Type of Mine/Activity	
Emission factor	Underground	Surface
Mining	10 - 25	0.3 - 2.0
Post-mining	0.9 - 0.4	0 - 0.2

page 1.22, margin - delete the note entitled "Treating Associated Oil and Gas Production"

page 1.23, in Table 1-8 change row labels under Oil and Gas Production as follows:

Oil ¹
Gas ¹
Oil/Gas ²

At the bottom of Table 1-8 delete the existing note and replace with:

¹ These emission factors are for fugitive and routine emissions from production of oil or gas. They do not include venting and flaring emissions. Emissions calculated using these factors should be added to the venting and flaring emissions.

² These are the default emission factors for all venting and flaring from oil and gas production.

pages 1.25-1.29, in Worksheet 1.1 - "Total" row should appear below "Gaseous Fossil". "Bunkers" and "Biomass" are information entries which should not be included in "Totals". Column A should be blacked out for all liquid fossil *secondary* fuels and all solid fossil *secondary* fuels. Columns A-D should be blacked out for the four rows of bunker fuels.

page 1.43

The first 3 rows of Worksheet 1-5 should be edited as follows:

Category	STEP 1			STEP 2
	A Activity	B Emissions Factor	C CH ₄ Emissions (kg CH ₄)	D Emissions CH ₄ (Gg CH ₄)
OIL SYSTEMS			C=(AxB)	D=(C/10 ⁶)

In Worksheet 1-5, for both Oil Systems and Gas Systems, add "2" after "production". Change the heading "Unallocated Oil/Gas Production" to read "Venting and Flaring from Oil and Gas Production³".

Add notes as follows:

"² If using default emission factors these categories will include emissions from production other than venting and flaring."

"³ If using default emission factors, emissions from venting and flaring from all oil and production should be accounted for here."

page 4.7, step 2, part 1, second paragraph edit as follows:

Replace: Table 4-3 provides default.....

With: Table 4-4 provides default.....

pages 4.14 and 4.15, continuation of Table 4-6, column headings should be repeated at the top of each page of the table as follows:

Country	1990 Area (1000s ha)	Season Length (days)	Continuously Flooded (%)	Dry (%)	Intermittently Flooded (%)
---------	-------------------------	----------------------------	--------------------------------	------------	----------------------------------

page 4.17, section "Methodology", paragraph 2, edit as follows:

Replace: First the quantity of biomass exposed to burning is calculated.....

With: First the quantity of biomass that actually burns is calculated.....

page 4.18, step 1, edit title as follows:

Replace: Estimating total biomass exposed to burning

With: Estimating total biomass that actually burns

page 4.18, step 1, part 2, line 2 table reference should be Table 4-8, not Table 4-9.

page 4.19, step 1, part 4 - table reference should be Table 4-8, not Table 4-9.

page 4.21

Introduction, line 3 - delete the sentence which starts "It has been estimated..." and ends "...highly uncertain)."

Data sources, line 3, delete "(e.g. FAO, 1986)"

page 4.23, step 3, part 3, line 1, edit as follows:

Replace: Multiply the Amount of Dry Residue by the Fraction Exposed to Burning.....

With: Multiply the Amount of Dry Residue by the Fraction Burned in Fields.....

page 4.24

In Table 4-13 edit row for CO as follows:

Gas	Default	Range
CO	0.06	0.04-0.08

Step 6, part 4, third line, edit as follows:

Replace: Enter the results in kilotonnes (the same as megagrams).....

With: Enter the results in kilotonnes (the same as gigagrams).....

page 4.25, Worksheet 4-1, column F, formula - should read " $F=(C+E)/1000$ ".

page 4.33, Worksheet 4-3, Sheet C - rows should be labelled for different trace gases at the left hand edge (as at right hand edge) as follows:

CH₄
CO
N₂O
NO_x

In column R all units should be Gg instead of Mg.

page 4.35, Worksheet 4-4, Sheet A, column E, edit title as follows:

Replace: Quantity of Residue
With: Quantity of Dry Residue

page 4.39, Worksheet 4-4, Sheet D, first 2 rows should be edited as follows:

M Emissions Ratio	N Trace Gas Emissions (kt C of kt N)	O Conversion Factors	P Trace Gas Emissions from Field Burning of Agricultural Wastes
	$N = J \times M$		$P = N \times O$

Rows should be labelled for different trace gases at left edge as at right edge:

CH₄
CO
N₂O
NO_x

In column P all units should be Gg instead of Mg.

page 5.4, Figure entitled "Relationships among categories", list of trace gases after top and bottom arrows should be edited as follows:

Replace: --> CH₄, CO₂, N₂O and NO_x Emissions
With: --> CH₄, CO, N₂O and NO_x Emissions

page 5.6, Data Sources - delete the last 2 bullet items:

- Areas of abandoned managed.....
- Numbers of trees in non-forest.....

page 5.7, Table 5-1 change the following values (those values not stated remain the same):

Table 5-1 ABOVEGROUND DRY MATTER IN TROPICAL FORESTS								
	Closed forests						Open forest	
	Broadleaf			Conifer				
	Undisturbed	Logged	Unproductive	Undisturbed	Logged	Unproductive	Productive	Unproductive
America			150	150	60	60		
Africa			185	130	60	110	36	16
Asia			230	160	135	130	61	

page 5.8, Step 3, part 1 edit as follows:

Replace: Enter the Fraction of Biomass Exposed to Burning Off site.....
With: Enter the Fraction of Biomass Burned Off site.....

page 5.12, Step 1, part 1 edit as follows:

Replace: Enter the estimate of Total Carbon Released from burning of
With: Enter the estimate of Total Carbon Released from on-site burning of

page 5.13, Table 5-4 - correct values to read as follows:

Compound	Ratio
CH ₄	unchanged
CO	0.06 (0.04-0.08)
N ₂ O	0.007 (0.005-0.009)
NO _x	0.121 (0.094-0.148)

page 5.13, step 2, part 6, edit as follows:

Replace: by the conversion factors in the table.....

With: by the conversion factors in column F.....

page 5.14

Step 1 - in parts 1, 4 and 5 change "20" to "25", and "twenty" to "twenty-five".

Step 1, part 2, edit as follows:

Replace: Enter the Soil Carbon Content of Grasslands in kilotonnes of carbon per hectare (kt C/ha)

With: Enter the Soil Carbon Content of Grasslands in tonnes of carbon per hectare (t C/ha)

page 5.15 - delete "emissions" and insert "removals" in 3 places -

Introduction, line 1

Methodology, line 1

Methodology, last line

page 5.15, Introduction, paragraph 4, line 3, edit as follows:

Replace: Abandoned areas are therefore split into those which reaccumulate carbon and those which do not continue to degrade.

With: Abandoned areas are therefore split into those which reaccumulate carbon and those which do not regrow or which continue to degrade.

page 5.16, step 1, part 2 - change kilotonnes to tonnes

page 5.17

Table 5-6 - delete the row labelled "secondary".

Step 2, part 1 - change kilotonnes to tonnes.

Step 3, part 2 - change kilotonnes to tonnes.

page 5.18

Step 4, part 1 - change kilotonnes to tonnes.

Step 5, change title to - "CALCULATE TOTAL CO₂ REMOVALS FROM ABANDONED LANDS".

page 5.19, in the margin - delete the note entitled "Fractions".

page 5.20, step 1, parts 3 and 4 - change kilotonnes to tonnes.

page 5.21, Step 1, part 8, line 2, edit as follows:

Replace: matter to give the Total Carbon content. Enter the result in column E.

With: matter to give the Total Carbon Increment. Enter the result in column E.

page 5.22, in the margin box entitled "Using Commercial Harvest Statistics" edit first bullet to read:

- The default conversion factor is 0.5 t dm/m³

page 5.22

Step 2, parts 2 and 3 replace "Expansion Factor" with "Conversion/Expansion Factor".
Step 2, part 4, line 1, edit as follows:

Replace: Total Fuelwood Consumption from.....

With: Total Fuelwood Consumption (including wood for charcoal production) from.....

Step 2, part 7, line 2:

Replace: Worksheet 5-1 Quantity of Biomass exposed to burning off site).....

With: Worksheet 5-1 Quantity of Biomass Burned off site).....

Step 4, part 2, line 2:

Replace: ... the Net Annual CO₂ Accumulation. Enter.....

With: ... the Annual CO₂ Removal (if a positive value) or Emissions (if a negative value). Enter.....

page 5.23-5.27, Worksheet 5-1, Sheets A, B and C - in heading for columns F,G, L and M delete "Exposed to Burning" and insert "Burned".

page 5.31, Worksheet 5-1, Sheet E - This worksheet should have the same Forest Types as Sheets A-D.

For all of these sheets (A-E), Boreal should be subdivided into "Primary" and "Secondary"

Worksheet 5-1, Sheet E, column B, change title from "Cleared Land" to "Forest Soil".

page 5.33, Worksheet 5-2, Sheet A, column A - note in the second row should be edited as follows:

Replace: (From column Q of Worksheet 5.1)

With: (From column K of Worksheet 5.1, Sheet B)

page 5.35

Worksheet 5-3, sheet A - in columns A and E, delete "20" and insert "25".

Worksheet 5-3, sheet A, column B - change units from kt C/ha to t C/ha.

pages 5.37 - 5.41

Worksheet 5-4, in columns B and I - change units from kt dm/ha to t dm/ha.

Worksheet 5-4, in columns F and M - change units from kt C/ha to t C/ha.

page 5.45, Worksheet 5-5, Sheet B - for columns I through M, all of the rows above the total row should be blacked out. Only totals should be reported for these values.

page 5.43, Worksheet 5-5, sheet A, column B - change units from kt dm/ha to t dm/ha.

page 5.47, Worksheet 5-5, column P, heading should read "Annual Carbon Uptake or Release".

page 6.5, Table 6-1, second column headed "Waste Generation", units should read "(Gg/10⁶ persons/yr)"

page 6.8, Table 6-3, change values in third column to read as follows:

BOD ₅ Values Gg/1000 persons/ year
0.0135
0.0146
0.0182

page 6.9, step 2, part 3, edit as follows:

Replace: Enter the Methane Emissions Factor, in gigagrams CH₄/kg BOD₅, in column F.
With: Enter the Methane Emissions Factor, in gigagrams CH₄/gigagrams BOD₅, in column F.

Replace: The recommended emissions factor is 22 gigagrams CH₄/gigagrams BOD₅.
With: The recommended emissions factor is 0.22 gigagrams CH₄/gigagrams BOD₅.

page 6.10, Table 6-5, alter the following rows:

Food and beverage industry	
Wine	20,000
Meat packing	16,000-20,000 litres/ton live weight

page 6.15, Worksheet 6-1 (supplemental), columns A and B - change "1000 persons" to "10⁶ persons"

page 6.17, Worksheet 6-2, column F - change units from "(Gg CH₄ / kg BOD₅)" to "(Gg CH₄ / Gg BOD₅)"

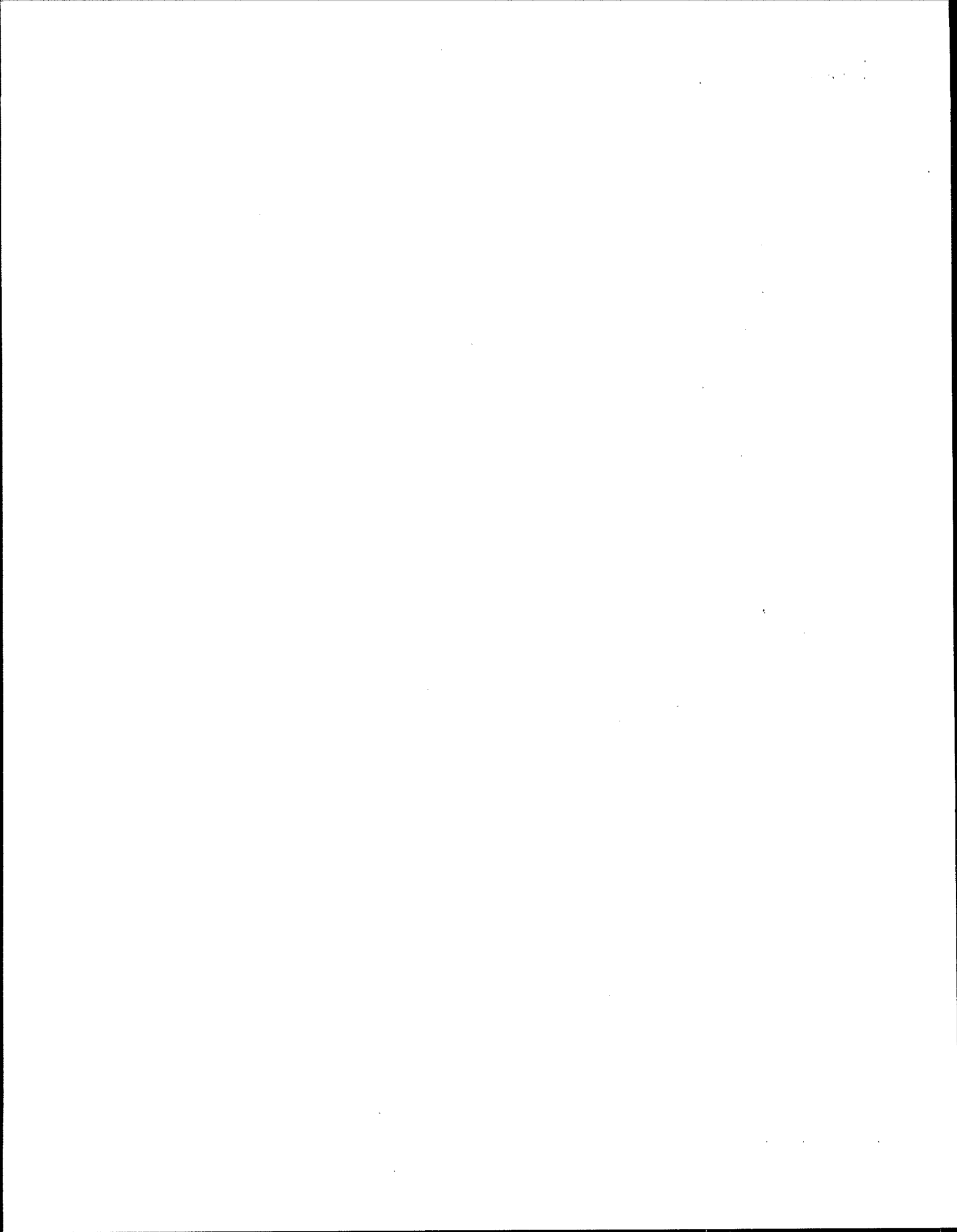
page 6.19, Worksheet 6-3, sheet A:

Column A - change units from "k litres" to "M litres"

Column B - change units from "Gg/litre" to "kg/litre"

Column F - change "22 Gg CH₄ / Gg BOD₅" to "0.22 Gg CH₄ / Gg BOD₅"

PREFACE



Signature of the UN Framework Convention on Climate Change (UNFCCC) by around 150 countries in Rio de Janeiro in June 1992 indicated widespread recognition that climate change is a potentially major threat to the world's environment and economic development. Human activities have substantially increased atmospheric concentrations of greenhouse gases, thus perturbing the earth's radiative balance. According to projections from climate models, a global rise of temperature is a likely consequence. The potential impacts of climate change such as sea level rises and changes in local climate conditions - such as temperatures and precipitation patterns - could have important negative impacts on the socio-economic development of many countries.

The ultimate objective of the Convention is the stabilisation of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level is to be achieved within a time frame sufficient to allow ecosystems to adapt naturally to climate change. The Convention also calls for all Parties to the Conference to commit themselves to three objectives:

- To develop, update periodically, publish, and make available to the Conference of the Parties their national inventories of anthropogenic emissions of all greenhouse gases not controlled by the Montreal Protocol.
- To use comparable methodologies for inventories of greenhouse gas emissions and removals, to be agreed upon by the Conference of the Parties.
- To formulate, implement, publish and update regularly national programmes containing measures to mitigate climate change by addressing anthropogenic emissions.

By the time of the Second World Climate Conference in Geneva in October - November 1990, the need for a standard methodology for compiling national emission inventories was obvious. Under the auspices of the Organisation for Economic Cooperation and Development (OECD) and the International Energy Agency (IEA), with support from the USA, the UK and Norway, an initial compendium of methods (covering all gases except chlorofluorocarbons (CFCs) which were already accounted for under the Montreal Protocol). This document was discussed in detail by a meeting of experts (including many representatives of non-OECD countries) in Paris in February 1991. It was then adopted in a slightly modified form at the fifth session of the Intergovernmental Panel on Climate Change (IPCC) in March 1991 as the starting point for a set of IPCC guidelines to be used by countries drawing up national inventories of greenhouse gas emissions.

The *IPCC Guidelines for National Greenhouse Gas Inventories* consists of three volumes: the *Greenhouse Gas Inventory Reporting Instructions*, the *Greenhouse Gas Inventory Workbook* and the *Greenhouse Gas Inventory Reference Manual*. The *Guidelines* are being distributed world-wide to national experts for review before adoption.

Further development of the methodology has been undertaken by the Scientific Assessment Working Group (WGI) of the IPCC, working in close collaboration with the OECD and the IEA under the IPCC/OECD programme on emissions inventories. The objectives of the programme are:

- Development and refinement of an internationally agreed methodology and software for calculation and reporting of national net emissions.
- Efforts to encourage widespread use of the methodology by countries participating in the IPCC and Parties to the UN Framework Convention on Climate Change.
- Establishment of procedures and a data management system for collection, review and reporting of national data.

In the Guidelines, default methods and assumptions have been developed for characterising the major sources and sinks of greenhouse gases. Countries have the option of using the various methods depending on their own needs and capabilities. Other more detailed methods are also discussed. However, the IPCC/OECD programme is developing a common reporting and documentation framework for all inventories. This will provide for comparison of these methodologically diverse national estimates. It is essential that guidelines for this methodology are internationally agreed upon, and this will be achieved through workshops and expert groups with a broad geographical base.

Additionally, the IPCC/OECD programme is charged with continuing to improve the methodology. This is being achieved through:

- expert groups which review and recommend changes to the method
- results from country studies
- comments and preliminary inventories from countries
- feedback from technical workshops held in Asia, Africa, Latin America and Central and Eastern Europe

About thirty five countries from all over the world have submitted their preliminary inventory data on anthropogenic greenhouse gas emissions and removals from different sources, using a range of approaches including the IPCC methodology. The results of all the above activities have been considered in developing the current *Guidelines*.

The IPCC/OECD programme gives technical support to the greenhouse gas inventory components of country study projects sponsored by UNEP, Asian Development Bank, individual countries etc.. Countries participating in these projects are developing national emission inventories. These country studies will contribute to:

- development of national capacity and capability (including improving baseline data)
- promulgation of the methodology
- realistic testing of the methodology and its guidelines in order to identify strengths and weaknesses

Over thirty countries are currently working on country studies with support from various sponsors.

ACKNOWLEDGEMENTS

The IPCC/OECD Programme on the Development of a Methodology for National Inventories of Net Greenhouse Gas Emissions would like to thank those governments, international organizations, and individuals whose contributions have made the development of this methodology possible.

Financial support for the programme has been provided by the United Nations Environment Programme, the Global Environment Facility, the Organization for Economic Co-operation and Development Environment Directorate, the International Energy Agency, the European Community, and the governments of the United States, the United Kingdom, Switzerland, Italy, Norway, Sweden, and the Netherlands, Germany, France, Canada, and Australia. Significant (non-financial) contributions and resources in kind came from the United Nations Environment Programme, the United States, the Netherlands, the United Kingdom, Japan, the Organization for Economic Cooperation and Development, and the International Energy Agency.

Many individuals have contributed in various ways to the programme. Those who have drafted, commented, and advised in the direct support of the production of these documents include: Jane Ellis, Tim Simmons, and Karen Treanton, of the International Energy Agency; Craig Ebert and Barbara Braatz of ICF Inc.; Karl Jörss of the Federal Environment Agency in Germany; Gordon McInnes of the CEC/European Environment Agency Task Force & UNECE Task Force on Emission Inventories; James Penman of the UK Department of the Environment; André van Amstel of the National Institute for Public Health and Environmental Protection (RIVM) in the Netherlands; Jan Feenstra, Ella Lammers, and Pier Vellinga, of the Institute for Environmental Studies in the Netherlands; Berrien Moore of the University of New Hampshire; Gerald Leach, Jack Siebert, Susan Subak, and Paul Raskin, of the Stockholm Environment Institute; Lucy Butterwick, Martin Parry, and Martin Price, of the University of Oxford;; Michael Short and Peter Usher of the United Nations Environment Programme; N Sundararaman of the IPCC Secretariat; Bert Bolin, Chairman of the Intergovernmental Panel on Climate Change; Tim Weston, Peter Bolter and Austin Pearce of TMS Computer Authors Ltd.; Sir John Houghton, Bruce Callander, Buruhani Nyenzi and Kathy Maskell of the IPCC Working Group I Secretariat; Paul Schwengels, Jan Corfee-Morlot, Jim McKenna, Scott Lurding, and Hans Sperling, of the OECD Environment Directorate.

The IPCC/OECD Programme would like to thank all the participants in the expert groups and in the various regional workshops, especially the

ACKNOWLEDGEMENTS

coordinators and co-chairs of expert groups process to provide improvements in technical methods; L Gylvan Meira Filho of the National Institute for Space Research, Brazil; Berrien Moore of the University of New Hampshire; Paul Crutzen of the Max Planck Institute for Chemistry; Elaine Matthews of NASA; A P Mitra, of the National Physics Laboratory in India; Nigel Roulet of York University in Canada; K Minami of the National Institute for Agro-Environmental Sciences in Japan; M A K Khalil of the Oregon Graduate Institute; Alan Williams of the University of Leeds; Dina Kruger, Susan Thornloe, and Lee Beck, of the US Environmental Protection Agency; Audun Rosland of the State Pollution Control Authority in Norway; Frank Shephard of British Gas plc; Richard Grant of the E&P Forum; Michael Gibbs and Jonathan Woodbury of ICF Inc.; Lis Aitchison of the Energy Technology Support Unit; Ron Leng of the University of New England in Australia; Mark Howden of the Bureau of Resource Sciences, Australia; T Ramasami of the Central Leather Institute in India; Robert Delmas of the Université Paul Sabatier; Dilip Ahuja of the Bruce Company; Chris Veldt and Jan Berdowski of the National Organisation for Applied Scientific Research (TNO-IMW) in the Netherlands; and Jos Olivier of the RIVM.

National case studies were contributed by: Audun Rosland of the State Pollution Control Authority in Norway, Peter Cheng of the Department of Arts, Sport, the Environment, and Territories in Australia, Jane Legget of the US Environmental Protection Agency, Art Jacques of Environment Canada, Sture Boström of Finland, and Karl Jörss of the Federal Environment Agency in Germany, Simon Eggleston of Warren Spring Laboratory in the United Kingdom, André van Amstel of the National Institute for Public Health and Environmental Protection (RIVM) in the Netherlands, I B Obioh of Obafemi Awolowo University Nigeria, P A Ratnasiri of the Ceylon Institute of Scientific and Industrial Research, Gordon McInnes of the CEC/European Environment Agency Task Force & UNECE Task Force on Emission Inventories, Anne Niederberger-Arquit of the Federal Office of Environment, Forests and Landscape in Switzerland, and Kendaro Doi of the Japan Environment Agency.

A very large number of experts have participated in IPCC/OECD expert groups and workshops. All of these contributors have played constructive roles in shaping methods presented here. These efforts reflect an important contribution to the implementation of the Framework Convention on Climate Change, and are greatly appreciated.

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PART 3 GLOSSARY & INDEX

Glossary

Index

PART I
INTRODUCING THE
WORKBOOK

I USING THE IPCC GUIDELINES

This document is one volume of the *IPCC Guidelines for National Greenhouse Gas Inventories*. The series consists of three books:

- THE GREENHOUSE GAS INVENTORY REPORTING INSTRUCTIONS
- THE GREENHOUSE GAS INVENTORY WORKBOOK
- THE GREENHOUSE GAS INVENTORY REFERENCE MANUAL

These books together provide the range of information needed to plan, carry out and report results of a national inventory using the IPCC system.

The *Reporting Instructions* (Volume 1) provide step-by-step directions for assembling, documenting and transmitting completed national inventory data consistently, regardless of the method used to produce the estimates. These instructions are intended for all users of the IPCC Guidelines and provide the primary means of ensuring that all reports are consistent and comparable.

The *Workbook* (Volume 2) contains suggestions about planning and getting started on a national inventory for participants who do not have a national inventory available already and are not experienced in producing such inventories. It also contains step-by-step instructions for calculating emissions of carbon dioxide (CO₂) and methane (CH₄) (also some other trace gases) from six major emission source categories. It is intended to help experts in as many countries as possible to start developing inventories and become active participants in the IPCC/OECD programme.

The *Reference Manual* (Volume 3) provides a compendium of information on methods for estimation of emissions for a broader range of greenhouse gases and a complete list of source types for each. It summarizes a range of possible methods for many source types. It also provides summaries of the scientific basis for the inventory methods recommended and gives extensive references to the technical literature. It is intended to help participants at all levels of experience to understand the processes which cause greenhouse gas emissions and the estimation methods used in compiling inventories.

The three books are designed to be used together and include these features:

- all three volumes use an identical arrangement and numbering by source category for ease of cross reference
- all the books have a common index which allows you to follow up all references to a topic

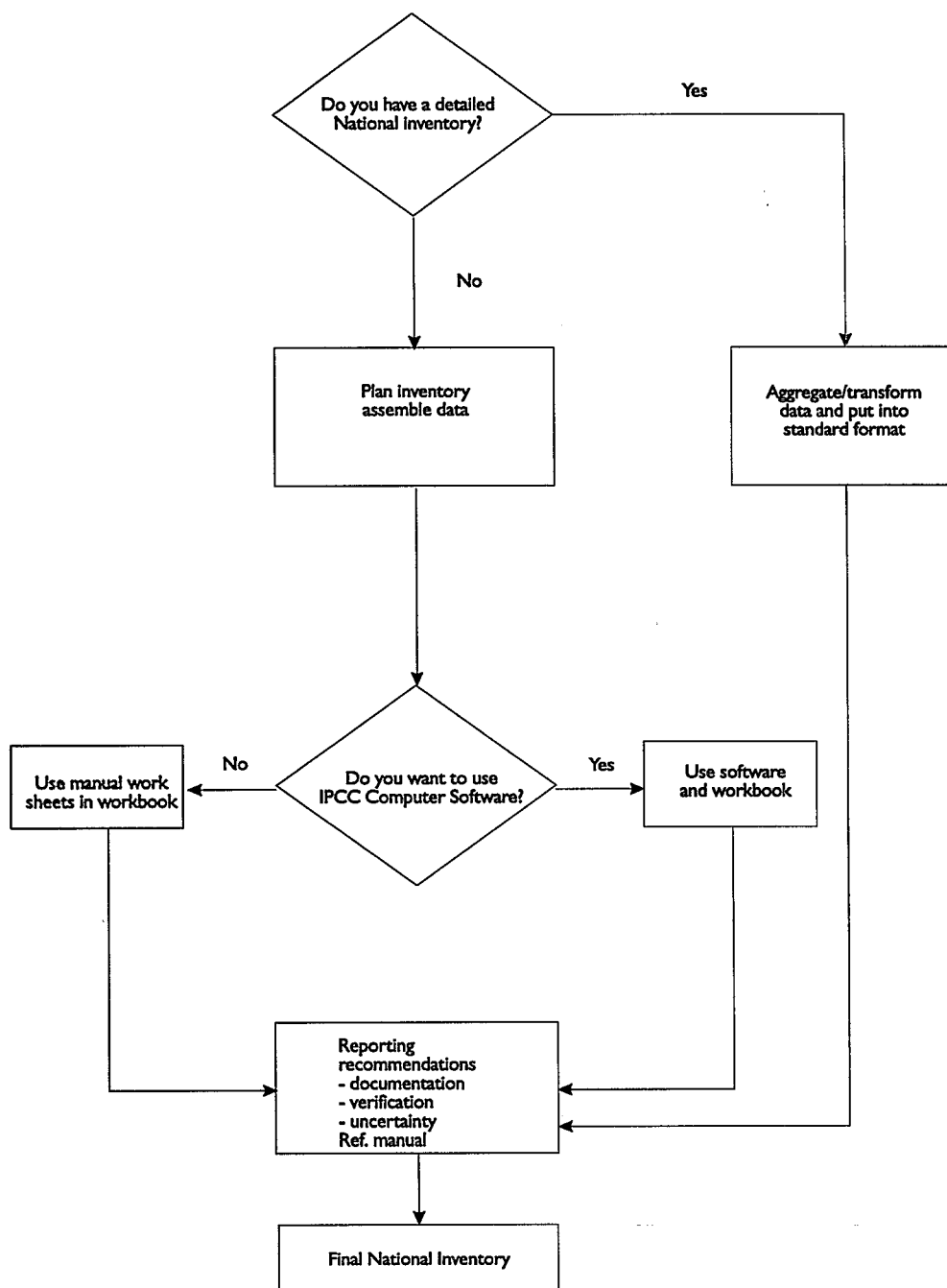
(The common index will be included in the final, approved version but not in the December 1993 review draft.)

- icons in the margin of each book indicate the source category
- colour coding on the page indicates source category.

(Colour will be included in the final, approved version but not in the December 1993 review draft.)

Before you start...

This diagram explains the stages needed to make a national inventory which meets IPCC standards.



The stages are:

Question 1

Do you have a detailed national inventory?

Answer: Yes

If your country already has a complete national inventory, you should transform the data it contains into a form suitable for use by IPCC. This means transforming it into a standard format. In order to do this, use Volume 1 of the *IPCC Guidelines, Reporting Instructions*. This gives details of the way in which data should be reported and documented.

Answer: No

You should start to plan your inventory and assemble the data you will need to complete the Worksheets in this book. Refer to the *Getting Started* section of this *Workbook*.

Question 2

Do you want to use the IPCC computer software?

Answer: Yes

If you want to use the IPCC software, you will still follow the instructions are included in the *Workbook* to assemble the data you have collected into an inventory (see margin box). You will use the software instead of the printed worksheets to enter data.

Answer: No

If you do not use the IPCC software, use the *Workbook* and the Worksheets it contains to assemble the data you have collected into an inventory.

Finally...

Inventory data should be returned to IPCC in the form recommended in the *Reporting Instructions*. It is important that, where 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.

General Notes on the Guidelines

- 1 The flow diagram above is intended as a simple schematic to illustrate the different types of users (working at different levels of inventory detail) and how they should be able to use the various volumes of the Guidelines. You should recognise that reality is more complex than this simplest explanatory chart. Many countries may have some parts 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 parts of their inventory.
- 2 Throughout the Guidelines there is an intentional double-counting of carbon released from human activities. On one hand, CO₂ is calculated based on the assumption that all of the carbon in original fuel, biomass, soils etc. which oxidizes produces CO₂. For combustion sources,

AVAILABILITY OF COMPUTER SOFTWARE

It is expected that IPCC computer software will be incorporated and distributed with the Final Approved IPCC Guidelines. Software is not included with this review draft version. Draft computer software is available for review and testing in English language only. This software includes the same simple default methods as presented in the *Workbook*. If you would like to receive a copy of the draft software, send a letter or fax to:

IPCC/OECD NATIONAL GHG
INVENTORY PROGRAMME
Attn: Scott Lurding
OECD, Environment Directorate
2, rue André-Pascal
75775 PARIS CEDEX 16
FRANCE
FAX 33-1-4524-7876

however, methods are also provided to estimate portions of the original carbon which are released as CH₄ and CO. The primary reason for double counting this is that carbon is that carbon released as CH₄ or CO is eventually converted to CO₂ in the atmosphere. This occurs in less than 15 years, which is short relative to the 100+ years lifetime of CO₂ in the atmosphere. Therefore carbon emitted as CH₄ and CO can have two effects. First, in the form initially emitted, and, second, as part of long term CO₂ accumulation in the atmosphere. In order to have a very precise estimate of the actual emissions of carbon species for a given year (i.e. as input to a complex atmospheric model) you should subtract carbon in reported CH₄ and CO from CO₂ to get net annual CO₂ emissions.

- 3 Many of the categories of greenhouse gas emissions and removals can only be estimated with large ranges of uncertainty. Quite naturally, some national experts have developed methods which are designed to produce ranges of estimates rather than point estimates for highly uncertain categories.. The IPCC Guidelines, however, require that users provide a single point estimate for each gas and emissions/removal category. This is simply to make the task of compilation, comparison and evaluation of national reports manageable. Users are encouraged to provide uncertainty ranges or other statements of confidence or quality along with the point estimates. The procedures for reporting uncertainty information are discussed in the *Greenhouse Gas Inventory Reporting Instructions*.

2 GETTING STARTED

Prefixes and multiplication factors

The following multiplication factors are used throughout this *Workbook*:

Multiplication Factor	Abbreviation	Prefix	Symbol
1 000 000 000 000 000	10^{15}	peta	P
1 000 000 000 000	10^{12}	tera	T
1 000 000 000	10^9	giga	G
1 000 000	10^6	mega	M
1 000	10^3	kilo	k
100	10^2	hecto	h
10	10^1	deca	da
0.1	10^{-1}	deci	d
0.01	10^{-2}	centi	c
0.001	10^{-3}	milli	m
0.0001	10^{-6}	micro	μ

Abbreviations for chemical compounds

The following abbreviations are used in this *Workbook*:

CH ₄	Methane
N ₂ O	Nitrous Oxide
CO ₂	Carbon Dioxide
CO	Carbon Monoxide
NO _x	Nitrogen Oxides
NM VOC	Non-Methane Volatile Organic Compound

Standard equivalents

1 tonne of oil equivalent (TOE)	1×10^{10} calories
10^3 TOE	0.041868 PJ
1 short ton	0.9072 metric tonnes
1 metric tonne	1.1023 short tons
1 metric tonne	1 megagram
1 kilotonne	1 gigagram
1 million tonnes	1 teragram
1 mt	1,490 m ³ CH ₄
1 kg	2.2102 lbs
1 hectare	10 ⁴ m ²

Units and abbreviations

The following abbreviations are used in this *Workbook*:

cubic meters	m ³
hectares	ha
grams	g
kilograms	kg
gigagrams	Gg
megagrams	Mg
teragrams	Tg
tonnes	t
kilotonnes	kt
megatonnes	Mt
joules	J
petajoules	PJ

Getting Started

Six gases are covered in the current version of the Guidelines. These are the direct greenhouse gases carbon dioxide (CO₂), methane (CH₄), and nitrous oxide (N₂O) and the indirect greenhouse gases carbon monoxide (CO), oxides of nitrogen (NO_x) and non-methane volatile organic compounds (NMVOCs). Other gases are being discussed and may be added in future versions of the Guidelines. Halogenated species (i.e. chloroflourocarbons (CFCs), hydrochloroflourocarbon 22 (HCFC-22), the halons, methyl chloroform and carbon tetrachloride) are not included because of parallel reporting requirements of countries in compliance with commitments under the Montreal Protocol.

Although estimation methods are not provided, countries are encouraged to report any emissions or removals for which they have data and which they consider significant to climate change. Procedures for reporting other gases are discussed in Volume I of the Guidelines, *Reporting Instructions*.

To estimate greenhouse gas emissions and removals you should begin by developing a plan or strategy. The first step is the identification of the range of possible source and sink activities that exist in your country. Second, you will need to establish priorities for inventory work based on several considerations. One is the priorities among various greenhouse gases. The IPCC has recommended the direct greenhouse gases CO₂, CH₄, as highest priority. A second is the relative importance of source and sink activities within the country and the availability of relevant information. Finally, once initial priorities have been developed, the analyst must identify and allocate resources to develop the inventory.

A description of greenhouse gas source and sink activities is provided in Volume I. The IPCC Scientific Assessment of 1990 and 1992 Supplement presented the current understanding of the contributions of various source and sink activities in the global atmospheric balances of CO₂, CH₄ and N₂O. This information is included here for consideration by national experts in prioritizing national inventory efforts. Of course, the relative importance of source and sink

categories for a specific country may be substantially different than at a global level.

Tables Introduction-1, Introduction-2 and Introduction-3 (below) summarize the global contributions:

TABLE INTRODUCTION-1 ESTIMATED BUDGET FOR CO ₂ (Gt C/YR) 1989/90		
Net Anthropogenic Sources	Gt C/yr	Range (+/-)
Fossil Fuel Combustion, Gas Flaring and Cement	6.0	0.5
Land Use Change and Deforestation	1.6	1.0
Total Net Sources	7.6	1.5
Natural		
Accumulation in the Atmosphere	(3.4)	(0.2)
Uptake by the Ocean	(2.0)	(0.8)
Terrestrial Sink	(1.0)	(1.0)
Total Accounted Carbon	(6.4)	(1.0)
Total Unaccounted Carbon ("missing sink")	1.2	(0.5)

TABLE INTRODUCTION-2 ESTIMATED BUDGET FOR METHANE (T _g CH ₄ PER YEAR)		
Sources		
<i>Natural</i>	<i>T_g CH₄/year</i>	<i>Range</i>
• Wetlands	115	(100-200)
• Termites	20	(10-50)
• Ocean	10	(5-20)
• Freshwater	5	(1-25)
• CH ₄ Hydrate	5	(0-5)
<i>Anthropogenic</i>		
• Coal Mining, Natural Gas and Petroleum Industry	100	(70-120)
• Rice Paddies	60	(20-150)
• Enteric Fermentation	80	(65-100)
• Animal Wastes	25	(20-30)
• Domestic Sewage Treatment	25	?
• Landfills	30	(20-70)
• Biomass burning	40	(20-80)
Sinks		
Atmospheric (tropospheric + stratospheric) removal	470	(450-520)
Removal by soils	30	(15-45)
Atmospheric Increase	32	(28-37)

TABLE INTRODUCTION-3 ESTIMATED BUDGET FOR NITROUS OXIDE (Tg N Per Year)	
Sources	
<i>Natural</i>	
Oceans	1.4 - 2.6
Tropical Soils	
Wet Forests	2.2 - 3.7
Dry Savannas	0.5 - 2.0
Temperate Soils	
Forests	0.05 - 2.0
Grasslands	
<i>Anthropogenic</i>	
Cultivated Soils	0.03 - 3.0
Biomass Burning	0.2 - 1.0
Stationary Combustion	0.1 - 0.3
Mobile Sources	0.2 - 0.6
Adipic Acid Production	0.4 - 0.6
Nitric Acid Production	0.1 - 0.3
Sinks	
Removal by Soils	?
Photolysis in the Stratosphere	7 - 13
Atmospheric Increase	3 - 4.5

The stages are:

STEP 1 PLANNING THE INVENTORY

1 Review Reporting Instructions

Review the *Reporting Instructions* (Volume I of IPCC Guidelines) so you know what data are required. Look in detail at Chapter 3: *Understanding the Common Reporting Framework*. This discusses standard definitions of pollutants, units, source/sink categories and time periods.

2 Identify priority sources/sinks and priority greenhouse gases. Ultimately, each country should report all important sources and sinks of all greenhouse gases. However, in practice, countries with little prior experience, which are getting started on national inventories, may wish to prioritize the possible gases and sources in terms of relative importance to global and national totals. Proceeding with highest priority sources first will reduce the initial burden on national experts and allow key results to be reported more quickly in international fora

General priorities for countries preparing inventories are (listed in order of highest to lowest priority):

- CO₂ from Energy sources
- CO₂ from Land Use Change

- CH₄ from major source categories: Rice Production; Coal Mining; Oil and Gas Systems; Enteric Fermentation and Animal Waste; Landfills and Other Waste, and Biomass Burning
- Other greenhouse gases

This *Workbook* provides simple methods for all of the CO₂ and CH₄ categories listed above to help national experts in the high priority areas. Countries can modify the suggested priorities based on the importance of these source and sink activities in their own national context.

STEP 2 USING THE IPCC DEFAULT METHODS/DATA

The *Workbook* contains default methods for the estimation of each of the main source categories for CO₂ and CH₄. The *Reference Manual* contains background information on these methods and more detailed options. It also contains information on methods for N₂O and ozone precursors - CO, NO_x, and NMVOC. These methods are in various stages of testing and therefore are associated with different levels of confidence or "quality." IPCC's default methodology aims to provide the simplest realistic procedures for countries to use when making greenhouse gas emissions inventories. Default values are provided for emission factors and (some) activity data. Because default information is frequently general, and applicable to all countries of the world, it may not capture the variations in activities at the regional and national level that may significantly influence emission levels. It is nevertheless a starting point for many countries that are preparing inventories of CO₂ and CH₄ for the first time.

Countries may use more detailed methodologies, emission factors or activity data where these are compatible with IPCC source categories, and can be shown to give consistent and accurate results. Default emission factors and activity data also provide useful points of comparison for national assumptions. If a country's data vary significantly from the default data, the IPCC asks that the difference be explained. The tables in the next section *Availability and Quality of Data* provide an overview of the availability and the quality of default data assumptions by major source category and gas. Some default information is found in the *Modules and Worksheets* part of this *Workbook*. Other country-specific default data are provided separately.

STEP 3 USING THE WORKBOOK

The Workbook

The *Workbook* is designed to be a working document. You use it as an integral part of making an inventory of your country's greenhouse gas emissions and removals. It is divided into six modules, each with its own colour code and icon:

[Colour codes will be provided only in the Final Approved Draft of the IPCC Guidelines, and not in this draft.]

- Energy
- Industrial Processes
- Solvent Use

[Solvent Use is included in this version of the *Workbook* as a placeholder only. No simple estimation methods are provided for this category.]

- Agriculture
- Land Use Change and Forestry
- Waste

Within each module a series of emission sources are identified. Each emission source contains one (or more) Worksheets. These are blank forms for making the inventory which you fill in and return to IPCC.

To help you to use the Worksheets, each emission source section also contains:

- a brief introduction
- a survey of data sources
- an overview of the methodology recommended for the source
- instructions for completing the Worksheet

If you want to know more about a particular emission source, refer to the *IPCC Greenhouse Gas Inventory Reference Manual*. For easy reference, you can use the colour code or the icon to find the relevant part of the Manual.

There is also a common index so you can look up items of interest in both books.

[The index will be provided in the Final Approved IPCC Guidelines and not in this draft.]

STEP 4 PROVIDING DOCUMENTATION

In every case written documentation should be provided explaining the sources of any input data which were not taken from the default data included in the *Workbook*. For example, for energy related GHG this includes energy data, conversion factors, emission factors, production data for products which store carbon and any other information which might affect the results in the inventory.

Preferably your documentation should cite published reports as the source of data. Government ministries, institutes or private firms which have provided data should be identified by a mailing address and a contact person. See Volume I *Reporting Instructions* for details of documentation requirements.

STEP 5 REPORTING FINER LEVELS OF DETAIL IN THE WORKSHEETS

For simplicity and clarity, the *Workbook* deals with calculation of emissions at a national level, with source categories broken down into relatively few sub-categories. The level of detail in the sub-categories is designed to match the available sources of default input data, carbon contents and other assumptions. However, as a user of the emissions methodology *Guidelines*, you are encouraged to carry out your national inventory at as fine a level of detail as possible. If your country has more detailed information on any of the source categories than that used in constructing the default values in this *Workbook*, you are encouraged to use it.

There are two ways in which this is possible:

- Finer geographic detail

Experts may find that it is necessary to divide a country into different regions to capture differences between ecosystems and biomass densities, agricultural practices, rates of burning etc.

- Finer detail by sub-category

Where data are available, experts may subdivide the categories of activity to reflect important differences in economic activity, ecology or species, land use or agricultural practices, rate of burning, etc.

Working at a finer level of disaggregation does not change the nature of the calculations although more locally developed data and assumptions will generally be required. Use multiple copies of the Worksheets for these calculations.

If you have calculated greenhouse gas emissions at a finer level of detail, you should also aggregate results up to the most detailed level of information requested by the IPCC methodology in order to report them. This allows comparisons to be made among the results from countries participating in the inventory. You are also encouraged to report at the underlying level of detail if it is manageable.

Make sure that you report data and assumptions to the IPCC in order to ensure transparency and replicability of methods. *Reporting Instructions* (Volume I of the *Guidelines*) discusses these issues in more detail.

3 DATA AVAILABILITY AND QUALITY TABLES

These tables provide a summary of the types of activity data, emission factors and other data needed to carry out the simplest, default calculations of emissions of CO₂, CH₄, and N₂O. They also indicate the data which are included in the *Workbook* or are readily available from international sources, and provide indicators of the quality of available default data. These indicators reflect the judgement of the IPCC/OECD programme technical staff regarding the likely technical accuracy or quality of default data or emission factors in the context of a national emissions/removals estimate. The differences reflect:

- The variations in availability and quality of international compilations of data on the different categories of human activity which cause emissions
- The representativeness of available global or regional default emission factors when used at as national level.
- Variations in the level of underlying scientific understanding of the various human induced phenomena which cause greenhouse gas emissions.

This information should be useful to national experts in prioritizing efforts to obtain and use more detailed national data, and assessing the quality of any estimates produced.

I Energy

SOURCE CATEGORIES	PRIORITY GASES	AVAILABILITY AND QUALITY OF DATA AND METHODS	
IA FUEL COMBUSTION Activities	CO ₂	Activity Data	Fuel consumption by detailed fuel subcategory. - Provided By IEA (1992). Also available from UN (1992a) (H-M)*
		EF and related data.	Country specific conversion factors (heat content); Global average C content, C emission factors (H-M)*
IA1-2 & IA4-7	CH ₄ , N ₂ O	Activity Data	Fuel consumption must be allocated to specific end-use subsectors and technology or process types to estimate these gases. IEA (1992) or UN (1992a) data provide control totals but no international data are available at the process/technology level (N-P).
	CH ₄	EF	Summarized in <i>Reference Manual</i> (M)
	N ₂ O	EF	Summarized in <i>Reference Manual</i> (L).
IA3 TRANSPORT	CH ₄ N ₂ O	Activity Data	Fuel combustion by vehicle type with fleet profiles, driving characteristics, technology. No international data sources. (NP)
	CH ₄	EF	Summarized in <i>Reference Manual</i> (M)
	N ₂ O	EF	Summarized in <i>Reference Manual</i> (L).
IB FUGITIVE EMISSIONS FROM ENERGY			
IB1 OIL AND GAS SYSTEMS	CH ₄ CO ₂	Activity Data	Oil/Gas production and consumption, oil loaded on tankers IEA (1992) and UN (1992) (H-M)* Number of wells drilled no default data.
	CH ₄	EF	Regional ranges provided. Large uncertainty at country level.
	CO ₂	EF	Do default factors.
IB2 COAL MINING	CH ₄	Activity Data	Underground and surface coal production available from IEA (1992) and UN (1992) (H-M).
		EF	Global average range provided . Large uncertainty at country level. (L)
	CO ₂	Activity Data & EF	(NP)

* In general these default data are quite good and should produce high quality estimates at the country level. There may be a few countries for which data have not been recently and carefully reported or which have unusual fuel characteristics. For these countries, application of default data may produce emission estimates of only moderate quality.

KEY TO ABBREVIATIONS:

GHG - Greenhouse Gas

EF - Emissions Factor

H - High Quality

M - Medium Quality

L - Low Quality

NAV - Not Available

NP - Not Provided

2 Industrial Processes

SOURCE CATEGORIES	PRIORITY GASES	AVAILABILITY AND QUALITY OF DATA AND METHODS	
2A IRON AND STEEL	CO ₂ CH ₄ N ₂ O	Activity Data	Available from UN (1992b) (M)
	CH ₄	EF	(NP)
	CO ₂ N ₂ O	EF	(NP)
2B NON-FERROUS METALS	CO ₂ N ₂ O	Activity Data & EF	(NP)
2C INORGANIC CHEMICALS	N ₂ O	Activity Data	Adipic acid and nitric acid production from UN (1992b) (M)
		EF	Reference Manual (L)
2D ORGANIC CHEMICALS	CH ₄ N ₂ O	Activity Data	Production of specific chemicals from UN (1992b) (M)
		EF	Reference Manual - global average (L)
2E NON-METALLIC MINERALS	CO ₂	Activity Data	Production of specific products from UN (1992b) (M) US Bureau of Mines (1992)
		EF	Reference Manual for cement (M). Other products (NP)
2F OTHER	CO ₂ CH ₄ N ₂ O	Activity Data & EF	(NP)

KEY TO ABBREVIATIONS:
GHG - Greenhouse Gas
EF - Emissions Factor
H - High Quality
M - Medium Quality
L - Low Quality
NAV - Not Available
NP - Not Provided

3 Solvents

[Not treated in this version of the *Workbook*]

4 Agriculture

SOURCE CATEGORIES	PRIORITY GASES	AVAILABILITY AND QUALITY OF DATA AND METHODS	
4A ENTERIC FERMENTATION	CH ₄	Activity Data:	International data on number of animals / country (FAO, 1991a)(H-M), Other data below not provided.
		Other Related Data:	Average weight by animal type, feed intake & type of feed.
		EF	Provided in the <i>Workbook</i> and <i>Reference Manual</i> (M) need testing in countries outside of OECD.
4B ANIMAL WASTES	CH ₄	Activity Data:	International data on number of animals/country FAO (1991a)(H-M). Other data (below) not provided.
		Other Related Data:	- waste production per animal per day - % volatile solids in waste - methane emission potential in volatile solids - fraction of methane potential realised - type of waste storage system.
		EF	Default factors provided for variables identified above but assumptions (and method) not yet extensively tested.(M-L)
4C RICE CULTIVATION	CH ₄	Activity Data:	International data on number of hectare days cultivated annually, (Mathews et al) FAO (1991a) (M)
		Other Related Data:	Irrigation regime, temperature.(M-L)
		EF:	Limited testing, some important parameters not yet included. (M-L)
4D AGRICULTURAL SOILS	N ₂ O	Activity Data:	Nitrogen fertilizer sales per country per year (FAO, 1991b) (M) Organic nitrogen applied, biological fixation (NP)
		Other Related Data:	Soil temperature, moisture content, nitrogen content, atmospheric deposition and others not yet included in method.
		EF:	Default assumptions provided (L)
4E AGRICULTURAL WASTE BURNING	CH ₄ , N ₂ O	Activity Data:	Production by crop FAO (1991a) (H-M) Residue, crop ratios etc. (M-L). Fraction burned in fields (NP)
		Other GHG EF:	Defaults provided (L)
5F SAVANNA BURNING	CH ₄ N ₂ O	Activity Data	Savanna area FAO (1993) (H-M) Crude rules of thumb provided for fraction burned, other biomass characteristics (L)
		Other GHG EF:	Defaults provided (L)

KEY TO ABBREVIATIONS:

GHG - Greenhouse Gas

EF - Emissions Factor

H - High Quality

M - Medium Quality

L - Low Quality

NAV - Not Available

NP - Not Provided

5 Land Use Change & Forestry

SOURCE CATEGORIES	PRIORITY GASES	AVAILABILITY AND QUALITY OF DATA AND METHODS	
5 LAND USE CHANGE & FORESTRY			
5A FOREST CLEARING (INCLUDING BURNING)	CO ₂ and Other GHG	Activity Data:	- quantity of biomass burned - biomass/soil carbon content - % biomass/soil carbon released as CO ₂ - nitrogen/carbon ratio of biomass - trace gas emissions ratios. FAO Assessments (1993) (L)
		EF:	Regional defaults provided (L), limited testing.
5B CONVERSION OF GRASSLANDS TO CULTIVATED LAND	CO ₂	Activity Data	NP
		EF	Regional defaults high uncertainty (L)
5C ABANDONMENT OF MANAGED LANDS	CO ₂	Activity Data	NP
		EF	Regional defaults high uncertainty (L)
5D LOGGING / MANAGED FORESTS	CO ₂	Activity Data	NP
		EF	Regional defaults high uncertainty (L)

KEY TO ABBREVIATIONS:

GHG - Greenhouse Gas

EF - Emissions Factor

H - High Quality

M - Medium Quality

L - Low Quality

NAV - Not Available

NP - Not Provided

6 Waste

SOURCE CATEGORIES	PRIORITY GASES	AVAILABILITY AND QUALITY OF DATA AND METHODS	
6 A LANDFILLS	CH ₄ CO ₂	Activity data:	International data on waste quantities produced by country can be derived from population UN (1991b), OECD (1992), Piccot et al 1990 (L).
		Other Related Data:	- % of total waste landfilled - % of degradable organic carbon (DOC) - % of carbon dissimilated - % CH ₄ in total biogas.
		EF	Based on above data. (L)
6 B WASTE WATER TREATMENT	CH ₄ N ₂ O	Activity Data	BOD in wastewater can be derived from population and industrial production data - UN (1991b) and crude rules of thumb (L)
	CH ₄	EF	Reference Manual (L)
	N ₂ O	EF	NP

KEY TO ABBREVIATIONS:

GHG - Greenhouse Gas

EF - Emissions Factor

H - High Quality

M - Medium Quality

L - Low Quality

NAV - Not Available

NP - Not Provided

Other gases

The IPCC Guidelines also cover methods for calculating and reporting those gases which contribute to the atmospheric formation of ozone. These "indirect" greenhouse gases are carbon monoxide (CO), nitrogen oxides (NO_x) and non-methane volatile organic compounds (NMVOCs). These gases have been treated differently in the Guidelines for several reasons:

- 1 They have been identified as lower priority in IPCC technical workshops on greenhouse gas emissions. It is clear that both the IPCC Guidelines and individual national inventories should ultimately deal comprehensively and consistently with all important greenhouse gases and their sources and sinks. However, development of simple methods and corresponding capacity building efforts in developing countries have focused initially on the highest priority gases - CO₂ and CH₄.
- 2 A great deal of effort has already been expended in individual countries and international organizations on emissions inventories for these gases because of their importance for local and regional air pollution. Thus, a great deal of literature already exists on methods and default information for calculating these emissions.
- 3 Emissions of these gases are largely from energy and industrial sources and are highly dependent on specific technologies, processes and product use, as well as on fuel used or industrial output. A great deal of additional information is required to estimate the major sources of these gases (using existing inventory methodologies) beyond the information needed to estimate the priority direct greenhouse gases. Thus, the inclusion of CO, NO_x and NMVOCs in national inventories implies a more detailed approach than in the existing IPCC simple default methods.

For all of these reasons, the Review Draft of the IPCC Phase I Guidelines does not include original work on methods for estimating CO, NO_x and NMVOCs. Instead, the relevant sections of the Greenhouse Gas Inventory *Reference Manual* and *Reporting Instructions* draw on and refer to the existing major compilations of methods and default factors for these gases. Some key examples are:

Commission of the European Communities (CEC), 1992, *CORINAIR Emission Factor Handbook*, Brussels.

USEPA 1986. *Compilation of Air Pollution Emissions Factors, Vol. 1: Stationary Point and Area Sources, AP.42, Supplement A*.

Piccot, S D, A Chadha, J De Waters, T Lynch, P Marsosudiro, W Tax, S Walata, and J D Winkler, 1990, *Evaluation of Significant Anthropogenic Sources of Radiatively Important Trace Gases*. Prepared for the Office of Research and Development, USEPA Washington DC.

Users who are planning to produce emissions estimates for CO, NO_x and NMVOCs should consult these or similar reference documents as well as the IPCC Guidelines. Information on the quality and availability of default data and assumptions would be discussed in these basic source documents rather than in the IPCC Guidelines.

References - Major Sources of Activity Data

- 1 FAO (Food and Agriculture Organization of the United Nations), 1991a, *Production Yearbook*, FAO, Rome (annual).
- 2 FAO (Food and Agriculture Organization), 1991b, *FAO 1991 Fertilizer Yearbook*, FAO, Rome (annual).
- 3 FAO (Food and Agriculture Organization), 1993, *Forest Resources in the Tropical World*, FAO, Rome (annual).
- 4 Griffin, R C , 1987, CO₂ release from cement production, 1950-1985. In Marland, G., T A Boden, R C Griffin, S F Huang, P Kanciruk and T R Nelson. *Estimates of CO₂ Emissions from Fossil Fuel Burning and Cement Manufacturing, Based on the United Nations Energy Statistics and the US Bureau of Mines Cement Manufacturing Data*. Report N° ORNL/CDIAC-25, Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, Oak Ridge, Tennessee, May 1989. 643-680.
- 5 IEA (International Energy Agency), 1992, *Energy Balances in OECD Countries, and Energy Statistics and Balances of Non-OECD Countries*, Paris, 1992 (annual).
- 6 Matthews, E , I Fung and J Lerner, 1991, Methane emission from rice cultivation: Geographic and seasonal distribution of cultivated areas and emissions. *Global Biogeochemical Cycles* 5:3-24.
- 7 OECD (Organisation for Economic Co-operation and Development/International Energy Agency), 1992, *Environmental Data Compendium* , OECD/IEA, Paris (annual).
- 8 Piccot, S D , A Chadha, J DeWaters, T Lynch, P Marsosudiro, W Tax, S Walata, and J D Winkler, 1990, *Evaluation of Significant Anthropogenic Sources of Radiatively Important Trace Gases*. Prepared for the Office of Research and Development, USEPA Washington DC.
- 9 United Nations, 1992a, *Energy Statistics Yearbook*, United Nations, New York (annual).
- 10 United Nations, 1992b, *United Nations Statistical Yearbook*, United Nations, New York (annual).
- 11 US Bureau of the Mines, 1988, *Cement Minerals Yearbook*, authored by Wilton Johnson, US Bureau of Mines, US Department of the Interior, Washington DC (annual).

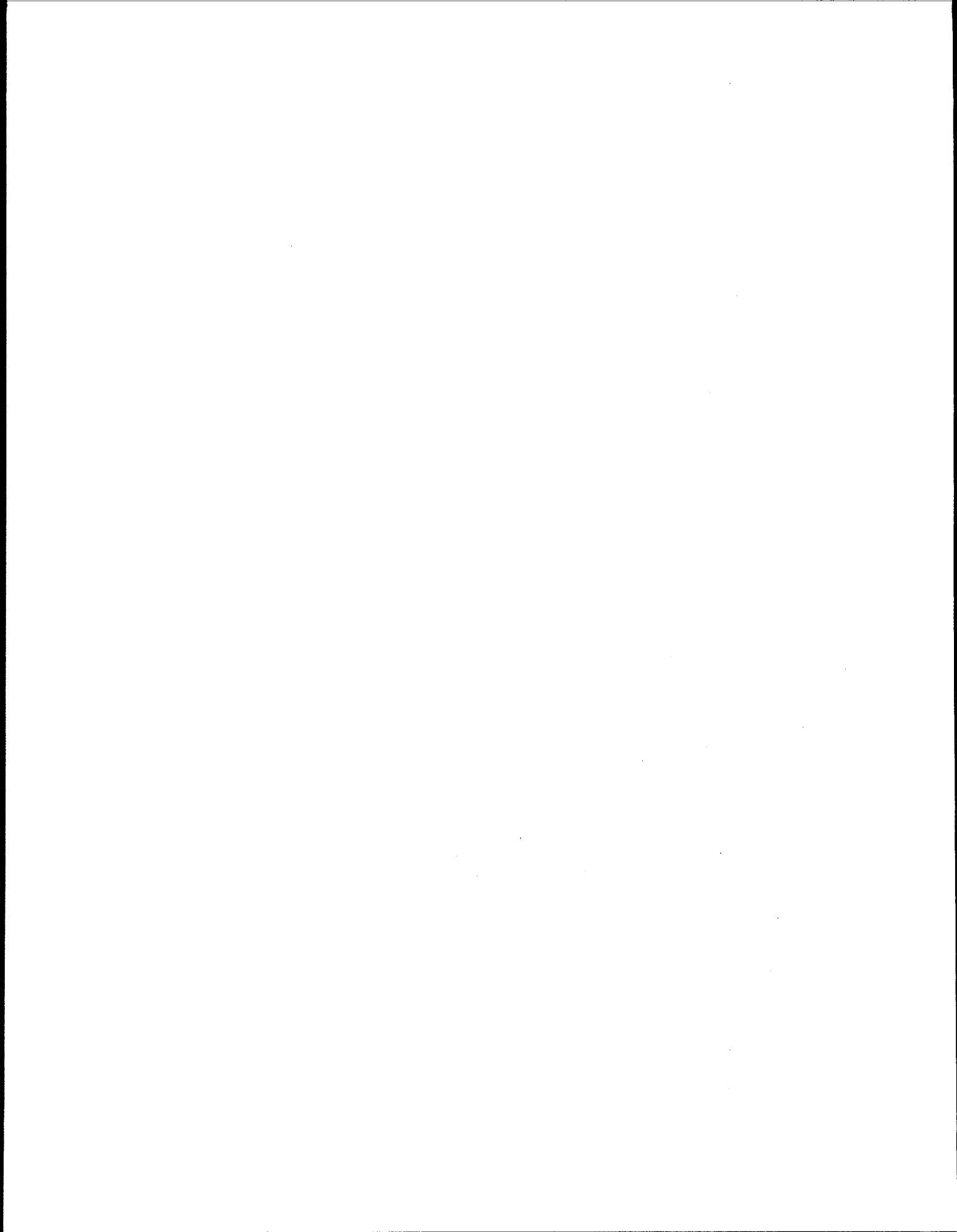
References used in developing emission factors and other default values used in the *Workbook* are discussed in the relevant sections of the *Greenhouse Gas Inventory Reference Manual*.

PART 2
MODULES AND
WORKSHEETS



MODULE I

ENERGY





I ENERGY

I.1 Introduction

This module gives instructions for estimating the emissions of greenhouse gases from energy activities. It is divided into two categories, each with two subcategories:

- Combustion
 - CO₂ from Energy
 - Methane and Other Gases from Traditional Biomass Fuels
- Fugitive
 - Methane Emissions from Coal Production
 - Methane Emissions from Oil and Gas Systems

COMBUSTION

I.2 CO₂ From Energy

Introduction

Carbon dioxide emissions are produced when carbon based fuels are burned. National emissions estimates are made based on amounts of fuels used and the carbon fraction of fuels.

Fuel combustion is widely dispersed throughout most activities in national economies and a complete record of the quantities of each fuel type consumed in each "end use" activity is a considerable task, which some countries have not undertaken. Fortunately, it is possible to obtain an accurate estimate of national CO₂ emissions, by accounting for the carbon in fuels supplied to the economy. The supply of fuels is simple to record and the statistics are more likely to be available in many countries.

In accounting for fuels supplied it is important to distinguish between *primary fuels* (i.e. fuels which are found in nature such as coal, crude oil, natural gas), and *secondary fuels* or fuel products, such as gasoline and lubricants, which are derived from primary fuels.

Accounting for carbon is based mainly on the supply of primary fuels and the net quantities of secondary fuels brought into the country.

To calculate supply of fuels to the country you require the following data for each fuel and year chosen:

- the amounts of primary fuels produced (production of secondary fuels is excluded)
- the amounts of primary and secondary fuels imported

- the amounts of primary and secondary fuels exported
- the net increases or decreases in stocks of the fuels

For each fuel, the production (where appropriate) and imports are added together and the exports and stock changes are subtracted to calculate the apparent consumption of the fuels.

The manufacture of secondary fuels should be ignored in the main calculation, as the carbon in these fuels has already been accounted for in the supply of primary fuels from which they were derived. However, information on production of some secondary fuel products is required to adjust for carbon stored in these products.

An examination of this procedure shows that, in effect, it calculates the supply of primary fuels to the economy with adjustments for net imports (imports-exports) and stock changes in secondary fuels. It is important to note that, in cases where exports of secondary fuels exceed imports or stock increases exceed net imports, negative numbers will result. This is correct, and should not give rise to concern.

Three other important points influence the accounting methodology:

- *Stored carbon*

Not all fuel supplied to an economy is burned for heat energy. Some is used as a raw material (or feedstock) for manufacture of products such as plastics or in a non energy use (e.g. bitumen for road construction), without oxidation (emissions) of the carbon. This is called *stored carbon*, and is deducted from the carbon emissions calculation. Estimation of the stored carbon requires data for fuel use by activities using the fuel as raw material. These requirements are explained later.

- *Bunker fuels*

The methodology for the estimation of the fuel requirements of a country satisfies the IPCC requirement that deliveries of fuels for international marine or aviation bunkers be included in domestic consumption. However, for information purposes, the quantities and types of fuels delivered for bunker purposes should be separately identified.

- *Biomass fuels*

Biomass fuels are included in the national energy and emissions accounts for information only. For completeness, biomass fuels are included in the Worksheet for this section (*Worksheet 1-1*), but not included in the summation of national CO₂ emissions from energy. If biomass is being regrown at roughly the same rate as it is being harvested on an annual basis, the net flux of CO₂ into the atmosphere is zero.

If energy use (or any other factor) is causing a long term decline in carbon stored in standing biomass, this net release of carbon should be evident in the calculation of CO₂ emissions in the **Land use Change and Forestry** modules in this *Workbook*.



Data Sources

For purposes of establishing consistency, the IPCC methodology recommends that all countries initially calculate emissions for the year 1990.

In addition to locally available sources in many countries, there are various international sources of energy data. Compendia of energy statistics, based on national reporting, are published by the International Energy Agency in Paris, and the United Nations Statistical Office in New York. These compendia are compiled from reports made to these bodies by the administrations of member countries. The categories and definitions of fuels and fuel products used in this *Workbook* are based on IEA reporting conventions.

Where available from the International Energy Agency, default energy data and conversion factors for individual countries are provided along with this document. Data for over a hundred countries are provided separately in the IPCC format.

In addition to energy data, default emissions factors, and other input assumptions, are provided in the *Workbook* methodology where available. In calculating national emissions, users of this method are free to override any of these assumptions or recommendations if other information is preferred. Wherever information is used other than the values recommended in the *Workbook*, this should be noted and documentation should be provided on the sources of the information.

Methodology

The IPCC methodology breaks the calculation of carbon dioxide emissions from fuel combustion into 6 steps:

- Step 1: Estimate Apparent Fuel Consumption in Original Units
- Step 2: Convert to Common Energy Units
- Step 3: Multiply by Emission Factors to Compute Potential Emissions
- Step 4: Compute Carbon Stored
- Step 5: Correct for Incomplete Combustion
- Step 6: Convert Carbon Oxidised to CO₂ Emissions

Completing the Worksheet

Use Worksheet I-1 Energy to enter the data for this sub module.

This section provides step-by-step instructions for calculating emissions at the detailed fuels and fuel products level.

This approach allows checking against data on actual flows (e.g. imports, exports) of commodities in order to provide greater detail and accuracy. In general, available international energy statistics are consistent with this level of detail, and locally available data should also be available for at least this level of detail. This is the IPCC recommended approach.

USING THE WORKSHEET

- Copy the Worksheet at the end of this section to complete the inventory.
- Keep the original of the Worksheet blank so you can make further copies if necessary.

NOTE: An aggregate approach is also possible, as described in the *Greenhouse Gas Inventory Reference Manual*. However you should note that it is much less accurate.

STEP 1 ESTIMATING APPARENT FUEL CONSUMPTION

STOCK CHANGE DATA

An increase in stock is a positive stock change and, since it is subtracted, will decrease Apparent Consumption; a stock reduction (use of fuel from existing stocks) is a negative value and will increase Apparent Consumption.

IEA DATA

IEA internationally reported data (if available) are provided separately in a country specific form. You can use these default data for input or for comparison if you wish.

BUNKER FUEL

Where indicated in Worksheet 1-1, enter the amount of a particular fuel consumed as bunker fuel (energy used in international transportation). Bunker consumption data and related emissions are listed separately for informational purposes only. These uses are already included in the total apparent consumption for relevant fuels and should not be summed in totalling national fuel combustion or emissions.

EXPORT DATA

In some data sources, Exports are shown as a negative number. For this method, all Exports data should be entered as positive.

- To calculate apparent consumption (or total fuel supplied) for each fuel, enter the following data for primary fuels.

- Production (column A)
- Imports (column B)
- Exports (column C)
- Stock Change (column D)

- For secondary fuels and products, the only figures to be entered are:

- Imports (column B)
- Exports (column C)
- Stock Change (column D)

These allow the overall calculation to account for all consumption.

Amounts of all fuels can be expressed in Joules (J), Megajoules (MJ), Gigajoules (GJ), Terajoules (TJ), Thousands of Tonnes of Oil Equivalent (ktoe). Solid or liquid fuels can be expressed as 10^3 tonnes (10^3 t) and Dry Natural Gas can be expressed as Teracalories (Tcal).

If you report quantities of fuel expressed in energy units (Terajoules, toe, etc.), you should ensure that the quantities have been calculated using the Net Calorific Values (**Lower Heating Value**) which is 95% of the higher heating value (HHV) for Liquid Fossil, Solid Fossil, and Biomass Fuels and 90% of HHV for Gaseous Fossil Fuels. Default energy data are provided in LHV. For other sources, you must determine if the figures are in LHV or HHV and make conversions if necessary.

- When you have entered data in columns A to D, calculate Apparent Consumption for each fuel using this formula:

$$\text{Apparent Consumption} = \text{Production} + \text{Imports} - \text{Exports} - \text{Stock Change}$$

Enter the result in column E.

- When you have estimated Apparent Consumption for each fuel, add the results for Solid Fossil, Liquid Fossil, Gaseous Fossil, and Biomass Fuels and enter the totals in the relevant boxes.



STEP 2 CONVERTING TO COMMON ENERGY UNITS (GJ)

**TABLE I-1
CONVERSION FACTORS**

UNIT	CONVERSION FACTOR
J, MJ or TJ	Multiply by the appropriate factor of 1,000 to convert to GJ.
10 ³ toe units	Multiply by the conversion factor, 41,868 GJ/10 ³ toe, to convert to GJ
Tcal units	Multiply by the conversion factor, 4.1868x10 ³ GJ/Tcal.
10 ³ t	Fuel specific and in some cases country specific conversion factors should be used to convert to GJ.

NOTE: When converting from 10³ t, for Coking Coal, Steam Coal, Lignite, and Sub-bituminous Coal, separately shown *Country Specific Conversion Factors* provide different conversion values for Production (column A), Imports (column B), and Exports (column C). For these fuels, the user should calculate Apparent Consumption by converting Production, Imports, Exports, and Stock Changes to GJ first. For Stock Change (column D), use either a weighted average conversion factor or select a factor appropriate to the dominant source of supply.

1 Enter the conversion factor used for each fuel in column F.

Tables I-1, I-2 and other tables provided separately show conversion factors.

**TABLE I-2
CONVERSION FACTORS FOR OTHER PRODUCTS**

	Factors (GJ/10 ³ tonnes)
Gasoline	44800
Kerosene	44750
Jet Fuel	44590
Gas/Diesel Oil	43330
Residual Fuel Oil	40190
LPG	47310
Naphtha	45010
Bitumen	40190
Lubricants	40190
Petroleum Coke	40190
Refinery Feedstocks	44800
Other Oil Products	40190
Other Products	
Coal Oils and Tars derived from Coking Coals	28000

See the *Greenhouse Gas Inventory Reference Manual* for sources.

CONVERSION FACTORS

If detailed conversion factors are available in your country, they should be used. Default conversion factors for oil and coal products for many countries are provided separately. If conversion values for your country are not listed that table, select conversion factors for a country that approximates the heat content values for fuels in your country.

Conversion Factors for Refined Petroleum Products and some other products are shown in Tables I-1 and I-2.

In all cases, you should report the conversion factors which you have used in column F. If you use values other than those provided, please include a note explaining the source of the factors.

TABLE 1-3 CARBON EMISSION FACTORS	
Fuel	Carbon Emission Factor (kg C/GJ)
LIQUID FOSSIL	
<i>Primary fuels</i>	
Crude oil	20.0
Natural Gas Liquids	15.2
<i>Secondary fuels/products</i>	
Gasoline	18.9
Kerosene	19.6
Jet Fuel	19.5
Gas/Diesel Oil	20.2
Residual Fuel Oil	21.1
LPG	17.2
Naphtha	(20.0) ¹
Bitumen	22.0
Lubricants	(20.0) ¹
Petroleum Coke	27.5
Refinery Feedstocks	(20.0) ¹
Other Oil	(20.0) ¹
SOLID FOSSIL	
<i>Primary Fuels</i>	
Coking Coal	25.8
Steam Coal	25.8
Lignite	26.1
Sub-bituminous Coal	27.6
Peat	28.9
<i>Secondary Fuels/Products</i>	
BKB & Patent Fuel	(25.8) ¹
Coke	29.5
GASEOUS FOSSIL	
Natural Gas (Dry)	15.3
BIOMASS	
Solid Biomass	(25.8) ¹
Liquid Biomass	(20.0) ¹
BUNKERS	
Jet Fuel Bunkers	19.5
Gas/Diesel Oil Bunkers	20.2
Residual Fuel Oil Bunkers	21.1
Other Oil Bunkers	(20.0) ¹
¹ This value is a default value until a fuel specific CEF is determined. For oil products and liquid biomass fuel, the default value is that for crude oil. For coal products and solid biomass fuel, the default value is that for steam coal.	

- 2 Multiply the Apparent Consumption by the relevant Conversion Factor to give Apparent Consumption in Gigajoules. Enter the result in column G.
- 3 Add the data into subtotals for Liquid Fossil, Solid Fossil, Gaseous Fossil, and Biomass Fuels Apparent Consumption. Enter the results in the appropriate sub-total boxes.

STEP 3 MULTIPLYING BY CARBON EMISSION FACTORS

- 1 Enter the Carbon Emission Factor (CEF) which you are using to convert Apparent Consumption into Potential Emissions in column H.

Table 1-3 shows default values which you can use if there are no locally available data.

- 2 Multiply the Apparent Consumption in GJ by the Carbon Emission Factor to give the Potential Emissions in kilograms. Enter the result in column I.
- 4 Divide Potential Emissions in kilograms C by 10^6 to give the Potential Emissions in Gigagrams of Carbon. Enter the result in column J.
- 5 Calculate subtotals for Liquid, Solid, Gaseous, and Biomass Fuel categories, then add the subtotals for Solid Fossil, Liquid Fossil, and Gaseous Fossil Fuels to give the Total figure (column J). This is for information purposes only.



STEP 4 CALCULATING CARBON STORED

1 Estimating Fuel Quantities

Enter the data from this calculation in column A of the Auxiliary Worksheet I-1.

For this calculation, new data are required for each fuel or fuel product:

Bitumen and lubricants

Add Domestic Production for Bitumen and Lubricants to the Apparent Consumption in column G of the Auxiliary Worksheet I-1 for these products.

Coal oils and tars

For coking coal, the default assumption is that 6% of the carbon in coking coal consumed is converted to oils and tars. Multiply the apparent consumption for coking coal (from Worksheet I-1, column G) by 0.06. If better information on production of coal oils and tars is locally available, this should be used and the source of the data noted.

Natural gas, LPG, Naphtha and Gas/Diesel oil

Estimate the amount of these fuels that is used as a feedstock for non-energy use.

2 Converting to GJ

Multiply Estimated Fuel Quantities (column A) by the relevant Conversion Factor to give the Estimated Fuel Quantities in GJ. Enter the result in column C of the Auxiliary Worksheet I-1.

3 Calculating Carbon Fraction

Multiply the Estimated Fuel Quantities in GJ (column C) by the Emission Factor (in kilograms carbon per Gigajoule) (column D) to give the Carbon Fraction in kilograms. Divide the figures by 10^6 to express the amount as gigagrams. Enter the results in columns E and F of the Auxiliary Worksheet I-1.

4 Calculating Actual Carbon Stored

Multiply the Carbon Fraction (column F) by the Fraction of Carbon Stored (column G) to give the Actual Carbon Stored. Enter the result in column H of the Auxiliary Worksheet I-1.

When you have completed the Auxiliary Worksheet I-1

- 5 Enter values for Carbon Stored for the relevant fuels/products in column K of Worksheet I-1.
- 6 Subtract the values for Carbon Stored (column K) from Carbon Fraction (column J) to give Net Carbon Emissions. Enter the results in column L.

IF YOU DO NOT WISH TO CALCULATE STORED CARBON...

Skip step four, enter the values from column J in column L of Worksheet I-1, and continue with step 5.

CALCULATING CARBON STORED

To calculate carbon stored, it is necessary to work at a more detailed fuel/fuel product level. In order to carry out this calculation, the user will have to provide some additional information. If this information is not available or considered credible, you may choose not to calculate stored carbon. This should be noted in the documentation of the submitted results.

Use the Auxiliary Worksheet I-1 at the end of this section for your calculations. The majority of stored carbon is accounted for using this list of fuels, but countries are encouraged to report carbon stored for any other fuels that they have data for.

BUNKER FUELS AND BIOMASS FUELS

Bunker fuel and biomass fuel subtotals are for informational purposes only. Bunker fuels are already included in totals and should not be added again. Biomass results should not be added to overall totals. Both should be shown as separate totals at the bottom of the Worksheet.

TABLE I-4 FRACTION OF CARBON OXIDIZED	
Coal	0.02 *
Oil and Oil products	0.01
Gas	0.15
* This figure is a global average but varies for different types of coal, and can be as high as 0.1.	

STEP 5 CORRECTING FOR INCOMPLETE COMBUSTION

- 1 Enter values for Fraction of Carbon Oxidized in column M of the Worksheet I-1. Table I.4 provides information on typical values measured from coal facilities and suggests global default values for solid, liquid and gaseous fuels. If more specific information is locally available, this should be used and documented.
- 2 Multiply Net Carbon Emissions (column L) by Fraction of Carbon Oxidized (column M) and enter the result in column N, Actual Carbon Emissions.

STEP 6 CONVERTING TO CO₂ EMISSIONS

- 1 Multiply Actual Carbon Emissions (column N) by the molecular weight ratio of CO₂ to C (44/12) to find Total Carbon Dioxide (CO₂) emitted from fuel combustion. Enter the results in column O.
- 2 Add the Total Carbon Dioxide emitted from each fuel, excluding emissions from Biomass and Bunkers, shown as separate lines.

This sum is total national emissions of carbon dioxide from fuel combustion.

The total includes bunker emissions because these are subsumed under the relevant fuels as well as shown on separate lines. The bunker and biomass totals should be entered separately for information purposes at the bottom of the Worksheet I-1.



1.3 Methane and other gases from Traditional Biomass Fuels Burned for Energy

Introduction

Emissions of Other gases from Biomass Fuel Combustion

In addition to CO₂ Emissions from Energy Consumption, this *Workbook* provides a method for calculating emissions of other gases - methane (CH₄), carbon monoxide (CO), nitrous oxide (N₂O) and nitrogen oxides (NO_x) - from the combustion of unprocessed biomass fuels (such as fuelwood and dung). "Unprocessed biomass" is intended to include all traditional, small scale use of biomass fuels, such as cookstoves and open fires. In these conditions, emissions can be estimated using ratios of CH₄ and other gases to total carbon oxidized in the biomass, as is done in the various non-energy types of open burning. This category is included in the *Workbook* because, unlike fossil fuel combustion, it is a globally significant methane source category and because it is very important in developing countries likely to be using the *Workbook* approach. For all burning of biomass fuels, the IPCC methodology requires that net CO₂ emissions are treated as zero in the energy sector. The Biomass fuels may be sustainably produced, in which case net emissions would be zero. However, even if all or part of the biomass fuel burned is extracted unsustainably from existing biomass stocks (i.e. forests) it would be difficult to determine, at the point of combustion, what fraction actually represents net emissions. Therefore net CO₂ emissions, which are reflected in reductions in standing biomass stocks, are accounted for in the Land Use Change and Forestry module of the methodology. For burning of biomass fuels it is important to account for the emissions of methane, carbon monoxide, nitrous oxide and oxides of nitrogen (i.e. NO_x, NO and NO₂) at the point of combustion.

The simple methodology has been developed to estimate methane emissions from this source category. However it is quite simple to add three additional emission ratios and to add three other gases of interest. For this reason, CO₂, N₂O and NO_x are included in this section of the *Workbook*. After the CO₂ calculations are completed, a series of worksheets and instructions is provided for calculating the other gases from biomass fuels.

Data Sources

FAO Forest Products Yearbooks.

FAO Forest Resources Assessment 1990: Tropical Countries. Rome 1993.

IEA and UNSO Energy Data

More detailed discussion of data is provided in the *Reference Manual*

Methodology

There are two basic components to the calculation.

First, it is necessary to estimate the amount of carbon released to the atmosphere from biomass fuel burning. This does not represent net emissions, but is needed to derive non-CO₂ trace gas emissions which are net emissions. The activity data required are the consumption of various types of biomass fuels. Based on the type of fuel burned, the amount of carbon released can be calculated (a reflection of Carbon Fraction and burning efficiencies (see Table I-4)).

Second, as with other biomass burning categories, emission ratios are applied to estimate the amount of non-CO₂ trace gas released based on the amount of carbon burned (Table I-5)

Completing the Worksheets

There are two worksheets in this sub module. The first Worksheet (I-2) is optional. You should use it if your country does not possess direct statistics for the consumption of traditional biomass fuels. The figures it contains are then transferred to the second worksheet.

If your country already possesses statistics for the consumption of traditional biomass fuels, you only need to complete the second Worksheet (I-3)

Optional Worksheet I-2 Unprocessed Biomass Burned for Energy (Fuelwood Consumption Accounting)

This Worksheet is intended to help you to estimate statistics on biomass fuel consumption if they are not directly available for your country or if they are incomplete.

USING THE WORKSHEET

- Copy the Worksheet at the end of this section to complete the inventory.
- Keep the original of the Worksheet blank so you can make further copies if necessary

STEP I ESTIMATING TOTAL ANNUAL WOOD CONSUMPTION

- 1 Enter the Population (in thousands) as total or in whatever categories can be supported by existing consumption survey data (e.g. rural, urban) in column A.
- 2 Enter Per Capita Annual Fuelwood Consumption (by population category where appropriate) in kilotonnes **dry matter** per 1000 persons, in column B.

No default data is provided. This approach depends upon the user supplying these *per capita* consumption rates. In many developing countries such fuel consumption surveys have been supported by the FAO, the World Bank or other development assistance agencies.
- 3 Multiply Population (column A) by Per Capita Annual Fuelwood Consumption (column B) to give Total Annual Wood Consumption. Enter the results, in kilotonnes of dry matter, in column C.
- 4 Sum the figures in column C (if appropriate) and enter the total in the Total box at the bottom of the column.



STEP 2 ESTIMATING TOTAL ANNUAL CHARCOAL CONSUMPTION

- 1 Enter Per Capita Annual Charcoal Consumption, in kilotonnes dry matter per 1000 persons, in column D.
- 2 Multiply Population (column A) by Per Capita Annual Charcoal Consumption (column D) to give Total Annual Charcoal Consumption. Enter the results, in kilotonnes of charcoal, in column E.
- 3 Sum the figures in column E (if appropriate) and enter the total in the Total box at the bottom of the column.

STEP 3 ESTIMATING WOOD CONSUMPTION FOR CHARCOAL PRODUCTION

- 1 Enter Charcoal Consumption Expansion Factor (in kilotonnes of fuel wood per kilotonne of charcoal) in column F.

The expansion factor accounts for wood which is lost in the production of charcoal. You should use locally available data where possible. A general default value of 4.0 can be used based on data showing that, on a dry matter basis, wood required for charcoal production is roughly four times the weight of charcoal produced.
- 2 Multiply Total Annual Charcoal Consumption (column E) by the Charcoal Consumption Expansion Factor (column F) to give the Wood Consumption for Charcoal. Enter the results, in kilotonnes of dry matter, in column G.
- 3 Sum the figures in column G (if appropriate) and enter the total in the Total box at the bottom of the column.

STEP 4 ESTIMATING TOTAL WOOD CONSUMPTION FOR FUEL

- 1 Add Total Annual Wood Consumption (column C) to Wood Consumption for Charcoal (column G) to give Total Wood Consumption for Fuel. Enter the results, in kilotonnes of dry matter, in column H.
- 2 Sum the figures in column H (if appropriate) and enter the total in the Total box at the bottom of the column.

The total for Total Annual Wood Consumption (column C), Total Annual Charcoal Consumption (column E) and Wood Consumption for Charcoal (column G) will be used in the next Worksheet.

USING THE WORKSHEET

- Copy the Worksheet at the end of this section to complete the inventory.
- Keep the original of the Worksheet blank so you can make further copies if necessary

MISSING DEFAULT VALUES

If you use fuels for which defaults are not provided in Tables 1-5 and 1-6, you should use locally available data if possible. Otherwise use values for the fuels which you judge to be most similar.

Worksheet 1-3

Unprocessed Biomass Burned for Energy

If there is a significant consumption of traditional biomass fuels in your country which is not included in commercial energy statistics, you should first complete Worksheet 1-2 *Unprocessed Biomass Burned for Energy (Fuelwood Consumption Accounting)*, then use Worksheet 1-3 to continue.

STEP 1 ESTIMATING ANNUAL AMOUNT OF BIOMASS BURNED FOR ENERGY

- 1 For each type of biomass fuel, estimate the annual consumption and enter a value in column A in kilotonnes of dry matter.

Consumption of wood as fuel, charcoal and wood as input to charcoal production may come from Optional Worksheet 1-2.
- 2 For each type of biomass fuel, estimate the combustion efficiency (fraction of biomass oxidized) and enter the fraction in column B.

Default data is shown in Table 1-5.
- 3 Multiply column A by column B to give the amount of Biomass Burned. Enter the result in column C in kilotonnes of dry matter.

TABLE 1-5
BIOMASS FUELS DEFAULT DATA

Fuel Type	Carbon Fraction	Nitrogen-Carbon Ratio	Fraction Oxidized (Combustion efficiency)
Fuelwood	0.45-0.5	0.01	0.87
Charcoal Consumption	0.87	?	0.88
Charcoal Production	0.45-0.5	0.01	0.30
Dung	0.36-0.42	?	0.85
Agricultural Residues ¹	0.4-0.48	0.01-0.02	0.88

¹These are general default values for crop residues. Specific data for residues are provided in the agricultural burning discussion in Module 4. If data on biomass fuels are specific by crop type, these crop specific values can be used.

See the *Greenhouse Gas Inventory Reference Manual* for sources.

STEP 2 ESTIMATING THE AMOUNT OF CARBON RELEASED FOR EACH FUEL TYPE

- 1 For each biomass fuel type, enter the Carbon Fraction (as a fraction of dry matter) in column D.

Default data is shown in Table 1-5.
- 2 Multiply Biomass Burned by the Carbon Fraction to give the Carbon Released for each biomass fuel type and enter the result in column E in kilotonnes of carbon.
- 3 Add the results in column E to give the Total Carbon Released.



STEP 3 ESTIMATING EMISSIONS OF METHANE

- For each fuel type, enter the CH₄-C Ratios in column F.

Use Table 1.6 if you require default values.

TABLE 1-6 NON-CO ₂ TRACE GAS EMISSIONS RATIOS				
Fuel type	CH ₄	CO	N ₂ O	NO _x
General Biomass	0.007-0.13	0.075-0.125	0.005-0.009	0.094-0.148
Fuelwood	0.012 (0.009-0.015)	NA	NA	NA
Agricultural Residues	0.012 (0.009-0.015)	NA	NA	NA
Dung	0.017	NA	NA	NA
Charcoal Combustion	0.0014	NA	NA	NA
Charcoal production	0.063 (0.04-0.09)	NA	NA	NA

See the *Greenhouse Gas Inventory Reference Manual* for sources

Note: Ratios for carbon compounds are mass of carbon released as CH₄ or CO (in units of C) relative to mass of total carbon released from burning (in units of C). Those for nitrogen compounds are expressed as the ratios of nitrogen released as N₂O and NO_x relative to the nitrogen content of the fuel (in units of N).

NA = No data available at present - use general biomass values.

- For each fuel type, multiply the Biomass Burned by the Methane-Carbon Ratio (column F) to give the Carbon Emitted as CH₄ from Biomass Burned for Energy. Enter the results in column G in kilotonnes of carbon.
- Multiply the results in column G by the Conversion Factor for CH₄ (16/12) to give C emitted as CH₄ Emissions from Biomass Burned for Energy. Enter the results in gigagrams CH₄ (which are the same as kilotonnes CH₄) in column H. Add the results in this column and enter the total in the Total box at the bottom of the column.

STEP 4 ESTIMATING EMISSIONS OF CARBON MONOXIDE

- Enter the CO-C Trace Gas Emissions Ratios in column I.
Default ratios are given in Table 1-5.
- Multiply Carbon Released (column E) by the Emissions Ratio for CO (column I) to give the amount of carbon emitted as CO. Enter the results in column J in kilotonnes of carbon.
- Multiply Carbon Emitted as CO (column J) by the C to CO Conversion Factor (28/12) to give CO Emitted. Enter the results in gigagrams CO (which are the same as kilotonnes CO) in column K. Add the results in this column and enter the total in the Total box at the bottom of the column.

STEP 5 ESTIMATING EMISSIONS OF NITROGEN AND NITROUS OXIDE

- 1 Enter Nitrogen-Carbon Fuel Ratios in column L.
These are ratios of carbon in biomass to nitrogen in biomass. See Table I-5 for default values.
- 2 Multiply Carbon Released (column E) by the Nitrogen-Carbon Fuel Ratios (column L) to give Total Nitrogen Released. Enter the result in kilotonnes of nitrogen in column M.
- 3 Enter the N_2O -N Trace Gas Emission Ratios in column N.
Default ratios are given in Table I-6.
- 4 Multiply Total Nitrogen Released (column M) by the N_2O -N Trace Gas Emission Ratio (column N) to give the amount of Nitrogen Emitted as N_2O . Enter the result in kilotonnes N in column O.
- 5 Multiply Nitrogen Released as N_2O (column O) by the N- N_2O Conversion Factor (44/28) to give the amount of N_2O released. Enter the result in gigagrams N_2O (which is the same as kilotonnes of N_2O) in column O. Add the results in this column and enter the total in the Total box at the bottom of the column.

STEP 6 ESTIMATING EMISSIONS OF NITROGEN AND NITROGEN OXIDES

- 1 Enter NO_x -N Trace Gas Emission Ratios in column Q.
Default ratios are given in Table I-6.
- 2 Multiply Total Nitrogen Released (column M) by the NO_x -N Trace Gas Emission Ratios (column Q) to give Nitrogen Emitted as NO_x . Enter the result in kilotonnes of nitrogen in column R.
- 3 Multiply Nitrogen Emitted as NO_x (column R) by the N- NO_x Conversion Factor (30/14) to give the amount of NO_x Emitted in kilotonnes of NO_x . Enter the result in gigagrams (which is the same as kilotonnes) of Nitrogen Oxides, in column S. Add the results in this column and enter the total in the Total box at the bottom of the column.



FUGITIVE SOURCES

1.4 Methane Emissions from Coal Production

Introduction

The process of coal formation, commonly called coalification, inherently generates methane and other by-products. The degree of coalification (defined by the rank of the coal) determines the quantity of methane generated and, once generated, the amount of methane stored in coal is controlled by the pressure and temperature of the coal seam and other, less well-defined characteristics of the coal. The methane will remain stored in the coal until the pressure on the coal is reduced, which can occur through the erosion of overlying strata or the process of coal mining. Once the methane has been released, it flows through the coal toward a pressure sink (such as a coal mine) and into the atmosphere.

The amount of CH_4 generated during coal mining is primarily a function of coal rank and depth, as well as other factors such as moisture. If two coal seams have the same rank, the deeper seam will hold larger amounts of CH_4 because the pressure is greater at lower depths, all other things being equal. As a result, most methane released to the atmosphere from coal mining is assumed to come from underground rather than surface mining.

A portion of the CH_4 emitted from coal mining comes from post-mining activities such as coal processing, transportation, and utilization. Methane is released mainly because the increased surface area allows more CH_4 to desorb from the coal. Transportation of the coal contributes to CH_4 emissions, because CH_4 desorbs directly from the coal to the atmosphere while in transit (e.g., in railroad cars). Utilization of metallurgical coal also emits methane. For instance, in metallurgical coke production coal is crushed to a particle size of less than 5 mm, vastly increasing the surface area of the coal and allowing more CH_4 to desorb. During the coking process, methane, carbon dioxide, and other volatile gases are released. In modern coke ovens, this gas is typically collected and utilized as a fuel source, but in older coke ovens, particularly those used in less developed regions, coke gas is vented to the atmosphere.

Data Sources

Use locally available data where this is available and reliable.

Country statistics on underground and surface coal production are available from the OECD/ IEA. Data on coal production by type (hard coal and lignite) are also available. These data are thought to be reliable.

Total coal production used in this module should be the same as that used for calculating apparent consumption in the CO_2 from Energy section above.

Methodology

On the advice of an expert group (see the *Greenhouse Gas Inventory Reference Manual*), calculations have been organised around a single formula which relates tonnes of coal production to total CH₄ emissions from *mining and post-mining* activities.

The *Workbook* enables the user to operate at several different levels of detail or *tiers* (discussed in more detail in the *Reference Manual*).

Tier 1 is the least accurate and is based upon global average emission factors.

Tier 2 is possible when a country has enough information to develop average emission factors of its own. More detailed calculations can be accommodated by making extra copies of the worksheet and breaking the calculations into sub-national components for which more specific emissions factors may be available.

Tier 3 is based on mine specific measurement of emissions from mine ventilation and degasification. This method is recommended if data are available as it should provide much more accurate country based estimates.

The equation for calculating CH₄ emissions from mining activities is:

CH₄ Emissions	=	Coal Production	x	Emission Factor	x	Conversion Factor
(tonnes)		(tonnes)		(m³ CH₄ / tonne coal)		(Gg CH₄ / m³ CH₄)



Completing the Worksheet

Use WORKSHEET I-4 METHANE EMISSIONS FROM COAL PRODUCTION to enter your data for this sub-module.

STEP 1 ESTIMATING CH₄ EMISSIONS FROM COAL PRODUCTION IN CUBIC METRES (m³)

- 1 Enter the amount of coal produced by each type of mining activity, in tonnes, in column A.

The total amount of coal should be the same as used in the CO₂ from Energy sub module (Worksheet I-1, column A).

- 2 Calculate an Emissions Factor using Table I-7 below. Do this for each type of mining activity involved in your inventory. Select a point within the possible range of values which is appropriate to your country. If you do not have the information to select a point, use an average value. Enter the value in column B.

TABLE I-7 HIGH AND LOW EMISSION FACTORS FOR MINING ACTIVITIES			
Emission Factor	Type of Mine/Activity		
	Underground	Surface	Post-mining
Mining	10 - 25	0.9 - 4.0	Underground: 0.9m ³ /tonne Surface: 0m ³ /tonne
Post-mining	0.9 - 4.0	0 - 0.2	Underground: 4.0m ³ /tonne Surface: 0.2m ³ /tonne

- 3 Multiply the Amount of Coal Produced (column A) by the Average Emissions Factor (column B) to give Methane Emission (in cubic metres) for each type of mining activity. Enter the result in column C.

STEP 2 CONVERTING METHANE EMISSIONS IN m³ TO METHANE EMISSIONS IN GIGAGRAMS

- 1 Enter a conversion factor in column D.

The default conversion factor converts volume of CH₄ to a weight measure (gigagrams) based on the density of methane at 20°C and 1 atm, which is 1.49×10^9 m³ per 1 million metric tonnes. This conversion factor, expressed in a form suitable for this Workbook, is 0.67 Gg/10⁶m³.

- 2 Multiply the Methane Emissions in m³ by the Conversion Factor to give the Methane Emissions in gigagrams. Enter the result in column E. Add the figures and enter the total in the Total box at the bottom of the column.

USING THE WORKSHEET

- Copy the Worksheet at the end of this section to complete the inventory.
- Keep the original of the Worksheet blank so you can make further copies if necessary.

1.5 Methane Emissions from Oil and Gas Systems

Introduction

Oil and gas systems are an important source of methane emissions, probably accounting for about 30 to 70 Teragrams per year (in the range of 10% of total emissions). Methane is emitted to the atmosphere during oil and gas production, processing, storage, transportation and consumption. Sources of emissions within oil and gas systems include: emissions during normal operation, such as emissions associated with venting and flaring during oil and gas production, chronic leaks or discharges from process vents; emissions during routine maintenance, such as pipeline repair; and emissions during system upsets and accidents.

This sub module (and the corresponding sections in other volumes of the Guidelines) deals with the *fugitive* emissions of greenhouse gases. That is, releases of gases due to leakage, venting, flaring or similar causes as opposed to emissions from combustion of fuels for energy purposes. Fugitive emissions from oil and gas systems are primarily methane and carbon dioxide, though smaller quantities of non-methane volatile organic compounds (NMVOCs), carbon monoxide and nitrogen oxides can be released.

Data sources

Levels of oil and gas production, imports and exports are available in published compendia of energy statistics. In addition to locally available sources in many countries there is a variety of international sources of energy data. Compendia of energy statistics, based on national reporting, are published by the International Energy Agency in Paris, and the United Nations Statistical Office in New York. These compendia are compiled from reports made to these bodies by the administrations of member countries. The categories and definitions of fuels and fuel products used in this *Workbook* are based on IEA reporting conventions.

Where available from the International Energy Agency, default energy data and conversion factors for individual countries are provided along with this document. Data for over a hundred countries are provided separately in the IPCC format.

In addition to energy data, default emissions factors, and other input assumptions, are provided in the *Workbook* methodology where available. In calculating national emissions, users of this method are free to override any of these assumptions or recommendations if other information is preferred. Wherever information is used other than the values recommended in the *Workbook*, this should be noted and documentation should be provided on the sources of the information.

Users should ensure that data used in this section are consistent with those entered in the *CO₂ from Energy* calculations. Only very limited data are available that describe methane emissions from natural gas and oil systems. The available published data are reviewed in some detail in the *Greenhouse Gas Inventory Reference Manual*. As described there, these data have been used to develop



broad ranges of default emission factors for major subcategories of oil and gas systems, which capture some of the variation by region. These tables are included in this *Workbook* and can be used to develop initial estimates. However, countries which have significant emissions from this category should consult the discussion in the *Reference Manual* and look for locally available data which will allow the development of more country-specific factors.

Methodology

Three different *tiers* or levels of detail for calculating these emissions are presented in the *Reference Manual*.

- Tier 1 Production based on average emission factors
- Tier 2 Mass balance
- Tier 3 Rigorous source-specific evaluations

Only Tier 1 is presented in this *Workbook*.

This requires assembling activity data (production etc.) for the country, selecting emission factors based on information in the tables of typical regional values (or from locally available data), and multiplying through to produce emissions estimates by major subcategory. Explanations of the regions used are provided below.

Regional Definitions

Regions have been defined considering the limitations in data on emissions factors and activity levels, but also recognizing the key differences in oil and gas systems that are found globally. The following five regions are recommended at this time:

- **US and Canada:** The US is a large producer and importer of oil and is a large producer of gas. Detailed emissions estimates are available for the U.S.
- **Former USSR and Eastern Europe:** Indications are that emissions rates from this region are much higher than emissions rates from other regions, in particular for the gas system. This region includes the former USSR (which is by far the largest oil and gas producer in the region), Albania, Bulgaria, Czech & Slovak Republics, Hungary, Poland, Romania, and Yugoslavia republics.
- **Western Europe:** This region is a net importer of oil and gas, and mainly produces oil and gas off shore. This region includes: Austria, Belgium, Denmark, Faroe Islands, Finland, France, Germany, Gibraltar, Greece, Iceland, Ireland, Italy, Luxembourg, Malta, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, and UK.
- **Other Oil Exporting Countries:** This region includes the world's other major oil producing countries: the 13 OPEC members (Algeria, Gabon, Libya, Nigeria, Ecuador, Venezuela, Indonesia, Iran, Iraq, Kuwait, Qatar, Saudi Arabia and the United Arab Emirates) and Mexico. Generally, these countries produce large quantities of oil and have limited markets for gas.
- **Rest of the World:** This region includes the remaining countries of Asia, Africa, Middle East, Oceania and Latin America.

ALTERNATIVE LEVELS OF DETAIL - TIERS

The information provided in this *Workbook*, including global default emission factors, allows for calculation at the *tier 1* level. *Tier 2* calculations follow the same structure, but would use country or basin specific emission factors if available locally. If a country is capable of *tier 3* estimate this would indicate that the emissions estimates are already available (having been directly measured) and the *Workbook* methodology for calculating emissions is not needed. Countries with *tier 3* estimates can move directly to the *Reporting Instructions* volume of these *Guidelines* for guidance on reporting and documenting emissions estimates.

The highest tier of estimation methodology possible should be used for each component of mining activity. It is acceptable to provide estimates using different tiers for various components, provided that the level of calculation is clearly identified in each component. For example, even if *tier 3* is used to estimate underground emissions, *tier 1* or *2* can be used to estimate emissions from other components of mining activity.

TREATING ASSOCIATED OIL AND GAS PRODUCTION

Oil and gas may be produced separately from different wells or they may be produced jointly from the same wells (associated production). Ranges of default emission factors are provided in Table 1-8 for each of these situations by region. Users working with default data should leave associated oil and gas together and apply factors from the ranges provided using the "Unallocated Oil and Gas Production" section of the Worksheet. Users with locally available emission factors may leave associated oil and gas production together, or may allocate these emissions to oil and gas systems depending on the data available in their countries.

EXPLORATION AND DRILLING

A category of exploration and drilling is included on the Worksheet.

However, no sources of activity data or default emissions are provided. If you have locally available data for these values, enter this. If you are working from default sources you should ignore this category which is only expected to be a small component of emissions.

Completing the Worksheet

Use WORKSHEET 1-5 METHANE EMISSIONS FROM OIL AND GAS SYSTEMS to enter your data for this sub-module.

STEP 1 ESTIMATING THE AMOUNT OF CH₄ EMITTED BY OIL AND GAS ACTIVITIES IN KILOGRAMS

- 1 Enter data for each type of oil and gas production activity in column A.
Data sources are discussed above. Ensure that the data you use are consistent with the activity data used to calculate CO₂ from Energy in the first sub module of this module.
- 2 For each type of activity enter an Emissions Factor in Column B.
Use locally available data or the data in Table 1-8 below. Note that these tables provide a range of values to account for the uncertainty implicit in this method. You should use your judgement to select a single value from this range. You are also encouraged to provide an estimate of uncertainty with the values (see the chapter on Uncertainty in *Greenhouse Gas Inventory Reporting Instructions*).
- 3 Multiply the amounts of oil and gas for each Activity (column A) by the Emission Factor (column B) to give the amount of CH₄ emitted in kilograms CH₄. Enter the results in kilograms in column C

STEP 2 CONVERTING CH₄ EMISSIONS FROM KILOGRAMS TO GIGAGRAMS

- 1 Divide the emissions of CH₄ in kilograms (column C) by 10⁶ to covert to gigagrams. Enter the results, in gigagrams CH₄, in column D.
- 2 Add emissions from Oil Systems and enter the total in the Total CH₄ from Oil Systems box in column D.
- 3 Add emissions from Gas Systems and enter the total in the Total CH₄ from Gas Systems box in column D.
- 4 Add the totals to make a grand total and enter it in the Total from Oil and Gas Systems box at the bottom of column D.



TABLE I-8
REGIONAL EMISSION FACTORS FOR METHANE FROM OIL AND GAS SYSTEMS (kg/PJ)

Source Type	Basis	Western Europe	US & Canada	Former USSR, Central & Eastern Europe	Other Oil Exporting Countries	Rest of the World
OIL & GAS PRODUCTION						
Oil	Oil Produced	300 - 5,000	300 - 5,000	300 - 5,000	300 - 5,000	300 - 5,000
Gas	Gas Produced	14,800 - 27,000	39,600 - 104,000	218,000 - 568,000	40,000 - 96,000	40,000 - 96,000
Oil/Gas ¹	Oil/Gas Produced		3,000 - 14,000			
	Gas Produced	3,000 - 16,000		6,300 - 29,700	739,000 - 1,019,000	170,000 - 209,000
CRUDE OIL TRANSPORTATION, STORAGE AND REFINING						
Transportation	Oil Loaded on Tankers	745	745	745	745	745
Refining	Oil Refined	90 - 1,400	90 - 1,400	90 - 1,400	90 - 1,400	90 - 1,400
Storage Tanks	Oil Refined	20 - 260	20 - 260	20 - 260	20 - 260	20 - 260
NATURAL GAS PROCESSING, TRANSPORT AND DISTRIBUTION						
Processing, Transport and Distribution	Gas Consumed	58,000 - 110,000	60,000 - 117,000	340,000 - 716,000	117,000 - 340,000	117,000 - 340,000
¹ Oil and gas are frequently produced together from the same wells. This category provides ranges of emission factors typical of associated oil and gas production by region. Note that in the US and Canada the emissions are based on total production of both oil and gas, while in the other regions they are based only on the gas portion of joint production.						

		1000000	
		1000000	



MODULE			ENERGY				
SUB MODULE			CO ₂ FROM ENERGY SOURCES (DETAILED FUELS APPROACH)				
WORKSHEET			I-I				
SHEET			A				
			STEP I				
			A	B	C	D	E
			Production	Imports	Exports	Stock Change	Apparent Consumption
FUEL TYPES							E=(A+B-C-D)
Liquid Fossil	Primary Fuels	Crude Oil					
		Natural Gas Liquids					
	Secondary Fuels	Gasoline					
		Kerosene					
		Jet Kerosene					
		Residual Fuel Oil					
		LPG					
		Naphtha					
		Bitumen					
		Lubricants					
		Petroleum Coke					
		Refinery Feedstocks					
		Other Oil					
		Liquid Fossil Totals					
Solid Fossil	Primary Fuels	Coking Coal					
		Steam Coal					
		Lignite					
		Sub-bituminous Coal					
		Peat					
	Secondary Fuels	BKB & Patent Fuel					
		Coke					
		Solid Fossil Totals					
Gaseous Fossil		Natural Gas (Dry)					
Bunkers	Jet Kerosene						
	Residual Fuel Oil						
	Other						
	Total Bunkers						
Biomass	Solid Biomass						
	Liquid Biomass						
	Total Biomass						
Total							

$$\frac{1}{2} \left(\frac{1}{2} + \frac{1}{2} \right) = \frac{1}{2}$$

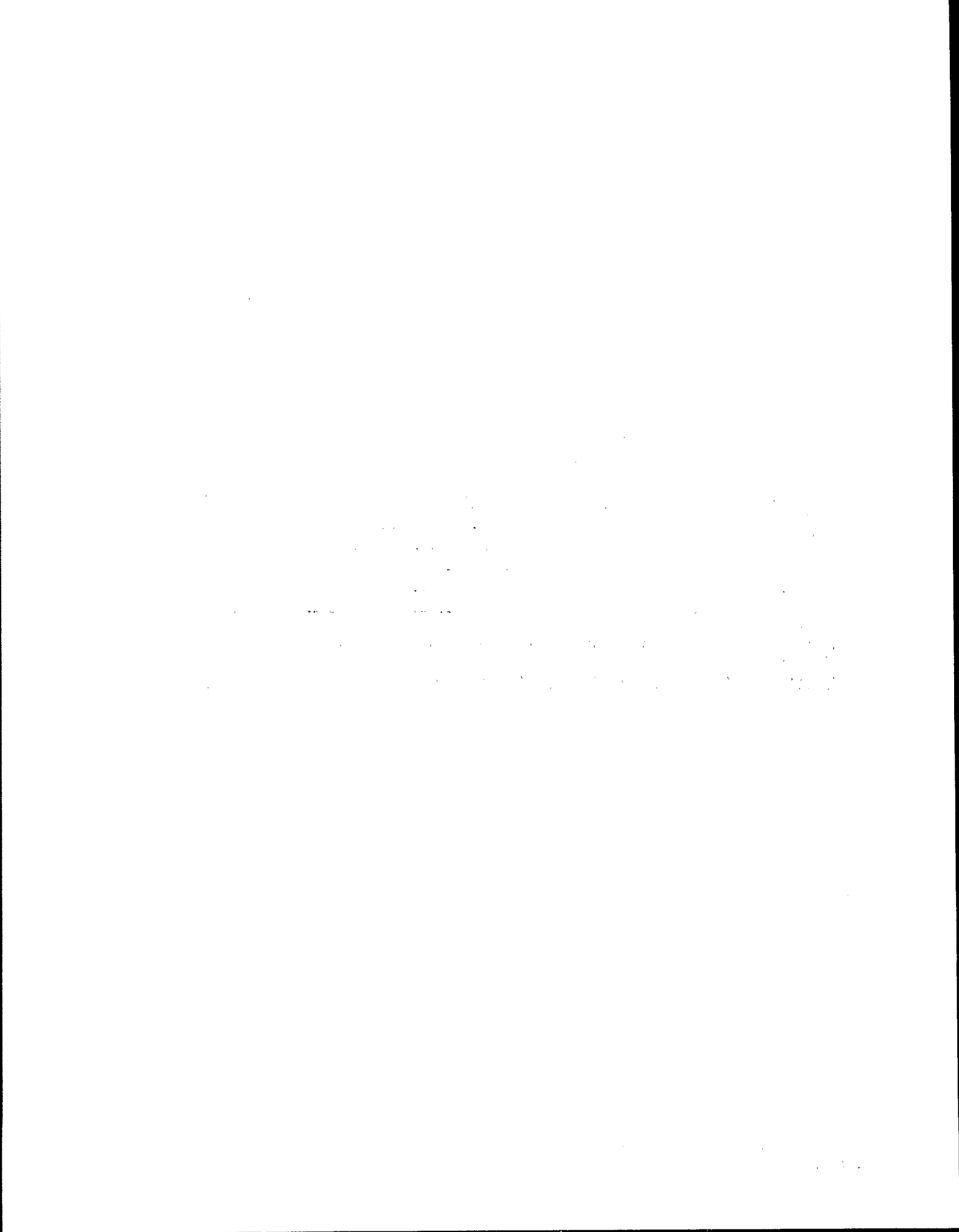
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MODULE			ENERGY				
SUB MODULE			CO ₂ FROM ENERGY SOURCES (DETAILED FUELS APPROACH)				
WORKSHEET			I-I				
SHEET			B				
			STEP 2		STEP 3		
			F Conversion Factor	G Apparent Consumption (GJ)	H Emission Factor (kg C/GJ)	I Carbon Fraction (kg C)	J Carbon Fraction (Gg C)
FUEL TYPES				G=(ExF)		I=(GxH)	J=(I × 10 ⁻⁶))
Liquid Fossil	Primary Fuels	Crude Oil					
		Natural Gas Liquids					
	Secondary Fuels	Gasoline					
		Kerosene					
		Jet Kerosene					
		Residual Fuel Oil					
		LPG					
		Naphtha					
		Bitumen					
		Lubricants					
		Petroleum Coke					
		Refinery Feedstocks					
		Other Oil					
Liquid Fossil Totals							
Solid Fossil	Primary Fuels	Coking Coal					
		Steam Coal					
		Lignite					
		Sub-bituminous Coal					
		Peat					
	Secondary Fuels	BKB & Patent Fuel					
		Coke					
Solid Fossil Totals							
Gaseous Fossil		Natural Gas (Dry)					
Bunkers	Jet Kerosene						
	Residual Fuel Oil						
	Other						
	Total Bunkers						
Biomass	Solid Biomass						
	Liquid Biomass						
	Total Biomass						
Total							

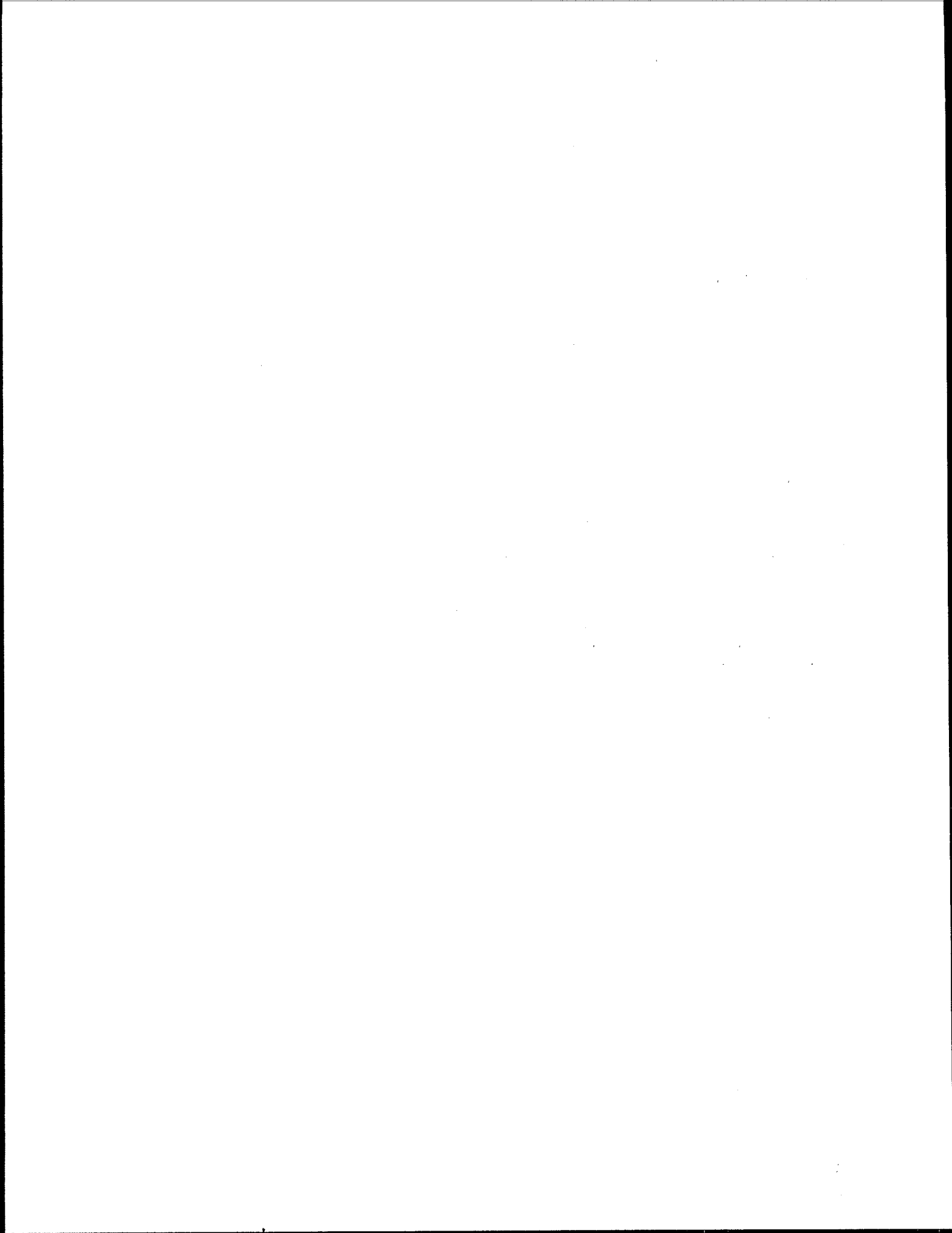


MODULE			ENERGY				
SUB MODULE			CO ₂ FROM ENERGY SOURCES (DETAILED FUELS APPROACH)				
WORKSHEET			I-I				
SHEET			C				
			STEP 4		STEP 5		STEP 6
			K Carbon Stored (Gg C)	L Net Carbon Emissions (Gg C)	M Fraction of Carbon Oxidized	N Actual Carbon Emissions (Gg C)	O Actual CO ₂ Emissions (Gg CO ₂)
FUEL TYPES				L=(J-K)		N=(LxM)	O=(Nx[44/12])
Liquid Fossil	Primary Fuels	Crude Oil					
		Natural Gas Liquids					
	Secondary Fuels	Gasoline					
		Kerosene					
		Jet Kerosene					
		Residual Fuel Oil					
		LPG					
		Naphtha					
		Bitumen					
		Lubricants					
		Petroleum Coke					
		Refinery Feedstocks					
		Other Oil					
Liquid Fossil Totals							
Solid Fossil	Primary Fuels	Coking Coal					
		Steam Coal					
		Lignite					
		Sub-bituminous Coal					
		Peat					
	Secondary Fuels	BKB & Patent Fuel					
		Coke					
Solid Fossil Totals							
Gaseous Fossil		Natural Gas (Dry)					
Bunkers	Jet Kerosene						
	Residual Fuel Oil						
	Other						
	Total Bunkers						
	Biomass	Solid Biomass					
Liquid Biomass							
Total Biomass							
Total							



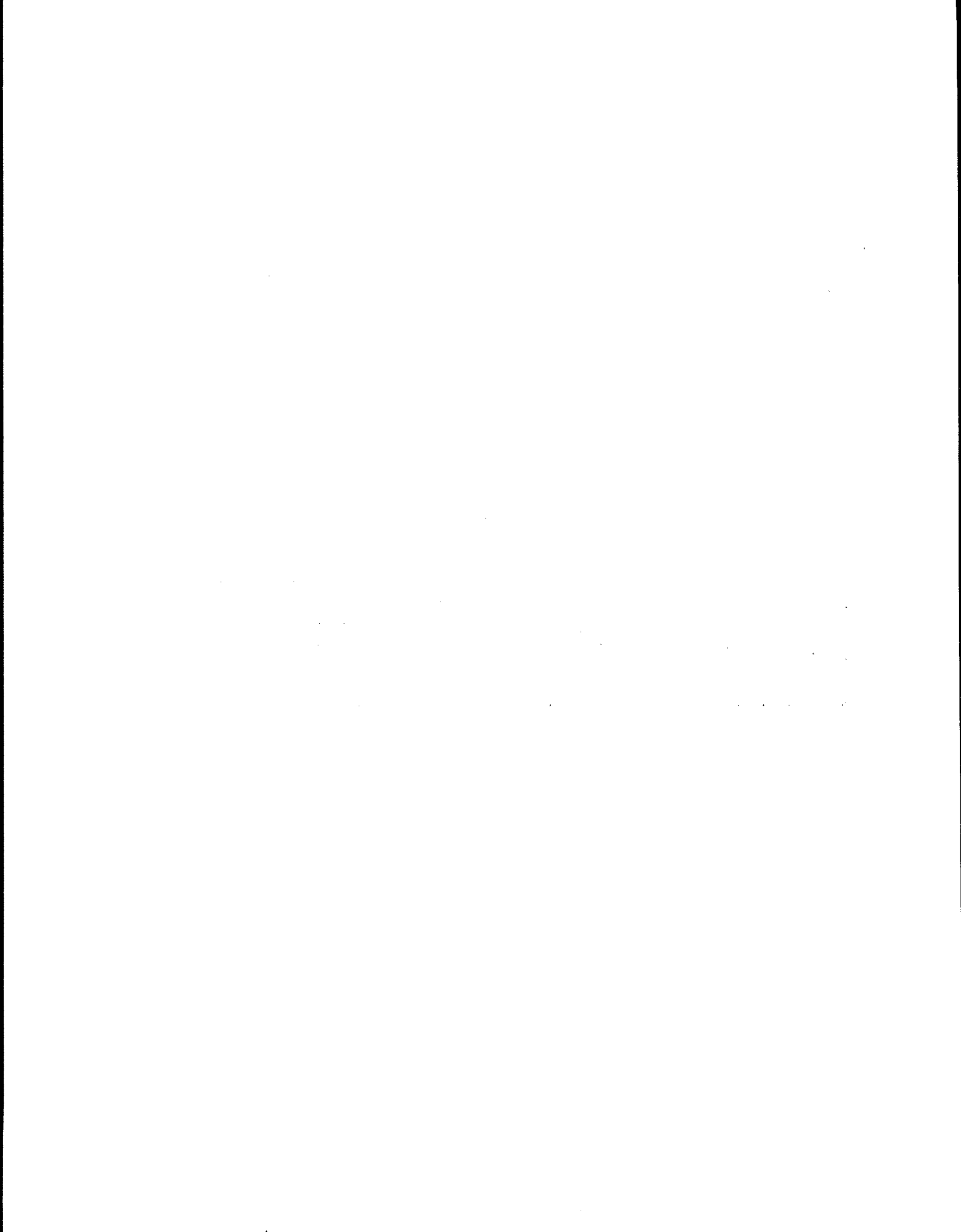


MODULE	ENERGY							
SUB MODULE	CO₂ FROM ENERGY							
WORKSHEET	AUXILIARY WORKSHEET I-I - ESTIMATING CARBON STORED IN PRODUCTS							
SHEET	A							
	A Estimated Fuel Quantities	B Conversion Factor (GJ/Units)	C Estimated Fuel Quantities (GJ)	D Emission Factor (kg C/GJ)	E Carbon Fraction (kg)	F Convert Fraction (Gg) (Divide by 10 ⁶)	G Fraction Carbon Stored	H Carbon Stored (Gg)
Naphtha ¹				20.0 ²			0.80	
Lubricants				20.0 ²			0.50	
Bitumen				22.0			1.0	
Coal Oils and Tars (from Coking Coal)				25.8			0.75	
Natural Gas ¹				15.3			0.33	
Gas/Diesel Oil ¹				20.2			0.50	
LPG ¹				17.2			0.80	
Other fuels ³								
Other fuels ³								
Other fuels ³								
¹ Enter these fuels when they are used as feedstocks. ² There is no CEF available for these products. The value in parentheses is a default value for liquid fuels to be used until a fuel-specific CEF is determined. ³ Use the Other fuels rows to enter any other products in which carbon may be stored								



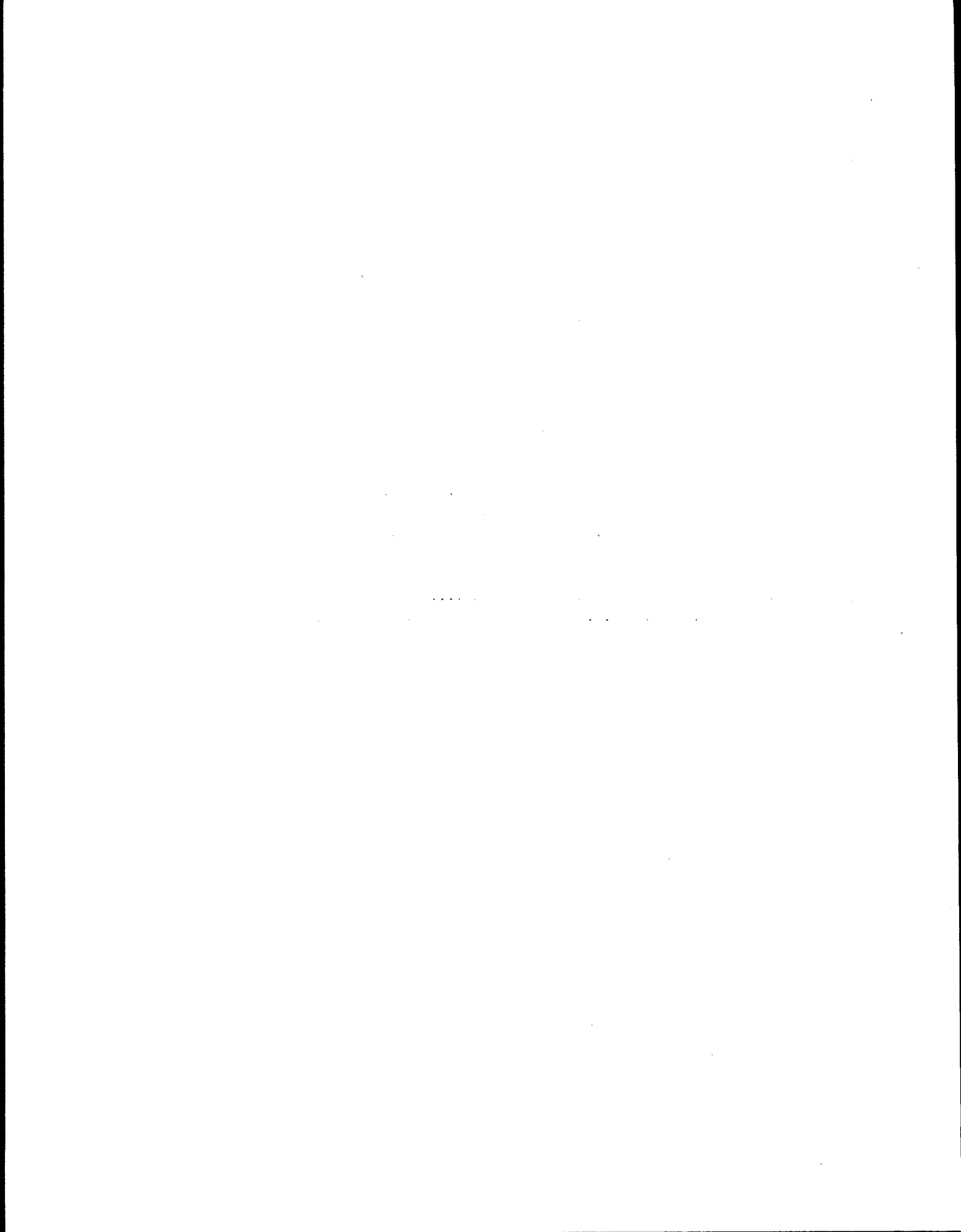


MODULE		ENERGY							
SUB MODULE		TRADITIONAL BIOMASS BURNED FOR ENERGY							
WORKSHEET		I-2 OPTIONAL FUELWOOD CONSUMPTION ACCOUNTING							
SHEET									
		STEP 1			STEP 2		STEP 3		STEP 4
Population Category (e.g. rural, urban, etc.) (specify)	A Population (by category) 1000 persons	B Per Capita Fuelwood Consumption kt dm/1000 persons	C Total Annual Wood Consumption kt dm	D Per Capita Charcoal Consumption kt dm/1000 persons	E Total Annual Charcoal Consumption kt charcoal	F Charcoal Consumption Expansion Factor kt fuelwood / kt charcoal	G Wood Consumption for Charcoal kt dm	H Total Wood Consumption for Fuel kt dm	
			C=(AxB)		E=(Ax D)		G=(ExF)	H=(C+G)	



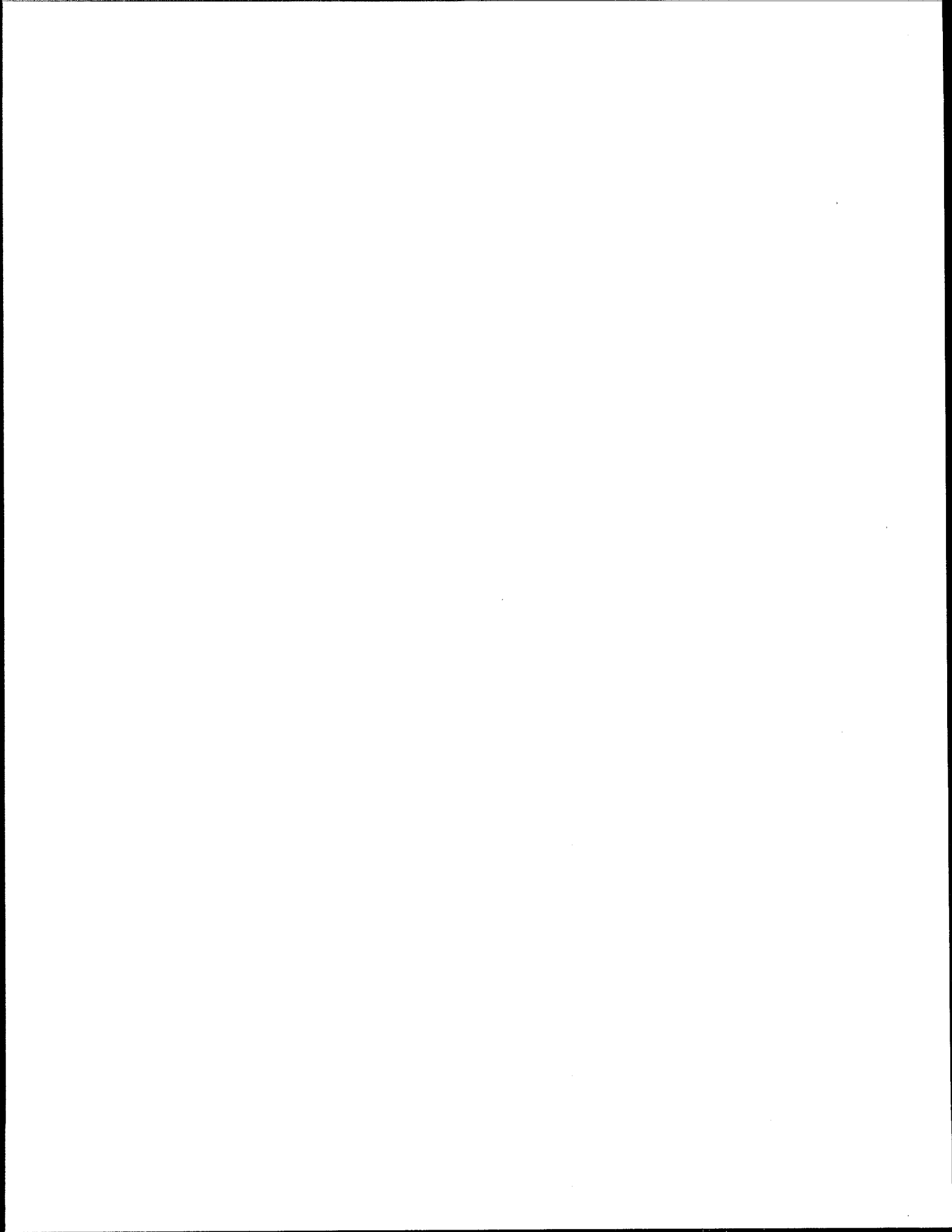


MODULE	ENERGY							
SUB MODULE	TRADITIONAL BIOMASS FUEL BURNED FOR ENERGY							
WORKSHEET	I-3							
SHEET	A							
	STEP 1			STEP 2		STEP 3		
	A Total Biomass Consumed kt dm	B Fraction of Biomass which Oxidizes (Combustion Efficiency)	C Biomass Burned kt dm	D Carbon Fraction of Biomass	E Total Carbon Released by Biomass Fuels kt C	F CH ₄ -C Ratio	G Carbon Emitted as CH ₄ kt C	H CH ₄ Emissions from Biomass Burned Gg CH ₄
			$C=(A \times B)$		$E=(C \times D)$		$G=(E \times F)$	$H=(G[16/12])$
Wood ¹								
Agricultural Wastes								
Dung								
Charcoal Consumption ²								
Charcoal Production ³								
Others (Specify)								
				Total				
¹ Consumption from column C of Worksheet I-2 if used. ² Consumption from column E of Worksheet I-2 if used. ³ Consumption from column G of Worksheet I-2 if used.								



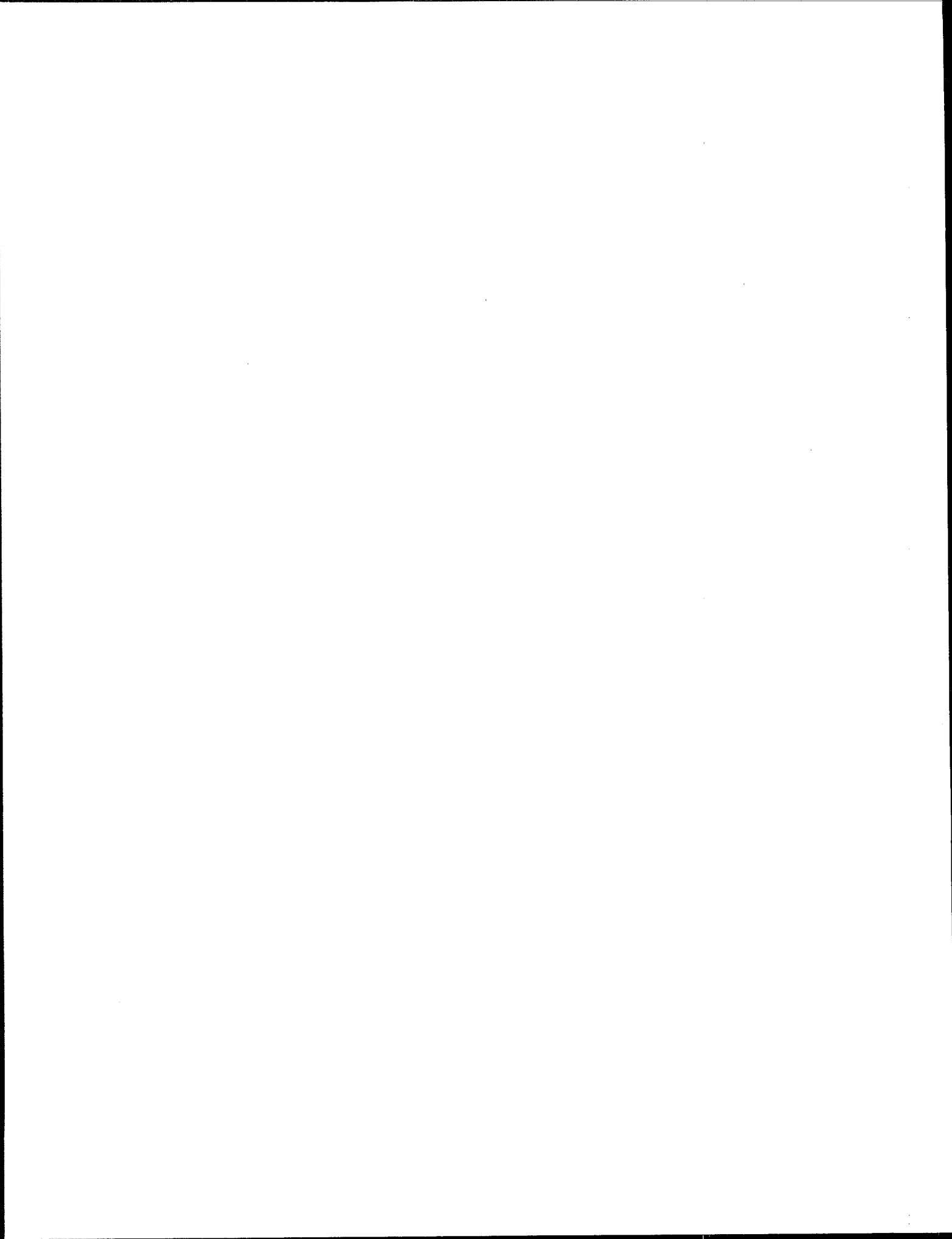


MODULE	ENERGY							
SUB MODULE	TRADITIONAL BIOMASS FUEL BURNED FOR ENERGY							
WORKSHEET	I-3							
SHEET	B							
	STEP 4			STEP 5				
	I CO-C Trace Gas Emission Ratio	J C Emitted as CO (kt C)	K CO Emitted (Gg CO)	L Nitrogen- Carbon Fuel Ratio	M Total Nitrogen Released (kt N)	N N ₂ O-N Trace Gas Emissions Ratio	O Nitrogen Emitted as N ₂ O (kt N)	P N ₂ O Emitted (Gg N ₂ O)
		J=(ExI)	K=(JX28/12)J		M=(ExL)		O=(MXN)	P=(Ox44/28)
Wood								
Agricultural Wastes								
Dung								
Charcoal Consumption								
Charcoal Production								
Others (Specify)								
		Total					Total	



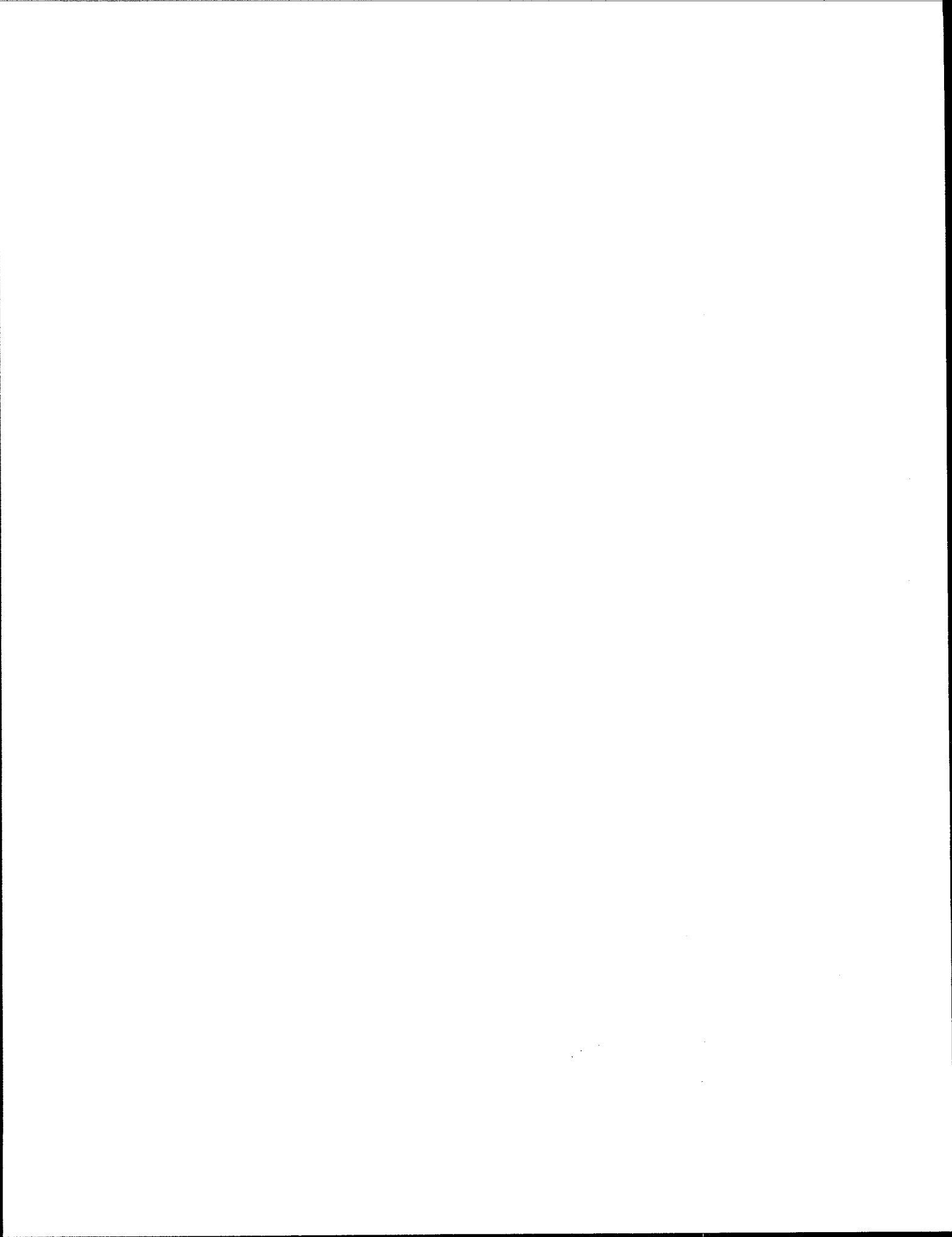


MODULE	ENERGY		
SUB MODULE	TRADITIONAL BIOMASS FUEL BURNED FOR ENERGY		
WORKSHEET	I-3		
SHEET	C		
	STEP 6		
	Q NO _x -N Trace Gas Emissions Ratio	R Nitrogen Emitted as NO _x (kt N)	S NO _x Emitted (Gg NO _x)
		$R=(M \times Q)$	$S=(R \times 30/14)$
Wood			
Agricultural Wastes			
Dung			
Charcoal Consumption			
Charcoal Production			
Others (Specify)			
		Total	



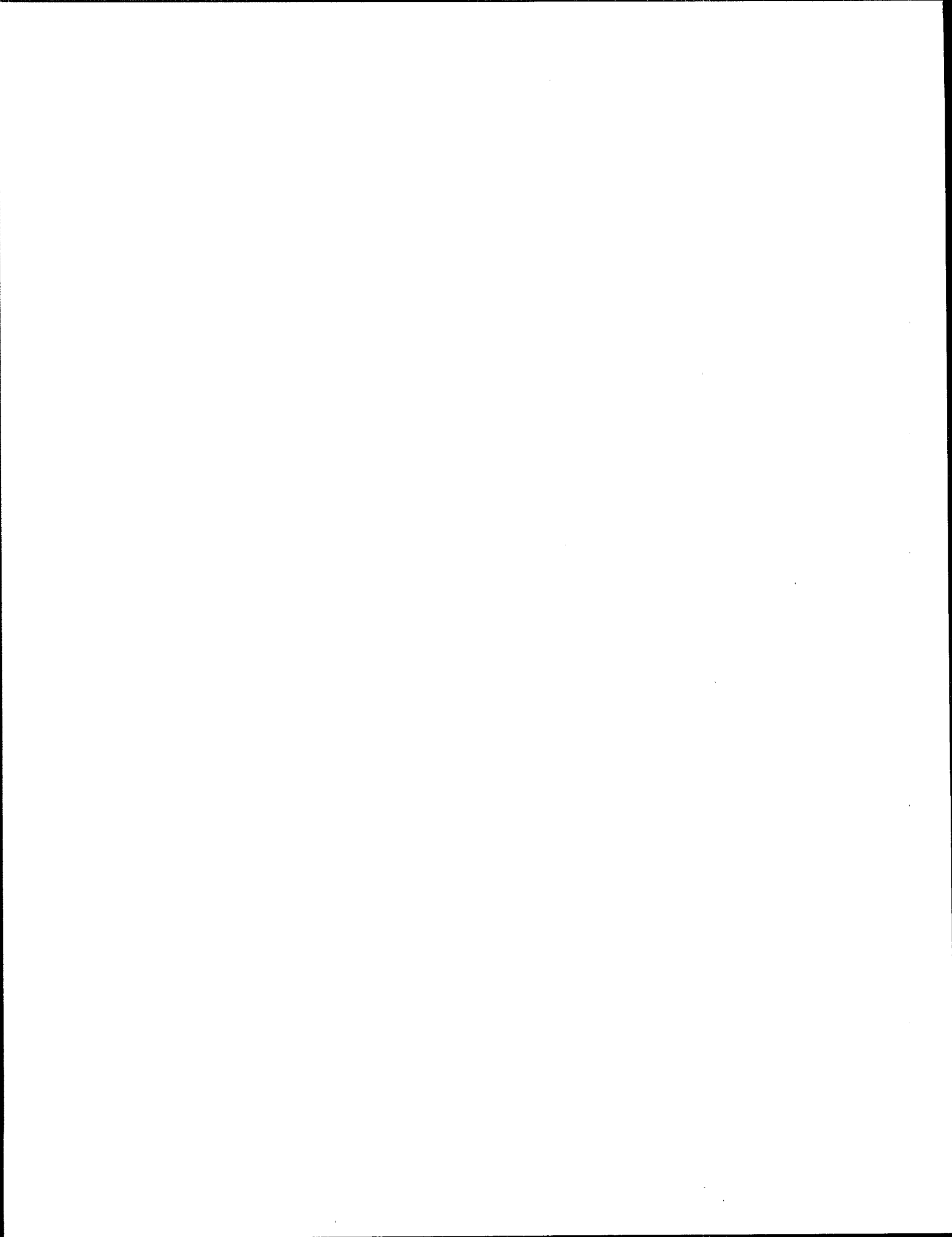


MODULE		ENERGY				
SUB MODULE		METHANE EMISSIONS FROM COAL PRODUCTION				
WORKSHEET		I-4				
SHEET		A				
		STEP 1			STEP 2	
Mining Activity		A Amount of Coal Produced (millions t)	B Average Emissions Factor (m ³ CH ₄ /t)	C Methane Emissions (millions m ³)	D Conversion Factors (Default 0.67 Gg/ CH ₄ 10 ⁶ m ³)	E Methane Emissions (Gg CH ₄)
				$C=(A \times B)$		$E=(C \times D)$
Underground Mines	Mining					
	Post-Mining					
Surface Mines	Mining					
	Post-Mining					
					Total	





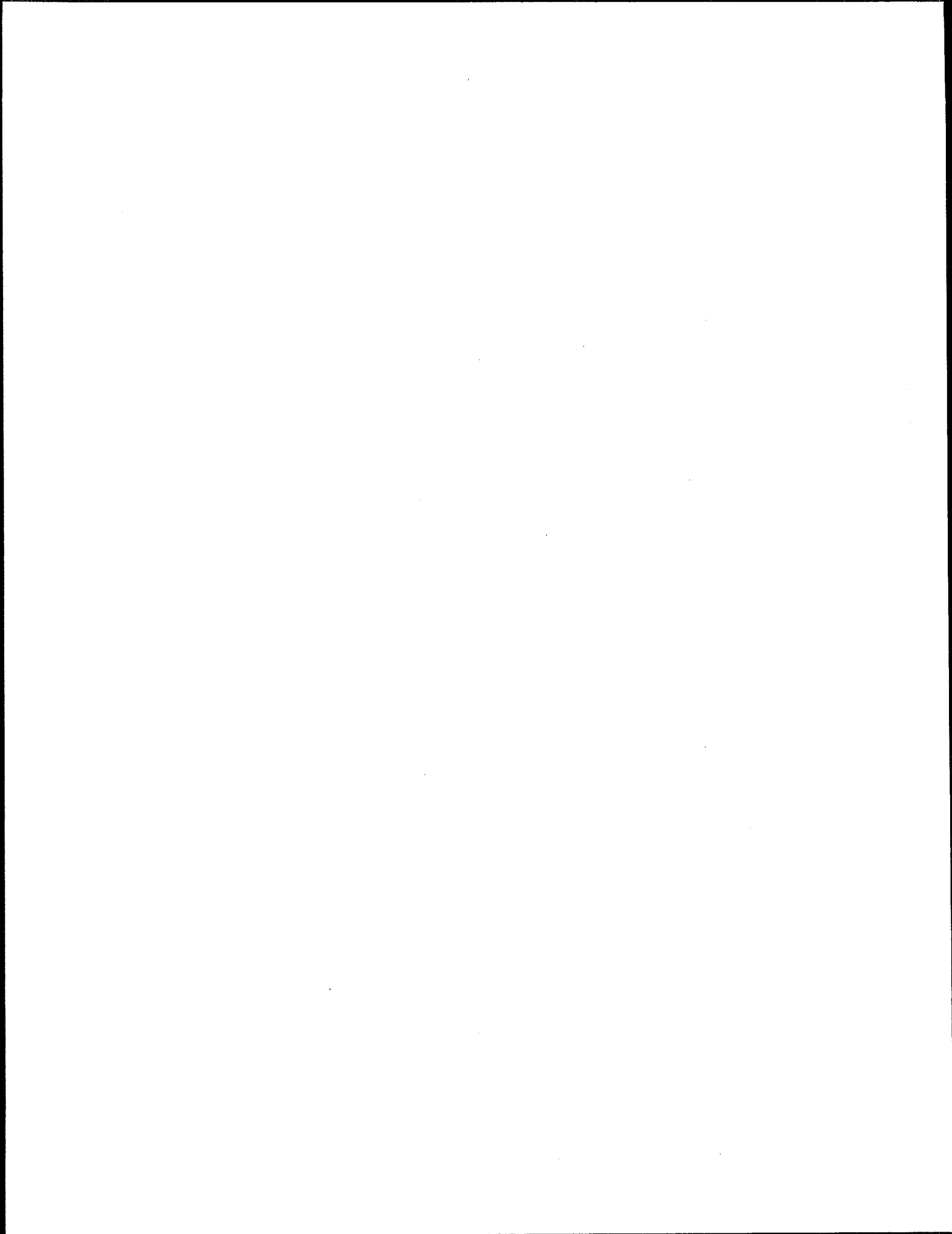
MODULE		ENERGY		
SUB-MODULE		METHANE FROM OIL AND GAS SYSTEMS (TIER I APPROACH)		
WORKSHEET		I-5		
SHEET		A		
	STEP 1		STEP 2	STEP 3
• • Category	A Activity	B Emission Factor	C CH ₄ Emissions (kg CH ₄) C=(AxB)	D Emissions CH ₄ (Gg CH ₄) D=(Cx10 ⁶)
OIL SYSTEMS				
Exploration & Drilling (Optional if data is locally available) ¹	number of wells drilled	kg CH ₄ /well drilled		
Production	PJ oil produced	kg CH ₄ /PJ		
Transport	PJ oil loaded in tankers	kg CH ₄ /PJ		
Refining	PJ oil refined	kg CH ₄ /PJ refined		
Storage	PJ oil refined	kg CH ₄ /PJ refined		
			TOTAL CH₄ FROM OIL SYSTEMS	
GAS SYSTEMS				
Production	PJ gas produced	kg CH ₄ /PJ		
Processing, Transport and Distribution	PJ gas consumed	kg CH ₄ /PJ		
			TOTAL CH₄ FROM GAS SYSTEMS	
UNALLOCATED OIL/GAS PRODUCTION	PJ oil and gas produced	kg CH ₄ /PJ		
			TOTAL CH₄ EMISSIONS FROM OIL AND GAS	
¹ Emission Factors are not provided.				





MODULE 2

INDUSTRIAL PROCESSES





2 INDUSTRIAL PROCESSES

2.1 Introduction

This module gives instructions for calculating greenhouse gas emissions from cement production. This is the most important industrial source of CO₂.

Other industrial sources of CO₂ and other greenhouse gases are discussed in the *Greenhouse Gas Inventory Reference Manual*.

No other default methods for industrial processes are provided in this version of the *Workbook*, although some additional sources are listed in the following section.

CO₂ from other Industrial processes

A variety of non-energy industrial processes produce CO₂ emissions. These are production processes in which materials are transformed from one state into another and in which CO₂ is emitted as a by-product of chemical reactions. Most of these processes also include fuel combustion which produces CO₂ emissions, but the IPCC methodology used in this *Workbook* treats combustion and non-combustion components separately. Cement production is believed to be the most important process source of CO₂ and is the only category for which an explicit method is included in the *Workbook*. However, many other processes may be significant for some other countries. In the national inventories collected by the IPCC/OECD programme CO₂ emissions from the following processes have been reported:

Production coke, iron, steel, aluminium, ferro alloys, carbon carbide, fertilizers, limestone, lime, dolomite, bricks, glass, paper, pulp and print.

Consumption limestone

In general we expect that most categories will follow the simple method recommended for cement production:

$$\begin{array}{lcl} \text{Physical units of production} & \times & \text{Emission Factor} \\ \text{(e.g. tonnes)} & & \text{(tonnes CO}_2\text{/tonne product)} \\ & = & \text{Emissions} \end{array}$$

As more national data is collected and evaluated in this area, we expect to be able to develop and provide formulae and default emissions factors for additional categories.

2.2 CO₂ from Cement Production

Introduction

EMISSION FACTORS

There are two ways of calculating the emission factor. The IPCC recommended method assumes the average CaO content of cement to be 63.5%, which gives an emission factor of 0.4985 CO₂/cement.

The second method is to assemble country or regional cement production and cement CaO content by type, then calculate a weighted average for cement lime content in the country.

If the fraction of lime in the cement clinker is known to be different from 0.635 then:

$$EF(\text{cement}) = 0.5 \times (f)/0.635$$

In most countries the difference in results between the two methods is likely to be small. Any error in the lime content assumption is likely to be smaller than the uncertainty in the cement production figures.

Carbon dioxide emitted during the cement production process represents the largest non-energy source of industrial carbon dioxide emissions. Cement production accounts for about 2.4 percent of total global industrial and energy CO₂ emissions (Marland et al., 1989). Carbon dioxide is produced during the production of clinker, an intermediate product from which cement is made. High temperatures in cement kilns chemically change raw materials into cement clinker. In a process called *calcination* or *calcining*, calcium carbonate is heated, forming lime and carbon dioxide. This lime then undergoes additional processes to form clinker, and finally cement.

Most of the structural cement currently produced in the world is of the "Portland" cement type, which contains 60 to 67 percent lime by weight. Other specialty cements are lower in lime, but are typically used in small quantities. Carbon dioxide emissions from cement production are essentially directly proportional to lime content, so production of cements lower in lime yield less CO₂. The methodology presented in the *Workbook* is for the Portland type cement.

Data sources

International cement production data are available from the United Nations (1988) and from the U.S. Bureau of Mines (1988). In some countries, national data may be available from appropriate government ministries. There is substantial overlap between U.S. Bureau of Mines and the UN data sets, but the former is more complete. A trade association, European Cement Associations (CEMBUREAU) also publishes information (see CEMBUREAU, 1990, *World Cement Market in Figures and World Statistical Review*).

Methodology

Because carbon dioxide is emitted specifically during clinker production, rather than during cement production itself, emission estimates should be based on the lime content and production of *finished cement* ignore the consideration that some domestic cement may be made from imported clinker, or that some finished cement may use additional lime that is not accounted for in the cement calculations. Clinker statistics, however, may not be readily available in some countries. If this is the case, cement production statistics can be used. The differences between the lime content and production of clinker and cement, in most countries, are not significant enough to affect the emission estimates.

Estimation of CO₂ emissions from cement production is accomplished by applying an emission factor, in tonnes of CO₂ released per tonne of clinker produced, to the annual clinker output. The recommended emission factor for clinker is 0.507 tonnes of CO₂ per tonne of clinker produced.

If information on clinker production is not readily available, an emissions factor in tonnes of CO₂ released per tonne of cement produced can be



applied to annual cement production instead. The recommended emission factor for cement production is 0.498 tonnes of CO₂ per tonne of cement produced.

Completing the Worksheet

Use WORKSHEET 2-1 CO₂ EMISSIONS FROM CEMENT PRODUCTION to enter data for this sub module.

STEP 1 ESTIMATING CO₂ EMITTED

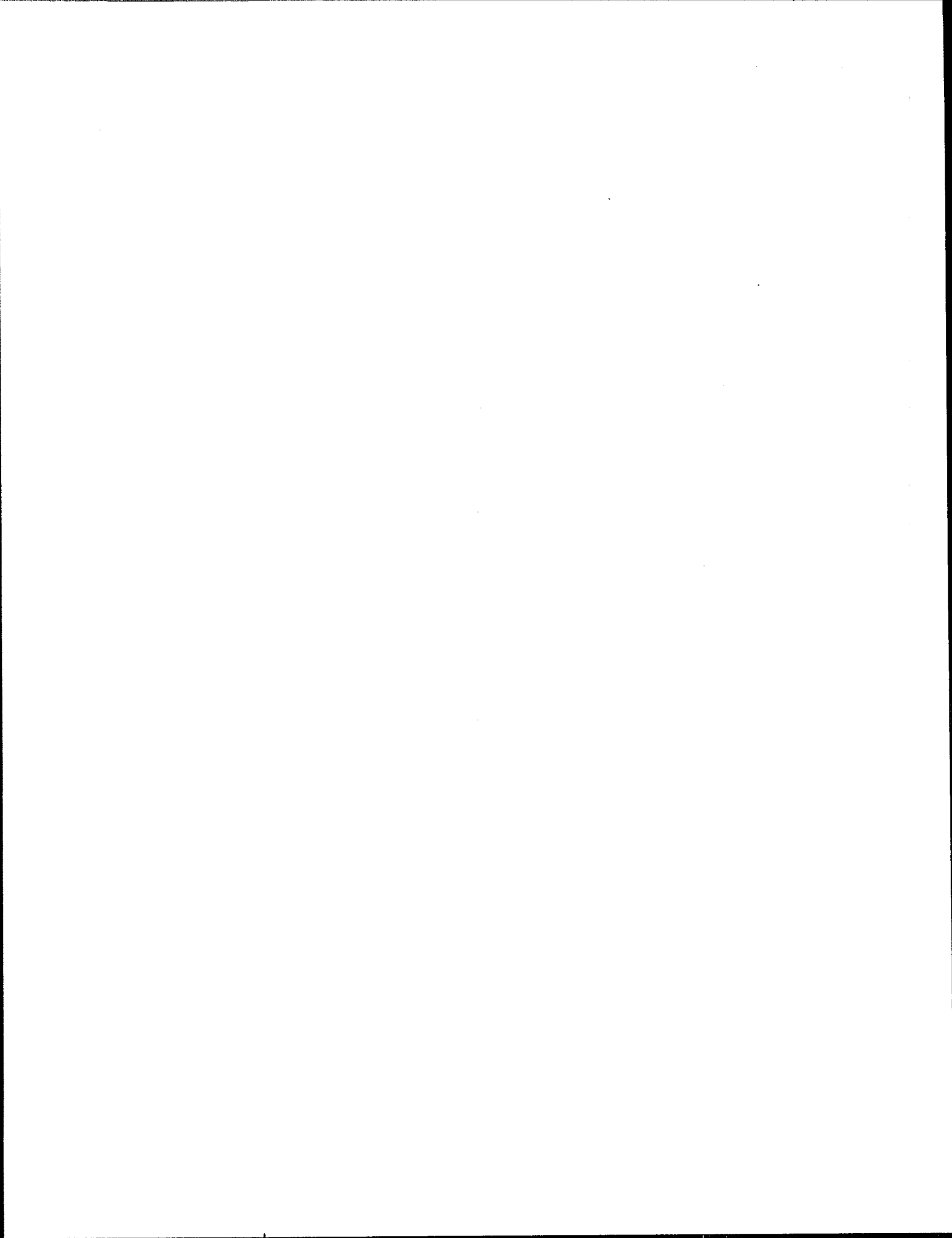
- 1 Estimate clinker production, or if data on clinker production is not available, estimate cement production, and enter this value in Column (A) in tonnes.
- 2 Enter the corresponding emissions factor in Column (B) in tonnes CO₂ per tonne of clinker or cement produced.
- 3 Multiply Column (A) by Column (B) to get CO₂ emitted in tonnes of CO₂, and enter this value in Column (C).

STEP 2 CONVERT TO Gg

- 4 Divide Column (C) by 1000 to convert to units of gigagrams CO₂, and enter this value in column (D).

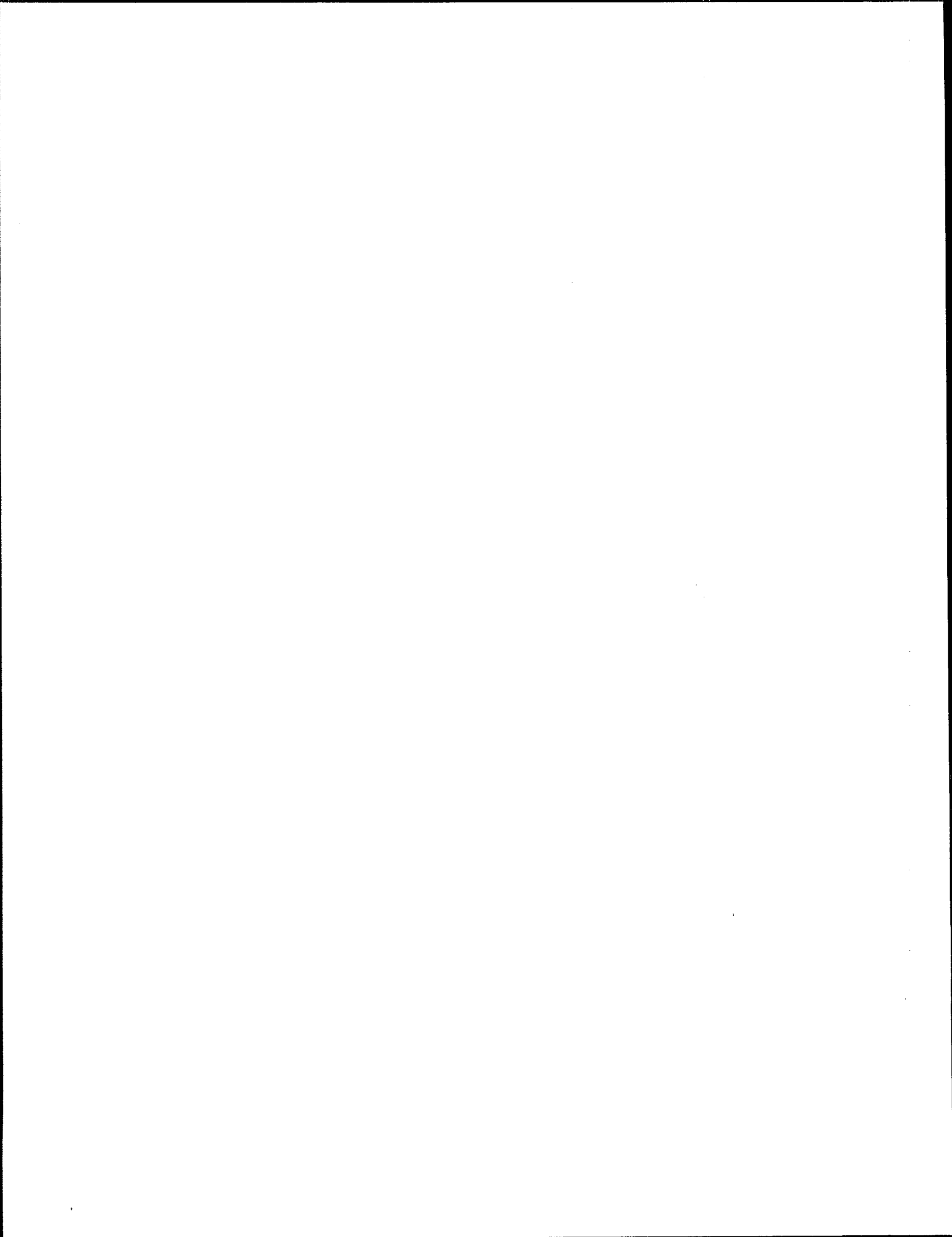
USING THE WORKSHEET

- Photocopy the Production processes Worksheet at the end of this section to complete the inventory.
- Keep the original clean so that you can make further copies if necessary.





MODULE	INDUSTRIAL PROCESSES		
SUB MODULE	CO₂ FROM CEMENT PRODUCTION		
WORKSHEET	2-1		
SHEET	-		
		STEP 1	STEP 2
A Amount of Clinker or Cement Produced: t	B Emissions Factor t CO ₂ /t Clinker or Cement Produced	C CO ₂ emitted: t	D CO ₂ emitted: Gg
		$C=(A*B)$	$D=C/1000$

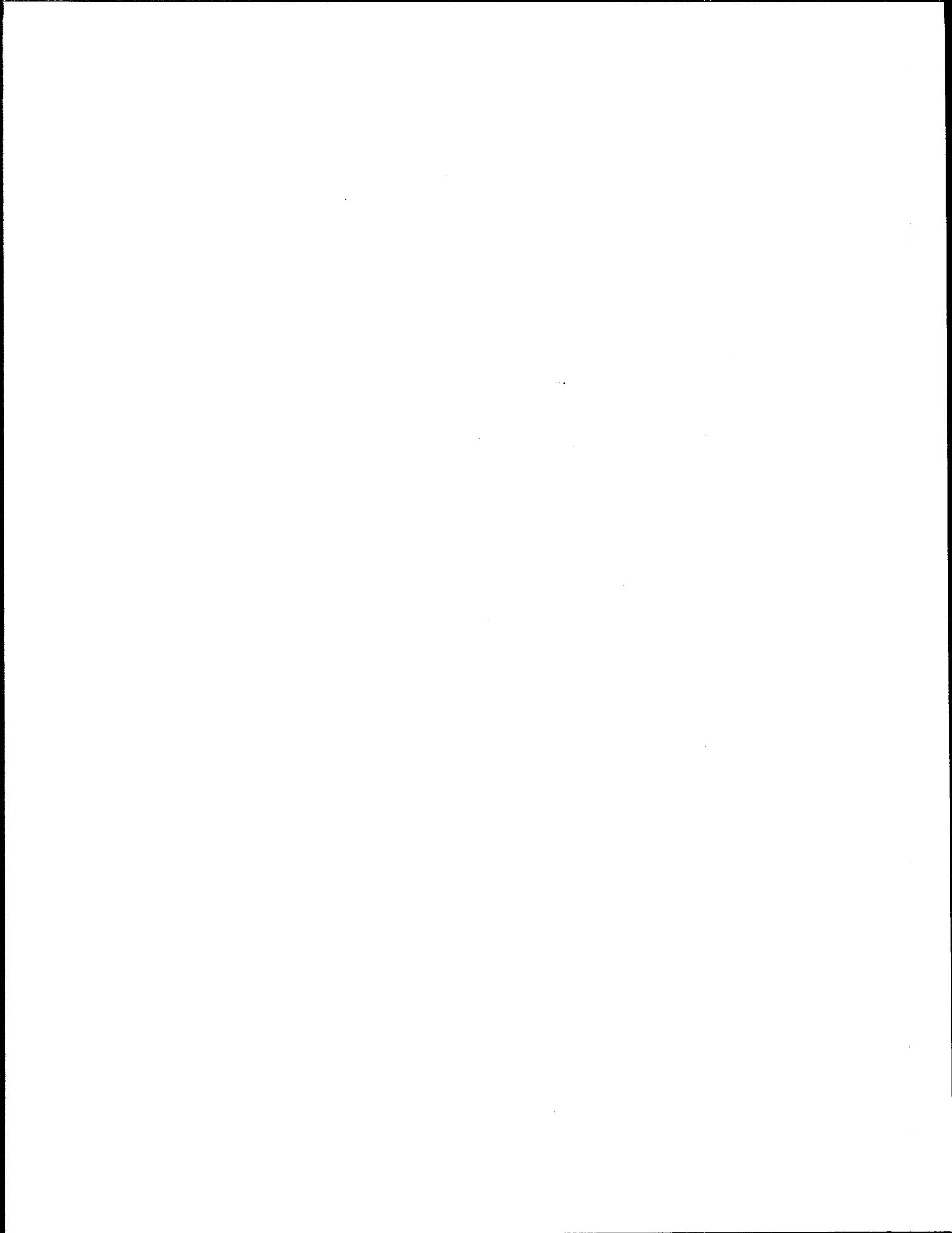




MODULE 3

SOLVENTS

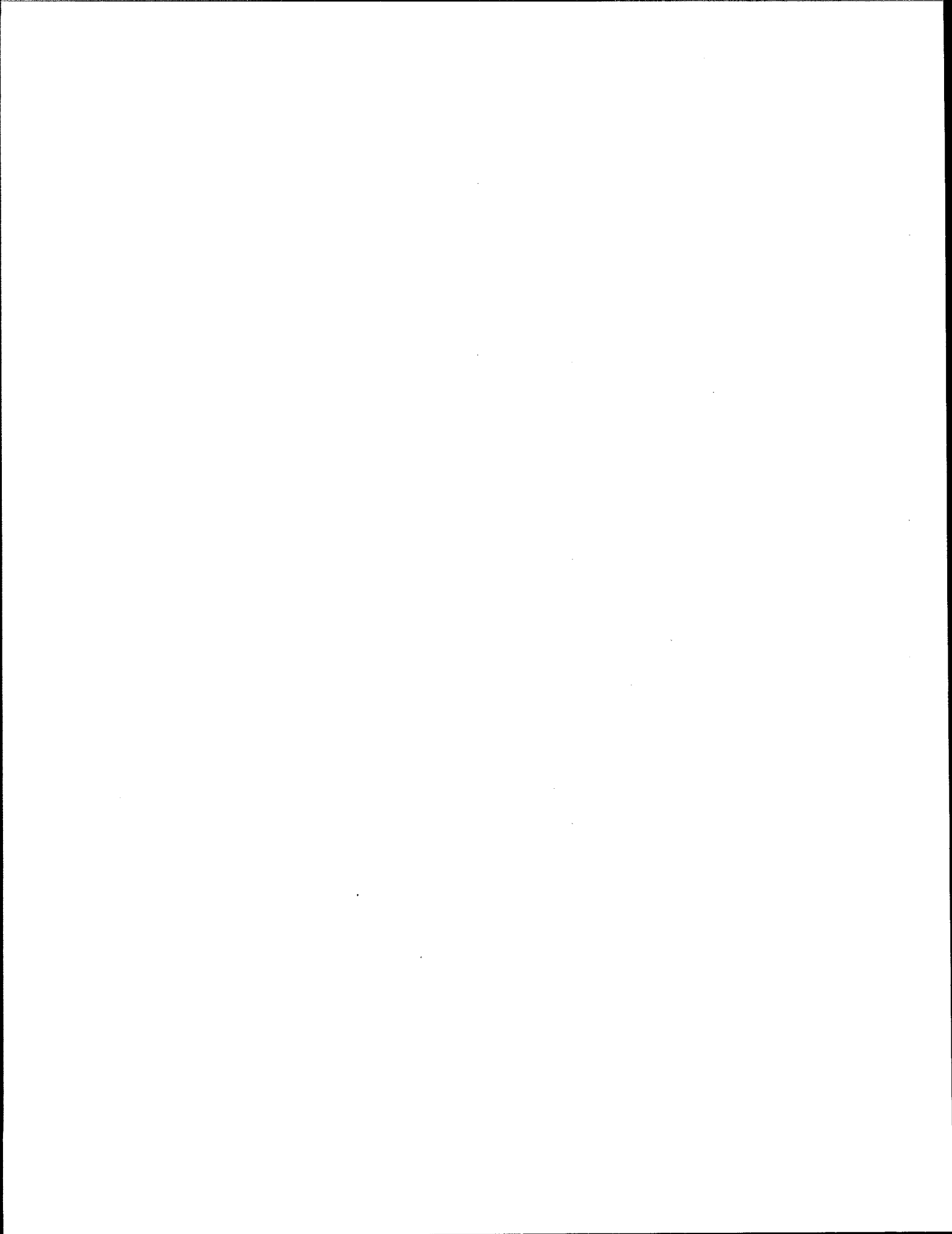
No methods for the calculation of greenhouse gases (primarily Non-Methane Volatile Organic Compounds) from solvent use are included in the phase I version of the workbook. This placeholder is provided to preserve numbering consistency with the *Greenhouse Gas Inventory Reference Manual*, (Guidelines Volume 3) and the *Greenhouse Gas Inventory Reporting Instructions*, (Guidelines Volume I).





MODULE 4

AGRICULTURE





4 AGRICULTURE

4.1 Introduction

The Agriculture module looks at greenhouse gas emissions from four sources:

- livestock and manure management
- rice cultivation
- savanna burning
- open burning of agricultural residues

The primary focus is on methane emissions in this Phase I edition of the *Workbook*. Other subcategories such as nitrous oxide from agricultural soils will be added in future editions.

4.2 Livestock

Introduction

This sub module deals with methane emissions from two sources:

- enteric fermentation in livestock
- animal manure

Methane from enteric fermentation is produced in herbivores as a by-product of the digestive process by which carbohydrates are broken down by micro-organisms into simple molecules for absorption into the bloodstream. Both ruminant animals (e.g. cattle, sheep) and some non-ruminant animals (e.g. pigs, horses) produce methane, although ruminants are the largest source. The amount of CH₄ that is released depends upon the type, age and weight of the animal, the quantity and quality of the feed consumed, and the energy expenditure of the animal.

Methane from animal manure occurs as result its decomposition under anaerobic conditions. These conditions often occur when a large number of animals are managed in a confined area (e.g. dairy farms, beef feedlots, and swine and poultry farms).

Emissions of methane from wild animals and termites are not included in this sub module. The focus in the IPCC Guidelines is on anthropogenic emissions. While there are human interactions with natural sources such as wild animals and termites, they are complex and highly uncertain.

Data sources

There are no individual sources that will provide all the data needed to estimate methane emissions from animals. The Food and Agriculture Organisation (FAO) of the United Nations publishes a series entitled *The FAO Production Yearbook* (e.g., FAO, 1991). This series has information about animal populations and the production and consumption of animal products. The FAO data should be supplemented with studies conducted for individual countries. Many countries publish results of their agricultural census that includes data on production levels in addition to animal populations. Table 4-1 summarizes the data needed.

TABLE 4-1 ANIMAL POPULATION DATA COLLECTED IN TIER I STEP I					
Livestock	Data Collected				
	Population (# head)	Milk Production (kg/head/yr)	Population By Climate (%)		
			Cool	Temperate	Warm
Dairy Cows	Average Annual Population	Milk Production per Head	% Cool	% Temp.	% Warm
Cattle Other than Dairy Cows	Average Annual Population	Not Applicable (NA)	% Cool	% Temp.	% Warm
Buffalo	Average Annual Population	(NA)	% Cool	% Temp.	% Warm
Sheep	Average Annual Population	(NA)	% Cool	% Temp.	% Warm
Goats	Average Annual Population	(NA)	% Cool	% Temp.	% Warm
Camels	Average Annual Population	(NA)	% Cool	% Temp.	% Warm
Horses and Mules	Average Annual Population	(NA)	% Cool	% Temp.	% Warm
Swine	Average Annual Population	(NA)	% Cool	% Temp.	% Warm
Poultry	Average Annual Population	(NA)	% Cool	% Temp.	% Warm

Methodology

Although the methodological issues are very complex, a simplified methodology is used for the purposes of this *Workbook*.

For a detailed discussion of the methodology, see the *IPCC Greenhouse Gas Inventory Reference Manual*. Broadly, emissions are calculated by applying an emissions factor to the number of animals of each type in the country to produce a total for enteric fermentation. Default emission factors are provided for developed and developing countries with more regional detail for cattle, the most important category.



Next, manure management is looked at, and emissions factors applied to give figures for emissions from manure management. In this area default emission factors are provided by region and for three different climate regimes. Simple multiplication of populations by emission factors produces emissions estimates.

Completing the Worksheet

Use WORKSHEET 4-1 METHANE EMISSIONS FROM ANIMALS AND ANIMAL MANURE at the end of this section to record the data.

STEP 1 ESTIMATING EMISSIONS FROM ENTERIC FERMENTATION

- 1 For each type of animal in the Worksheet, enter the number in thousands in column A.

Refer to FAO Production Yearbooks (e.g. FAO 1991) if there are no locally available data.

- 2 For each type of animal, enter an average Emission Factor in column B in kilograms per head per year (this is the same as megagrams per thousand head per year). Use a figure from the tables below or more precise locally available data. Because cattle are the most important source, region specific default factors are provided. Choose emission factors for cattle which are most appropriate for your national situation.

USING THE WORKSHEET

- Copy the Worksheet at the end of this section to complete the inventory.
- Keep the original of the Worksheet blank so you can make further copies if necessary.

TABLE 4-2		
ENTERIC FERMENTATION EMISSIONS FACTORS		
(kg per head per year or Mg per 1000 head per year)		
Livestock	Developed Countries	Developing Countries
Buffalo	55	55
Sheep	8	5
Goats	5	5
Camels	46	46
Horses	18	18
Mules and Asses	10	10
Swine	1.5	1.0
Poultry	Not estimated	Not estimated
All Estimates are + or - 20%.		
See the <i>Greenhouse Gas Inventory Reference Manual</i> for sources.		

- 3 Multiply the number of cattle by the Average Emissions Factors to give Emissions from Enteric Fermentation in megagrams per year. Enter the result in column C.

TABLE 4-3 (A)
ENTERIC FERMENTATION EMISSION FACTORS FOR CATTLE

Regional Characteristics	Animal Type	Emissions Factor (kg/head/yr)	Comments
North America: Highly productive commercialized dairy sector feeding high quality forage and grain. Separate beef cow herd, primarily grazing with feed supplements seasonally. Fast-growing beef steers/heifers finished in feedlots on grain. Dairy cows are a small part of the population.	Dairy Cows	118	Average milk production of 6,700 kg/yr
	Non-Dairy Cattle	47	Includes beef cows, bulls, calves, growing steers/heifers, and feedlot cattle
Western Europe: Highly productive commercialized dairy sector feeding high quality forage and grain. Dairy cows also used for beef calf production. Very small dedicated beef cow herd. Minor amount of feedlot feeding with grains.	Dairy Cows	100	Average milk production of 4,200 kg/yr
	Non-Dairy Cattle	48	Includes bulls, calves, and growing steers/heifers
Eastern Europe: Commercialized dairy sector feeding mostly forages. Separate beef cow herd, primarily grazing. Minor amount of feedlot feeding with grains.	Dairy Cows	81	Average milk production of 2,550 kg/yr
	Non-Dairy Cattle	56	Includes beef cows, bulls, and young.
Oceania: Commercialized dairy sector based on grazing. Separate beef cow herd, primarily grazing range lands of widely varying quality. Growing amount of feedlot feeding with grains. Dairy cows are a small part of the population.	Dairy Cows	68	Average milk production of 1,700 kg/yr
	Non-Dairy Cattle	53	Includes beef cows, bulls, and young.
Latin America: Commercialized dairy sector based on grazing. Separate beef cow herd grazing pastures and range lands. Minor amount of feedlot feeding with grains. Growing beef cattle comprise a large portion of the population.	Dairy Cows	57	Average milk production of 800 kg/yr
	Non-Dairy Cattle	49	Includes beef cows, bulls, and young.
Asia: Small commercialized dairy sector. Most cattle are multi-purpose, providing draft power and some milk within farming regions. Small grazing population. Cattle of all types are smaller than those found in most other regions.	Dairy Cows	56	Average milk production of 1,650 kg/yr
	Non-Dairy Cattle	44	Includes multi-purpose cows, bulls, and young.



TABLE 4-3 (B)
ENTERIC FERMENTATION EMISSION FACTORS FOR CATTLE

Regional Characteristics	Animal Type	Emissions Factor (kg/head/yr)	Comments
Africa and Middle East: Commercialized dairy sector based on grazing with low production per cow. Most cattle are multi-purpose, providing draft power and some milk within farming regions. Some cattle graze over very large areas. Cattle of all types are smaller than those found in most other regions.	Dairy Cows	36	Average milk production of 475 kg/yr
	Non-Dairy Cattle	32	Includes multi-purpose cows, bulls, and young.
Indian Subcontinent: Commercialized dairy sector based on crop by-product feeding with low production per cow. Most bullocks provide draft power and cows provide some milk in farming regions. Small grazing population. Cattle in this region are the smallest compared to cattle found in all other regions.	Dairy Cows	46	Average milk production of 900 kg/yr
	Non-Dairy Cattle	25	Includes cows, bulls, and young. Young comprise a large portion of the population.

See the *Greenhouse Gas Inventory Reference Manual* for sources.

STEP 2 ESTIMATING EMISSIONS FROM MANURE MANAGEMENT SYSTEMS

- I For each type of animal, enter the Emissions Factor for Manure Management in column D in kilograms per head per year. Use default data in the tables which follow or more precise locally available data.

Table 4-3 provides default emission factors for most animal types with different values for developed and developing countries to reflect different conditions and typical practices. Factors are also provided for 3 different climates. Users should select the factors which best represent their conditions. For large countries it may be necessary to subdivide populations into more than one climate region. In that case the user can proceed with calculations in one of two ways.

- a Develop an average emissions factor. For example:

If 25% of sheep are in a temperate region and 75% in a warm region, then

$$EF = (0.25 \times 0.16) + (0.75 \times 0.21) = 0.20 \text{ kg/head/yr}$$

- b An alternative approach is to make extra copies of the Worksheet and complete one for each region for the manure portion, then add the results and enter the sum on the main Worksheet.

Swine, buffalo and cattle are the most important source of manure emissions and the most variable by region, therefore most detailed emission factors are provided in a separate table.

- 2 Multiply the Number of Animals by the Emission Factor for Manure Management to give the Emissions from Manure Management in Mg/yr. Enter the results in column E.

TABLE 4-4 MANURE MANAGEMENT EMISSIONS FACTORS (kg PER HEAD PER YEAR)						
Livestock	Developed Countries			Developing Countries		
	Cool	Temp. ^a	Warm	Cool	Temp. ^a	Warm
Sheep	0.19	0.28	0.37	0.10	0.16	0.21
Goats	0.12	0.18	0.23	0.11	0.17	0.22
Camels	1.6	2.4	3.2	1.3	1.9	2.6
Horses	1.4	2.1	2.8	1.1	1.6	2.2
Mules and Asses	0.76	1.14	1.51	0.60	0.90	1.2
Poultry ^b	0.078	0.117	0.157	0.012	0.018	0.023

The range of estimates reflects cool to warm climates. Climate regions are defined in terms of annual average temperature as follows: Cool = less than 15°C; Temperate = 15°C to 25°C; and Warm = greater than 25°C. The Cool, Temperate and Warm regions are estimated using MCFs of 1%, 1.5% and 2%, respectively.

a Temp. = Temperate climate region.

b Chickens, ducks, and turkeys.

All estimates are ±20 percent.

See the *Greenhouse Gas Inventory Reference Manual* for sources.



TABLE 4-5
MANURE MANAGEMENT EMISSION FACTORS FOR CATTLE, SWINE, AND BUFFALO

TABLE 4-5 MANURE MANAGEMENT EMISSION FACTORS FOR CATTLE, SWINE, AND BUFFALO				
Regional Characteristics	Animal Type	Emissions Factor by Climate Region ^a (kg/head/year)		
		Cool	Temperate	Warm
North America: Liquid-based systems are commonly used for dairy and swine manure. Non-dairy manure is usually managed as a solid and deposited on pastures or ranges.	Dairy Cows	36	54	76
	Non-Dairy Cows	1	2	3
	Swine	10	14	18
Western Europe: Liquid / slurry and pit storage systems are commonly used for cattle and swine manure. Limited cropland is available for spreading manure.	Dairy Cows	14	44	81
	Non-Dairy Cows	6	20	38
	Swine	3	11	20
	Buffalo	3	8	17
Eastern Europe: Solid based systems are used for the majority of manure. About one-third of livestock manure is managed in liquid-based systems.	Dairy Cows	6	19	33
	Non-Dairy Cows	4	13	23
	Swine	4	7	11
	Buffalo	3	9	16
Oceania: Virtually all livestock manure is managed as a solid on pastures and ranges. About half of the swine manure is managed in anaerobic lagoons.	Dairy Cows	31	32	33
	Non-Dairy Cows	5	6	7
	Swine	19	19	20
Latin America: Almost all livestock manure is managed as a solid on pastures and ranges. Buffalo manure is deposited on pastures and ranges.	Dairy Cows	0	1	2
	Non-Dairy Cows	1	1	1
	Swine	1	2	3
	Buffalo	1	1	2
Africa: Almost all livestock manure is managed as a solid on pastures and ranges.	Dairy Cows	1	1	1
	Non-Dairy Cows	0	1	1
	Swine	0	1	2
Middle East: Over two-thirds of cattle manure is deposited on pastures and ranges. About one-third of swine manure is managed in liquid-based systems. Buffalo manure is burned for fuel or managed as a solid.	Dairy Cows	1	2	2
	Non-Dairy Cows	1	1	1
	Swine	1	3	6
	Buffalo	4	5	5
Asia: About half of cattle manure is used for fuel with the remainder managed in dry systems. Almost forty percent of swine manure is managed as a liquid. Buffalo manure is managed in drylots and deposited in pastures and ranges.	Dairy Cows	7	16	27
	Non-Dairy Cows	1	1	2
	Swine	1	4	7
	Buffalo	1	2	3
Indian Subcontinent: About half of cattle and buffalo manure is used for fuel with the remainder managed in dry systems. About one-third of swine manure is managed as a liquid.	Dairy Cows	5	5	6
	Non-Dairy Cows	2	2	2
	Swine	3	4	6
	Buffalo	4	5	5

a Cool climates have an average temperature below 15°C; temperate climates have an average temperature between 15°C and 25°C; warm climates have an average temperature above 25°C. All climate categories are not necessarily represented within every region. For example, there are no significant warm areas in Eastern or Western Europe. Similarly, there are no significant cool areas in Africa and the Middle East. See Appendix B for the derivation of these emission factors.

Note: Significant buffalo populations do not exist in North America, Oceania, or Africa.

See the *Greenhouse Gas Inventory Reference Manual* for sources.

STEP 3 ESTIMATING METHANE EMISSIONS FROM ENTERIC FERMENTATION AND MANURE

- 1 Sum emissions for Enteric Fermentation and Manure and enter the totals at the bottom of the Worksheet.
- 2 Add the two totals together to give total Emissions from animals and manure. Enter the results in column F.
- 3 Divide the final result by 1,000 to express it as gigagrams.



4.3 Rice cultivation

Introduction

Anaerobic decomposition of organic material in flooded rice fields produces methane which escapes to the atmosphere primarily by transport through the rice plants. The amount of methane emitted is believed to be a function of rice species, number and duration of harvests, soil type and temperature, water management practices and fertilizer use.

Of the wide variety of sources for atmospheric CH₄, rice paddy fields are considered an important source. IPCC estimated the global emission rate from rice paddy fields to be ranging from 20 to 150 teragrams per year. This is about 5-30% of emissions from all sources. The figure is based mainly on field measurements of fluxes from paddy fields in the United States, China, Italy, India, Australia and Japan.

The measurements at various locations of the world show that there are temporal variations of CH₄ fluxes and that flux is critically dependent upon several factors including climate, characteristics of soils and paddy, and agricultural practices. About 90% of the world's harvested area of rice fields is located in Asia. Of all the harvested area in Asia, 60% is located in India and China.

Data sources

Data on cultivated rice area can be found by country and year in the annual United Nations Food and Agriculture Organization (FAO) Production Yearbooks (an annual publication containing annual agricultural statistics for generally the four most recent years). The most recent Production Yearbook (FAO, 1993) should be used, since each new issue updates previously published annual statistics. However, the annual cultivated areas presented in the Yearbooks combine all rice cultivation types, including wetland and upland areas.

A number of researchers have estimated the distribution of rice by water management type by country. Table 4-6 summarizes the results of one of these efforts.

See the *Greenhouse Gas Inventory Reference Manual* for a more detailed discussion of available data sources.

Methodology

Emissions of CH₄ from rice fields can be calculated using a simple formula as follows:

CH₄ Flux (in Gg, by category)

$$= \text{Aggregate Emission Factor (kilograms per hectare-day, by category)} \times \text{Number of hectare-days of flooded cultivation (megahectare-days, by category)}$$

ESTIMATING HARVESTED AREA

Harvested area is defined as the physical area under cultivation times the number of harvests. That is, if some areas are double cropped, they would be counted twice in harvested area.

From field experiments it is apparent that methane emissions from rice fields are affected by many factors. An expert group has recommended the factors for which there is sufficient information on both the emission factors and the hectare-days of cultivation. Including the available information in the present estimates of country-by-country emissions may improve the accuracy, but at present it is not certain which factors have the greatest effect on emissions.

The factors clearly identified by field experiments are:

- water level and its history in the growing season
- soil temperature
- fertilizer application
- soil type
- cultivar
- agricultural practices such as seeding or planting

Data show that higher temperatures, continuously flooded fields, some types of organic fertilizers, and certain cultivars lead to higher emissions compared to rice grown at lower temperatures with intermittent or managed irrigation in which the fields are not continuously inundated and use of chemical fertilizers.

At present there are insufficient data to incorporate most of these factors. Nonetheless the estimates can be improved substantially by incorporating the current knowledge on the first two factors - water management regime and temperature (the temperature is in °C.) For some countries the effects of organic and mineral fertilizer can be included. Inclusion of the remaining factors may be possible within one to two years.

Data on rice agriculture under different water management techniques may be available from most of the rice producing countries. Therefore the minimal equation for estimating emissions from each country has to include estimates for the three water regimes, namely flooded, intermittently flooded and dry rice agriculture. The dry category does not produce significant emissions and can be excluded from methane calculations.

Individual countries may use as much detail as can be scientifically justified based on laboratory and field experiments and theoretical calculations to arrive at the estimate of emissions from rice agriculture. These details should be incorporated into subcategories under each of the three main water management categories so that they can be compared with equivalent data from other countries.



Completing the Worksheet

Use WORKSHEET 4-2 METHANE EMISSIONS FROM RICE PRODUCTION at the end of this section to enter your data. Table 4-6 gives default data for the distribution of rice growing areas and water management types throughout the world.

STEP 1 ESTIMATING THE HARVESTED AREA AND DAYS OF CULTIVATION

- 1 Enter the Harvested Area by water management type (in millions of hectares or megahectares) in column A.

Harvested area is defined as land under cultivation times the number of harvests per year. Area cultivated under upland or dry conditions is excluded from methane calculations. Table 4-6 provides some default information which can be used if data are not locally available.

- 2 Enter the Season Length for each category (in days) in column B.

Default values are provided in Table 4-6 and can be used if more detailed data are not locally available.

- 3 For each category, multiply Harvested Area (column A) by Season Length (column B) to give the Megahectare-Days Flooded and enter this figure in column C.

USING THE WORKSHEET

- Copy the Worksheet at the end of this section to complete the inventory.
- Keep the original of the Worksheet blank so you can make further copies if necessary.

TABLE 4-6
DEFAULT ACTIVITY DATA - HARVESTED RICE

Country	1990 Area (1000s ha)	Season Length (days)	Continuously Flooded (%)	Dry (%)	Intermittently Flooded (%)
AMERICAS					
USA	1114	123	100	0	0
Belize	2	139	10	90	0
Costa Rica	53	103	10	90	0
Cuba	150	139	100	0	0
Dominican Republic	93	103	98	2	0
El Salvador	15	123	10	90	0
Guatemala	15	139	10	90	0
Haiti	52	123	40	60	0
Honduras	19	123	10	90	0
Jamaica	0	123	40	60	0
Mexico	123	130	41	59	0
Nicaragua	48	123	10	90	0
Panama	92	103	5	95	0
Puerto Rico	0	123	75	25	0
Trinidad & Tobago	5	103	45	55	0
Argentina	103	121	100	0	0
Bolivia	110	101	25	75	0
Brazil	4450	101	18	76	6
Chile	35	121	79	21	0
Colombia	453	124	53	47	0
Ecuador	266	100	40	10	50
Guyana	68	123	95	5	0

AMERICAS (CONT.)					
Paraguay	34	101	50	50	0
Peru	185	167	84	16	0
Surinam	58	123	100	0	0
Uruguay	108	138	100	0	0
Venezuela	119	103	90	10	0
ASIA					
Brunei	1	82	79	21	0
Hong Kong	0	123	100	0	0
Syria	0	123	100	0	0
Turkey	52	123	100	0	0
India	42321	107	53	15	32
Pakistan	103	103	100	0	0
Bangladesh	10303	132	14	14	72
Burma	4774	139	42	15	43
Nepal	1440	90	29	4	67
Afghanistan	173	103	100	0	0
Bhutan	25	169	21	15	64
China	33265	115	93	2	5
Indonesia	10403	110	78	15	7
Iran	570	103	100	0	0
Iraq	78	123	100	0	0
Japan	2073	123	96	4	0
Malaysia	2073	109	64	12	24
Philippines	3413	98	54	12	34
Sri Lanka	793	122	65	7	28
Taiwan	700	119	97	3	0
Thailand	9878	123	22	12	66
Kampuchea	1800	134	34	27	39
Laos	625	123	11	49	40
Vietnam	6069	119	65	7	28
N Korea	673	103	67	13	20
S Korea	1237	103	91	1	8
EUROPE					
Albania	2	123	100	0	0
Bulgaria	11	103	100	0	0
France	20	139	100	0	0
Greece	15	103	100	0	0
Hungary	11	123	100	0	0
Italy	208	102	100	0	0
Portugal	33	123	100	0	0
Romania	37	123	100	0	0
Spain	81	103	100	0	0
Former USSR	624	103	100	0	0
Former Yugoslavia	8	123	100	0	0
PACIFIC					
Australia	97	128	100	0	0
Fiji	13	81	50	50	0
Solomon Islands	0	102	38	62	0
Papua/New Guinea	0	102	38	62	0



AFRICA					
Algeria	1	138	100	0	0
Angola	18	121	100	0	0
Benin	7	123	10	90	0
Burkina Faso	19	123	89	11	0
Burundi	12	167	25	75	0
Cameroon	15	103	25	75	0
C African Republic	10	123	25	75	0
Chad	39	123	25	75	0
Comoros	13	100	100	0	0
Congo	4	121	25	75	0
Egypt	427	123	100	0	0
Gabon	0	121	25	75	0
Gambia	14	123	90	10	0
Ghana	85	139	24	76	0
Guinea Bissau	57	123	25	75	0
Guinea	608	123	8	47	45
Ivory Coast	583	123	6	87	7
Kenya	15	139	25	75	0
Liberia	168	123	0	94	6
Madagascar	1135	167	35	19	46
Malawi	29	137	25	75	0
Mali	222	123	25	75	0
Mauritania	14	123	100	0	0
Morocco	6	138	100	0	0
Mozambique	109	121	25	75	0
Niger	29	102	35	65	0
Nigeria	1567	103	28	55	17
Rwanda	3	167	25	75	0
Senegal	73	103	25	75	0
Sierra Leone	339	139	1	67	32
Somalia	5	103	50	50	0
South Africa	1	167	100	0	0
Sudan	1	103	50	50	0
Swaziland	0	167	25	75	0
Tanzania	375	137	10	26	64
Togo	21	139	4	96	0
Uganda	37	137	25	75	0
Zaire	393	101	5	90	5
Zambia	11	121	25	75	0
Zimbabwe	0	121	25	75	0

STEP 2 ESTIMATING CH₄ EMISSIONS BY WATER MANAGEMENT REGIME

REFLECTING MORE DETAIL

If you have the necessary data, you can sub-divide your data further to account for different fertilizing practices. Furthermore, if regional variations in temperature, cultivation practices, etc. justify it, calculations can be done at sub-national regional level. In either case you should use extra copies of the Worksheet and label them clearly by sub-category or region. You should then aggregate the results to provide a national summary table from the basic categories described in the method. This is done by summing *Harvested Area, megahectare-days* and *CH₄ Emissions* from the subsidiary worksheets. Weighted averages by category can be derived for:

- **Days Flooded per Year**
(divide megahectare-days by *Harvested Area*)
- **Emission Factor**
(divide CH₄ Emissions by megahectare-days)

Growing Season Average Temperature	Emission Factor kg/ha/day	
	Continuously Flooded	Intermittently Flooded
15	2.91	1.75
16	3.09	1.85
17	3.28	1.97
18	3.48	2.09
19	3.68	2.21
20	3.91	2.34
21	4.14	2.49
22	4.39	2.64
23	4.66	2.80
24	4.94	2.97
25	5.24	3.15
26	5.56	3.34
27	5.90	3.54
28	6.25	3.75
29	6.63	3.98
30	7.03	4.22
31	7.46	4.48
32	7.91	4.75
33	8.39	5.03
34	8.90	5.34
35	9.44	5.66

- 1 Enter annual average Emission Factors by water management regime (in kilograms per hectare) in column D.

If emissions factors based on local measurement data are available, these should be used and documented. If data are available in grams per square meter-day (g/m²-day), the values should be multiplied by 10 to convert to kilograms per hectare-day (kg/ha-day). Default values are provided in Table 4-7 by water management regime and average temperature. Information on average temperature can be used in either of two ways:

- You can select the temperature which reflects the average for the growing season of all rice grown in the country and enter this national average.
- In larger countries, you can sub-divide the area harvested into sub-regions with different growing temperatures and use an appropriate emission factor for each sub-region. When you do this, you should use multiple copies of the Worksheet 4-2.

- 2 For each category, multiply megahectare-days (column C) by the Emission Factor (column D) to give CH₄ Emissions in Gigagrams. Enter the result in column E.
- 3 Sum emissions and enter the total at the bottom of column E.



4.4 Savanna burning

Introduction

Savannas are tropical and sub-tropical formations with continuous grass coverage. The growth of savannas is controlled by alternating wet and dry seasons: most of the growth occurs during the wet season. Man made and natural fires frequently occur during the dry season, resulting in nutrient recycling and regrowth. Large scale burning takes place primarily in the humid savannas because the arid savannas lack sufficient grass cover to sustain fire. Savannas are burned every one to four years on average, with the highest frequency in the humid savannas of Africa.

Savanna burning results in instantaneous emissions of carbon dioxide. However, because the vegetation regrows between the burning cycles, the carbon dioxide released to the atmosphere is reabsorbed during the next vegetation growth period. Therefore, this *Workbook* assumes that CO₂ emissions are zero.

Savanna burning also releases gases other than CO₂, including methane, carbon monoxide, nitrous oxide and oxides of nitrogen. Unlike CO₂ emissions these are net emissions.

Data sources

There are no routinely published data on the amount of savanna burned, but several assessment papers have been published. The *FAO Forest Resource Assessment 1990: Tropical Countries* (FAO 1993) provides country estimates of savanna (grassland) area, and the *IPCC Greenhouse Gas Inventory Reference Manual* gives a full bibliography of savanna burning.

Methodology

The non-CO₂ trace gas emissions from savanna burning may be estimated through a series of simple calculations using locally available data or defaults provided in the tables provided in this *Workbook*.

First the quantity of biomass exposed to burning is calculated by multiplying area of savanna burned by average biomass density and by the fraction of exposed biomass which actually burns.

Second, carbon released is calculated multiplying quantity of biomass burned by combustion efficiency (fraction oxidized) and then by carbon fraction.

The second calculation can be greatly improved by first dividing the quantity of biomass burned into living and dead fractions. The calculation is then carried out for each of these fractions using different combustion efficiencies and carbon contents for the living and dead fractions.

Third, several ratios are applied to total carbon released to derive estimates of non-CO₂ trace gas emissions, as follows:

- a nitrogen-carbon ratio is applied to estimate total nitrogen content
- ratios for CH₄ and CO as fractions of total carbon
- ratios of N₂O and NO_x as fractions of total nitrogen

FRACTIONS

In order to determine the amount of savanna biomass which actually oxidizes to release carbon to the atmosphere, several *fractions* must be applied sequentially. To start with, the quantity of biomass exposed to fire is calculated by multiplying the area of savanna burned in the inventory year by the average biomass density (in tonnes of dry matter per hectare). The fractions are then applied as follows.

Fraction which Actually Burns

Under normal open burning conditions all biomass in each hectare does not actually burn. The *Fraction which Actually Burns* (generally 0.80 - 0.85 but may be higher in very dry regions) is applied to derive the kilotonnes of dry matter which actually burn.

Fraction Oxidized

This next fraction to be applied expresses the combustion efficiency of the biomass which actually burns. Not all of the burning biomass oxidizes - a small fraction may remain as charcoal. The fraction oxidized is usually 0.8 to 1.0.

Carbon Fraction

The last fraction to be applied determines the amount of carbon which is released from the fraction of biomass which has oxidized.

The resulting estimates of emissions are converted to total weight (i.e. from CH₄ as C to CH₄ total) using standard factors.

One country may possess more than one type of savanna with different characteristics; that burns may vary in efficiency; and that burns may take place at different times during the dry season, causing the burning to vary with the state of the vegetation (such as the moisture content and whether the biomass is alive or dead).

If data are locally available savanna burned should be subdivided into relevant subcategories reflecting these variations and entered into the worksheet. If you are relying on the default values in this *Workbook* you will only be able to carry out calculations at a national level.

Completing the Worksheet

USING THE WORKSHEET

- Copy the Worksheet at the end of this section to complete the inventory.
- Keep the original of the Worksheet blank so you can make further copies if necessary

STEP 1 ESTIMATING TOTAL BIOMASS EXPOSED TO BURNING

Use WORKSHEET 4-3 SAVANNA BURNING - RELEASE OF CARBON AND TRACE GASES at the end of this section to record inventory data. You should do this for a single national average category or subdivide if data are locally available for each relevant sub-category of savanna.

- 1 For each category of savanna, enter the Area Burned (in kilohectares) in column A.

If possible use locally available data in hectares of savanna burned annually. If this is not possible, a crude default approach is to determine the total savanna area and multiply by typical regional defaults for percent burned annually from Table 4-8 (below).

TABLE 4-8 REGIONAL SAVANNA STATISTICS				
Region	Area Burned Annually (%/year)	Aboveground Biomass Density (t dm/ha)	Fraction of Biomass Actually Burned	Fraction of Aboveground Biomass that is Living
Tropical America	50	6.6 ±1.8		
Tropical Asia	50	4.9		
Tropical Africa	75	6.6 ±1.6		
Sahel zone	5-15	0.5-2.5*	0.95	0.20
North Sudan zone	25-50	2-4*	0.85	0.45
South Sudan zone	25-50	3-6*	0.85	0.45
Guinea zone	60-80	4-8*	0.90-1.0	0.55
Australia	5-70	2.1-6		

Regional defaults are for seasonal average densities which should be used for emissions calculations. Values marked with * are maximum, season end densities which are appropriate defaults for these very dry sub-regions.
See the *Greenhouse Gas Inventory Reference Manual* for sources of these figures.

- 2 For each category of savanna, enter the Biomass Density of the Savanna (in tonnes of dry matter per hectare) in column B. Table 4-9 provides available summary information by region which can be used as default data.



- 3 Multiply the Area Burned by the Biomass Density of the Savanna to give the Total Biomass Exposed to Burning (in kilotonnes of dry matter). Enter the result in column C.
- 4 Enter the Fraction of Biomass Actually Burned in column D.
Use locally available data if available. You can use a general default figure in the range 0.80 - 0.85. Some specific values for African sub-regions are given in Table 4-9.
- 5 Multiply Total Biomass Exposed to Burning (column C) by the Fraction Actually Burned (column D) to give the Quantity Actually Burned. Enter the results in column E.

STEP 2 ESTIMATING THE PROPORTIONS OF LIVING AND DEAD BIOMASS

- 1 Enter the Fraction of Biomass Living at the time of burning in column F.
Some default figures are in Table 4-9 for specific sub-regions in Africa. In other regions users must provide these values. If no information is available, users can do the calculation using "combined values".
- 2 Multiply the Quantity of Biomass Actually Burned by the Fraction of Biomass Living to give the quantity of Living Biomass Burned (in kilotonnes of dry matter). Enter the result in column G.
- 3 Subtract the Living Biomass Burned from the Quantity of Biomass Actually Burned to give the quantity of Dead Biomass Burned (in kilotonnes of dry matter). Enter the result in column H.

STEP 3 ESTIMATING THE TOTAL CARBON RELEASED

- 1 For each category of savanna, enter the Fraction Oxidized (that is, the combustion efficiency) for *living* and *dead* biomass. Enter the results in the appropriate boxes in column I. Default figures are in Table 4-10.
- 2 For each category of savanna multiply the Living Biomass Burned by the Fraction Oxidized for living biomass. **Also**, multiply Dead Biomass Burned by the Fraction Oxidized for dead biomass. Enter the results, in kilotonnes of dry matter, in the appropriate boxes in column J.
- 3 For each category of savanna, living and dead, enter the Carbon Fraction (of dry matter) of living and dead biomass in column K. Default figures are in Table 4-10.
- 4 Multiply the Total Biomass Burned by the Carbon Fraction for each category of savanna, living and dead, to give the Total Carbon Released. Enter the results in column L in kilotonnes of carbon.
- 5 Add the totals in column L and enter the result in the Total box at the bottom of the column. Carry the result forward to column L at the start of sheet C on the next page.

NOTE

From this point on in the worksheet, each original category is split into two parts - living and dead - for which calculations are made separately. Each row in the worksheet splits into living and dead rows for columns I through J. If users are not able to report living and dead fractions, the default calculation can be done using "combined" values from Table 4-10.

TABLE 4-10
GENERAL DEFAULT VALUES

	Fraction Oxidized (Combustion Efficiency)	Carbon Fraction
Living Fraction	0.80	0.45
Dead Fraction	1.0	0.40
Combined	0.90	0.45

STEP 4 ESTIMATING NON-CO₂ TRACE GAS EMISSIONS FROM SAVANNA BURNING

- 1 Enter the Nitrogen-Carbon Ratio in column M.

If no data specific to biomass type are locally available, use the general default value for savannas, which is 0.006.

- 2 Multiply Total Carbon Released (column L) by the Nitrogen-Carbon Ratio to give the Total Nitrogen Content (in kilotonnes of Nitrogen). Enter the result in the appropriate box in column N.
- 3 For each gas - methane (CH₄), carbon monoxide (CO), nitrous oxide (N₂O) and nitrogen oxides (NO_x) - enter a Trace Gas Emission Ratio in column O.

Table 4-11 shows the default ratios.

TABLE 4-11 EMISSION RATIOS AND RANGES FOR BIOMASS BURNING CALCULATIONS		
Compound	Default value	Range
CH ₄	0.004	0.002 - 0.006
CO	0.06	0.04 - 0.08
N ₂ O	0.007	0.005 - 0.009
NO _x	0.120	0.094 - 0.148
<p>Note: Ratios for carbon compounds are mass of carbon released as CH₄ or CO (in units of C) relative to mass of total carbon released from burning (in units of C). Those for nitrogen compounds are expressed as the ratios of nitrogen released as N₂O and NO_x relative to the nitrogen content of the fuel (in units of N). See the <i>Greenhouse Gas Inventory Reference Manual</i> for sources.</p>		

- 4 Multiply Total Carbon Released (column L) (for CH₄ and CO), or Total Nitrogen Content (column N) (for N₂O and NO_x) by the emissions ratios in column O to give the total emissions for each non-CO₂ trace gas. Enter the results in column P.

STEP 5 CONVERT TRACE GAS EMISSIONS OF CARBON AND NITROGEN INTO METHANE, CARBON MONOXIDE, NITROUS OXIDE AND NITROGEN OXIDE EMISSIONS.

- 1 Multiply the emissions of each gas expressed as C or N by the appropriate conversion factor in column Q to give the Total Weight of each gas emitted. Enter the results in column R.



4.5 Field Burning of Agricultural Residues

Introduction

Large quantities of agricultural wastes are produced from farming systems world-wide. Burning of crop residues in the fields is a common agricultural practice, particularly in developing countries. It has been estimated that 80% of the crop residues are burned in developing countries and about 50% in developed countries (these estimates are highly uncertain). It is important to note that some crop residues are removed from the fields and burned as a source of energy, especially in developing countries. Emissions from this type of burning are calculated in the Energy module of this *Workbook*. Users should ensure that residue burning is properly allocated to these two components and not double counted.

This sub module deals exclusively with non-CO₂ trace gas emissions from crop residues. In this *Workbook*, field burning of crop residues is not treated as a net source of carbon dioxide because it is assumed that the carbon released to the atmosphere is reabsorbed during the next growing season. However crop residue burning is a significant net source of emissions of methane, carbon monoxide, nitrous oxide and nitrogen oxides.

Data sources

Annual crop production statistics by country for most of the crops from which residues are burned may be found in FAO Production Year Books (e.g. FAO, 1986). Crop specific data for each country on ratios of residue to crop production, fraction of residue burned, dry matter content of residue and carbon and nitrogen contents of residue should be provided by individual countries if available. Table 4-12 *Selected Crop Residue Statistics* shows default data for crop residues.

TABLE 4-12
SELECTED CROP RESIDUE STATISTICS

Product	Residue / Crop Ratio	Dry Matter Content (fraction)	Carbon Content (fraction)	Nitrogen Carbon Ratio
Wheat	1.3	0.78-88	0.4853	0.012
Barley	1.2	0.78-88	0.4567	
Maize	1	0.30-50	0.4709	0.02
Oats	1.3			
Rye	1.6			
Rice	1.4	0.78-88	0.4144	0.014
Millet	1.4			0.016
Sorghum	1.4			0.02
Pea	1.5			
Bean	2.1			
Soya	2.1			0.05
Potatoes	0.4	0.30-60	0.4226	
Feedbeet	0.3	0.10-20 ¹	0.4072	
Sugarbeet	0.2	0.10-90 ¹	0.4072	
Jerusalem artichoke	0.8			
Peanut	1			

Note: Crop statistics in this table are not complete. For values not specified you should use values for the most similar crop type as defaults.

See the *Greenhouse Gas Inventory Reference Manual* for sources.

¹ These statistics are for beet leaves.

Completing the Worksheet

STEP 1 CALCULATING THE AMOUNT OF RESIDUE

Use **WORKSHEET 4-4 BURNING OF AGRICULTURAL RESIDUES** to enter data for this sub module.

- 1 Specify the important crops which produce residues burned in fields and enter these as categories on the Worksheet.
- 2 For each type of crop, enter Annual Production in kilotonnes of crop product in column A.
- 3 Enter the Residue to Crop Ratio for each crop type in column B. Use Table 4-12 above if there are no local statistics.
- 4 Multiply the Annual Production of each crop by the Residue to Crop Ratio to give the Amount of Residue in kilotonnes. Enter the result in column C.



STEP 2 ESTIMATING THE AMOUNT OF DRY RESIDUE

- 1 Enter Dry Matter Fraction for each crop type in column D.
Default values for some crop types are shown in Table 4-12.
- 2 Multiply the Amount of Residue by the Dry Matter Content to give the Amount of Dry Residue. Enter the result in column E.

STEP 3 ESTIMATING TOTAL BIOMASS BURNED

- 1 Enter the Fraction Burned in Fields for each crop type in column F.
Values should reflect an average of practices for the individual country.
No default data is available.
- 2 Enter the Fraction of Biomass Which Oxidizes (combustion efficiency) for each crop type in column G (default value 0.90).
- 3 Multiply the Amount of Dry Residue by the Fraction Exposed to Burning and the Fraction of Biomass Which Oxidizes to give the Total Biomass Burned (in kilotonnes of dry matter). Enter the result in column H.

STEP 4 CALCULATING THE TOTAL CARBON RELEASED

- 1 Enter the Carbon Fraction of each residue in column I.
Default values for some crop types are shown in Table 4-12. If no other information is available, use the general default for live biomass, which is 0.45.
- 2 Multiply the Total Biomass Burned by the Carbon Content of each residue to give the amount of Carbon Released in kilotonnes of carbon. Enter the results in column J.
- 3 Add the totals for each crop type in column J and enter the result in the Total box at the bottom of the column.

STEP 5 ESTIMATING TOTAL NITROGEN RELEASED

- 1 Enter the Nitrogen-Carbon Ratio for each crop type in column K.
The general default Nitrogen-Carbon ratio for crops is 0.01- 0.02. Some specific values for individual crops are given in Table 4-12.
- 2 Multiply the Total Carbon Released (column J) by the Nitrogen-Carbon Ratio (column K) to give the Total Nitrogen Released. Enter the result in column L.
- 3 Add the Total Nitrogen Released for each crop type and enter the result in the Total box at the bottom of column L.

STEP 6 ESTIMATING NON-CO₂ TRACE GAS EMISSIONS

- 1 Enter Trace Gas Emission Ratios in the relevant boxes in column M.
Table 4-13 shows default emission ratios and ranges.

TABLE 4-13 DEFAULT EMISSION RATES FOR AGRICULTURAL RESIDUE BURNING CALCULATIONS		
Gas	Ratios	
	Default	Range
CH ₄	0.005	0.003-0.007
CO	0.1	0.075-0.12
N ₂ O	0.007	0.005-0.009
NO _x	0.12	0.09-0.15

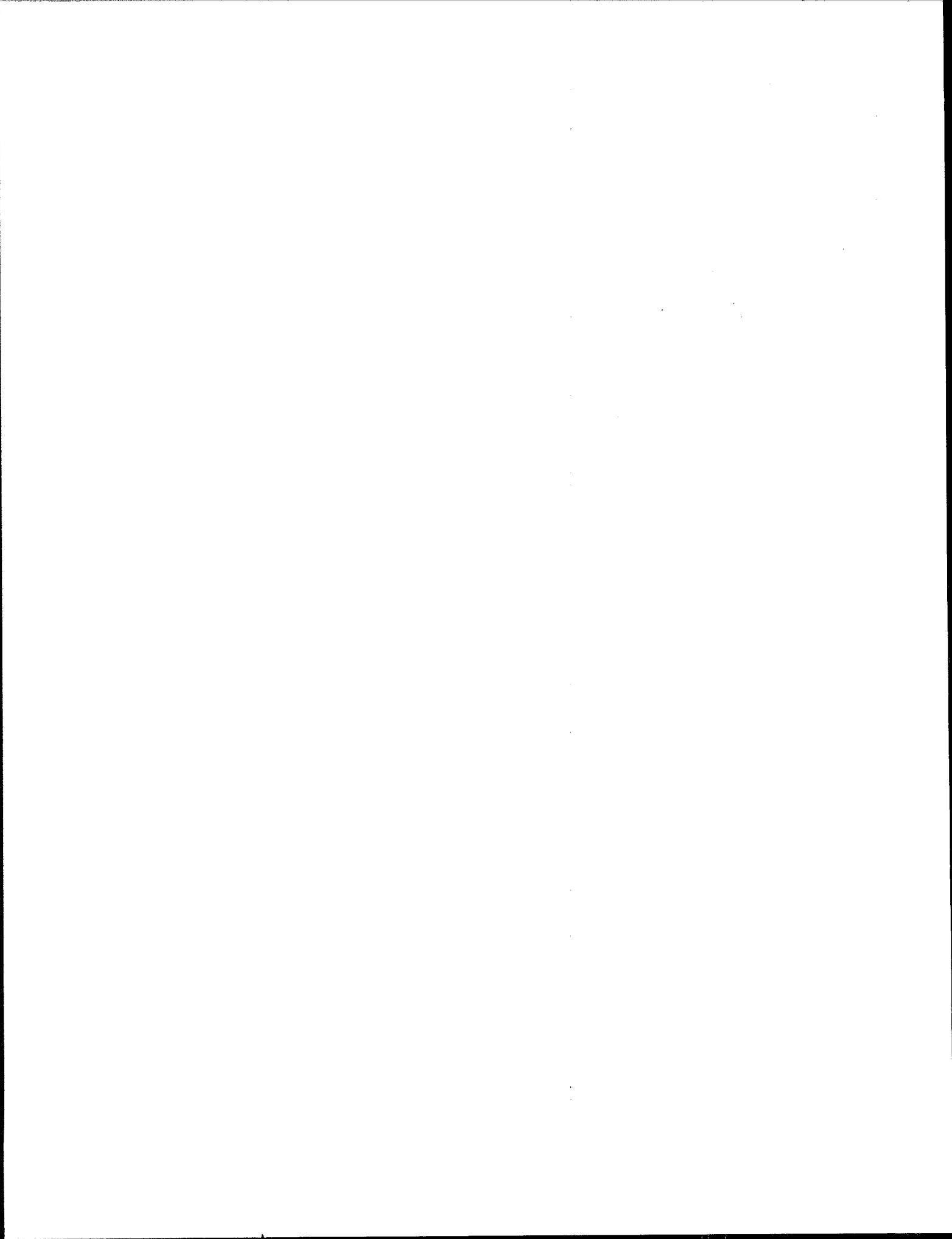
Note: Ratios for carbon compounds are mass of carbon released as CH₄ or CO (in units of C) relative to mass of total carbon released from burning (in units of C). Those for nitrogen compounds are expressed as the ratios of nitrogen released as N₂O and NO_x relative to the nitrogen content of the fuel (in units of N).

See the *Greenhouse Gas Inventory Reference Manual* for sources.

- 2 Multiply Carbon Released (Total from column J) by the Trace Gas Emission Ratios for CH₄ or CO (column M) to give the Trace Gas Emissions of Carbon as methane and carbon monoxide. Enter the results in the appropriate boxes in column N.
- 3 Multiply Nitrogen Released (Total from column L) by the Trace Gas Emission Ratios for N₂O or NO_x (column M) to give the Trace Gas Emissions of Nitrogen as nitrous oxide and nitrogen oxides. Enter the results in the appropriate boxes in column N.
- 4 For each gas, multiply by the Conversion Factor in column O to give the amount of Trace Gas Emissions from Burning Agricultural Residues. Enter the results, in kilotonnes (the same as megagrams) of each gas, in the appropriate boxes in column P.

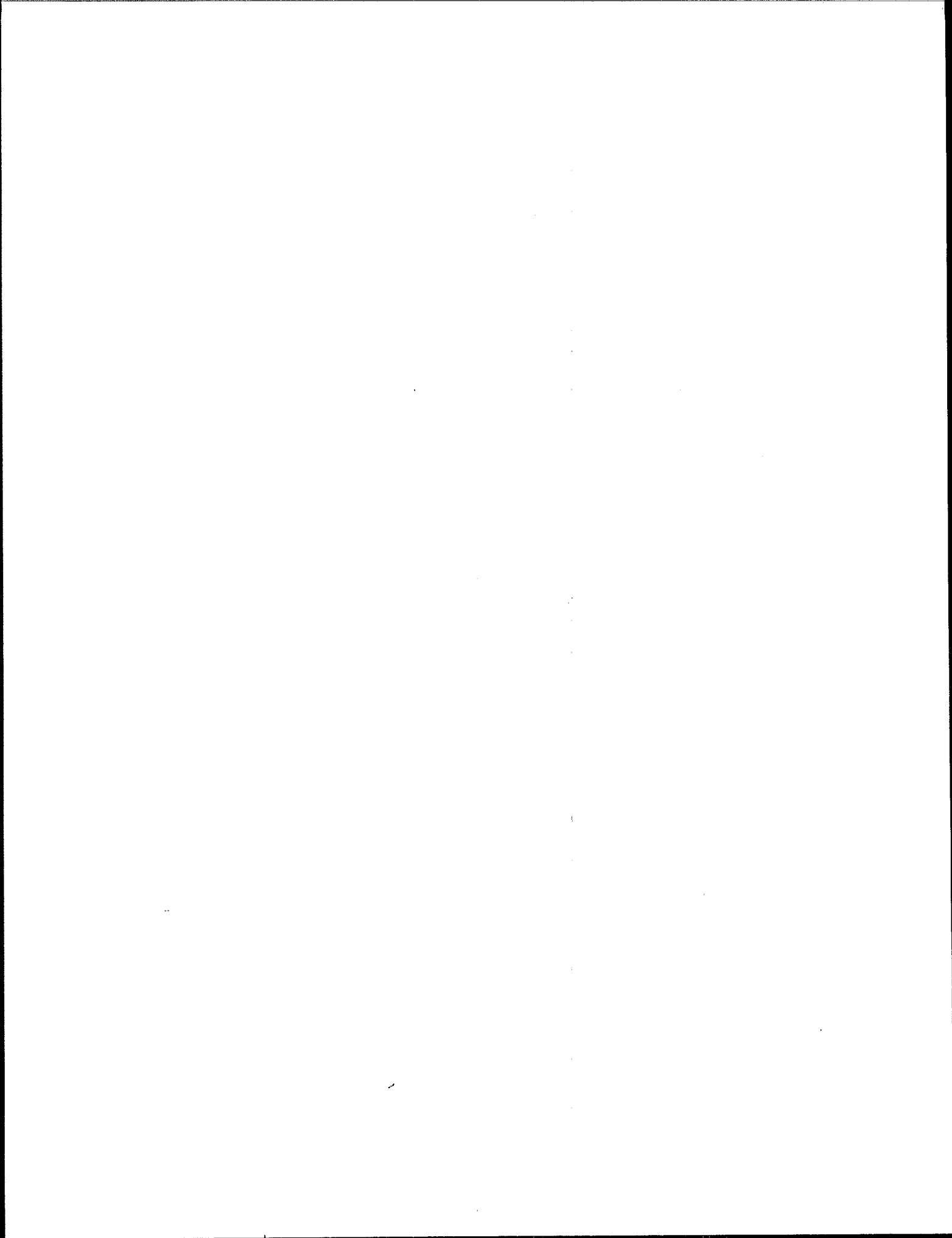


MODULE			AGRICULTURE			
SUB MODULE			METHANE EMISSIONS FROM ANIMALS AND ANIMAL MANURE			
WORKSHEET			4-1			
SHEET			A			
Livestock Type	A Number of Animals (1000s)	B Emissions Factor for Enteric Fermentation (kg/head/year)	C Emissions from Enteric Fermentation (Mg/year)	D Emissions Factor for Manure Management (kg/head/year)	E Emissions from Manure Management (Mg/year)	F Total Emissions from Animals and Manure (Gg)
			$C=(A \times B)$		$E=(A \times D)$	$F=(C+E)$
Dairy Cattle						
Other Cattle						
Buffalo						
Sheep						
Goats						
Camels						
Horses & Mules						
Swine						
Poultry						
		Totals				



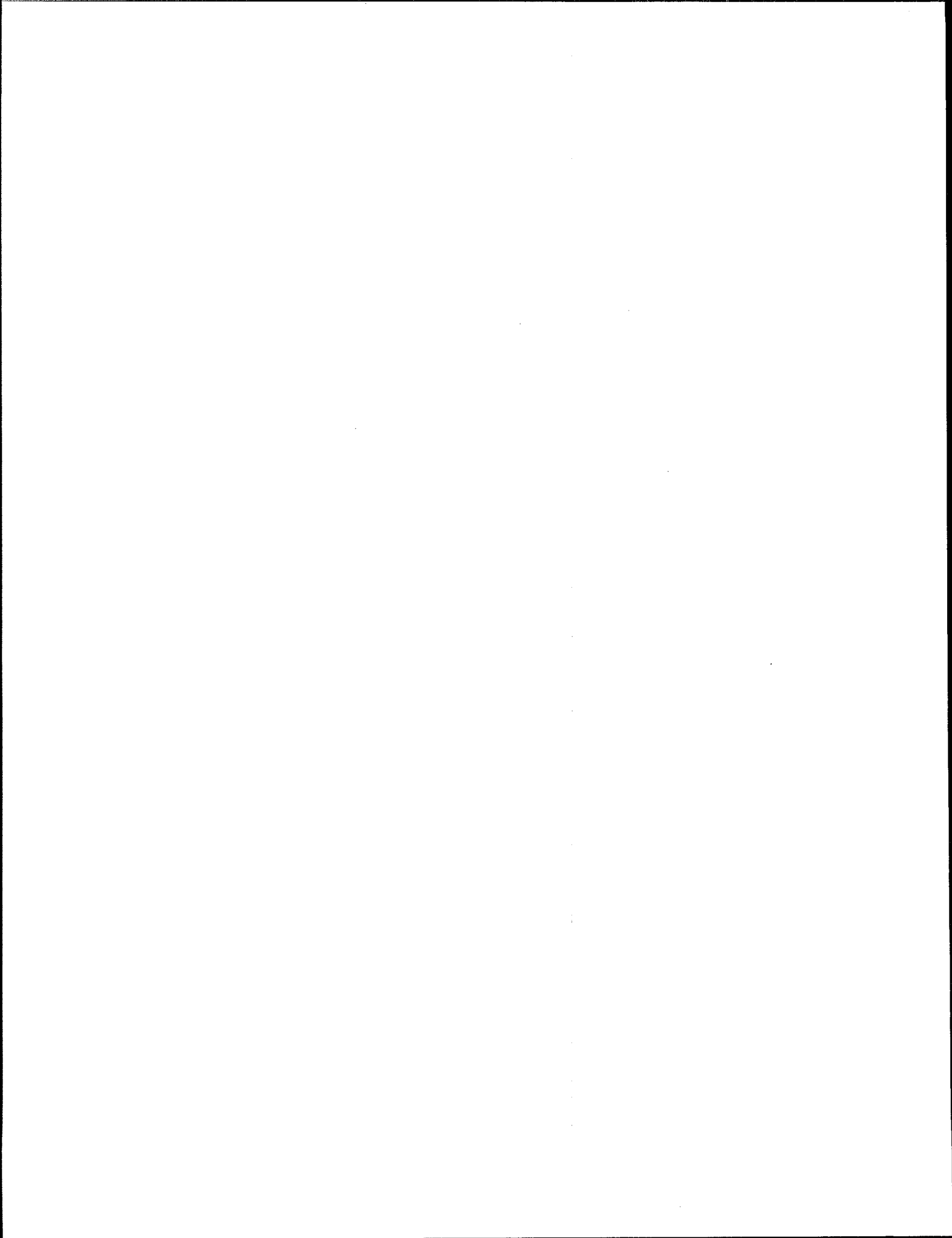


MODULE	AGRICULTURE				
SUB MODULE	METHANE EMISSIONS FROM RICE PRODUCTION				
WORKSHEET	4-2				
SHEET	A				
		STEP 1		STEP 2	
Water Management Regime	A Harvested Area (Mha)	B Season Length (days)	C Megahectare-Days (Mha-days)	D Emission Factor (kg/ha-day)	E CH ₄ Emissions by Irrigation Regime (Gg)
			C=(AxB)		E=(Cx D)
Continuously Flooded					
Intermittently Flooded					
Totals					





PART 2





MODULE	AGRICULTURE		
SUB MODULE	SAVANNA BURNING. RELEASE OF NON-CO₂ TRACE GASES		
WORKSHEET	4-3		
SHEET	B		
STEP 3			
I Fraction Oxidised (Combustion Efficiency) of living and dead biomass	J Total Biomass Oxidized (kt dm)	K Carbon Fraction of Living & Dead Biomass	L Total Carbon Released (kt C)
	Living: $J=(G \times I)$ Dead: $J=(H \times I)$		$L=(J \times K)$
Living			
Dead			
Living			
Dead			
Living			
Dead			
Living			
Dead			
Living			
Dead			
Living			
Dead			
Living			
Dead			
		Total	

100

101

102

103

104

105

106

107

108

109

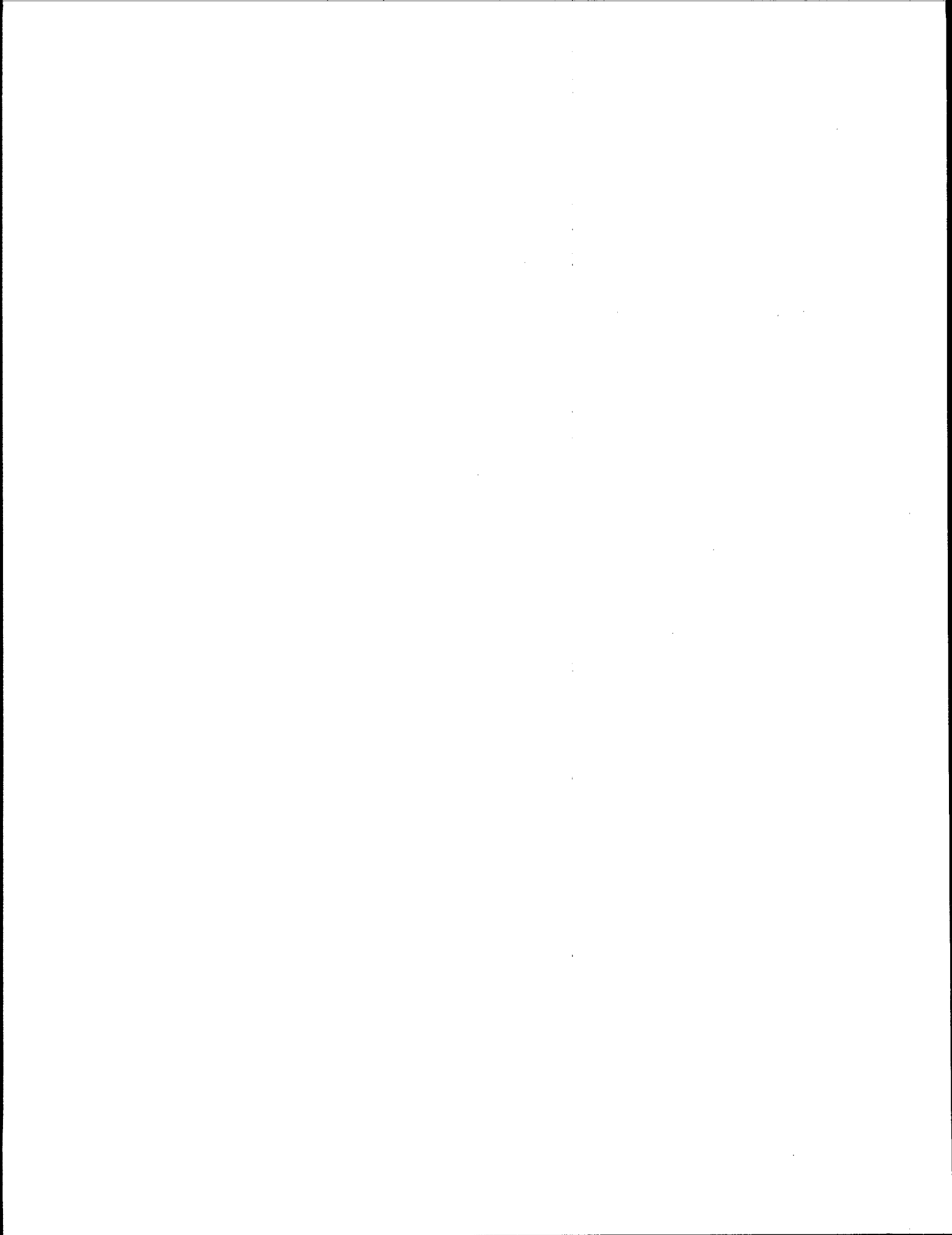
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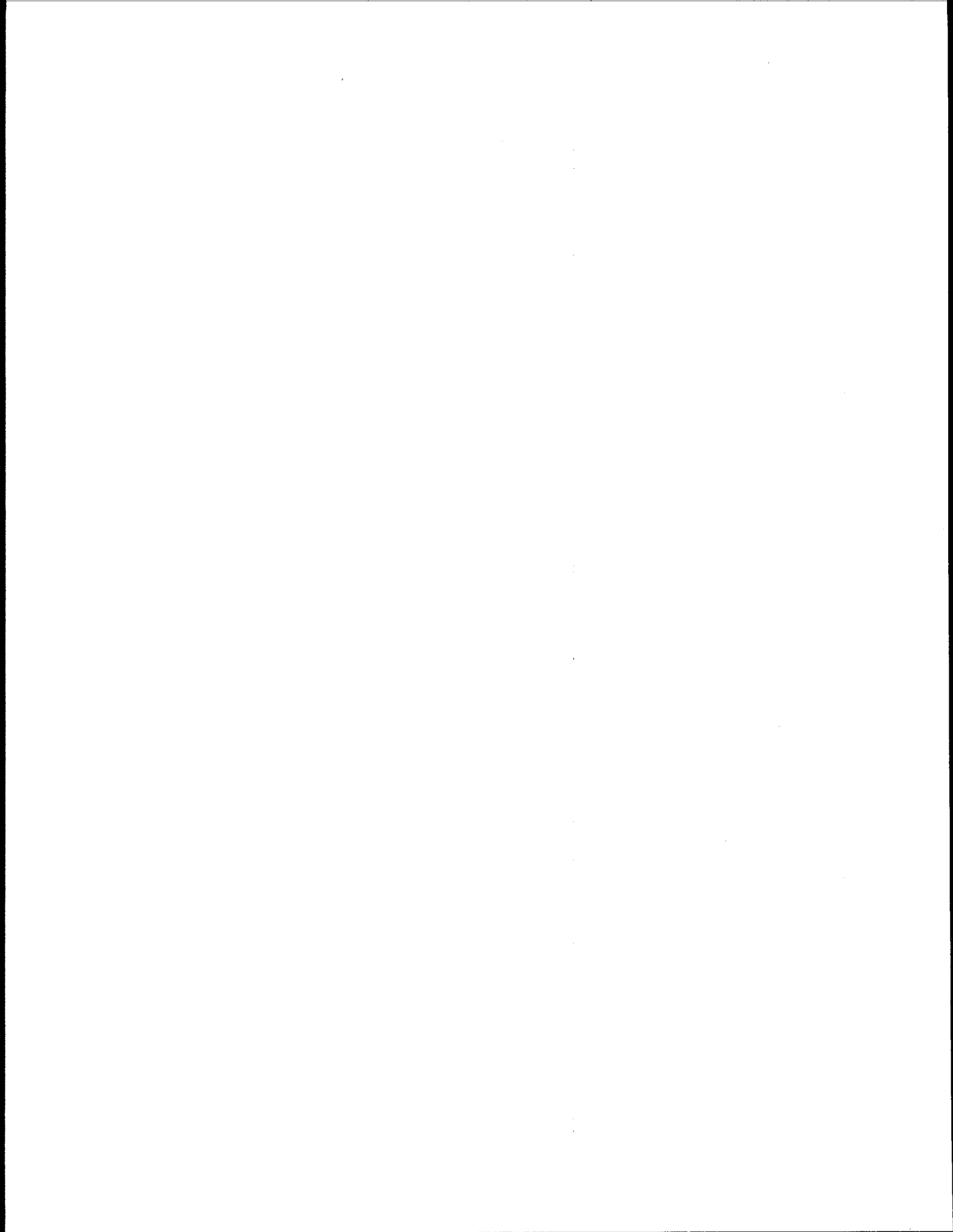
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MODULE		AGRICULTURE				
SUB MODULE		SAVANNA BURNING. RELEASE OF CARBON AND NON-CO ₂ TRACE GASES				
WORKSHEET		4-3				
SHEET		C				
STEP 4			STEP 5			
L	M	N	O	P	Q	R
Total Carbon Released (kt C)	Nitrogen-Carbon Ratio	Total Nitrogen Content (kt N)	Emissions Ratio	Trace Gas Emissions (kt C or kt N)	Conversion Factors	Trace Gas Emissions from Savanna Burning
				$P=(L \times O)$		$R=(P \times Q)$
					16/12	Mg CH ₄
					28/12	Mg CO
		$N=(L \times M)$		$P=(N \times O)$		$R=(P \times Q)$
					44/28	Mg N ₂ O
					30/14	Mg NO _x

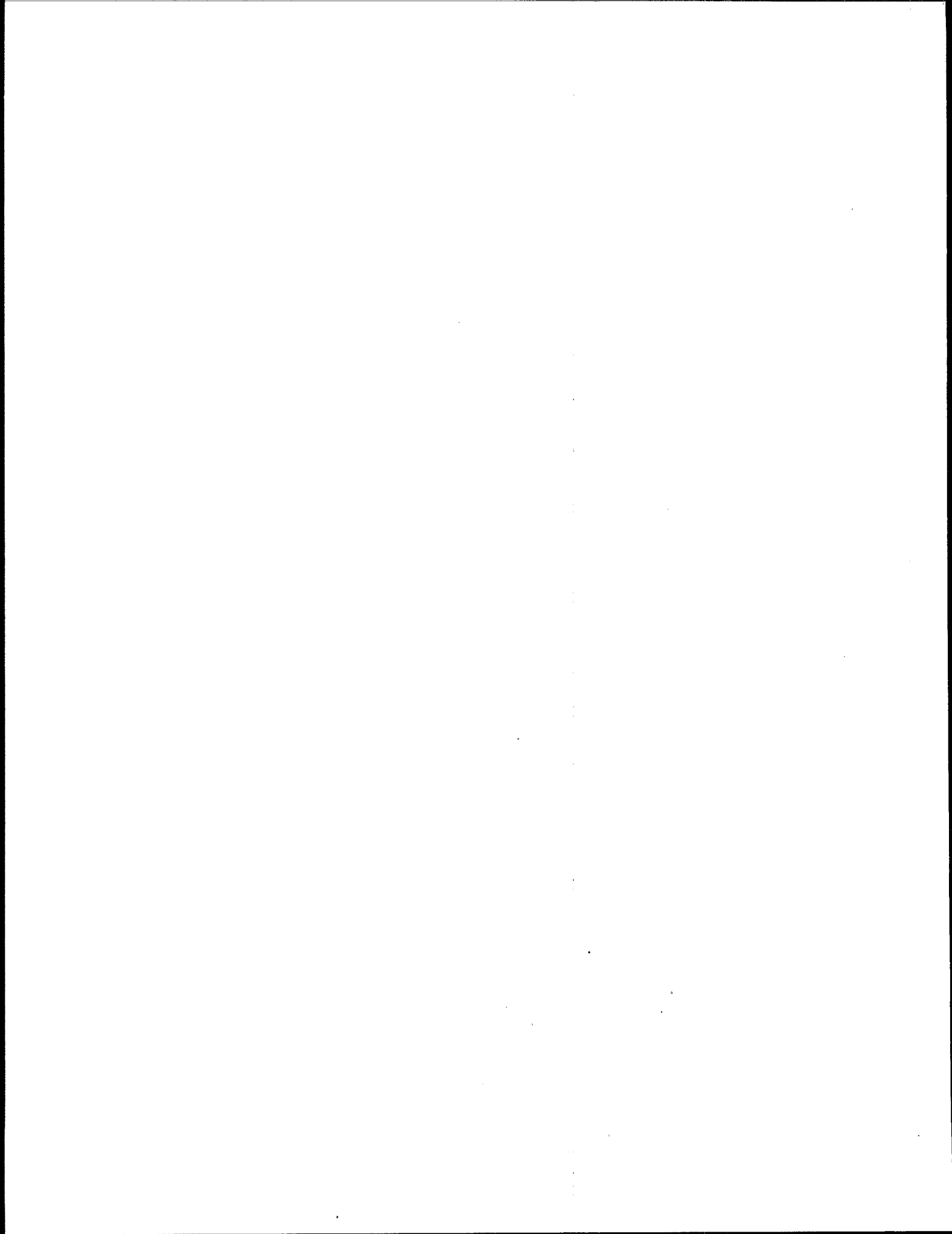


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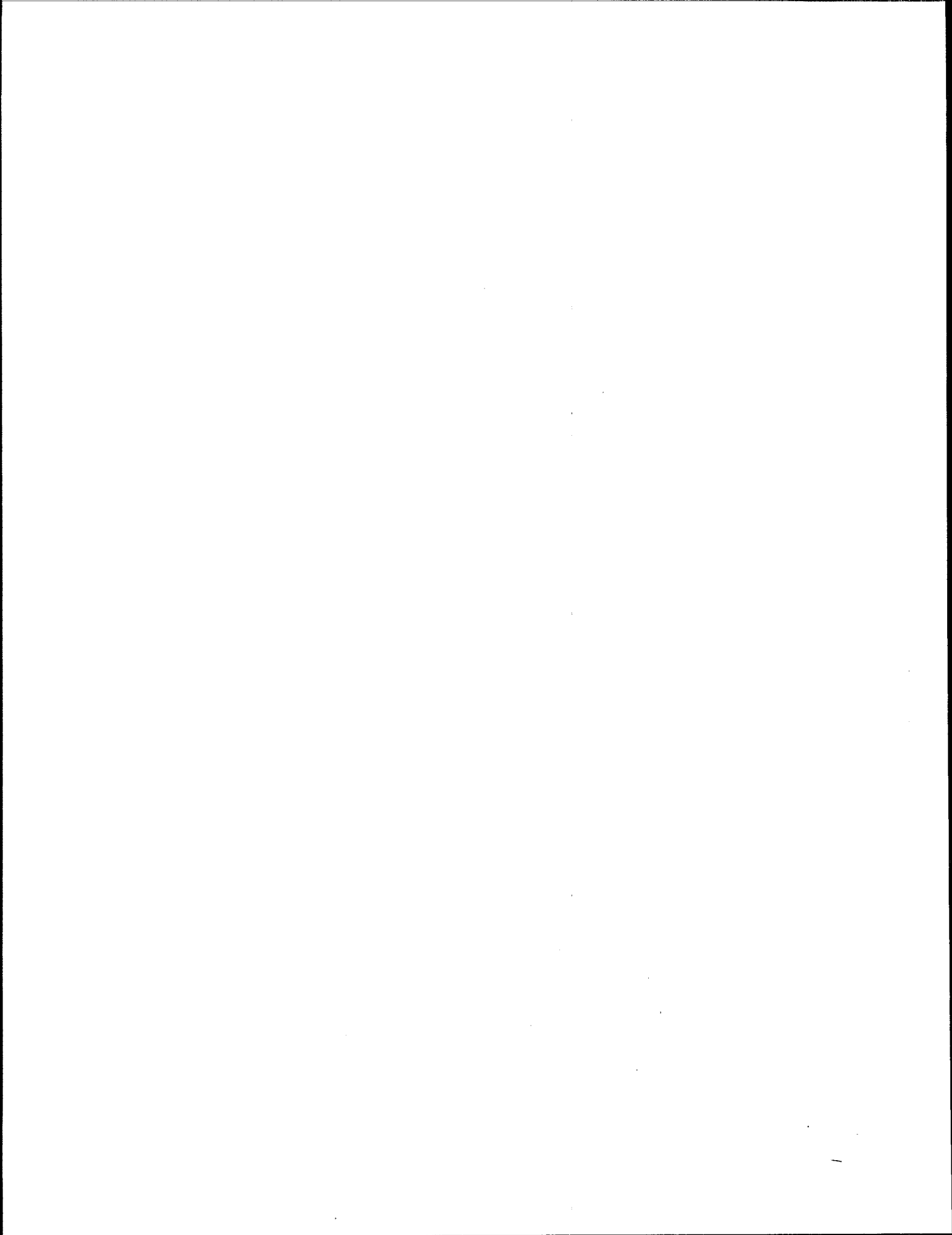


PART 2





MODULE		AGRICULTURE	
SUB MODULE		BURNING OF AGRICULTURAL RESIDUES, RELEASE OF NON-CO ₂ TRACE GASES	
WORKSHEET		4-4	
SHEET		D	
STEP 6			
M	N	O	P
Emissions Ratio	Trace Gas Emissions (kt C or kt N)	Conversion Factors	Trace Gas Emissions from Field Burning of Agricultural Wastes
	N=(jam)		P=(no)
		16/12	Mg CH ₄
		28/12	Mg CO
	N=(LxM)		P=(NxO)
		44/28	Mg N ₂ O
		30/14	Mg NO _x





MODULE 5
LAND USE CHANGE
& FORESTRY



5 LAND USE CHANGE & FORESTRY

5.1 Introduction

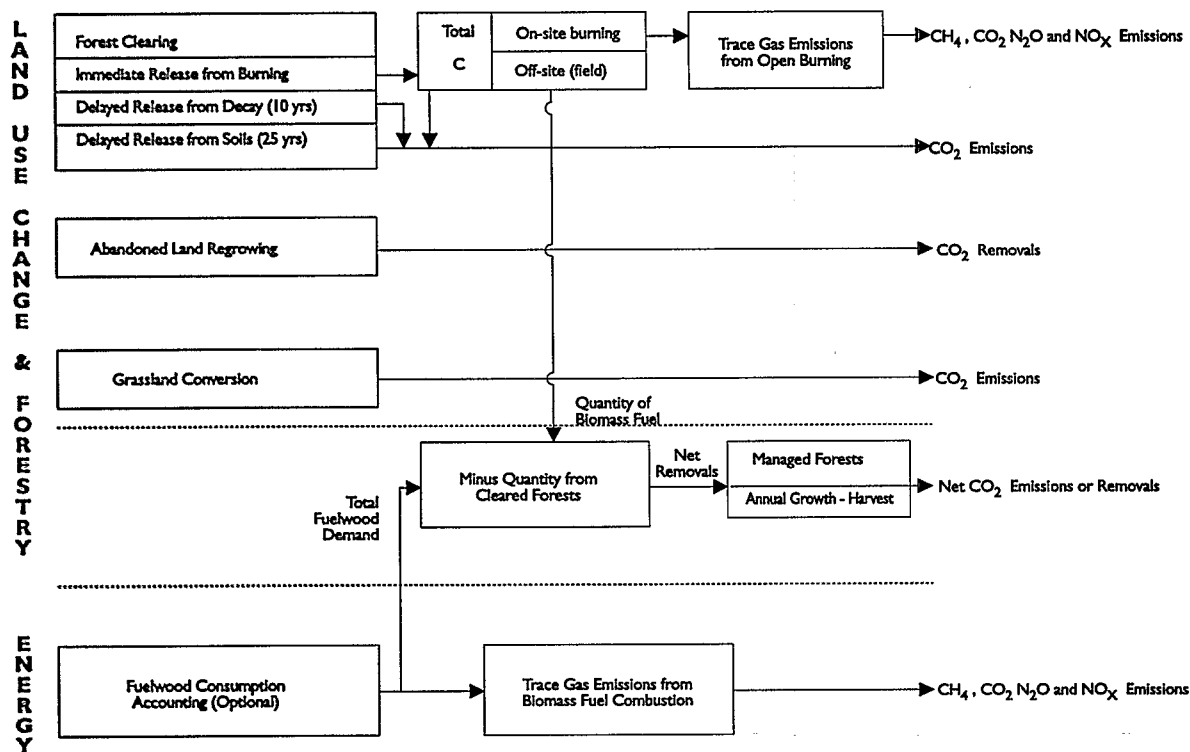
The priority calculations of emissions from land use change and forestry focus upon four activities which are sources or sinks of carbon dioxide. One of these activity types is also a source of other non-CO₂ trace gas (CH₄, CO, N₂O, and NO_x) emissions, and these are also calculated here.

On a global scale the most important land-use changes and management practices that result in CO₂ emissions and uptake are:

- forest clearing
the conversion of forests to non-forests (e.g. to pasture or cropland)
- grassland conversion
the conversion of grasslands to cultivated (tilled) or pasture lands
- abandonment of managed lands
regrowth into forests or grasslands
- managed forests
logging, harvesting fuel wood, plantations, afforestation programmes

The immediate release of non-CO₂ trace gases from the burning associated with forest clearing is also calculated. These calculations are very similar to calculations of non-CO₂ trace gas emissions of other major types of biomass burning: biomass fuel combustion (in the Energy module) and burning of savannas and agricultural residues (in the Agriculture module).

Relationships among categories



The diagram above illustrates the relationships between the categories in this module and also with biomass fuel combustion in the Energy module. The key linkages are:

- 1 To estimate CO₂ emissions from Burning of Cleared Forests it is only necessary to know the total amount of Biomass Burned in the inventory year.
- 2 Total Biomass Burned must be divided into *on-site* and *off-site* (fuelwood) portions for other reasons:
 - the type of burning affects the emissions of non-CO₂ trace gases such as methane, and therefore different emissions factors may be applied to open burning (on-site) and to fuelwood use (off-site)
 - the Amount of Fuelwood Removed from cleared forests must be subtracted from Total Fuelwood Consumed in order to determine net harvests from managed forests



- 3 Countries which have good statistics on direct harvesting of all types of wood from managed forests and all uses of biomass for fuel should use these data. In many countries, significant amounts of wood removed from forests (primarily for domestic use) are not included in commercial harvest statistics. These countries can use the optional Fuelwood Consumption Accounting approach. This is based on household and other fuel consumption surveys, scaled to population, in order to estimate annual demand for fuelwood and other traditional fuels. This information can be used **instead of or in combination with** commercial harvest and sales statistics.

Fuelwood consumption information is used in two ways:

- for estimating non-CO₂ trace gas emissions from biomass fuel combustion
- total wood consumption, corrected to deduct any wood which has come from forest clearing (CO₂ already accounted for) is also a key input for calculating net CO₂ emissions or removals in managed forests.

5.2 Forest clearing

Introduction

Clearing of forests for conversion to permanent cropland or pasture, primarily an activity of the tropics, is usually accomplished by cutting undergrowth and felling trees followed by burning on-site or as fuelwood. By this process some of the biomass is burned while some remains on the ground where it decays slowly (usually over a period of ten years in the tropics). Of the burned material, a small fraction (5-10%) is converted to charcoal which resists decay for 100 years or more, and the remainder is released instantaneously into the atmosphere as CO₂.

Carbon is also lost from the forest soils after clearing, particularly when the land is cultivated. This can occur over 25 years or more.

Data sources

To carry out the inventory task in this section you need the following forest and agriculture area statistics, in many cases over long historical time periods.

- Forest areas cleared for cropland and pasture, by forest type for the inventory year, the past ten years, and the past 25 years
- Areas of abandoned managed lands that regrow (past twenty years and possibly further back)
- Numbers of trees in non-forest locations (e.g. village and farm trees, urban trees etc.)

Satellite images, aerial photography and land-based surveys are all possible sources of data.

There is also a number of international databases with country-specific statistics, as well as studies of individual countries. These include:

Forest Resources Assessment 1990: Tropical Countries (FAO 1993).

The Forest Resources of the ECE Region (Europe, the USSR and America), (FAO/ECE 1985).

For a fuller bibliography, see *The IPCC Greenhouse Gas Inventory Reference Manual*.

Methodology

Three sets of calculations are used to produce estimates of CO₂ emissions due to forest clearing:

- Carbon emitted by burning aboveground biomass (*immediate* emissions, occurring in the year of clearing)
- Carbon released by decay of aboveground biomass (*delayed* emissions, occurring over a ten year period)
- Carbon released from soil (*delayed* emissions, occurring over a 25 year period)



The totals are added together to arrive at total for carbon released. Total carbon released is then converted to CO₂ emissions.

Completing the Worksheet

STEP 1 ESTIMATING BIOMASS CLEARED

Use WORKSHEET 5-1 FOREST CLEARING - CO₂ RELEASE FROM BURNING ABOVEGROUND BIOMASS ON AND OFF SITE, at the end of this section to record inventory data. You should do this for each forest type:

- 1 Enter the figures for Area Cleared Annually in kilohectares in column A.

See the *Reference Manual*, Chapter 6 Technical Appendix for a discussion of international sources of data.

- 2 Enter the figures for dry matter *before* clearing in tonnes per hectare (t/ha) in column B. Default values are shown in Tables 5-1 and 5-2.
- 3 Enter the figures for dry matter *after* clearing in tonnes per hectare (t/ha) in column C.

This figure includes any biomass not fully cleared (default value = 0) and regrowth in agricultural use (the default is 10 tonnes dry matter per hectare).

- 4 Subtract the figures in column C from the figures in column B to produce the figure for Net Change in Biomass in tonnes per hectare and enter the result in column D.
- 5 Multiply the Area Cleared Annually (in kilohectares) by the Net Change in Biomass (in tonnes per hectare) to calculate the Annual Loss of Biomass for each forest type in kilotonnes (kt). Enter the results in column E.

STEP 2 ESTIMATING CARBON RELEASED BY BURNING ABOVEGROUND BIOMASS ON-SITE

- 1 Enter figures for the fraction of biomass by forest type burned on site in column F.

TABLE 5-1
ABOVEGROUND DRY MATTER IN TROPICAL FORESTS
(t dm / ha)

	Closed Forests						Open Forests	
	Broadleaf			Conifer			Productive	Unproductive
	Undisturbed	Logged	Unproductive	Undisturbed	Logged	Unproductive		
America	230	190	110	172	70	70	60	25
Africa	300	240	160	150	80	130	35	45
Asia	300	150	165	184	155	150	60	20

See the *Greenhouse Gas Inventory Reference Manual* for sources.

USING THE WORKSHEET

- Copy the Worksheet at the end of this section to complete the inventory.
- Keep the original of the Worksheet blank so you can make further copies if necessary.

FRACTIONS

Various fractions are used in calculating the emissions from forest clearing.

- Fraction burned on-site and off-site
- Fraction left to decay

This is the portion of the wood which is simply left to decay and so releases gases at a slower rate.

- Fraction which oxidizes

This is the fraction of burned wood which actually oxidizes instead of turning to charcoal.

TABLE 5-2
ABOVEGROUND DRY MATTER IN TEMPERATE AND BOREAL FORESTS
(t dm / ha)

	Temperate Forests		Boreal Forests
	Evergreen	Deciduous	
Primary	295	250	165
Secondary	220	175	120

Sources: See *Greenhouse Gas Inventory Reference Manual*

- 2 Multiply the Annual Loss of Biomass (in kilotonnes) by the Fraction of Biomass Burned On Site to calculate the Quantity of Biomass Burned On Site (in kilotonnes) for each forest type. Enter the result in column G.
- 3 Enter the Fraction Oxidized for Biomass Burned On Site in column H (default fraction 0.9).
- 4 Multiply Quantity of Biomass Burned On Site (in kilotonnes) by the Fraction of Biomass Oxidized On Site to calculate the Quantity of Biomass Oxidized On Site (in kilotonnes). Enter the figures in column I.
- 5 Enter the Carbon Fraction of the Aboveground Biomass (burned on site) in column J (default fraction 0.45).
- 6 Multiply the Quantity of Biomass Oxidized On Site (in kilotonnes) by the Carbon Fraction of the Aboveground Biomass to calculate the Quantity of Carbon Released (in kilotonnes carbon). Enter the results in column K.
- 7 Total the figures in column K and enter the figure in the Sub-total box at the bottom of column on the Worksheet.

This sub-total will be used later to estimate emissions of other gases from burning on-site. (Worksheet 5-2)

STEP 3 ESTIMATING CARBON RELEASED BY BURNING ABOVEGROUND BIOMASS OFF-SITE

Use WORKSHEET 5-1 FOREST CLEARING - CO₂ RELEASE FROM BURNING ABOVEGROUND BIOMASS ON AND OFF SITE, at the end of this section to record inventory data. You should do this for each forest type.

- 1 Enter the Fraction of Biomass Exposed to Burning Off Site in column L.
This is the average fraction for fuelwood removed.
- 2 Multiply the Annual Loss of Biomass (in kilotonnes) from column E by the Fraction of Biomass Burned Off Site to calculate the Quantity of Biomass Burned Off Site (in kilotonnes) for each forest type. Enter the result in column M.
- 3 Total the figures in column M and enter the figure in the Sub-total box at the bottom of column on the Worksheet.
This sub-total will be used in Worksheet 5-5 Managed Forests.
- 4 Enter the Fraction Oxidized for Biomass Burned Off Site for each forest type in column N (default value 0.9).



- 5 Multiply Quantity of Biomass Burned Off Site (in kilotonnes) by the Fraction Oxidized to calculate the Quantity of Biomass Oxidized Off Site (in kilotonnes). Enter the figures in column O.
- 6 Enter the Carbon Fraction of the Aboveground Biomass (burned off site) in column P (default fraction 0.45).
- 7 Multiply the Quantity of Biomass Oxidized Off Site (in kilotonnes) by the Carbon Fraction of the Aboveground Biomass to calculate the Quantity of Carbon Released as CO₂ (in kilotonnes). Enter the results in column Q.
- 8 Total the figures in column Q and enter the figure in the Sub-total box at the bottom of column on the Worksheet

STEP 4 ESTIMATING TOTAL CARBON RELEASED BY BURNING ABOVEGROUND BIOMASS ON- AND OFF-SITE

Use WORKSHEET 5-1 FOREST CLEARING - CO₂ RELEASE FROM BURNING ABOVEGROUND BIOMASS ON AND OFF SITE at the end of this section to record inventory data. You should do this for each forest type.

- 1 Add the sub-total for the Quantity of Carbon released as CO₂ (from biomass burned on-site) in column K to the sub-total for the Quantity of Carbon released as CO₂ (from biomass burned off-site) in column Q. The result is the Total Carbon Released as CO₂. Enter the result in the sub-total box at the bottom of column R.
- 2 Multiply the Total Carbon Released as CO₂ by 44/12 to calculate the Total CO₂ Released (in kilotonnes). Enter the result in the sub-total box at the bottom of column S.

STEP 5 ESTIMATING CO₂ RELEASED BY DECAY OF ABOVEGROUND BIOMASS

Use WORKSHEET 5-1 FOREST CLEARING - CO₂ RELEASE FROM DECAY OF ABOVEGROUND BIOMASS at the end of this section to record inventory data. You should do this for each forest type.

- 1 Enter figures for Annual Average Area Cleared Over Ten Years for each forest type in column A.

Some information on international data sources is provided in the *Reference Manual* Chapter 6, *Technical Appendix*.
- 2 Enter the average biomass density in tonnes per hectare (t/ha) of dry matter *before* clearing in column B. Default values are provided in Table 5-1.
- 3 Enter the average biomass density in tonnes per hectare (t/ha) of dry matter *after* clearing in column C.

This figure includes any biomass not fully cleared (default value = 0) and regrowth in agricultural use (the default is 10 tonnes dry matter per hectare).

ESTIMATING FRACTION LEFT TO DECAY

In the Amazon, *Fraction Left to Decay* is typically about 0.5 but this varies greatly by region. Country experts must provide this value.

There is a relationship between the fraction left to decay here and the fraction burned on and off site. For a given year the fraction burned, the fraction left to decay (and possibly a fraction harvested as commercial timber or other non-fuel use) should sum to 1.0, accounting for all biomass cleared. Because the burning and decay portions are averaged over different time periods in the methodology, the relationship need not be precise.

However, assumptions made for these different fractions should be consistent.

- 4 Subtract the value in column C from the value in column B to produce Net Change in Biomass in tonnes per hectare. Enter the results in column D.
- 5 Multiply the Annual Average Area Cleared Over Ten Years in kilohectares (column A) by the Net Change in Biomass in tonnes per hectare (column D) to calculate the 10-Year Average Annual Loss of Aboveground Biomass for each forest type in kilotonnes (kt). Enter the results in column E.
- 6 Enter Fraction Left to Decay (10-Year average) in column F.
- 7 Multiply the Average Annual Loss of Biomass for each forest type by the Fraction Left to Decay to calculate the Quantity of Biomass Left to Decay. Enter the result in column G.
- 8 Enter the Carbon Fraction in Biomass in column H (default fraction 0.45).
- 9 Multiply the Quantity of Biomass Left to Decay (column G) by the Carbon Fraction (column H) to calculate Carbon Released from Decay of Aboveground Biomass. Enter the figures in column I.
- 10 Add the figures in column I and enter the total in the Total box at the bottom of the column.

STEP 6 ESTIMATING CARBON RELEASED BY SOIL

Use WORKSHEET 5-1 FOREST CLEARING - SOIL CARBON RELEASE at the end of this section to record inventory data.

- 1 Enter the Annual Average Area of Forest Converted to Pasture or Crops over the last 25 years in kilohectares in column A.

There are no default data for this figure.

CAUTION

There is no scientific consensus on whether clearing leads to significant soil carbon loss in tropical forests. This calculation is optional for tropical forests.

TABLE 5-3
CARBON IN SOILS IN FOREST SOILS
(t C / ha)

Tropical Forests	Moist	Seasonal	Dry
America	115	100	60
Africa	115	100	60
Asia	115	100	60
Temperate Forests	Evergreen	Deciduous	
Primary	134	134	
Secondary	120	120	
Boreal Forests			
Primary	206		
Secondary	185		
See the Greenhouse Gas Inventory Reference Manual for sources.			

- 2 Enter the Soil Carbon Content Before Clearing by forest type in column B (see Table 5-3 for defaults).



- 3 Multiply Annual Average Area of Forest Converted (column A) by the Soil Carbon Content (column B) to calculate the total Annual Potential Soil Carbon Losses. Enter the result in column C.
- 4 Enter Fraction of Carbon Released over 25 years in column D (default fraction 0.5).
- 5 Multiply Annual Potential Carbon Loss by the Fraction of Carbon Released to give the Carbon Release from Soil Carbon. Enter the result in column E.
- 6 Add the totals for each forest type and enter the total in the Total box at the bottom of column E.

STEP 7 ESTIMATING TOTAL CO₂ EMISSIONS FROM FOREST CLEARING

Use WORKSHEET 5-1 FOREST CLEARING - TOTAL CO₂ EMISSIONS at the end of this section to record inventory data. You should do this for each forest type.

- 1 Enter the total for Immediate Release from Burning (contained in the Total box of column R in Worksheet 5-1, Sheet C) in column A.
- 2 Enter the total for Delayed Emissions from Decay (contained in the Total box of column I in Worksheet 5-1, Sheet D) in column B.
- 3 Enter the total for Current Emissions from Soil caused by long term (25 years) clearing (contained in the total box of column E in Worksheet 5-1, Sheet E) in column C.
- 4 Add the figures in columns A, B and C to calculate the Annual Carbon Release (in the inventory year from clearing over a 25 year period) from Forest Clearing. Enter the result in column D.
- 5 Multiply the Annual Carbon Release from Forest Clearing by 44/12 to convert it into the Total Annual CO₂ Release from Forest Clearing (in kilotonnes). Enter the result in column E.

5.3 On-site burning of cleared forests

Introduction

For on-site burning of cleared forests, the method of calculation is very similar to those for non-CO₂ trace gases from burning of biomass. All burning of biomass (e.g. fuelwood, dung) for energy and of savannas and agricultural wastes is a significant source of CH₄, N₂O, CO and NO_x. Net CO₂ emissions from forest clearing were calculated in Section 5-2 above. Emissions of non-CO₂ trace gases from on-site burning associated with the clearing are calculated here.

Methodology

The method relies on estimation of the gross carbon flux based on work done in section 5.2 of this *Workbook*.

CH₄ and CO are estimated as ratios to carbon fluxes emitted during burning. Total nitrogen content is estimated based on the nitrogen-carbon ratio. N₂O and NO_x are estimated as ratios to total nitrogen.

Completing the Worksheet

Use WORKSHEET 5-2 ON-SITE BURNING OF CLEARED FORESTS to enter data for this sub module.

STEP 1 ESTIMATING NITROGEN RELEASED

- 1 Enter the estimate of Total Carbon Released from burning of cleared forests (in kilotonnes carbon) in column A.
Take this figure from the Total in column K of Worksheet 5-1, Sheet B, *Forest Clearing*.
- 2 Enter the Nitrogen/Carbon Ratio of Biomass Burned in column B.
The general default value is 0.01.
- 3 Multiply Total Carbon Released by the Nitrogen/Carbon Ratio to give the Total Nitrogen Released. Enter the total in kilotonnes of nitrogen in column C.



STEP 2 ESTIMATING NON-CO₂ TRACE GAS EMISSIONS

- 1 Enter Trace Gas Emissions Ratios in column D.

Refer to Table 5-4 for non-CO₂ trace gas emissions ratios.

TABLE 5-4 NON-CO ₂ TRACE GAS EMISSION RATIOS FOR OPEN BURNING OF CLEARED FORESTS	
Compound	Ratio
CH ₄	0.012 (0.009- 0.015)
CO	0.075 - 0.125
N ₂ O	0.005 - 0.009
NO _x	0.094 - 0.148
Note: Ratios for carbon compounds are mass of carbon released as CH ₄ or CO (in units of C) relative to mass of total carbon released from burning (in units of C). Those for nitrogen compounds are expressed as the ratios of nitrogen released as N ₂ O and NO _x relative to the nitrogen content of the fuel (in units of N).	
See the <i>Greenhouse Gas Inventory Reference Manual</i> for sources.	

- 2 Multiply Total Immediate Carbon Released (column A) by the emissions ratio for CH₄ to give the Amount of CH₄ released. Enter the amount in kilotonnes of C in column E.
- 3 Multiply Total Immediate Carbon Released (column A) by the emissions ratio for CO to give the Amount of CO released. Enter the amount in kilotonnes of C in column E.
- 4 Multiply the Total Nitrogen Released (column C) by the emissions ratio for N₂O to give the Amount of N₂O Released. Enter the amount in kilotonnes of N in column E.
- 5 Multiply the Total Nitrogen Released (column C) by the emissions ratio for NO_x to give the Amount of NO_x Released. Enter the amount in kilotonnes of N in column E.
- 6 Multiply the figures in column E by the conversion factors in the table to give total for the release of CH₄, CO, N₂O and NO_x. Enter the results in kilotonnes in column G.

5.4 Grassland conversion

Introduction

This sub module calculates net CO₂ emissions resulting from the conversion of grasslands into cultivated lands in the twenty five years up to the inventory year (1990).

Data sources

Default international data for grassland conversion are not available: national statistics must be used.

Methodology

To calculate the net release of CO₂, the area of grassland converted into cultivated land in the last twenty five years is multiplied by the difference in aboveground biomass carbon and soil carbon before and after conversion.

Completing the Worksheet

USING THE WORKSHEET

- Copy the Worksheet at the end of this section to complete the inventory.
- Keep the original of the Worksheet blank so you can make further copies if necessary

STEP 1 ESTIMATE AREA OF GRASSLAND CONVERTED INTO CULTIVATED LAND

Use WORKSHEET 5-3 CONVERSION OF GRASSLANDS TO CULTIVATED LANDS at the end of this section to record inventory data.

- 1 Enter the 20 year Total Area of Grassland Converted to Cultivated Lands in the twenty years to the inventory year (in kilohectares) in column A.
There are no defaults for these figures.
- 2 Enter the Soil Carbon Content of Grasslands in kilotonnes of carbon per hectare (kt C/ha) in column B.
The default values are 60 tonnes per hectare for tropical and 70 tonnes per hectare for temperate regions.
- 3 Enter the Annual Rate of Carbon Released from Soil in column C.
If there are no national data, use the default value of 2.0% (0.02).
- 4 Multiply the 20 year Total Area of Grassland Converted to Cultivated Lands (column A) by the Soil Carbon Content of Grasslands (column B) and the Annual Rate of Carbon Release from Soil (column C) to give the Total Annual Release of Carbon from Conversions over the previous twenty years. Enter the result in column D.
- 5 Multiply annual loss of carbon from conversions by 44/12 to give the Total Carbon Dioxide Released from Grassland Conversions Over Twenty Years. Enter the result in column E.



5.5 Abandonment of managed lands

Introduction

This sub module deals with emissions resulting from the abandonment of *managed* lands. Managed lands include:

- Cultivated lands (arable land used for the cultivation of crops)
- Pasture (land used for grazing animals)

Carbon accumulation on abandoned lands is sensitive to the type of natural ecosystem (forest type or grasslands) which is regrowing. Therefore abandoned lands regrowing should be entered by type. For grasslands there is no net accumulation aboveground. Only soil carbon is affected.

Because regrowth rates become slower after a time, the periods considered are

- Land abandoned during the 20 years prior to the inventory year (i.e. 1990)
- Land abandoned more than 20 years ago (i.e. before 1970)

When managed lands are abandoned, carbon may or may not reaccumulate on the land. Abandoned areas are therefore split into those which reaccumulate carbon and those which do not continue to degrade.

Only natural lands which are regrowing towards a natural state should be included. Lands which do not regrow or degrade should be ignored in this calculation.

As with forest clearing, there is controversy over the effect of forest regrowth on soil carbon in tropical regions. These calculations are all optional but you should ensure that you treat soil carbon from forest clearing, grassland conversion and abandoned lands consistently.

Methodology

These sets of figures are used to arrive at the total CO₂ emissions from the abandonment of managed lands. They relate to the quantity of land abandoned and the length of time for which it has been abandoned.

- Annual carbon uptake in aboveground biomass (land abandoned in the last twenty years)
- Annual carbon uptake in soils (land abandoned in the last twenty years)
- Annual carbon uptake in aboveground biomass (land abandoned for between twenty and a hundred years, if applicable)
- Annual carbon uptake in soils (land abandoned for between twenty and a hundred years, if applicable)

These are then totalled and the carbon uptake is converted into CO₂ emissions.

USING THE WORKSHEET

- Copy the Worksheet at the end of this section to complete the inventory.
- Keep the original of the Worksheet blank so you can make further copies if necessary.

Completing the Worksheet

Use WORKSHEET 5-4 ABANDONMENT OF MANAGED LANDS at the end of this section to record inventory data.

STEP 1 CALCULATE ANNUAL CARBON UPTAKE IN ABOVEGROUND BIOMASS (LAND ABANDONED IN LAST TWENTY YEARS)

- 1 Enter the Total Area Abandoned and Regrowing for the last twenty years (in kilohectares) in column A.
There are no default data for these figures.
- 2 Enter the Annual Rate of Aboveground Biomass Uptake (in kilotonnes dry matter per hectare) in column B. See Table 5-5 for defaults.

TABLE 5-5 AVERAGE ANNUAL UPTAKE BY NATURAL REGENERATION (t dm/ha)					
Region		Forest Types			
		Closed Forests		Open Forests	
Tropical		0-20 years	20-100 years	0-20 years	20-100 years
	America	8	0.9	4.0	0.25
	Africa	11	1.0	4.0	0.25
	Asia	11	1.0	4.0	0.25
Temperate		0-20 years	20-100 years		
	Evergreen	7.5	1.8		
	Deciduous	5.5	1.4		
Boreal		4.0	1.1		

These growth rates are derived by assuming that tropical forests regrow to 70% of undisturbed forest biomass and temperate and boreal forests regrow to 50% of primary forest biomass in the first twenty years. All forests are assumed to regrow to 100% of primary forest biomass in 100 years.

See the *Greenhouse Gas Inventory Reference Manual* for sources.

- 3 Multiply the Total Area Abandoned (column A) by the Annual Rate of Aboveground Biomass Uptake (column B) to give the Annual Aboveground Biomass Uptake (in kt dm). Enter the result in column C.
- 4 Enter the Carbon Fraction of Aboveground Biomass in column D (default fraction 0.45).
- 5 Multiply the Annual Aboveground Biomass Uptake (column C) by the Carbon Fraction of Aboveground Biomass (column D) to give the Annual Carbon Uptake in Aboveground Biomass. Enter the result in column E.
- 6 Add the figures in column E and enter the total in the Total box at the bottom of the column.



STEP 2 CALCULATE ANNUAL CARBON UPTAKE IN SOILS (LAND ABANDONED IN LAST TWENTY YEARS)

- 1 Enter the Annual Rate of Uptake of Carbon in Soils (in kilotonnes of carbon per hectare) in column F.

Default values for soil carbon accumulation in temperate and boreal forests are provided in Table 5-6. No values are available for tropical systems or grasslands.

TABLE 5-6 SOIL CARBON ACCUMULATION IN TEMPORAL AND BOREAL FORESTS (tons c/yr)			
	Temperate		Boreal
	Evergreen	Deciduous	
Primary	1.3	1.3	2.0
Secondary	1.2	1.2	1.8

- 2 Multiply the Total Area Abandoned (column A) by the Annual Rate of Uptake of Carbon in Soils (column F) to give the Total Annual Carbon Uptake in Soils (in kilotonnes of carbon). Enter the results in column G.
- 3 Add the figures in column G and enter the total in the Total box at the bottom of the column.

STEP 3 CALCULATE ANNUAL CARBON UPTAKE IN ABOVEGROUND BIOMASS (LAND ABANDONED FOR MORE THAN TWENTY YEARS)

- 1 Enter the Total Area Abandoned for more than twenty years (in kilohectares) in column H.
- 2 Enter the Annual Rate of Aboveground Biomass Uptake (in kilotonnes of dry matter per hectare) in column I. Table 5-5 provides default values.
Table 5-5 provides default values.
- 3 Multiply the Total Area Abandoned by the Annual Rate of Aboveground Biomass Uptake to give the Annual Aboveground Biomass Uptake (in kt dm). Enter the result in column J.
- 4 Enter the Carbon Fraction of Aboveground Biomass in column K (default fraction 0.45).
- 5 Multiply the Annual Aboveground Biomass Uptake by the Carbon Content of Aboveground Biomass to give the Annual Carbon Uptake in Aboveground Biomass. Enter the result in column L.
- 6 Add the figures in column L and enter the total in the Total box at the bottom of the column.

STEP 4 CALCULATE ANNUAL CARBON UPTAKE IN SOILS (LAND ABANDONED FOR MORE THAN TWENTY YEARS)

- 1 Enter the Annual Rate of Uptake of Carbon in Soils (in kilotonnes carbon/hectare) in column M.
Default values are 0.5 times the values in Table 5-5
- 2 Multiply the Total Area Abandoned by the Annual Rate of Uptake of Carbon in Soils to give the Total Annual Carbon Uptake in Soils (in kilotonnes of carbon). Enter the results in column N.
- 3 Add the figures in column N and enter the total in the Total box at the bottom of the column.

STEP 5 CALCULATE TOTAL CO₂ EMISSIONS FROM ABANDONED LANDS

- 1 Add the totals from columns E, G, L and N and enter the Total Carbon Uptake from Abandoned Lands in column O.
- 2 Multiply the Total Carbon Uptake from Abandoned Lands by 44/12 to give the Total Carbon Dioxide Uptake from the Abandonment of Managed Lands. Enter the result in column P.



5.6 Managed forests

Introduction

This sub module deals with the emissions or removals of carbon (and carbon dioxide) due to plantations, managed forests, and other trees affected by human activity.

Data sources

FAO Yearbooks of Forest Products (annual)

There is also a number of international databases with country-specific statistics, as well as studies of individual countries. These include:

Forest Resources Assessment 1990: Tropical Countries (FAO 1993).

The Forest Resources of the ECE Region (Europe, the USSR and America), (FAO/ECE 1985).

For a fuller bibliography, see *The IPCC Greenhouse Gas Inventory Reference Manual*.

Methodology

To calculate the net uptake of CO₂, the annual increment of biomass in plantations, forests which are logged or otherwise harvested, afforestation programs, and the growth of trees in villages, farms and urban areas is estimated.

Wood harvested for fuelwood, commercial timber and other uses is also estimated. There are two approaches you can use when estimating wood removals:

- commercial harvest statistics
- traditional fuelwood consumption estimates from the CO₂ from Energy sub module

For some countries commercial statistics will give only a partial account of wood removals and using both sources of statistics may provide the most accurate picture.

The net carbon uptake due to these sources is then calculated. If the figure is positive then this counts as a removal, and if the figure is negative, it counts as an emission. Finally, the carbon uptake is expressed as CO₂.

FRACTIONS

Various fractions are used in calculating the emissions from forest clearing.

- Fraction burned on-site and off-site
- Fraction left to decay

This is the portion of the wood which is simply left to decay and so releases gases at a slower rate.

- Fraction which oxidizes

This is the fraction of burned wood which actually oxidizes instead of turning to charcoal.

CATEGORIES OF TREES

Village, farm or urban trees and other afforestation programmes are included to allow users to account for biomass in trees outside normal forests. These may be important for fuel wood accounting in some countries. Users must provide all data for these categories. Ignore them if no data are available.

Completing the Worksheet

USING THE WORKSHEET

- Copy the Worksheet at the end of this section to complete the inventory.
- Keep the original of the Worksheet blank so you can make further copies if necessary

STEP 1 ESTIMATING TOTAL CARBON CONTENT IN ANNUAL GROWTH OF LOGGED AND PLANTED FORESTS

Use WORKSHEET 5-5 MANAGED FORESTS at the end of this section to record inventory data.

- 1 For each type of forest and tree, enter the Area of Managed Forest in kilohectares (kha) in column A.
- 2 For afforestation programs and for planting of urban, village and farm trees, enter the number of trees (in 1000s of trees) in column A.
- 3 For each type of forest and tree, enter the Annual Growth Rate (in kilotonnes of dry matter per hectare) in column B.

Use the default statistics in Table 5-5 or 5-7 if national data are not available.

TABLE 5-7 AVERAGE ANNUAL ACCUMULATION OF DRY MATTER AS BIOMASS IN PLANTATIONS		
Forest Types		Annual Increment in Biomass (tonnes dm/ha/year)
Tropical	Acacia spp.	15.0
	Eucalyptus spp.	14.5
	Tectona grandis	8.0
	Pinus spp	11.5
	Pinus caribaea	10.0
	Mixed Hardwoods	6.8
	Mixed Fast-Growing Hardwoods	12.5
	Mixed Softwoods	14.5
Temperate	Douglas fir	6.0
	Loblolly pine	4.0
<p>Note: These are average accumulation rates over expected plantation lifetimes; actual rates will depend upon the age of the plantation.</p> <p>The data for the temperate species are based upon measurements in the US. Data on other species and from other regions should be supplied by individual countries (as available).</p> <p>Additional temperate estimates by species and country can be derived from data in ECE/FAO (1985), assuming that country averages of net annual increment for managed and unmanaged lands are reasonable approximations for plantations.</p>		

- 4 For village and farm trees and other non-forest trees, enter the Annual Growth Rate in kilotonnes of dry matter per thousand trees in column B.
- 5 For each type of forest, multiply the Area of Managed Forest by the Annual Growth Rate to give the Annual Biomass Increments in kilotonnes of dry matter. Enter the result in column C.



6 For afforestation programs and for village and farm trees, multiply the Number of Trees by the Annual Growth to give the Annual Biomass Increments in kilotonnes of dry matter. Enter the result in column C.

7 For each type of forest or tree, enter the Carbon Fraction of dry matter.

The default value is 0.45 for all if biomass specific values are not available.

8 Multiply the Annual Biomass Increments by the Carbon Content of Dry matter to give the Total Carbon Content. Enter the result in column E.

9 Add the figures in column E and enter the total in the Total box at the bottom of the column.

USING COMMERCIAL HARVEST STATISTICS

Commercial harvest statistics are often provided for the commercial portion of the biomass only, in cubic meters (m^3) of roundwood. In this case the harvested amounts must be adjusted in two ways to reflect the values needed for the emissions/removals calculations. The volume of biomass expressed as m^3 must be converted to mass of dry matter expressed as tonnes (t dm).

- The default conversion factor is 2.5 t dm/ m^3 .

In addition, an expansion factor can be applied to account for the non-commercial biomass (limbs, small trees etc.) harvested with the commercial roundwood and left to decay. The following default factors can be used:

- Undisturbed forests 1.75
- Logged forests 1.90
- Unproductive forests 2.00

If the forest type from which commercial roundwood has been harvested is known, the appropriate factor can be applied. The value for logged forests could be used as a general default. More detailed formulae for deriving expansion factors as a function of pre-harvest biomass density are discussed in the Reference Manual.

If both conversion and expansion are needed, they can be combined by using factors which are the product of the two:

Forest type	t dm total biomass/ m^3 commercial roundwood
Undisturbed forests	0.88
Logged forests	0.95
Unproductive forests	1.0

Some harvest statistics are provided on a total biomass basis (expansion factors already applied) or may be provided in mass of dry matter rather than volume. It is important that users determine carefully the nature of the values in their sources of commercial harvest data, then apply the appropriate conversions or expansions to get total biomass harvested. This can be:

- a volume to mass conversion alone
- b expansion from commercial to total mass of dry matter
- c a combination of both (a and b)

STEP 2 ESTIMATE THE AMOUNT OF BIOMASS HARVESTED

- 1 Enter the amount of the Commercial Harvest in column F.
These values should be taken from local sources. FAO published values can be used as defaults. See the margin box *Using Commercial Harvest Statistics*.
- 2 Enter the Biomass Expansion Factor in column G if necessary.
- 3 Multiply the Commercial Harvest by the Biomass Expansion Factor (if necessary) to give the Total Biomass Harvest in kilotonnes of dry matter. Enter the result in column H.
- 4 Enter Total Fuelwood Consumption from survey-based accounting (if applicable) in column I. This accounting should have been done in Biomass Fuels in Section I. See Worksheet I-2 D.
- 5 Enter the quantity of Other Wood Use in kilotonnes dm in column J.
If any wood is removed but is not accounted for in harvest statistics for commercial harvest or fuelwood consumption accounts, it can be entered here.
- 6 Add the Total Fuelwood Consumed (column I) to the Total Biomass Harvest and Other Wood Use to give Total Biomass Consumption. Enter the result in column K. Sum this column.
- 7 Enter Wood Removed From Forest Clearing (figure from column M, Worksheet 5-1 Quantity of Biomass Exposed to Burning Off Site) at the bottom of column L.
- 8 Subtract Wood Removed From Forest Clearing from Total Fuelwood Consumption to give Total Biomass Consumption from Managed Forests in kilotonnes of dry matter. Enter the result in the box at the bottom of column M.

STEP 3 CONVERT WOOD HARVESTED TO CARBON REMOVED

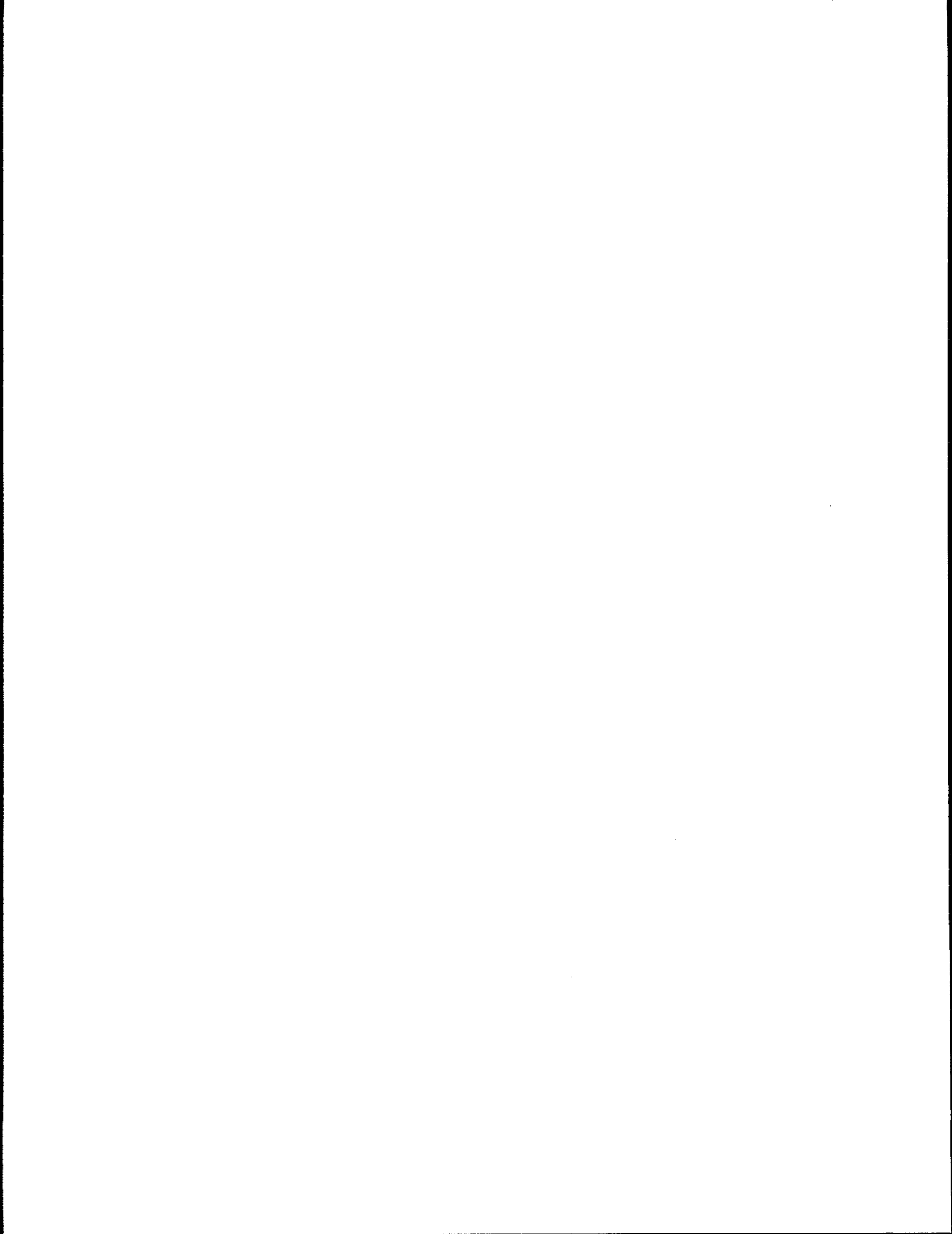
- 1 Enter the Carbon Fraction in column N (the general default value for live biomass is 0.45).
- 2 Multiply Total Biomass Consumption by Carbon Fraction to give Annual Carbon Release (in kilotonnes of carbon). Enter the result in column O.

STEP 4 ESTIMATE THE NET ANNUAL AMOUNT OF CARBON UPTAKE

- 1 Subtract Annual Carbon Release from Annual Carbon Increment (column E) to give Net Annual Carbon Uptake. Enter the result in column P.
- 2 Multiply the Net Annual Carbon Uptake (column O) by 44/12 to give the Net Annual CO_2 Accumulation. Enter the result in column Q.

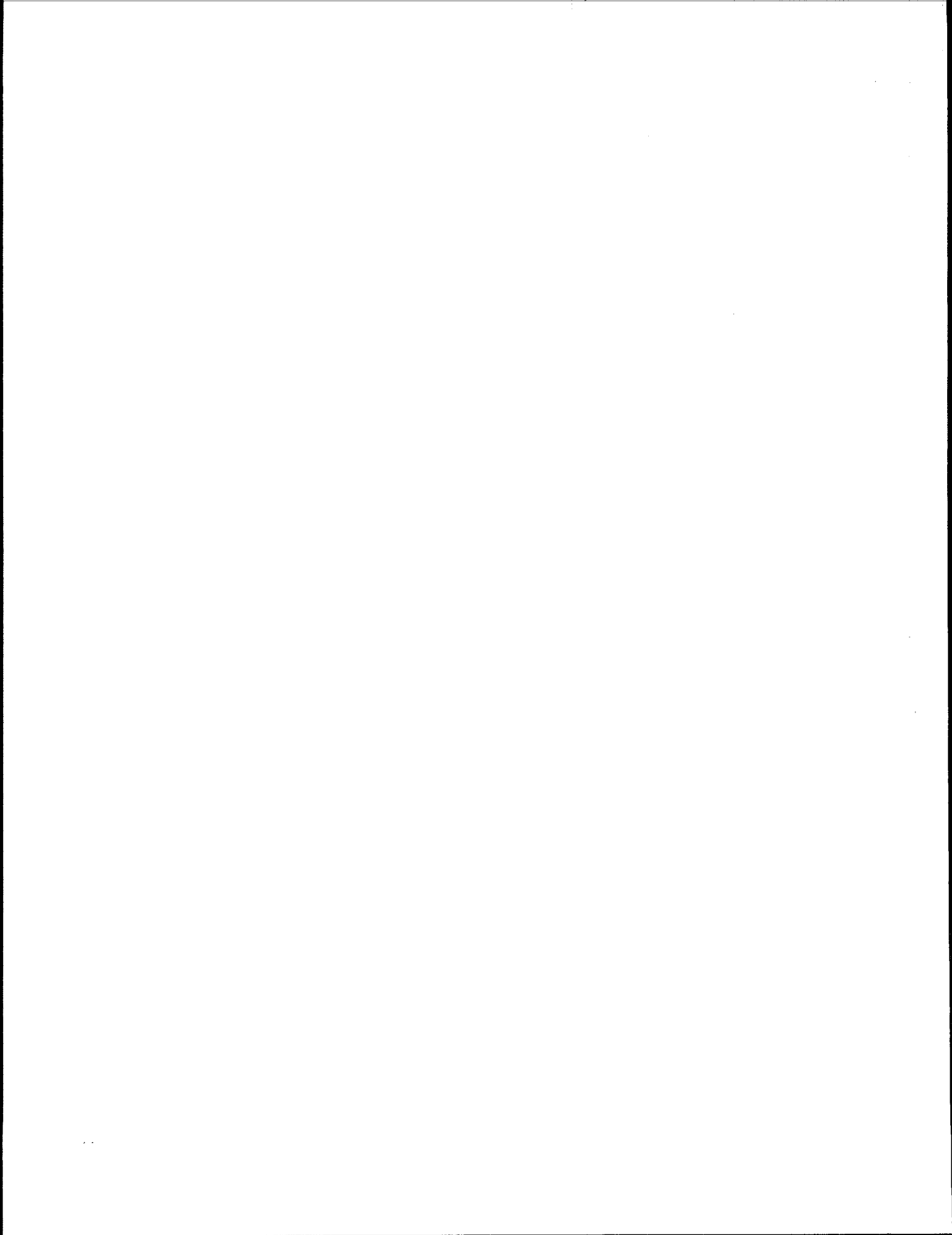


MODULE				LAND USE CHANGE AND FORESTRY					
SUB MODULE				FOREST CLEARING - CO ₂ RELEASE FROM BURNING ABOVE GROUND BIOMASS ON AND OFF SITE					
WORKSHEET				5-1					
SHEET				A					
				STEP 1					STEP 2
Forest types				A Area Cleared Annually (kha)	B Biomass Before Clearing (t dm/ha)	C Biomass After Clearing (t dm/ha)	D Net Change in Biomass (t dm/ha)	E Annual Loss of Biomass (kt dm)	F Fraction of Biomass Exposed to Burning On Site
							D=(B-C)	E=(AxD)	
Tropical	Closed Forests	Broadleaf	Undisturbed						
			Logged						
		Conifer	Undisturbed						
			Logged						
	Open Forests	Unpro- ductive							
Temperate	Evergreen:	Primary							
		Secondary							
	Deciduous	Primary							
		Secondary							
Boreal									
Other									



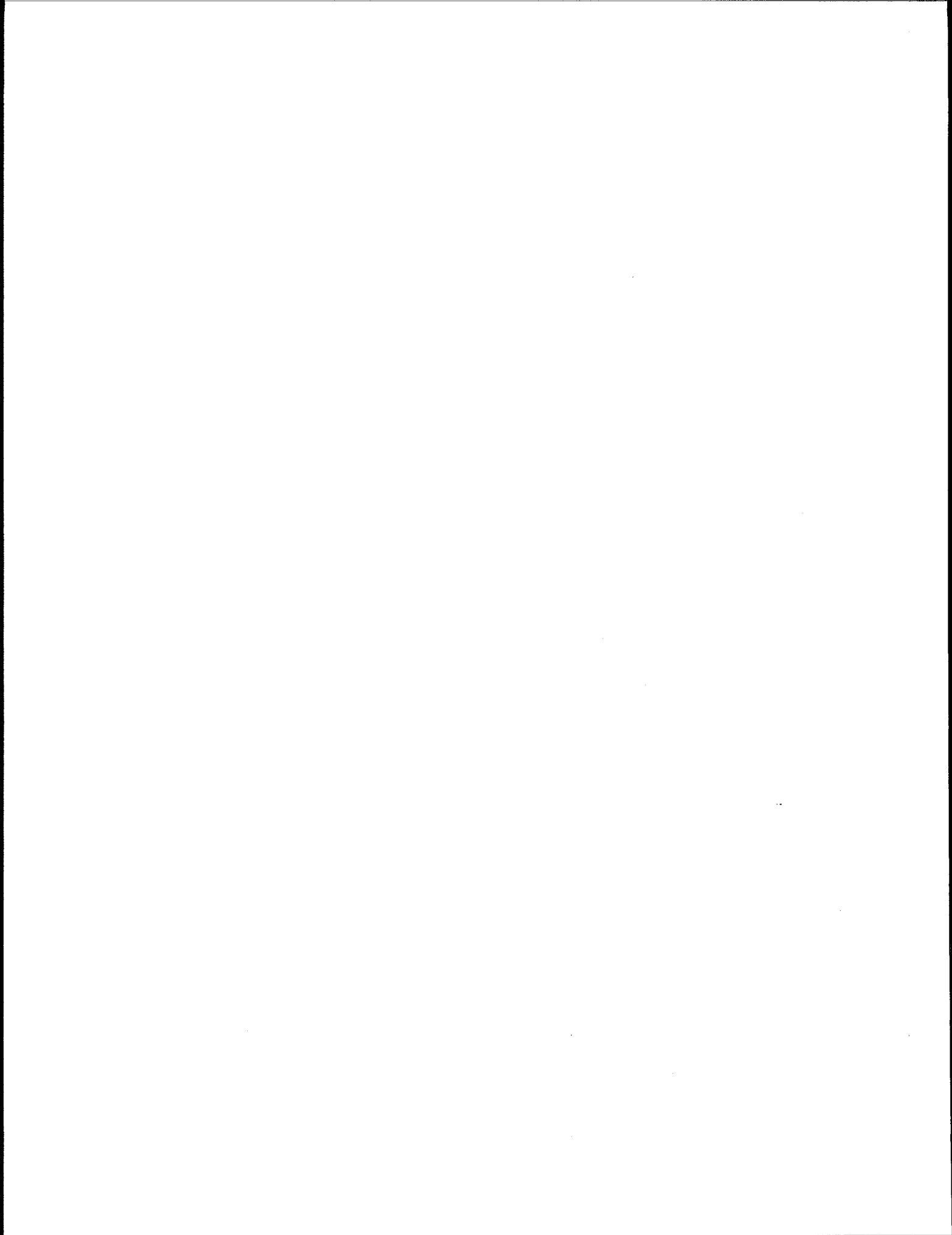


MODULE				LAND USE CHANGE AND FORESTRY				
SUB MODULE				FOREST CLEARING - CO ₂ RELEASE FROM BURNING ABOVE GROUND BIOMASS ON AND OFF SITE				
WORKSHEET				5-I				
SHEET				B				
				STEP 2 continued				
Forest types				G	H	I	J	K
				Quantity of Biomass Exposed to Burning On Site (kt dm)	Fraction of Biomass Oxidized On Site (Combustion Efficiency)	Quantity of Biomass Oxidized On Site (kt dm)	Carbon Fraction of Above-ground Biomass (burned on site)	Quantity of Carbon Released (kt C)
				$G=(ExF)$		$I=(G \times H)$		$K=(I \times J)$
Tropical	Closed Forests	Broadleaf	Undisturbed					
			Logged					
		Conifer	Undisturbed					
			Logged					
		Unproductive						
	Open Forests		Productive					
			Unproductive					
Temperate	Evergreen:	Primary						
		Secondary						
	Deciduous	Primary						
		Secondary						
Boreal								
Other								
							Sub-Total	



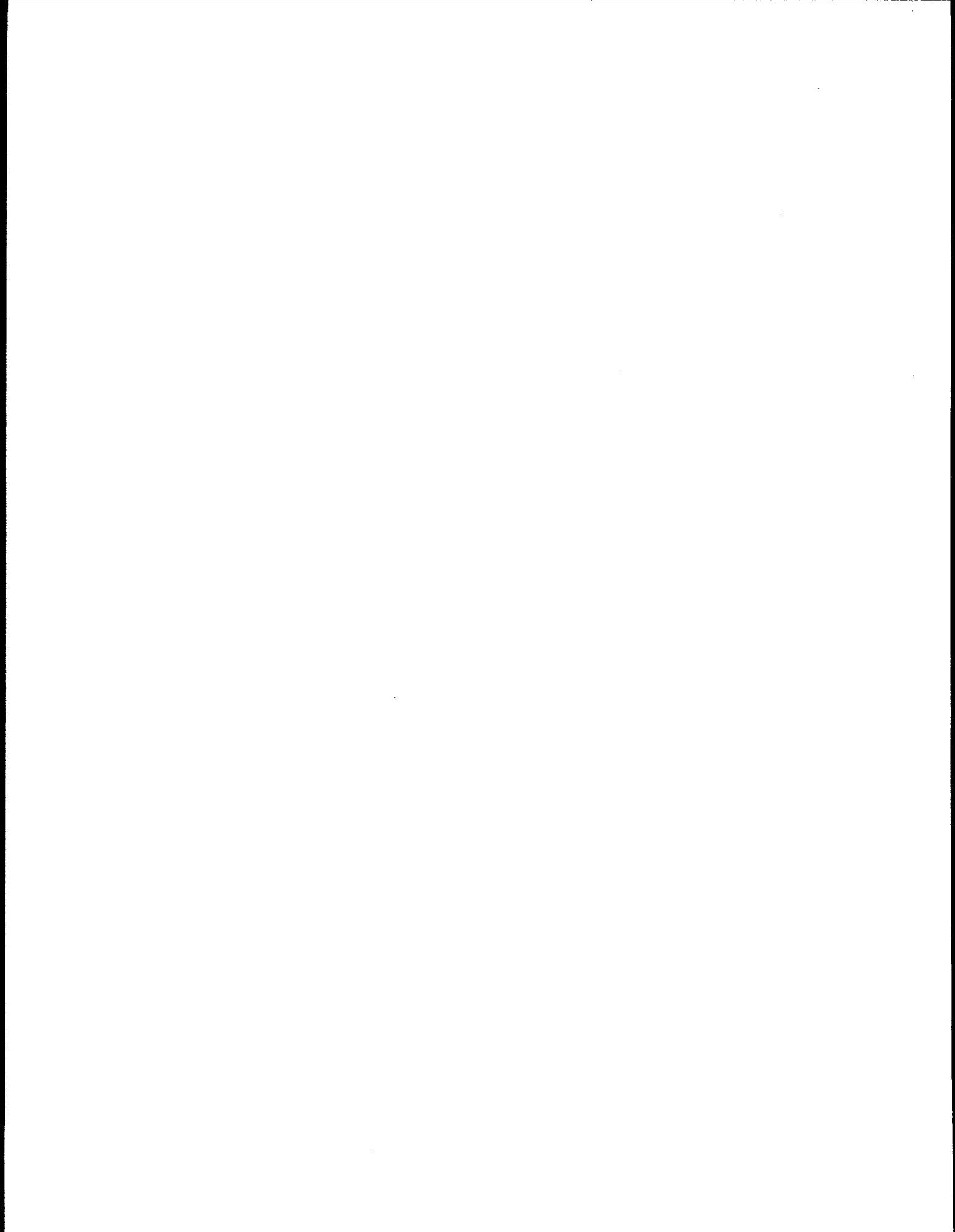


MODULE				LAND USE CHANGE AND FORESTRY							
SUB MODULE				FOREST CLEARING - CO ₂ RELEASE FROM BURNING ABOVE GROUND BIOMASS ON AND OFF SITE							
WORKSHEET				5-I							
SHEET				C							
				STEP 3						STEP 4	
Forest types				L	M	N	O	P	Q	R	S
				Fraction of Biomass Exposed to Burning Off Site	Quantity of Biomass Exposed to Burning Off Site (kt dm)	Fraction of Biomass Oxidized Off Site (Combustion Efficiency)	Quantity of Biomass Oxidized Off Site (kt dm)	Carbon Fraction of Above ground Biomass (burned off site)	Quantity of Carbon Released as CO ₂ (from biomass burned off site)	Total Carbon Released as CO ₂ (from on & off site burning)	Total CO ₂ released (kt CO ₂)
					M=(ExL)		O=(MxN)		Q=(OxP)	R=(K+Q)	S= Rx[44/12]
Tropical	Closed Forests	Broadleaf	Undisturbed								
			Logged								
		Conifer	Undisturbed								
			Logged								
		Unproductive									
	Open Forests	Productive									
Unproductive											
Temperate	Evergreen:	Primary									
		Secondary									
	Deciduous	Primary									
		Secondary									
Boreal											
Other											
				Sub-total				Sub-total			





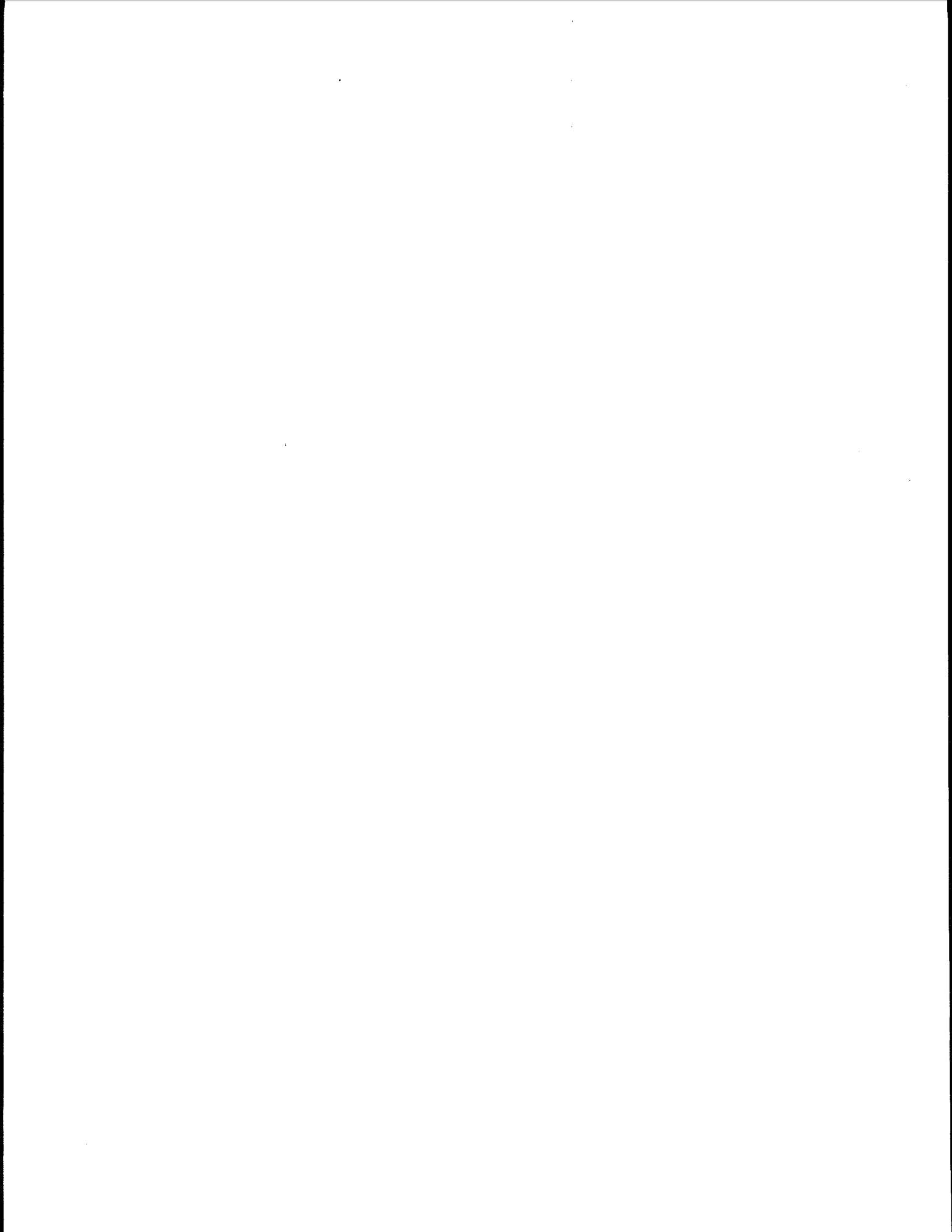
MODULE				LAND USE CHANGE AND FORESTRY								
SUB MODULE				FOREST CLEARING - CO2 RELEASE FROM DECAY OF ABOVE GROUND BIOMASS								
WORKSHEET				5-1								
SHEET				D								
				STEP 5								
Forest types				A	B	C	D	E	F	G	H	I
				Annual Area Cleared (10 Year Average) (kha)	Biomass Before Clearing (t dm/ha)	Biomass After Clearing (t dm/ha)	Net Change in Biomass (t dm/ha)	Average Annual Loss of Biomass (kt dm)	Fraction Left to Decay	Quantity of Biomass to Decay (kt dm)	Carbon Fraction in Above-ground Biomass	Portion C Released as CO ₂ (kt C)
							D=(B-C)	E=(AxD)				
Tropical	Closed Forests	Broadleaf	Undisturbed									
			Logged									
		Conifer	Undisturbed									
			Logged									
		Unproductive										
	Open Forests		Productive									
			Unproductive									
Temperate	Evergreen:	Primary										
		Secondary										
	Deciduous	Primary										
		Secondary										
Boreal												
Other												
											Sub-totals	





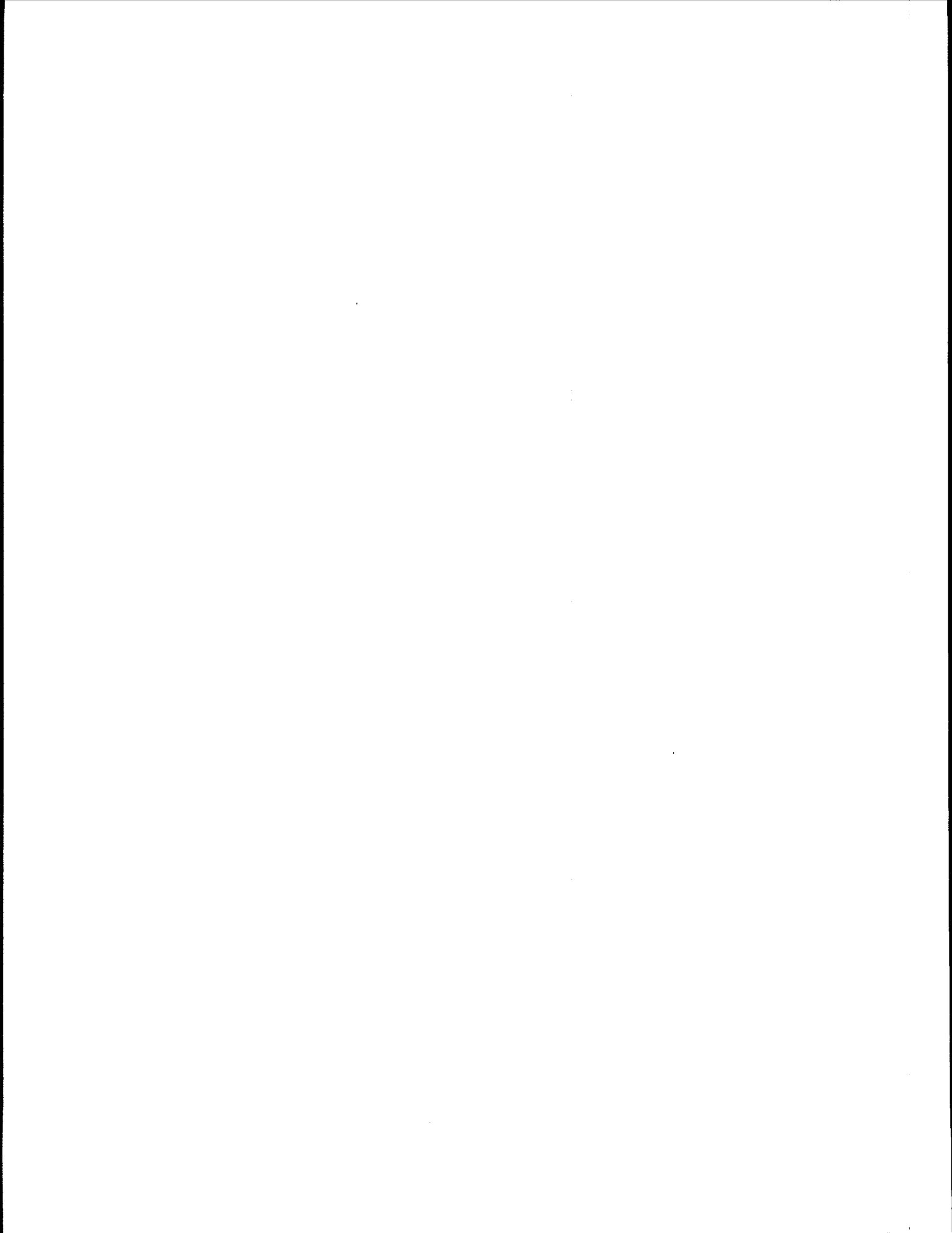
MODULE		LAND USE CHANGE AND FORESTRY				
SUB MODULE		FOREST CLEARING - SOIL CARBON RELEASE				
WORKSHEET		5-I				
SHEET		E				
		STEP 6				
Forest Type	A	B	C	D	E	
	Average Annual Forest Cleared (25 year average)	Soil Carbon Content of Cleared Land	Total Annual Potential Soil Carbon Loss	Fraction of Carbon Released	Carbon Release from Soil Carbon	
	(kha)	(t/ha)	(kt C)		(kt C)	
			C=AxB		E=(CxD)	
Tropical						
Temperate	Evergreen					
	Deciduous					
Boreal						

MODULE		LAND USE CHANGE AND FORESTRY		
SUB MODULE		FOREST CLEARING - TOTAL CO2 EMISSIONS		
WORKSHEET		5-I		
SHEET		F		
STEP 7				
A	B	C	D	E
Immediate Release From Burning (kt C)	Delayed Emissions From Decay (kt C)	Long Term Emissions From Soil (kt C)	Total Annual Carbon Release From Forest Clearing (kt C)	Total Annual CO ₂ Release From Forest Clearing (kt CO ₂)
			D=(A+B+C)	E=(Dx[44/12])





MODULE			LAND USE CHANGE AND FORESTRY				
SUB MODULE			ON-SITE BURNING OF CLEARED FORESTS				
WORKSHEET			5-2				
SHEET			A				
STEP 1			STEP 2				
A	B	C		D	E	F	G
Carbon Released	Nitrogen-Carbon Ratio	Total Nitrogen Released		Trace Gas Emissions Ratios	Trace Gas Emissions	Conversion Factors	Trace Gas Emissions from Burning of Cleared Forests
kt C		kt N			kt C		kt CH ₄ , CO
(From column Q of Worksheet 5.1)					$E=(A \times D)$		$G=(E \times F)$
			CH ₄			16/12	
			CO			28/12	
					kt N		kt N ₂ O, NO _x
		$C=(A \times B)$			$E=(C \times D)$		$G=(E \times F)$
			N ₂ O			44/28	
			NO _x			30/14	

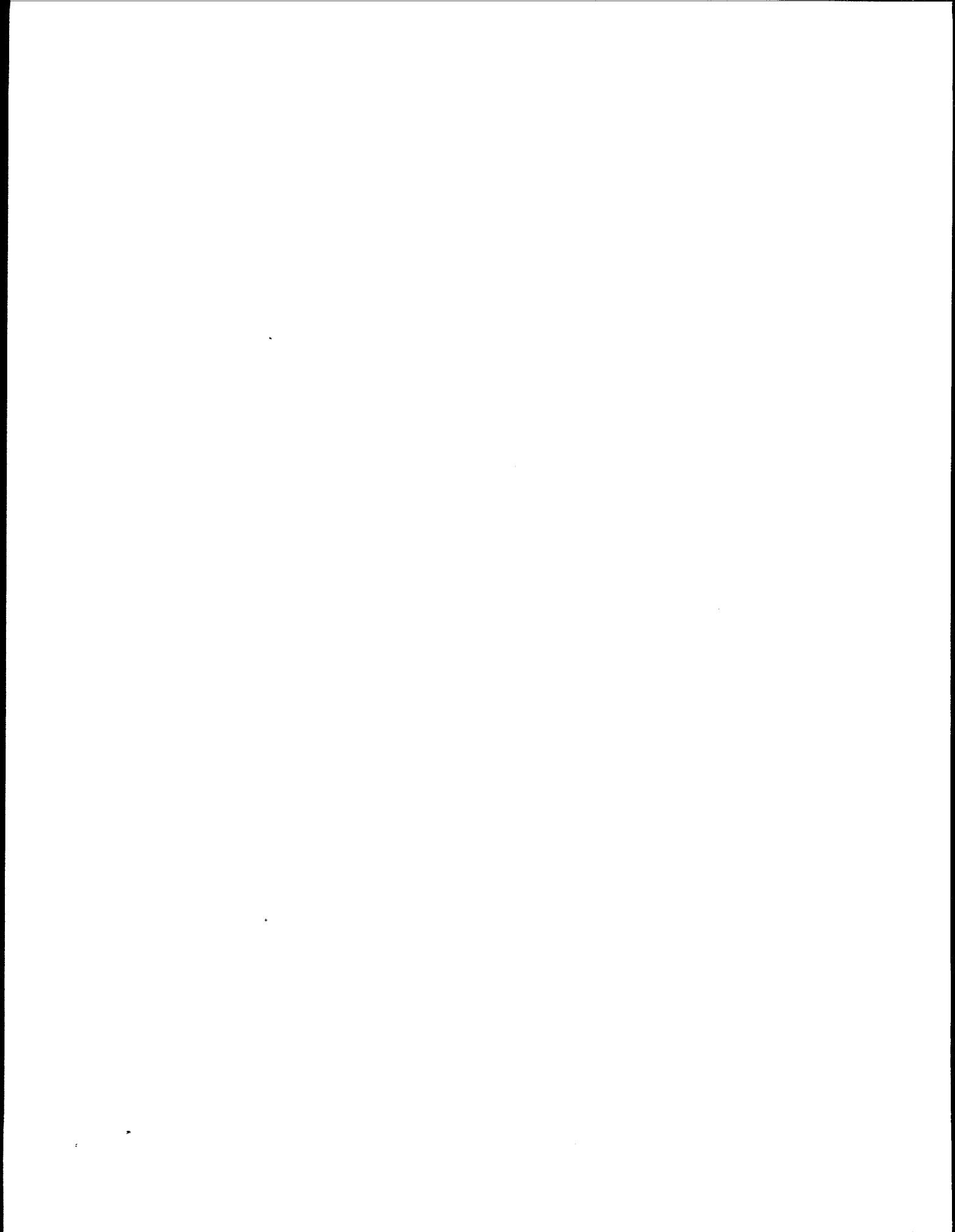




MODULE		LAND USE CHANGE AND FORESTRY		
SUB MODULE		CO₂ EMISSIONS FROM CONVERSION OF GRASSLAND TO CULTIVATED LANDS		
WORKSHEET		5-3		
SHEET		A		
1	2	3	4	5
A	B	C	D	E
20 Year Total Conversion of Grasslands to Cultivation (kha)	Soil Carbon Content of Grasslands (kt C/ha)	Annual Rate of Carbon Release from Soil	Total Annual Soil Carbon Release From Grassland Conversion (kt C)	Total CO ₂ Released from Historic Conversion Over 20 Years (kt CO ₂)
			D=(AxBxC)	E=(Dx[44/12])



MODULE		LAND USE CHANGE AND FORESTRY				
SUB MODULE		ABANDONMENT OF MANAGED LANDS				
WORKSHEET		5-4				
SHEET		A				
		STEP I				
Regrowth Land Type		A 20 Year Total Area Abandoned (kha)	B Annual Rate of Above- ground Biomass Uptake (kt dm/ha)	C Annual Aboveground Biomass Uptake (kt dm)	D Carbon Content of Aboveground Biomass	E Annual Carbon Uptake in Aboveground Biomass (kt C)
				$C=(A \times B)$		$E=(C \times D)$
Tropical Forests	Closed Broadleaf					
	Closed Coniferous					
	Open Forests					
Temperate Forests	Evergreen					
	Deciduous					
Boreal Forest						
Grasslands						
Other						
					Sub-total	

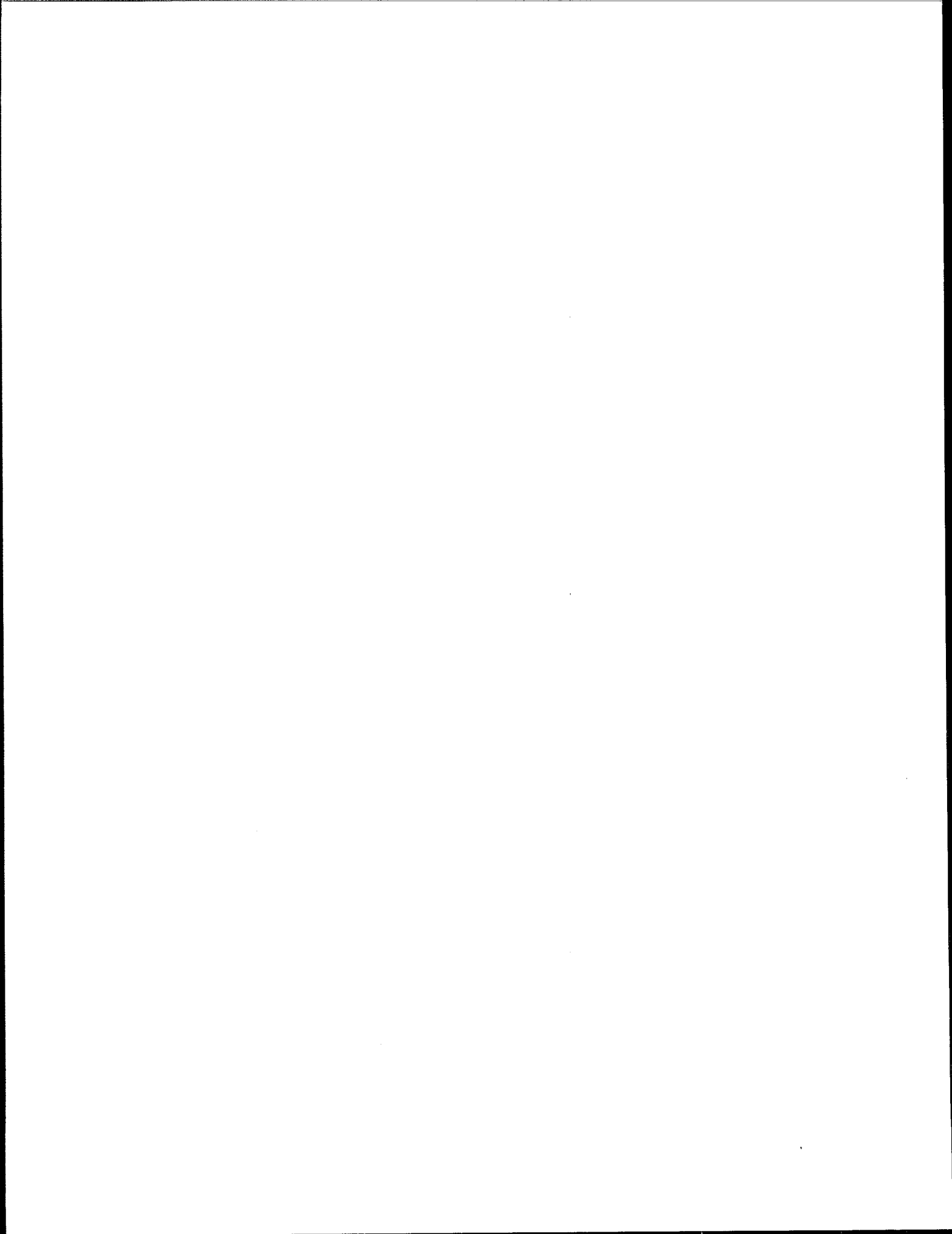




MODULE		LAND USE CHANGE AND FORESTRY						
SUB MODULE		ABANDONMENT OF MANAGED LANDS						
WORKSHEET		5-4						
SHEET		B						
		STEP 2			STEP 3			
Regrowth Land Type		F Annual Rate of Uptake of Carbon in Soils (kt C/ha)	G Total Annual Carbon Uptake in Soils (kt C)	H Total Area Abandoned More than Twenty Years (kha)	I Annual Rate of Above- ground Biomass Uptake (kt dm/ha)	J Annual Above- ground Biomass Uptake (kt dm)	K Carbon Content of Above- ground Biomass	L Annual Carbon Uptake in Above- ground Biomass (kt C)
			$G=(A \times F)$			$J=(H \times I)$		$L=(J \times K)$
Tropical Forests	Closed Broadleaf							
	Closed Coniferous							
		Open Forests						
Temperate Forests	Evergreen							
	Deciduous							
Boreal Forest								
Grasslands								
Other								
							Sub-totals	

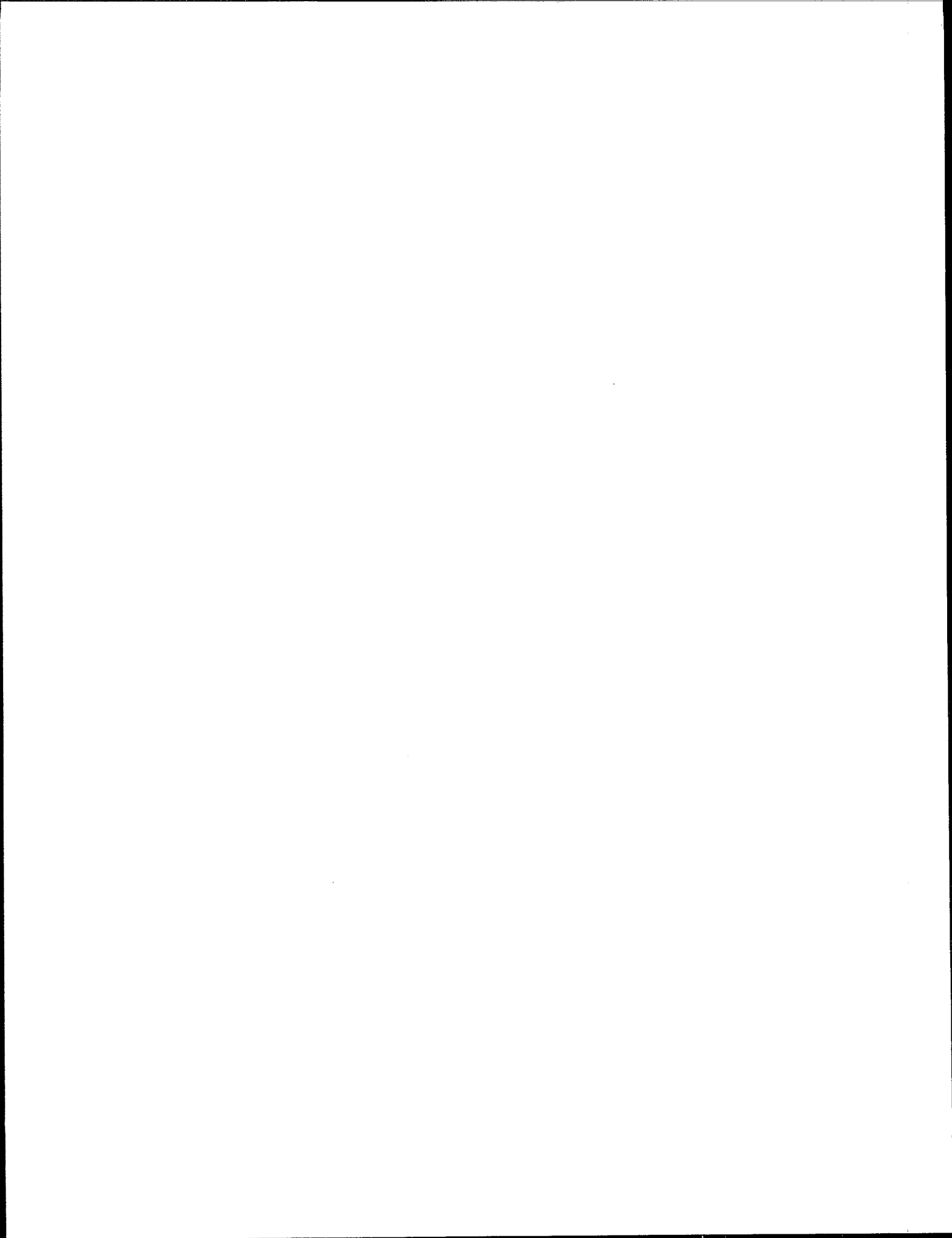


MODULE		LAND USE CHANGE AND FORESTRY			
SUB MODULE		ABANDONMENT OF MANAGED LANDS			
WORKSHEET		5-4			
SHEET		C			
		STEP 4		STEP 5	
Regrowth Land Type		M Annual Rate of Uptake of Carbon in Soils (kt C/ha)	N Total Annual Carbon Uptake in Soils (kt C)	O Total Carbon Uptake from Abandoned Lands (kt C)	P Total Carbon Dioxide Uptake (kt CO ₂)
			$N=(H \times M)$	$O=(E+G+L+N)$	$P=(O \times [44/12])$
Tropical Forests	Closed Broadleaf				
	Closed Coniferous				
	Open Forests				
Temperate Forests	Evergreen				
	Deciduous				
Boreal Forest					
Grasslands					
Other					
	Totals				



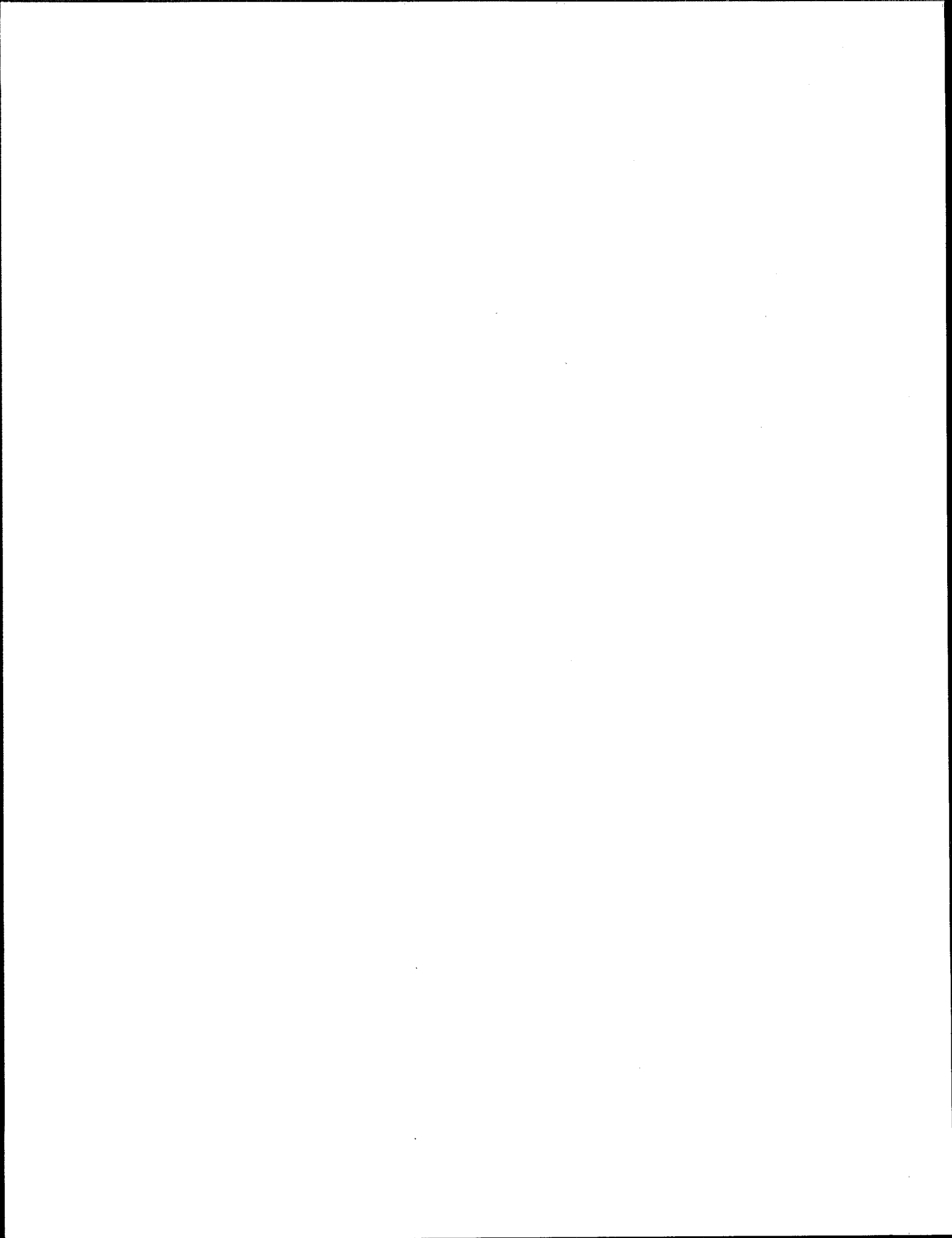


MODULE			LAND USE CHANGE AND FORESTRY				
SUB MODULE			MANAGED FORESTS				
WORKSHEET			5-5				
SHEET			A				
			STEP I				
			A	B	C	D	E
			Area of Managed Forest (kha)	Annual Growth Rate (kt dm/ha)	Annual Biomass Increment (kt dm)	Carbon Content of Dry Matter	Total Carbon Increment (kt C)
					C=(AxB)		
Tropical	Plantations	Acacia spp.					
		Eucalyptus spp.					
		Tectona grandis					
		Pinus spp					
		Pinus caribaea					
		Mixed Hardwoods					
		Mixed Fast- Growing Hardwoods					
		Mixed Softwoods					
	Logged	Closed Broadleaf					
		Closed Coniferous					
		Open					
	Other						
	Temperate	Plantations	Douglas fir				
Loblolly pine							
Commercial		Evergreen					
		Deciduous					
Other							
Boreal							
			A	B			
			Number of Trees (1000s of trees)	Annual Growth (kt dm/1000 trees)			
Afforestation Programs							
Village & Farm Trees							



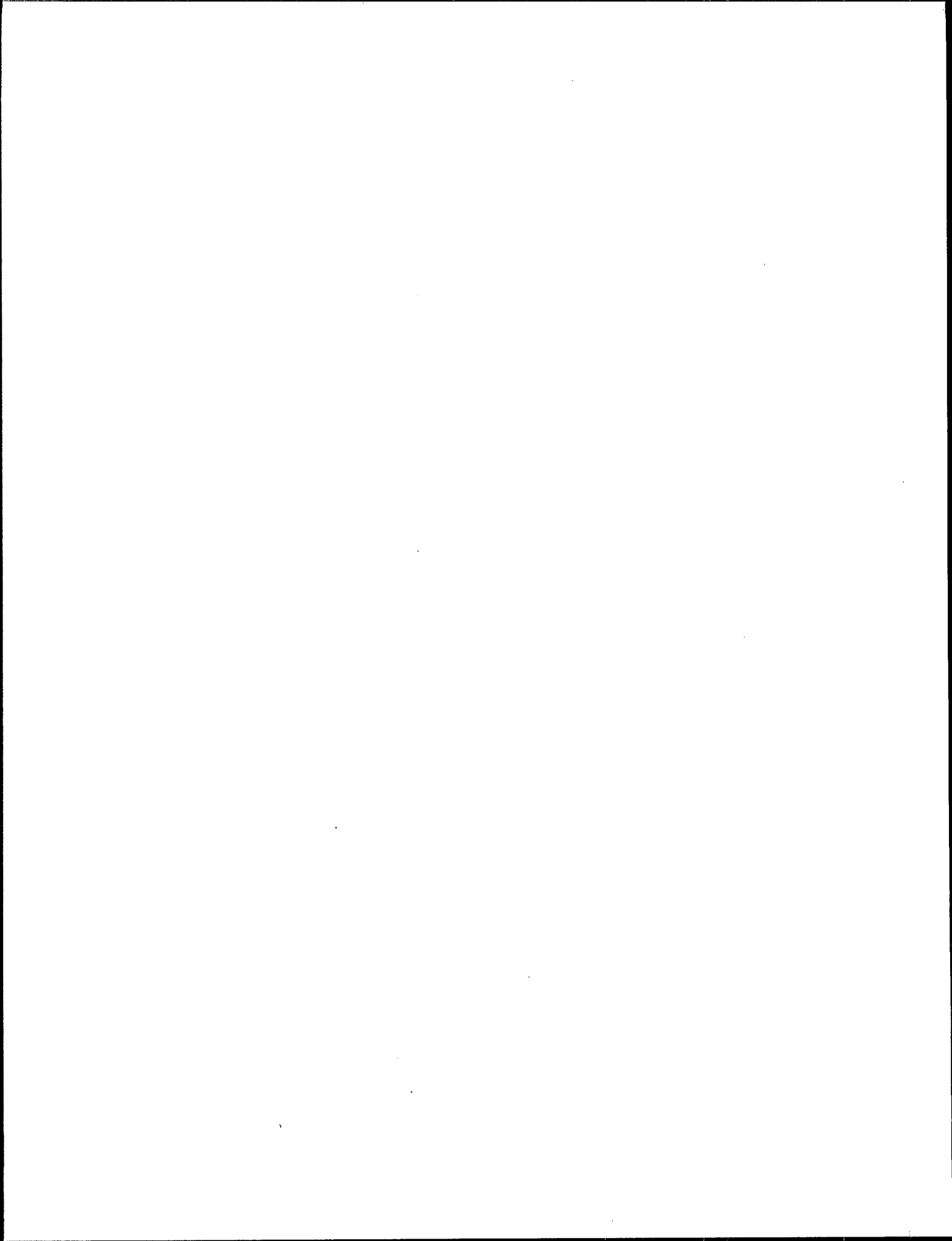


MODULE		LAND USE CHANGE AND FORESTRY						
SUB MODULE		MANAGED FORESTS						
WORKSHEET		5-5						
SHEET		B						
STEP 2								
Harvest Categories (specify)	F Commercial Harvest (km ³ roundwood)	G Biomass Expansion Factor t dm/m ³	H Total Biomass Removed in Commercial Harvest (kt dm)	I Total Traditional Fuelwood Consumed (kt dm)	J Other Wood Use (kt dm)	K Total Biomass Consumption (kt dm)	L Wood Removed From Forest Clearing (kt dm)	M Total Biomass Consumption From Managed Forests (kt dm)
			H=(F×G)	(From column A, Worksheet 1-2 (D))		K=(H+I+J))	(From column M, Worksheet 5-1)	M=K-L
Totals								





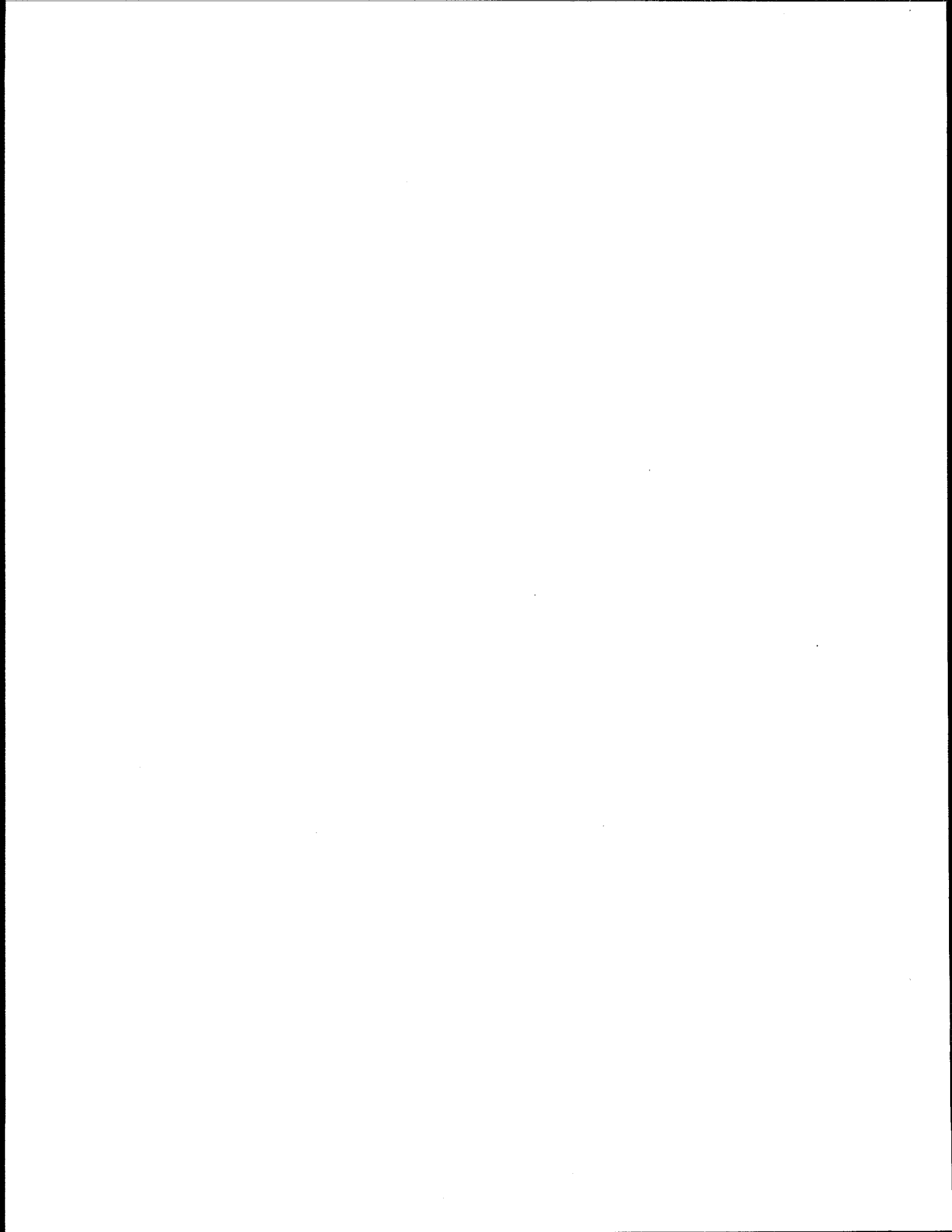
MODULE		LAND USE AND FORESTRY	
SUB MODULE		MANAGED FORESTS	
WORKSHEET		5-5	
SHEET		C	
STEP 3			
N	O	P	Q
Carbon Fraction	Annual Carbon Release	Annual Carbon Uptake and Release	Convert to CO ₂ Annual Emission or Removal
	(kt C)	(kt C)	(Gg CO ₂)
	O=(MxN)	P=(E-O)	Q=(Px[44/12])





MODULE 6

WASTE





6 WASTE

6.1 Introduction

This module provides methodologies for estimating emissions of CH_4 from landfills and wastewater treatment.

6.2 Landfills

Introduction

Anaerobic decomposition of organic matter in landfills by methanogenic bacteria results in 6-18% of the annual global emissions of methane.

Organic waste first decomposes aerobically (in the presence of oxygen) and is then attacked by anaerobic non-methanogenic bacteria, which convert organic material to simpler forms like cellulose, amino acids, sugars, and fats. These simple substances are further broken down to gases and short-chain organic compounds, which form the substrates for methanogenic bacteria. The resulting biogas consists of approximately 50% CO_2 and 50% CH_4 by volume, although the percentage of CO_2 may be smaller because some CO_2 dissolves in landfill water.

Numerous factors affect the amount of CH_4 produced in landfills. The factors may be divided into two general categories: management practices and physical factors.

The simple method for calculating emissions described here does not include time lags, but assumes that methane is released in the year in which the waste is placed in a landfill. This is not what actually occurs but gives a crude approximation of the current year emissions if the amount and composition of Municipal Solid Waste (MSW) landfilled has been relatively constant over the last five to ten years. If there have been large fluctuations over the period then the simple method will not represent the current emissions well.

The simple method is considered to produce a high estimate for a number of reasons. Detailed assessments by some OECD countries include factors such as aerobic decomposition, microbial biomass, leachate generation and methane oxidation which are not explicitly accounted for in the simple method. In an inventory by Canada which applied the simple method as well as the more complicated kinetic modelling, the more detailed methods gave results which were 22% lower than the simple method. Additionally, some of the factors mentioned could be more important in developing countries where less compact disposal methods (open dumps instead of highly compacted sanitary landfill) might be employed.

Future IPCC work will focus on improving the simple method so that it is capable of accounting for time lags and the other factors mentioned above.

Data Sources

Data on Municipal Solid Waste (MSW) generation rates and percentage of MSW landfilled are available for most developed countries, and these should be used when available.

Data on waste characteristics and waste management practices for individual countries are limited in international data sources, especially for developing regions.

Data for centrally planned economies, however, are scarce, and MSW generation rates and composition for developing countries, as used by Bingemer and Crutzen (1987), are available only for major cities (e.g., Cointreau, 1984); however, wide scatter among data exist for some individual countries.

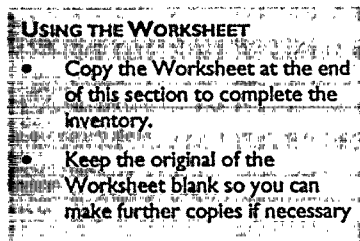
For emission coefficients, we suggest using the country-specific data on MSW generation rates and landfilled amount from OECD (1989) or from the regional data developed by Bingemer and Crutzen (1987) as default factors if country-specific estimates are not available.

Table 6.1 summarizes default values derived from available published literature. See the *Reference Manual* for more details about the sources of data.

Methodology

The simple methodology allows for the calculation of CH₄ emissions based on:

- a the amount of waste landfilled,
- b the fraction of degradable organic carbon and the amount which actually degrades, and
- c the fraction of CH₄ in landfill gas.



Completing the worksheet

STEP 1 ESTIMATING TOTAL MUNICIPAL SOLID WASTE LANDFILLED

- I If your country has detailed statistics on landfilled waste, enter it in column A of the main Worksheet then go directly to Step 2.

Otherwise use the supplemental Worksheet 6.1 to estimate waste landfill for your country.

- a Enter total population for the inventory year (in the case of developing countries, enter the total urban population) in column A.
- b Enter the waste generation rate in column B.

Default values by region and for some countries are provided in Table 6-1.



TABLE 6-1 REGIONAL WASTE DISPOSAL, COMPOSITION, AND WASTE GENERATION DATA				
Region	Fraction MSW Landfilled	Fraction DOC of MSW	Waste Generation (kg/cap/day)	Waste Generation Gg/1000 persons/yr
U.S. / Canada/ Australia	0.91	0.22	1.8	657
U.S.	0.62	NA	2.0	730
Canada	0.93	NA	1.7	620
Australia	0.98	NA	1.9	694
Other OECD	0.71	0.19	0.8	292
Japan	0.28	NA	0.9	328
New Zealand	0.95	NA	1.8	657
Austria	0.57	NA	0.6	219
Belgium	0.50	NA	0.9	328
Denmark	0.63	NA	1.2	438
Finland	0.87	NA	1.1	402
France	0.47	NA	0.7	256
Germany	0.69	NA	0.9	328
Greece	0.10	NA	0.7	256
Ireland	0.10	NA	0.9	328
Italy	0.35	NA	0.7	256
Luxembourg	0.27	NA	1.0	365
Netherlands	0.55	NA	1.2	438
Norway	0.78	NA	1.3	474
Portugal	0.24	NA	0.6	219
Spain	0.76	NA	0.8	292
Sweden	0.42	NA	0.9	328
Switzerland	0.18	NA	1.0	365
UK	NA	NA	1.0	365
USSR/E.Europe	85	17.5	0.6	219
Developing Countries	80	15	0.5	182

See the *Greenhouse Gas Inventory Reference Manual* for sources.

- c Multiply Population by Waste Generation Rate to give Waste Generated. Enter the result in column C.
- d Enter Fraction Landfilled in column D.
This is the fraction of total MSW which is placed in landfills expressed as a decimal fraction. Default values are provided in Table 6-1 above.
- e Multiply Total Waste Generated by Fraction Landfilled to give MSW Landfilled. Enter the result (in gigagrams of MSW) in column E.
- f Enter the figure from column E in column A of the main Worksheet.

STEP 2 ESTIMATING THE ANNUAL RELEASE OF BIOGAS

- 1 Estimate the Fraction of Degradable Organic Carbon (DOC) in the MSW which is landfilled. Enter the result, in gigagrams of DOC/gigagrams MSW, in column B of the main Worksheet.
Use locally available figures for the fraction if these are available. Document your sources if you do so. Some default values are included in Table 6-1.
- 2 Multiply Annual MSW Landfilled by Fraction DOC to give the Annual DOC Landfilled. Enter the result in column C.
- 3 Estimate the Fraction which Actually Degrades in the landfill in column D.
This is the fraction of the total DOC which actually degrades in a landfill. The decomposition of DOC is not perfectly complete and some of the potentially degradable material always remains in the landfill over the long term. A default value of 0.75 is recommended, based on scientific literature.
- 4 Multiply Annual DOC Landfilled by the Fraction which Actually Degrades to give the Annual Carbon released as Biogas. Enter the result, in gigagrams, in column E.

STEP 3 ESTIMATING NET METHANE EMISSIONS

- 1 Enter the Fraction of carbon in biogas which is released as CH₄ and enter the result, in gigagrams C-CH₄/gigagrams C-Biogas, in column F.
Even in anaerobic decomposition conditions only part of the total carbon release is methane. The default value is 0.5.
Use locally available figures for the fraction if these are available. Document your sources if you do so.
- 2 Multiply Annual Carbon released as Biogas by the Fraction which is methane (column F) to give Annual Carbon Released as Methane. Enter the result, in gigagrams carbon, in column G.
- 3 Multiply Annual Carbon Released as Methane by the conversion factor in column H to give Methane Emissions. Enter the result, in gigagrams CH₄, in column I.
- 4 Enter the amount of CH₄ Recovered and used for energy in column J.
No default information is available. Use locally available figures for the amount recovered if these are available. Document your sources if you do so.
- 5 Subtract CH₄ Recovered from Methane Emissions to give Net Methane Emissions. Enter the result, in gigagrams CH₄, in column K.



6.3 Methane Emissions from Wastewater

Introduction

Wastewater streams with high contents of organic material, including municipal wastewater and some industrial wastewater streams, can emit significant amounts of methane. The IPCC (1992) estimated the total emissions from this source at 30 to 40 Tg/year, which represents 8 - 11% of the total global methane emissions of 360 Tg/year.

There are two basic types of wastewater treatment which should be calculated separately. These are:

- Municipal wastewater
- Industrial wastewater

The principal factor which determines methane generation potential of wastewater is the amount of organic material in the wastewater stream. This is indicated by the Biochemical Oxygen Demand (BOD) of the wastewater, which is the amount of oxygen consumed by the organic material in the wastewater during decomposition. A standardized measure of BOD is the 5 day test (BOD₅), expressed in milligrams per litre (mg/l).

Data Sources

Available data from international sources is summarized in Tables. See the *Reference Manual* for a detailed discussion of data sources.

Methodology

For both municipal and industrial wastewater the method is to estimate the amount of organic material in wastewater. Then this is multiplied by the fraction of wastewater which is anaerobically treated. The final calculation is the quantity of BOD anaerobically treated times the emissions factor gives emissions. BOD for municipal waste water is a function of population. For industrial waste water, it is dependent on flow and industry type. This method should be viewed as a very rough first approach. Research and country specific data collection should produce improved methods in the future.

Completing the Worksheets

USING THE WORKSHEET

- Copy the Worksheet at the end of this section to complete the inventory.
- Keep the original of the Worksheet blank so you can make further copies if necessary

Use WORKSHEET 6-2 METHANE FROM MUNICIPAL WASTEWATER and WORKSHEET 6-3 METHANE FROM INDUSTRIAL WASTEWATER to enter data for this submodule.

Municipal Wastewater

STEP 1 ESTIMATING BIOCHEMICAL OXYGEN DEMAND

- 1 Enter total population for the inventory year (in the case of developing countries, enter the total urban population) in column A.

Developing countries may choose to base estimates on urban, rather than total population if wastes produced in rural areas decompose in an aerobic environment. See Table 6-2 for a list of aerobic and anaerobic treatment methods.

TABLE 6-2 AEROBIC AND ANAEROBIC METHODS OF WASTEWATER TREATMENT		
Treatment method	Type of country	Details
Aerobic	Developing	<ul style="list-style-type: none"> • Open pits/latrines • Aerobic (shallow) ponds • Ocean dumping • River dumping
	Developed	<ul style="list-style-type: none"> • Sewer systems with aerobic treatment
Anaerobic	Developing	<ul style="list-style-type: none"> • Anaerobic (deep) ponds • Sewer systems with aerobic treatment
	Developed	<ul style="list-style-type: none"> • Septic tanks
Anaerobic with methane recovery	Primarily developed	

- 2 Enter Wastewater BOD Generation Rate (gigagrams/1000 persons/year) in column B.

Default values by region are shown in Table 6-3. TABLE 6-3 ESTIMATED BOD ₅ VALUES BY REGION		
Region	BOD ₅ Values kg/person/day	BOD ₅ Values Gg/1000 persons/year
Africa	0.037	13.5
Asia, Middle East, Latin America	0.04	14.6
N America, Europe, Former USSR, Oceania	0.05	18.2
See the Greenhouse Gas Reference Manual for sources.		



- 3 Multiply Population by Wastewater BOD Generation Rate to give Annual BOD Generated. Enter the result, in gigagrams BOD₅, in column C.

STEP 2 ESTIMATING TOTAL METHANE EMISSIONS

- 1 Enter Fraction of BOD Anaerobically Treated in column D.

Default values by region are shown in Table 6-4.

TABLE 6-4 ESTIMATED TOTAL (URBAN) WASTEWATER FRACTION ANAEROBICALLY TREATED	
Region	Fraction Treated
Africa	0.10
Asia and Oceania	0.15
N America and Europe	0.15
Latin America	0.10
<p>These default values are very rough approximations.</p> <p>See the <i>Greenhouse Gas Reference Manual</i> for sources.</p> <p>Note: For many developing countries, industrial wastewater is often discharged with domestic wastewater.</p>	

- 2 Multiply Annual BOD Generated by Fraction of BOD Anaerobically Treated to give the Quantity of BOD Treated Anaerobically. Enter the result, in gigagrams BOD₅, in column E.
- 3 Enter the Methane Emissions Factor, in gigagrams CH₄/kg BOD₅, in column F.

The recommended emissions factor is 22 gigagrams CH₄/gigagrams BOD₅.
- 4 Multiply the Quantity of BOD Treated Anaerobically by Methane Emissions Factor to give Total Methane Emissions. Enter the result in gigagrams CH₄ in column G.

STEP 3 ESTIMATING NET ANNUAL METHANE EMISSIONS

- 1 Estimate the amount of Methane Recovered (if any) from municipal wastewater treatment. Enter the result, in gigagrams CH₄, in column H.
- 2 Subtract Methane Recovered from Total Methane Emissions to give Net Methane Emissions. Enter the result, in gigagrams CH₄, in column I.

USING THE WORKSHEET

- Copy the Worksheet at the end of this section to complete the inventory.

- Keep the original of the Worksheet blank so you can make further copies if necessary

Industrial Wastewater

STEP 1 ESTIMATING BIOCHEMICAL OXYGEN DEMAND

- Estimate Annual Wastewater Outflow for key industries and enter the result in column A.

If wastewater information is not directly available, outflows can be estimated based on industrial production. Table 6-5 provides typical default values in litres of water consumed per ton of product produced for some key industrial activities. As a rough estimate, water consumed is assumed to be equal to wastewater produced. Multiply the default values by domestic production statistics to estimate domestic wastewater outflow volumes.

TABLE 6-5 METHANE EMISSIONS FACTORS FOR WASTEWATER TREATMENT AT PAPER AND FOOD PROCESSING FACILITIES	
Process	Water Consumption litres/mt
Canneries	
Green beans	80,000
Peaches and pears	22,000
Other fruit and vegetables	8,000 - 40,000
Food and beverage industry	
Beer	60,000
Wine	20,000 (litres/ton live weight)
Meat packing	16,000 - 20,000
Pulp and paper	
Pulp	344,000 - 966,000
Paper	200,000 litres
Textiles	
Bleaching	300,000 - 400,000 litres/ton cotton
Dyeing	40,000 - 80,000 litres/ton cotton
Fish processing	14,000 - 20,000
Slaughterhouses	5000 litres/ton live weight
Oil/grease	1,500 - 7,000
Soft drinks	2,500
Grain/cereals	500
See the Greenhouse Gas Reference Manual for sources.	



- 2 Enter BOD Concentration Rates by industry in column B.

Table 6-6 gives default values by industry.

TABLE 6-6 BIOCHEMICAL OXYGEN DEMAND (BOD) ESTIMATES FOR VARIOUS INDUSTRIAL WASTEWATERS	
Industry	BOD ₅ * kg/litre
Iron and steel	0.001
Non-ferrous metals	0.001
Fertilizer	0.001
Food and beverages	0.035
Fruits and vegetables	0.003
Cereals	0.001
Meat packing	0.020
Butter	0.003
Cheese	0.003
Cane sugar	0.002
Beet sugar	0.010
Wine	0.135
Beer	0.085
Other beverages	0.083
Pulp and paper	0.004
Petroleum refining (petrochemical)	0.004
Textiles	0.001
Rubber	0.001
Miscellaneous	0.002
Fish processing	0.004
Oil and grease	0.007 - 0.031
Coffee	0.0015
Soft drinks	0.0008
*Some of these values are "ultimate" BOD from literature. They are used as an approximation of BOD ₅ . See the <i>Greenhouse Gas Reference Manual</i> for sources.	

- 3 Multiply the Annual Wastewater Outflow by industry by BOD Concentration Rates to give Total BOD Generated. Enter the result in gigagrams in column C.

STEP 2 ESTIMATING TOTAL METHANE EMISSIONS

- 1 Enter the Fraction of Wastewater Treated Anaerobically, by industry, in column D.

Very little information is available on typical values and there is probably considerable variation across regions and industries. In developing countries, industrial wastewater is often treated with municipal wastewater. If no other information is available, use the

regional default values for municipal waste in Table 6-4 as a first approximation.

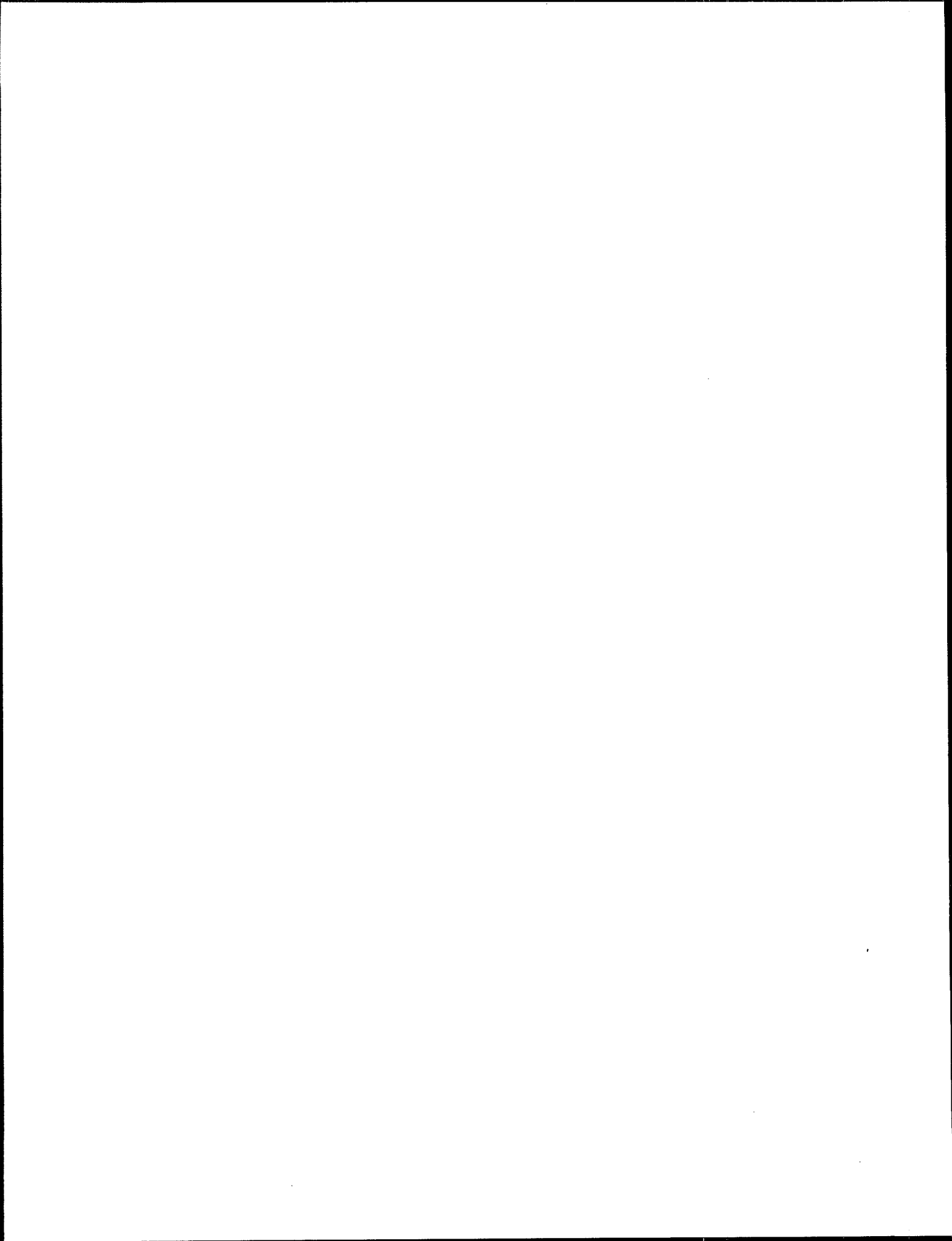
- 2 Multiply Total BOD Generated by Fraction of Wastewater Treated Anaerobically to give the Quantity of BOD Treated Anaerobically. Enter the result, in gigagrams BOD, in column E.
- 3 Enter the Methane Emission Factor in column F.
The IPCC recommended default value for all cases is 22 gigagrams CH_4 / gigagrams BOD_5 .
- 4 Multiply the Quantity of BOD Treated Anaerobically by the Methane Emission Factor to give Total Methane Released. Enter the result, in gigagrams CH_4 , in column G.

STEP 3 ESTIMATING NET ANNUAL METHANE EMISSIONS

- 1 Estimate the amount of Methane Recovered (if any) from municipal wastewater treatment. Enter the result, in gigagrams CH_4 , in column H.
- 2 Subtract Methane Recovered from Total Methane Emissions to give Net Methane Emissions. Enter the result, in gigagrams CH_4 , in column I.

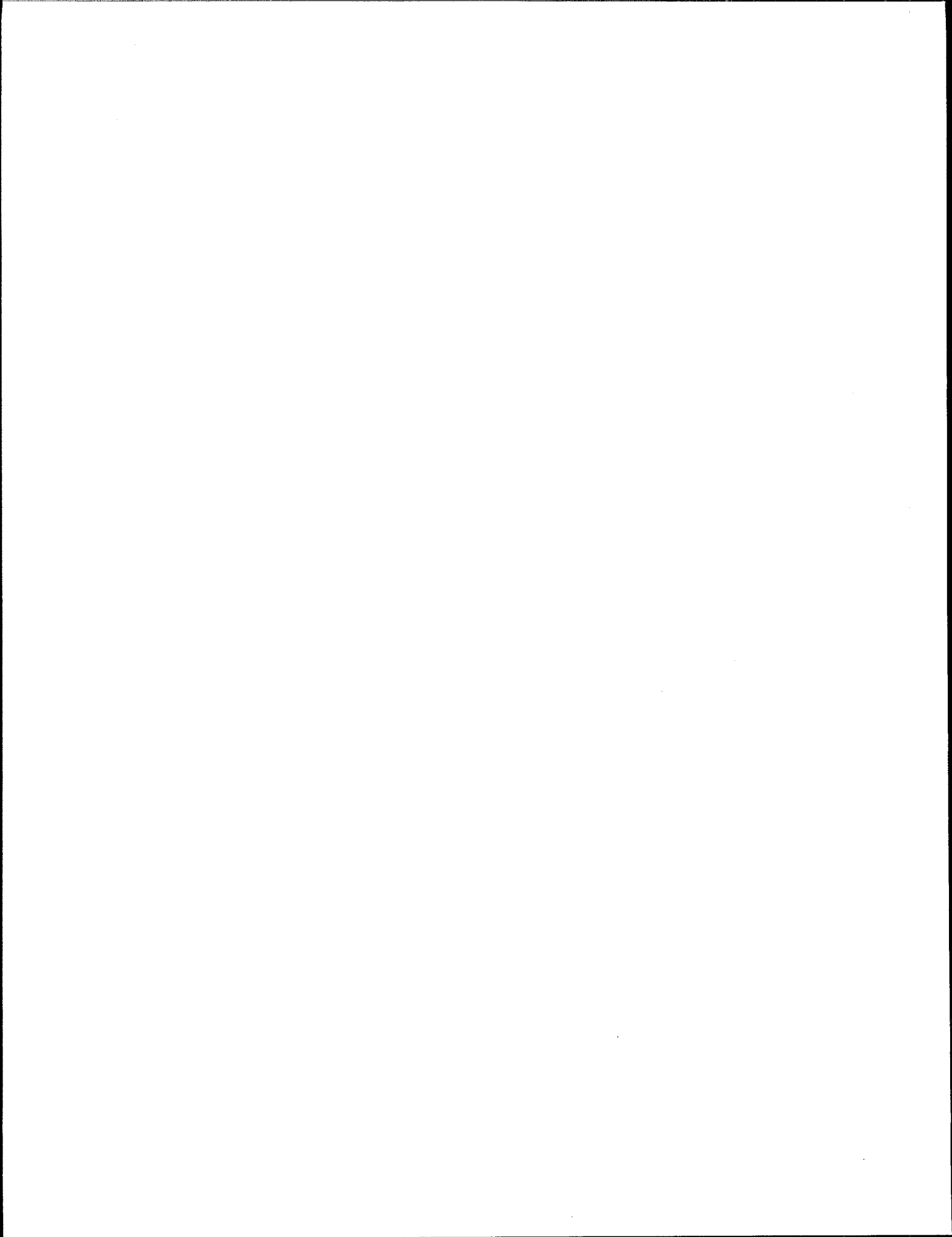


MODULE		WASTE								
SUB MODULE		METHANE EMISSIONS FROM LANDFILLS								
WORKSHEET		6-1								
SHEET		I								
A Annual MSW Landfilled (Specify sub- categories if any) (Gg)	B Fraction DOC (Gg DOC / Gg MSW)	C Annual DOC Landfilled (Gg)	D Fraction which Actually Degrades	E Annual Carbon Released as Biogas (Gg)	F Fraction CH ₄ Gg C-CH ₄ / Gg C-Biogas	G CH ₄ -C Emissions (Gg C)	H Conversion Factor (16/12)	I CH ₄ Emissions (Gg CH ₄)	J CH ₄ Recovered (Gg CH ₄)	K Net CH ₄ Emissions (Gg CH ₄)
		C=(AxB)		E=(CxD)		G=(ExF)		I=(GxH)		K=(I-J)



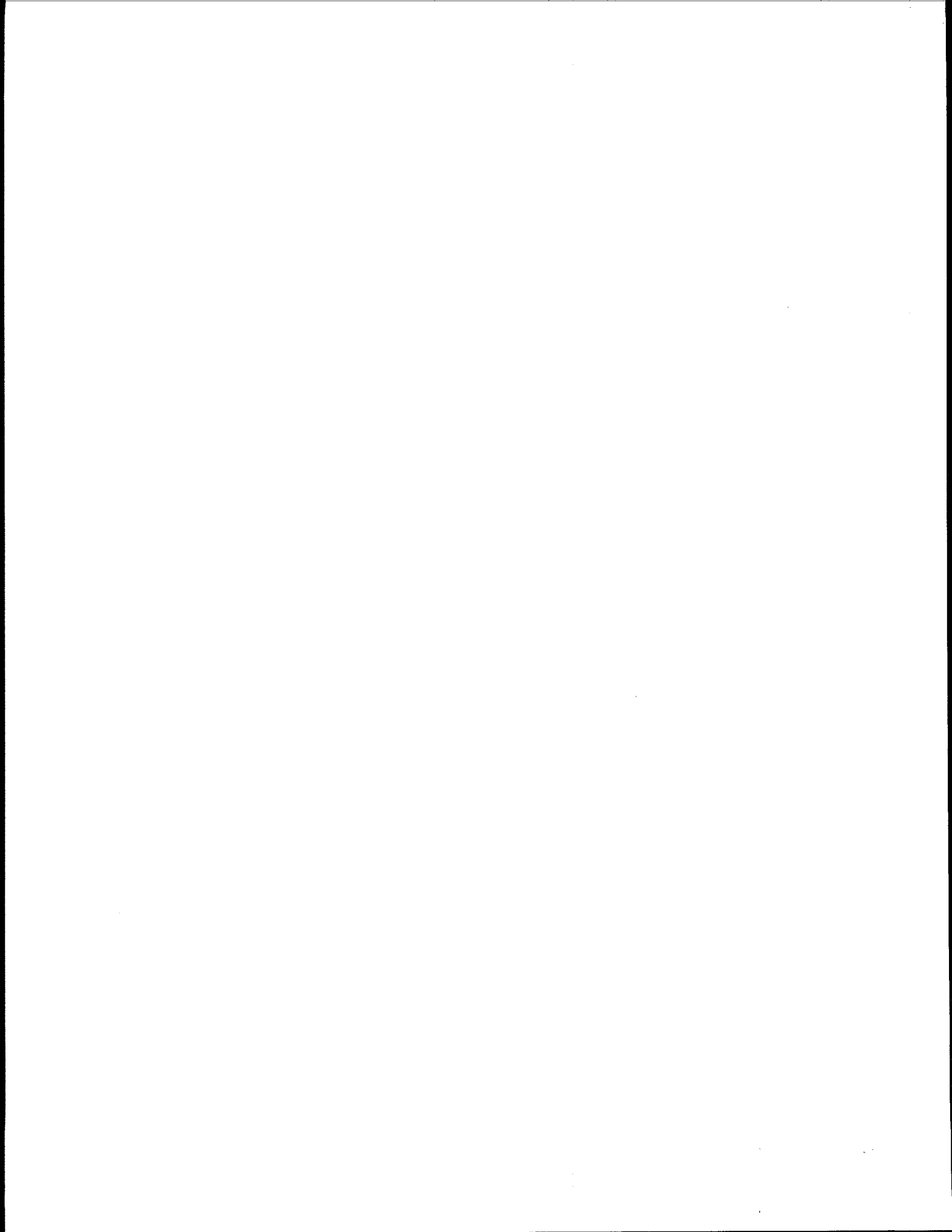


MODULE		WASTE		
SUB MODULE		METHANE EMISSIONS FROM LANDFILLS		
WORKSHEET		6-1 (SUPPLEMENTAL)		
SHEET				
A Population (or Urban Population) (Specify sub- categories if any) (1000 persons)	B Waste Gen- eration Rate (Gg MSW/1000 persons/year)	C Waste Generated (Gg MSW)	D Fraction Landfilled	E MSW Landfilled (Gg MSW)
		$C=(A \times B)$		$E=(C \times D)$



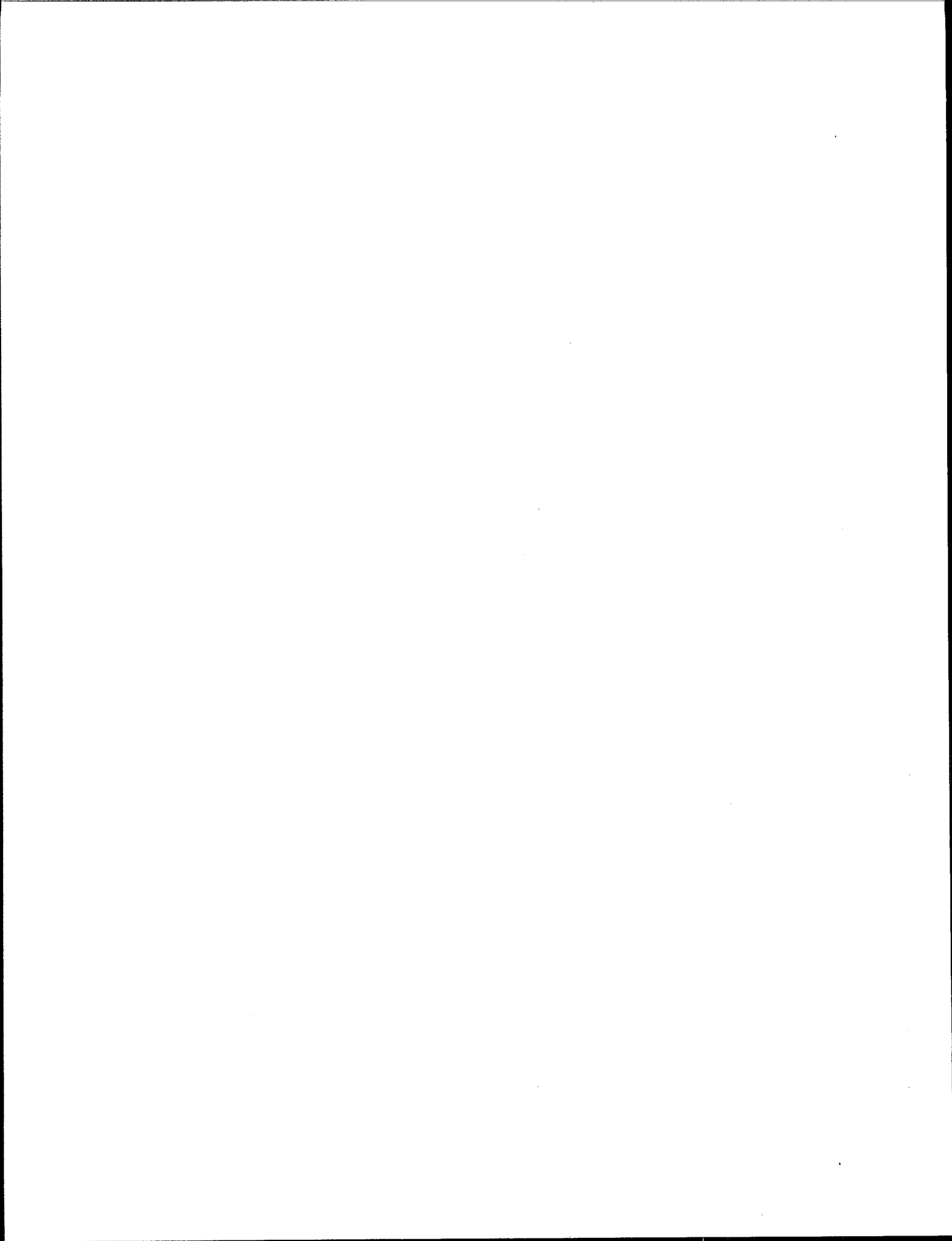


MODULE		WASTE						
SUB MODULE		METHANE EMISSIONS FROM MUNICIPAL WASTEWATER						
WORKSHEET		6-2						
SHEET		I						
A	B	C	D	E	F	G	H	I
Population (Specify sub-categories if any) (1,000 persons)	Wastewater BOD Generation Rate (Gg BOD ₅ / 1,000 persons / year)	BOD Generated (Gg BOD ₅)	Fraction Anaerobically Treated (Gg BOD ₅)	Quantity of BOD Treated Anaerobically (Gg BOD ₅)	Methane Emission Factor (Gg CH ₄ / kg BOD ₅)	CH ₄ Emissions (Gg CH ₄)	Methane Recovery (Gg CH ₄)	Net CH ₄ Emissions (Gg CH ₄)
		$C=(A \times B)$		$E=(C \times D)$		$G=(E \times F)$		$I=(G \times H)$



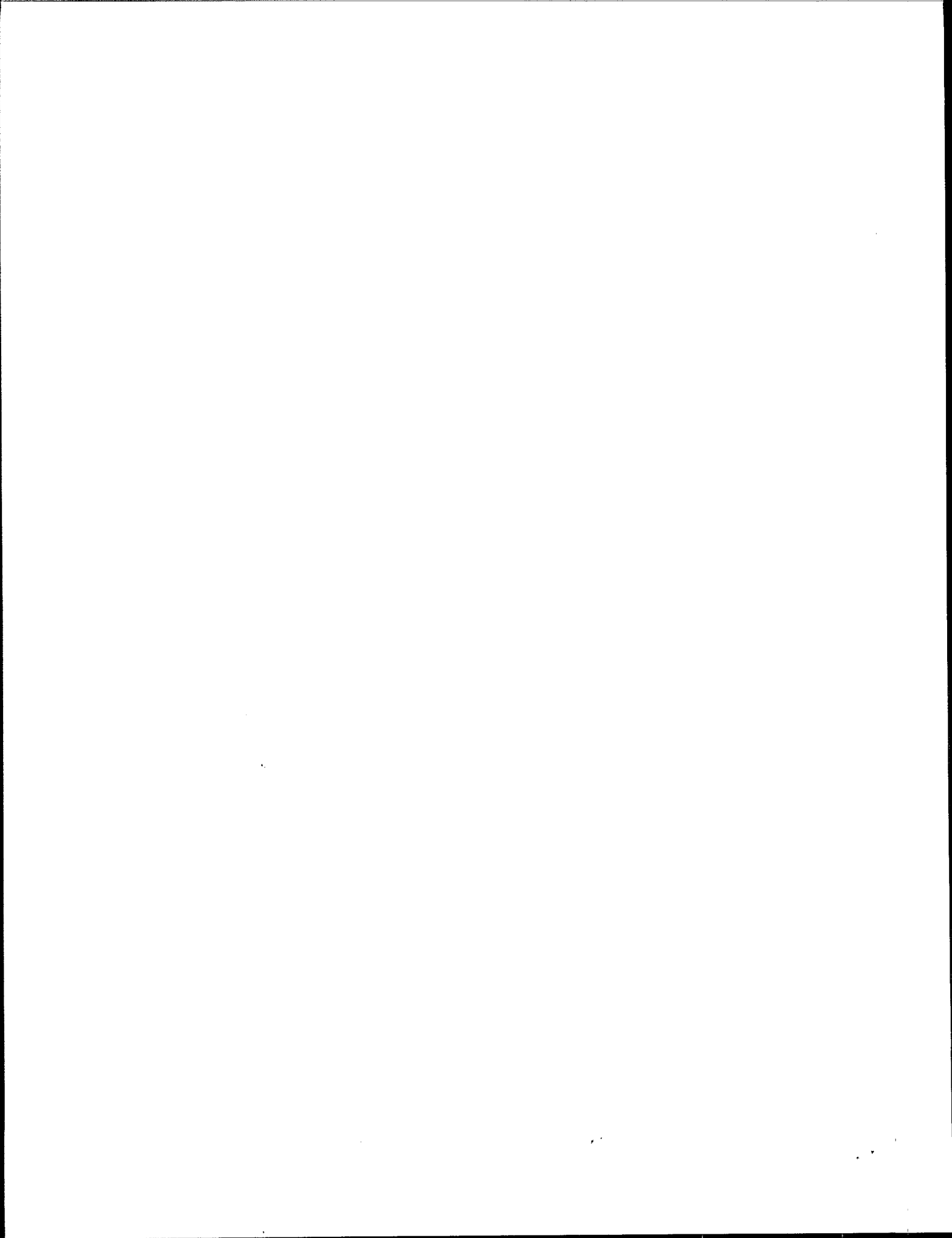


MODULE		WASTE					
SUB MODULE		METHANE EMISSIONS FROM INDUSTRIAL WASTEWATER					
WORKSHEET		6-3					
SHEET		A					
		STEP 1			STEP 2		
		A Annual Wastewater Outflow k litres	B BOD Concentration Rates Gg / litre	C Total BOD Generated Gg BOD	D Fraction of Wastewater Treated Anaerobically	E Quantity of BOD Treated Anaerobically Gg BOD	F Methane Emission Factor 22 Gg CH ₄ / Gg BOD ₅
				$C=(A \times B)$		$E=(C \times D)$	
Iron and steel							
Non-ferrous metals							
Fertilizer							
Food & Beverages	Canneries						
	Beer						
	Wine						
	Meat packing						
	Dairy products						
	Sugar						
	Fish processing						
	Oil & grease						
	Coffee						
	Soft drinks						
	Other						
Pulp and paper	Pulp						
	Paper						
	Other						
Petroleum refining/ Petrochemicals							
Textiles	Bleaching						
	Dyeing						
	Other						
Rubber							
Other							





MODULE		WASTE		
SUB MODULE		METHANE EMISSIONS FROM INDUSTRIAL WASTEWATER		
WORKSHEET		6-3		
SHEET		B		
		STEP 3		
		G Total Methane Released Gg CH ₄	H Methane Recovered Gg CH ₄	I Net Methane Emissions Gg CH ₄
		G=(ExF)		I=(G-H)
Iron and steel				
Non-ferrous metals				
Fertilizer				
Food & Beverages	Canneries			
	Beer			
	Wine			
	Meat packing			
	Dairy products			
	Sugar			
	Fish processing			
	Oil & grease			
	Coffee			
	Soft drinks			
Pulp and paper	Other			
	Pulp			
	Paper			
	Other			
Petroleum refining/ Petrochemicals				
Textiles	Bleaching			
	Dyeing			
	Other			
Rubber				
Other				
Totals				



PART 3

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 (PJ). Annual activity data for methane emissions from enteric fermentation are the total number of animals being raised, by species,

Adipic acid

A raw material primarily used in the chemical industry as an intermediate step in the production of nylon. The process of producing adipic acid also produces nitrous oxide (N_2O) as a by-product.

Afforestation

Planting of new forests on lands which, historically, have not contained forests. These newly created forests are included in the category Managed Forests in the Land Use Change and Forestry module of the emissions inventory calculations. See also reforestation.

Agricultural emissions

The five main types of agricultural emissions included in the *Workbook* are:

- CH_4 emissions from enteric fermentation in domestic animals
- CH_4 emissions from animal manure
- CH_4 emissions from rice cultivation
- N_2O emissions from the use of nitrogen fertilisers
- Non- CO_2 trace gases from the burning of savannas and agricultural residues

Alcohol

Alcohol produced from non-biomass sources should be included with crude oil figures in the inventory.

Anaerobic

Conditions in which oxygen is not readily available. These are important for the production of methane emissions. Whenever organic material decomposes in anaerobic conditions (in landfills, flooded rice fields etc.) methane is likely to be formed.

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.

Apparent Consumption

A concept used in the calculation of CO₂ emissions from fossil fuel consumption. This concept deals with *apparent* rather than *actual* consumption because it tracks the consumption of primary fuels to an economy with adjustments for net imports and stock changes in secondary fuels. While this procedure ensures that all of the carbon in fuels is accounted for, it is important to note that it does not produce actual consumption by specific fuel or fuel product. In cases where exports of secondary fuels exceed imports, it will produce negative numbers. This is clearly not an accurate estimate of the consumption of secondary fuel. It is merely an adjustment to the primary fuel balance calculated elsewhere in the worksheet.

Base year

The year for which the inventory is to be taken. This is currently 1990. In some cases (such as estimating CH₄ from rice production) the base year is simply the last year of a number of years over which an average must be taken.

Benzole

Benzole should be included with crude oil figures in the inventory.

Biomass

Organic material both above ground and below ground, and both living and dead, e.g., trees, crops, grasses, tree litter, roots etc.. When burned for energy purposes, these are referred to as *biomass fuels*.

Bitumen

Solid, semi-solid or viscous hydrocarbon with a colloidal structure, brown to black in colour, obtained as a residue in the distillation of crude oil, vacuum distillation of oil residues from atmospheric distillation. It is soluble in carbon bisulphate, non-volatile, thermoplastic (between 150°C and 200°C) with insulating and adhesive properties. Bitumen is used mainly in road construction.

BKB (Braunkohlenbriketts) and Patent Fuel

BKB (includes peat briquettes)

A composition fuel manufactured from brown coal. The brown coal is crushed, dried and moulded under high pressure into an even shaped briquette without the addition of binders.

Patent Fuel

A composition fuel manufactured from coal fines by shaping with the addition of a binding agent (pitch). Note that the amount of patent fuel produced can be slightly higher than the amount of coal consumed in the transformation process because of the addition of pitch.

Biochemical Oxygen Demand

The amount of oxygen consumed by the organic material in waste water during decomposition.

Brown coal

See Lignite.

BOD

See Biochemical Oxygen Demand.

Bunker fuels

Fuels used in international marine and air transportation.

Calcination

Chemical process in the manufacture of cement in which the raw materials (primarily limestone - calcium carbonate) are heated in kilns producing lime and CO₂.

CFCs

See Chloroflourocarbons.

Chloroflourocarbons

Also known as CFCs, chloroflourocarbons are set of chemical substances which 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.

Clinker

An intermediate product created during the manufacture of cement. In the production of clinker, calcium carbonate is heated, producing lime and carbon dioxide. The carbon dioxide is normally released to the atmosphere as a waste product and is a significant global source of CO₂ emissions.

Closed Forest

A dense forest with closed canopy through which sunlight does not penetrate sufficiently for grasses to grow on the forest floor. These forests contain a significantly greater amount of biomass per hectare than open forests.

Coke

Coke is subdivided into:

Coke-oven coke

The solid product obtained from the carbonisation of coal, principally coking coal, at high temperature, low in moisture and volatile matter. Coke oven coke is used mainly in the iron and steel industry acting as energy source and chemical agent. Semi-coke, the product obtained from the carbonisation of coal at a low temperature, should be included in this category. Semi-coke is used as a domestic fuel or by the transformation plant itself. This heading also includes coke and semi-coke made from lignite.

Gas coke

A by-product of hard coal used for the production of town gas in gas works. Gas coke is used for heating purposes.

Conversion Factor

The factor by which the amount of fuel consumed must be multiplied in order to reach a total in the common reporting unit, Gigajoules (Gj). In some cases conversion factors are *country specific*, which means that the amount of energy produced by a particular fuel type varies from country to country. Where country specific conversion factors exist, these should always be used in calculating energy use.

Crude Oil

Mineral oil consisting of a mixture of hydrocarbons of natural origin, yellow to black in colour of variable specific gravity and viscosity. It includes lease condensate (separator liquids) which is recovered from gaseous hydrocarbons in lease separation facilities.

Inputs other than crude oil and NGL should be included with crude oil and footnoted. these include hydrogen, synthetic crude oil (including mineral oils extracted from shales, bituminous sand etc.) benzole, alcohol (except alcohol produced from biomass) and methanol produced from natural gas. Although not hydrocarbons, additives and other chemical alloys such as tetraethyl lead should be included.

Dry Biomass

See Dry Matter.

DM

See Dry Matter.

Degradable Organic Carbon

Organic material which can decay, expressed as weight of carbon. Usually 15 to 25% of total waste.

DOC

See Degradable Organic Carbon.

Dry Matter

In this *Workbook* dry matter refers to biomass which has dried to an *oven dry* state. This means that all loose water has been driven off but water that is part of the carbohydrate molecule and various volatiles still remains. By contrast, dry matter which is only *air dry* may contain 15% moisture.

ECE

Economic Commission for Europe. A United Nations body.

Emission Factor

A coefficient that relates actual emissions to activity data as a standard rate of emission per unit of activity. Emission factors are often based on a sample of measurement data, averaged to develop a representative rate of emission for a given activity level under a given set of operating conditions.

Enteric fermentation

A product of digestion in herbivores (plant-eating animals) which produces methane as a by-product.

Evaporative emissions

Evaporative emissions are released from area (rather than point) sources. These are often Non-Methane Volatile Organic Compounds (NMVOCs), and the emissions are produced when a portion of the product is exposed to the air - for example in the use of paints or solvents.

FAO

Food and Agriculture Organization of the United Nations.

Flaring

A practice used to dispose of gas which cannot be contained or used productively. In some cases, when associated natural gas is released along with oil from production fields remote from energy users, the gas is burned off as it escapes, primarily for safety reasons. Some flaring may also occur in the processing of oil and gas. See also venting.

Fugitive Emissions

Emissions resulting from the leakage of chemical substances during various human activities. Fugitive emissions are distinguished from other emissions in the energy sector which are a direct result of fuel combustion. In calculations in the Energy module, emissions from energy lost through

leakage or flaring are counted as *fugitive* emissions, while the productive use of fuels as feedstock or for other non-energy uses is treated separately.

Gas/Diesel Oil (Distillate Fuel Oil)

Refers to heavy oils. Gas oils are obtained from the lowest fraction from atmospheric distillation of crude oil, but heavy gas oils are obtained by vacuum redistillation of the residual from atmospheric distillation. Gas diesel oil distils between 200°C and 300°C but less than 65% in volume at 250°C including losses, and 85% or more at 350°C. Their flash point is always above 50°C and their specific gravity is higher than 0.82.

Heavy oils obtained by blending are grouped together with gas oils, on condition their kinematic viscosity does not exceed 115 secs. Redwood I at 38°C

Gasoline

Gasoline includes the following products:

Gasoline Type Jet Fuel

This includes all light hydrocarbon oils for use in aviation gas turbine power units. They are distilled between 100°C and 250°C, distil at least 20% of their volume at 143°C and are obtained by blending kerosene and gasolines or naphthas in such a way that the aromatic content does not exceed 25% in volume. Additives are included to reduce the freezing point to -58°C or lower and to keep the Reid vapour pressure between 0.14 and 0.21 kg/cm².

Motor Gasoline

Motor Gasoline is a light hydrocarbon oil for use in internal combustion engines excluding aircraft.

Motor Gasoline is distilled between 70°C and 200°C and treated to reach a sufficiently high octane number (\geq RON). Treatment may be by reforming, blending with an aromatic fraction, or the addition of benzole or other additives (such as tetraethyl lead).

Greenhouse gases

The current draft IPCC inventory includes six major greenhouse gases.

The direct greenhouse gases included are:

- Carbon Dioxide (CO₂)
- Methane (CH₄)
- Nitrous Oxide (N₂O)

The indirect greenhouse gases included are:

- Carbon Monoxide (CO)
- Oxides of nitrogen (NO_x)
- Non-Methane Volatile Organic Compounds (NMVOCs)

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

Hard Coal

Coal of calorific value greater than 23,865 kJ/kg (57,000 kcal/kg) on an ash free but moist basis with a mean random reflectance of vitrinite of at least 0.6. Hard coal divides into:

Coking coal

Coal with a quality that allows the production of coke suitable to support a blast furnace charge. The following classification codes cover coals which fall into this category.

- International classification codes: (UN Geneva 1956): 323, 333, 334, 423, 433, 434, 435, 523, 533, 534, 535, 623, 633, 634, 635, 723, 733, 823.
- USA classification codes: Class II Group 2 "Medium volatile Bituminous".
- British classification: Classes 202, 203, 204, 301, 302, 400, 500, 600.
- Polish classification: Classes 33, 34, 35.1, 35.2, 36, 37.
- Australian classification: Classes 4a, 4B, 5.

Steam Coal (Other bituminous coal and anthracite)

Steam coal is used for steam raising and space heating purposes and includes all Anthracite coals and Bituminous coals not included under Coking coal.

Heavy Fuel Oil (Residual)

The heavy oils which make up the distillation residue. They comprise all fuel oils (including those obtained by blending). Their viscosity is above 115 secs. Redwood I at 38°C. The flash point is always above 50°C and the specific gravity is more than 0.90.

IEA

The International Energy Authority. An autonomous body attached to the OECD. See also OECD.

IPCC

The Intergovernmental Panel on Climate Change. A special organization set up 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).

Jet Fuel

Fuel which meets the specification for aviation gas turbine units.

Jet fuel is a medium oil with the same distillation and flash characteristics as kerosene, with a maximum aromatic content of 20% in volume and treated to give a kinematic viscosity of less than 15 cST at -34°C and a freezing point below -50°C. Its octane number varies between 80 and 105 RON.

Kerosene

Kerosene is a refined petroleum distillate which is intermediate in volatility between gasoline and gas/diesel oil.

It distills at between 150°C and 300°C and distills at least 65% of its volume at 250°C. Its specific gravity is in the region of 0.80 and the flash point is above 38°C. It is used as a heating fuel and as fuel for certain types of internal combustion engines.

Kilns

Equipment used in the manufacture of cement. Vessels in which the raw materials (primarily limestone - calcium carbonate) are heated to cause a chemical process known as calcination which produces lime and CO₂.

Landfill emissions

The emission of greenhouse gases from landfills. The two sorts of landfill involved are:

- open dumping
- sanitary land filling

Typically, landfill gas is 50-70% CH₄ and 30-50% CO₂ with traces of other gases.

Land-Use Change Emissions

Emissions resulting from changes in the way an area of land is used. The types of changes which produce emissions or removals of greenhouse gases include:

- conversion of forests to non-forests (for example to pasture or cropland)
- conversion of cultivated lands to grasslands
- abandonment of managed lands
- conversion of wetlands to non-wetlands

Although these changes result mainly in emission or removals of CO₂, factors such as clearing by burning release gases other than CO₂. Conversion of wetlands to non-wetlands results also in a lowering of natural methane emissions.

Lignite

Non-agglomerating coals with a gross calorific value less than 17,435 kJ/kg (4165k cal/kg) and greater than 31% volatile matter on dry mineral matter free basis.

See Sub-bituminous coal. The distinction between Sub-bituminous coal and Lignite is not normally made in Europe.

Liquid Petroleum Gas (LPG)

LPGs are light hydrocarbon fractions of the paraffin series derived from the refinery processes and crude oil stabilisation plant. They are primarily

propane (C_3H_8) and butane (C_4H_{10}) or a mixture of these two hydrocarbons.

Commercial propanes may be of less than 99% purity. They can be liquefied at low pressure (5-10 atmospheres). In the liquid state and at temperature of $38^{\circ}C$, they have a relative vapour pressure less than or equal to 24.5 bars (ASTM D standard method). Their specific gravity varies from 0.50 to 0.58.

LHV

See Lower Heating Value.

Locally Available Data

The term used throughout the *Guidelines* to refer to data assembled at the national level and used as input for emissions calculations. This is distinguished from default data which are provided or referred to in the *Workbook* methodologies.

Lower Heat Value

If you report quantities of fuel expressed in energy units (terajoules, toe, etc.), you should ensure that the quantities have been calculated using the Net Calorific Values (**Lower Heating Value**) which is 95% of the higher heating value (HHV) for Liquid Fossil, Solid Fossil, and Biomass Fuels and 90% of HHV for Gaseous Fossil Fuels. Default energy data are provided in LHV.

LPG

See Liquid Petroleum Gas.

Lubricants

Lubricants are liquid distillates obtained by refining crude petroleum. They are viscous or liquid hydrocarbons rich in paraffin waxes, distilling between $380^{\circ}C$ and $500^{\circ}C$ obtained by vacuum distillation of oil residues from atmospheric distillation. They include all grades of lubricant oil from spindle oil to cylinder oil, cutting oils and those used in grease. The main characteristics of lubricating oils are flash point less than $125^{\circ}C$, pour point between $-25^{\circ}C$ and $+5^{\circ}C$ depending on the grade, strong acid number normally 0.5 mg/g, ash content less than 0.3% and water content less than 0.2%.

Manure

Waste materials produced by animals that are managed for agricultural purposes. When manure is managed in a way that involves anaerobic decomposition, significant emissions of methane can result.

Methanol

Methanol produced from natural gas should be included with crude oil figures.

Montreal Protocol

The international agreement which requires signatories to control and report emissions of CFCs and related chemical substances which 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.

MSW

See Municipal Solid Waste.

Municipal Solid Waste

Solid waste that is collected regularly by municipalities, e.g. household trash and garbage.

Naphtha

Naphtha includes light or medium oils from the end of the motor spirit to the beginning of the kerosene range. Naphtha distils between 30°C and 210°C. The properties depend upon consumer specifications. the C:H ratio is usually 84:14 or 84:16 with a very low sulphur content (equal to or less than 0.1%). The two main types are: full-range naphtha and narrow-cut naphtha. Narrow-cut naphtha is divided into light naphtha (distilling at between 30°C and 70°C), medium naphtha (distilling between 70°C and 125°C) and heavy naphtha (distilling between 125°C and 210°C). Some narrow-cut naphthas may meet the specifications of industrial spirit.

Naphtha imported for blending in refineries is reported as refinery feedstocks. It is used as refinery feedstocks for reforming processes and in the chemical industry.

Natural Gas

Gases consisting mainly of methane occurring in underground deposits. Production is measured after the purification and extraction of NGL and sulphur, and excludes re-injected gas and losses. Include gas consumed by processing plants and gas transported by pipelines. Also include quantities vented and flared and natural gas produced in association with crude oil as well as methane recovered from coal mines (colliery gas) and sewage gas.

Natural Gas Liquids (NGL)

Liquid or liquefied hydrocarbons produced in the manufacture, purification and stabilisation of natural gas. Their characteristics vary, ranging from those of butane and propane to heavy oils. NGL are either distilled with heavy oil in refineries, blended with refined petroleum products, or used directly, depending on their characteristics.

NGL

See Natural Gas Liquids.

Nitric Acid

A raw material used mainly as feedstock in fertilizer production and in the production of adipic acid. The process of producing nitric acid can also produce nitrous oxide (N_2O).

NMVOC

See Non Methane Volatile Organic Compounds.

Non-Methane Volatile Organic Compounds

A class of emissions which includes a wide range of specific organic chemical substances. Non-Methane Volatile Organic Compounds (NMVOC) play a major role in the formation of ozone in the troposphere (lower atmosphere). Ozone in the troposphere is a greenhouse gas. It is a major local and regional air pollutant, causing significant health and environmental damage. Because they contribute to ozone formation, NMVOC are considered "indirect" greenhouse gases.

OECD

The Organization for Economic Cooperation and Development. A regional organization of 24 free-market democracies in North America, Europe and the Pacific.

Open Forests

Open forests are less dense than closed forests, do not have a closed canopy and have grasses growing on the forest floor. These forests contain less biomass per hectare than closed forests.

Other products

The category Other products included in the energy statistic provided by the IEA includes the following:

Refinery gas (not liquefied)

Non-condensable gases obtained during the distillation of crude oil products (e.g. cracking) in refineries, mainly consisting of hydrogen, methane, ethane and olefins.

White Spirit and SBP

White Spirit and SBP are distillate intermediates with a distillation range between gasoline and kerosene.

- Industrial Spirit (SBP): Light oils distilling between 30°C and 200°C with a temperature difference between the 5% volume and the 30% volume distillation points, including losses, of not more than 60°C. In other words a light oil of a narrower cut than motor spirit. There are 7 or 8 grades of industrial spirit, depending on the position of the distillation range as defined above.
- White Spirit: Industrial spirit with a flash point above 21°C (generally above 30°C). The distillation range of white spirit is 135°C to 200°C.
- Paraffin waxes: Saturated aliphatic hydrocarbon. The waxes are extracted when dewaxing lubricant oils and they have a crystalline

structure with $C > 12$. They are colourless, odourless and translucent with a melting point above 45°C , specific gravity of 0.76 to 0.78 at 80°C and kinematic viscosity between 3.7 and 5.5 cST at 99°C .

- Other Petroleum products: products not mentioned above, for example, sulphur, tar and grease.

Peat

Combustible, soft porous or compressed sedimentary deposit of plant origin with a high water content (up to 90%), easily cut, light to dark brown colour.

Petroleum Coke

Petroleum coke is a shiny black solid residue obtained by cracking and carbonisation in furnaces and distillation of heavier petroleum oils, consisting mainly of carbon (90% to 95%), which burns without leaving ash.

Process emissions

Processes in which physical materials are chemically transformed from one state to another, in the course of which greenhouse gases are emitted.

See also Source emissions

Refinery Feedstocks

A refinery feedstock is a combination of products derived from crude oil destined for further processing in the industry other than blending. It is transformed into one or more components and/or finished products. This includes those finished products imported for refinery intake and those returned from the chemical industry to the refining industry. In the case of refineries integrated with petro-chemical plants, the amount of this flow is estimated wherever possible.

Reforestation

Planting of forests on lands which have, historically, previously contained forests but which have been converted to some other use. Replanted forests are included in the category "Managed Forests" in the Land Use Change and Forestry module of the emissions inventory calculations. See also afforestation.

Ruminant animals

Herbivores (grazing animals such as cattle, buffalo, sheep, goats and camels) which have a large free stomach or rumen. Digestion in anaerobic conditions in the rumen can create significant emissions of methane from ruminant animals.

Savanna burning emissions

Savannas are tropical and sub-tropical formations with continuous grass cover occasionally interrupted by trees and shrubs. They may be burnt intentionally or unintentionally, releasing CO_2 , CH_4 , CO , N_2O and NO_x (oxides of nitrogen).

Intentional savanna burning is treated as an agricultural emission source.

Sequestered carbon

See Stored carbon.

Stored carbon

The amount of a fuel which is not burnt for energy uses and which must be subtracted from apparent consumption before calculating emissions.

Synthetic crude oil

Synthetic crude oil, including mineral oils extracted from shales, bituminous sand etc. should be included with the figures for crude oil.

Sub-bituminous coal

Non-agglomerating coals with a gross calorific value between 17,435 kJ/kg (4165 kcal/kg) and 23,865 kJ/kg (5700 cal/kg) containing more than 31% volatile matter on dry mineral matter free basis.

See Lignite. The distinction between Sub-bituminous coal and Lignite is not normally made in Europe.

Trace gas emission ratios

Ratios for carbon compounds are mass of carbon released as CH₄ or CO (in units of C) relative to mass of total carbon released from burning (in units of C). Those for nitrogen compounds are expressed as the ratios of nitrogen released as N₂O and NO_x relative to the nitrogen content of the fuel (in units of N).

UNEP

United Nations Environment Programme.

Venting

A practice used to dispose of gas which cannot be contained or used productively. In some cases, when associated natural gas is released along with oil from production fields remote from energy users, the gas is allowed to escape into the atmosphere. See also flaring.

Volatile Solids

The amount of organic material that disappears after drying.

Water Management Regime

A variety of practices used to classify rice production into categories for estimating emissions of methane. The two major water management regimes (or practices) are *dry* (or *upland*) production and *continuously flooded* rice paddies. The dry category produces little or no methane, while the continuously flooded category is a significant source.

WMO

The World Meteorological Organization of the United Nations.

