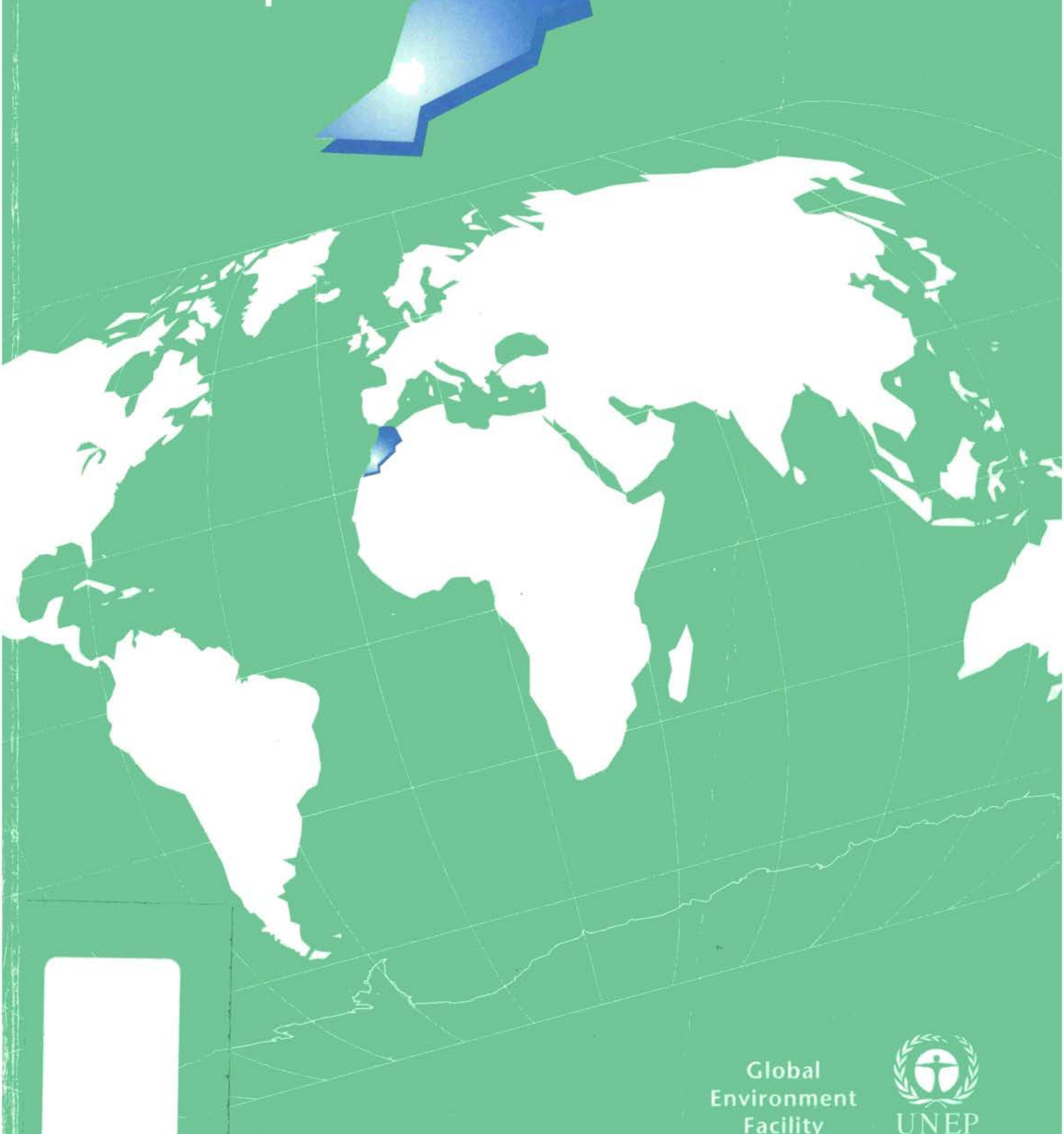
Country Case Study on Sources and Sinks in Morocco

Final Report



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PREFACE

In accordance with Article 4 of the United Nations Framework Convention on Climate Change (UNFCCC), all Parties are required to develop, periodically update, publish and make available to the Conference of the Parties, national inventories of anthropogenic emissions by sources and removals by sinks of all greenhouse gases not controlled by the Montreal Protocol using comparable methodologies to be agreed upon by the Conference of the Parties.

A methodology for conducting such inventories was developed by the OECD Environment Directorate, the International Energy Agency (IEA), and the IPCC Working Group I Technical Support Unit and was proposed as the standard methodology as required under the Convention.

In order to test and further refine the method, the UNEP Atmosphere Unit, working in collaboration with the UNEP Global Environment Facility (GEF), implemented a series of nine complementary national studies using these "IPCC Guidelines for National Greenhouse Gas Inventories".

This report is one of the nine technical reports resulting from this effort. Based partly on this study and on a series of regional workshops sponsored by UNEP under the GEF funded programme and with the assistance of experts from a number of countries, an improved version of the IPCC Guidelines was prepared and approved at the Tenth Plenary Session of the IPCC in Nairobi (November 1994).

The First Conference of the Parties to the UNFCCC (Berlin, April 1995) also adopted the IPCC methodology as the recommended standard to be employed by all Parties in making their inventories in accordance with Article 4.

It is hoped that this report will assist other country study teams in the development and updating of future inventories of greenhouse gases.

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KINGDOM OF MOROCCO

MINISTERE DE L'ENVIRONNEMENT

Project GF / 0103-92-34

U N E P

United Nations Environment Programme

STUDY OF THE SOURCES OF EMISSION OF GREENHOUSE GASES

Volume 1 **28 April 1995**

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LIST OF ABBREVIATIONS AND SYMBOLS

Organisations

ACTS:	African centre for technology studies
BNDE:	Banque Nationale pour le développement économique
CDER:	Centre de développement des énergies renouvelables
CERED:	Centre d'étude et de recherches démographiques
COP:	Conference of the parties
CRTS:	Centre royal de télédétection spatiale
CSE:	Conseil supérieur de l'eau
DEFCS:	Direction des eaux et forêts et de la conservation des sols
DGCL:	Direction générale des collectivités locales
FAO:	Food and Agriculture Organization of the United Nations
FERTIMA:	Société des fertilisants du Maroc
GEF:	Global environment facility
GEM:	Gestion de l'énergie au Maroc
IAV:	Institut Agronomique et Vétérinaire Hassan II
IBRD:	International Bank for Reconstruction and Development (World Bank)
ICID:	International Commission on Irrigation and Drainage
IPCC:	Intergovernmental Panel on Climate Change
MAMVA:	Ministère de l'agriculture et de la mise en valeur agricole (formerly MARA)
MARA:	Ministère de l'agriculture et de réforme agraire
ME:	Ministère de l'environnement (formerly SSEE)
MEM:	Ministère de l'énergie et des mines
MII:	Ministère de l'intérieur et de l'information
MTP:	Ministère des travaux publics
OECD:	Organization for Economic Co-operation and Development
ONE:	Office national de l'électricité
PNED:	Programme nationale d'électrification décentralisée
PNER:	Programme nationale d'extension du réseau
PPER:	Programme pilote d'électrification rurale
SAMIR:	Société marocaine des industries du raffinage
SCP:	Société Chérifienne des Pétroles
SEI:	Stockholm Environment Institute
SNPP:	Société nationale des produits pétroliers
SSEE:	Sous Secrétariat d'Etat chargé de la protection de l'Environnement
UNCED:	United Nations Conference on Environment and Development
UNEP:	United Nations Environment Programme
UNFCCC:	United Nations Framework Convention on Climate Change
USAID:	Unites States Agency for International Development
WHO:	World Health Organization
WMO:	World Meteorological Organization of the United Nations

Other abbreviations

ATK:	Aviation turbine kerosene (jet fuel)
CH_4:	Methane
CO:	Carbon monoxide
CO_2:	Carbon dioxide
E-CO_2:	Equivalent CO_2
GDP:	Gross domestic product
GHG:	Greenhouse gas
GWP:	Global warming potential
LPG:	Liquid petroleum gas
N_2O:	Nitrous oxide
NMCH:	Non-methane hydrocarbons
NO_x:	Nitrogen oxides
UAS:	Usable agricultural surface

Units

DH:	dirham (Moroccan)
GJ:	gigajoule = 10^9 J
Gg:	gigagramme = 10^9 g = 1 kilotonne - 1 kt
ha:	hectare
kWh:	kilowatt hour
MW:	megawatt
t E-CO_2:	tonne equivalent CO_2
t:	tonne
toe:	tonne oil equivalent
USD:	US dollar

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FOREWORD

Presentation of the project

In June 1992 Morocco signed the *United Nations Framework Convention on Climate Change* (UNFCCC) on the occasion of the UNCED in Rio de Janeiro. The UNFCCC entered into force on 21 March 1994 and the first meeting of the Conference of the Parties is scheduled for 27 March to 7 April 1995 in Berlin.

Article 2 of the UNFCCC states that its objective is *"in accordance with the relevant provisions of the Convention, to stabilise the concentrations of greenhouse gases in the atmosphere at a level which prevents any dangerous anthropogenic disruption of the climatic system. This level should be reached within a time frame sufficient to allow ecosystems to adapt naturally to climate changes, which does not jeopardise food production and which allows economic development to continue on a long-term basis."*

With a view to identifying the actions to be taken to stabilise and even reduce the emission of greenhouse gases, preliminary work has been undertaken to create a national inventory of anthropogenic emissions by sources and absorption by sinks of all greenhouse gases not controlled by the Montreal Protocol.

Following the example set by the other signatory developing countries, with effect from March 1997 Morocco is obliged to provide, in accordance with Article 12, *"national inventories of anthropogenic emissions from sources and absorption by sinks of all greenhouse gases not controlled by the Montreal Protocol, using comparable methods which will be approved by the Conference of the Parties (COP)".*

The methodology drawn up by the IPCC, in collaboration with the Organization for Economic Co-operation and Development (OECD) should provide all countries with a joint basis for compiling these inventories; it will be approved at the 1st meeting of the COP (28 March - 7 April 1995, Berlin). The COP is the supreme body of the Convention.

Between July 1994 and January 1995, Morocco prepared a national inventory financed by the GEF/UNEP, as part of a project coordinated by the ECU (Environmental Change Unit) of the University of Oxford and ENDA-TM.

Reminder of the objective of the study

According to the contract signed on 8 July 1994 between the SSEE and the GERERE, "the objective of the study is to establish a national inventory in Morocco of the sources of greenhouse gas emissions".

Within this context, the following are required:

* compilation of existing data
* presentation of a full inventory of greenhouse gases
* implementation of a survey of industries
* development of specific software to compile a database and its installation at the SSEE.

Presentation of the team

Coordinated by the SSEE (which became the *Ministère de l'Environnement* in March 1995), the project was carried out by the *Groupe d'études et de recherches sur les énergies renouvelables et l'environnement* (GERERE), with the collaboration of a monitoring committee composed of representatives from the following ministries:

* *Ministère de l'Energie et des Mines*
* *Ministère de l'Agriculture et de la Mise en Valeur Agricole*
* *Ministère du Commerce, de l'Industrie et de l'Artisanat*
* *Ministère des Transports*
* *Ministère des Travaux Publics (Direction de la Météorologie Nationale).*

In order to perform the various activities related to the study, GERERE called upon the services of a five-strong team, composed of three researchers, one statistician and one computer scientist. These were:

* Mrs. Jamila BURET, professor at the Faculty of Sciences in Rabat, director of the solar energy laboratory;

* Mr. Ali AGOUMI, professor at the *Ecole Hassania des Travaux Publics* in Casablanca and environmental adviser to the *Ministère des Travaux Publics;*

* Mr. Faouzi SENHAJI, professor at the *Institut Agronomique et Vétérinaire Hassan II,* coordinator of this study;

* Mr. Abdelilah ZERROU, statistical engineer in the *Direction de la Statistique;*

* Mr. Mouanis LAHLOU, professor at the *Institut Agronomique et Vétérinaire Hassan II,* computer scientist.

In order to carry out the survey, GERERE called on the services of around twenty young, recently graduated engineers searching for work or final-year engineering pupils.

Furthermore, the results of the study on land use change, carried out by the *Centre Royal de Télédétection Spatiale* (CRTS), which we obtained at the end of March, allowed us to confirm the data on forests and usable agricultural surface (UAS) provided by the department of agriculture (MAMVA).

Presentation of the report

This report is divided into three parts (A, B and C), which correspond to the three tasks described above.

Part A, sources and balance sheet of emissions, is divided into 5 chapters ranked in order of importance and relational logic (i.e. 4. Energy, 5. Forestry, 6. Agriculture, 7. Industrial Process and 8. Waste).

The 6th chapter is devoted to an attempted forecast for the year 2010 and to a discussion of the strategic options (9).

The 7th chapter (10) presents general remarks, conclusions and recommendations on the methodology of the inventory.

Part B is a concise presentation of the database which was provided in diskette format and which was installed on the computer equipment of the *Ministère de l'Environnement*.

The appendices relating to parts A and B are incorporated into volume 2 of this document, entitled Appendices.

The tables summarising the inventory of emissions of greenhouse gases, an example of "outputs" from the database and the corresponding results obtained using the Minergg software are contained in volume 3 of this document.

1. SUMMARY AND CONCLUSIONS OF THE STUDY

i. Morocco signed the Framework Convention on Climate Change in Rio in June 1992. This convention is currently being ratified. The existing structures (*Ministère de l'Environnement, Conseil National de l'Environnement, Laboratoire National de l'Environnement,* Interministerial monitoring committees, *Centre Royal de Télédétection Spatiale,* etc.) and recently acquired expertise will soon enable Morocco to meet all of its obligations pursuant to the Convention.

The human and technical potential currently available in Morocco enable it to launch emission reduction programmes concurrent with its new strategy of sustainable development.

ii. Morroco's interest in the climate was provoked by the serious drought between 1979 and 1983. Since then, several research programmes have been launched, in particular in collaboration with American universities, but there have been virtually no studies on climate changes related to the greenhouse effect. However, the potential for performing research in this field does exist.

iii. This **initial assessment of GHG emissions carried out in Morocco** produces the following results:

> **1990**: approximately **44,000 Gg of gas equivalent CO_2** emitted
> of which **32,500 Gg of CO_2** (74% of GHGs)
> or **1.7 tonnes E-CO_2 per inhabitant**
> of which **1.3 tonnes of CO_2 per inhabitant**

The uptake of CO_2 by the forest in 1990 has been estimated at approximately 4,600 Gg, which represents 14% of total CO_2 emitted. This figure, which confirms the low productivity of the Moroccan forest, will fall as deforestation continues:

> **2010**: approximately **88,000 Gg of gas equivalent CO_2** would be emitted
> of which **73,000 Gg of CO_2** (83% of GHGs)
> or **2.6 tonnes E-CO_2 per inhabitant**
> of which **2.1 tonnes of CO_2 per inhabitant**

Average annual rate of increase for the period 1990-2010:

> 3.5% for total emissions in E-CO_2
> 3.7% for total emissions of CO_2
> 2% for emissions in E-CO_2 per inhabitant.

- Morroco thus makes a small contribution to the increase in the concentration of GHGs in the atmosphere; by contrast, it is a country at high risk from the potential impact of climate change (water resources, forestry, coast).

- Taking into account the proportion of the various sources of GHGs in the assessment of Moroccan emissions, we have identified the chief sectors in which **action** is **desirable** with a view to limiting these emissions while maintaining the country's objective of sustainable development:

*** sectors which are major consumers of fossil fuels:**
thermal electric power stations / road transport / industry

*** the residential sector, major consumer of biomass.**

The technical options for reducing GHG emissions which seemed to us the most appropriate to the situation in Morocco are as follows:

1. **The use of natural gas, particularly in thermal electric power stations**

2. **The control of energy and the use of clean technologies in industry**

3. **Action at the level of urban transport: introduction of electric public transport systems in large towns (elevated railway or trams in Casablanca)**

4. **More intense use of renewable energy in rural areas (photovoltaic electricity, solar- powered ovens and water heaters, etc.)**

5. **Introduction and spread of improved stoves and LPG in rural areas**

6. **Improvement in carbonisation yields (from 18% to 25%)**

7. **Afforestation for energy purposes.**

iv. A **database** of all the information available and required to make an inventory of GHGs has been compiled. It incorporates all the data on energy, transport, industry, agriculture, forestry and waste in particular. It provides all the inputs for running the Minergg software for calculation GHG emissions.

v. The **survey**, performed on a sample of 592 industrial establishments, representing branches of the sector and the regions of Morocco, has been 60% completed; the information requested related chiefly to:

- energy consumption
- solid, liquid and gaseous waste
- technological level.

2. INTRODUCTION

2.1 Presentation of Morocco

Geographical context

Morocco lies in the north-west of the African continent. Its geographical diversity is characterised firstly by the Mediterranean and Atlantic coasts and the Rif and Atlas mountain ranges (Toubkal, 4167 m) and secondly by the semi-arid and arid regions to the east and south of the country.

The climate of Morocco, which is Mediterranean, is influenced by the ocean, the mountains and the Sahara. It is characterised by two well-defined seasons: a hot, dry summer (25-45 °C) and a short winter (0-15 °C) with violent, concentrated rainfall (150-200 mm). Morocco's climate varies from one region to another and is also marked by severe irregularities from year to year and within a given year.

Demographic context

Morocco is the most densely populated country of the Maghreb, with over 26 million inhabitants (1994), closely followed by Algeria. Almost half of these inhabitants (48.2%) is concentrated in two economic regions: the north-west and the centre. The rate of population growth rose from 2.08% in the period 1971-1982 to 2.1% in 1991-1992. At this growth rate, the population of Morocco will reach 29.6 million by the year 2000 and 34.2 million by 2010 (Appendix 2). Morocco's population is young: 42% were below the age of 15 and 6.4% were over 60 in 1982. The urban population, which accounted for 35% in 1971, rose to 42% in 1982 and 51.4% in 1994. Women represented almost 51% of the total population in 1992.

Economic context

Over the past ten years, GDP (in current prices) has risen by an average of 3.8% per year, from 93 million dirham in 1982 to 242.5 million dirham in 1992.

In 1990, GDP (in current terms) was 8,300 dirham per inhabitant (approximately 900 USD) and 9,500 dirham per inhabitant in 1992 (approximately 1050 USD).

The **primary sector** is still of considerable importance in Morocco. Agriculture and fishing account for over 50% of jobs and 13% of GDP. The large dam policy (35 built since independence in 1956) has been pursued to accompany the modernisation of the agricultural sector. These dams ensure a regular year-long supply of more than 6.5 billion m^3 of water.

In the **secondary sector**, mining and energy represent 10% of GDP, industry 18% (average 1965-1990). Morocco, with the world's largest reserves of phosphate, is its number one exporter and third largest producer.

The **tertiary sector** is one of the largest employers in Morroco and accounts for over 50% of GDP (trade, tourism, public administration, etc.). Morocco essentially exports staple commodities with very little added value (fertilisers, citrus fruits, fish, etc.).

Energy context

The energy sector is heavily dominated by imports of crude oil which account for 80% of consumption of conventional primary energy and 88% of imports of energy products (high dependence: 92% in 1992) and which is a heavy burden on the Moroccan economy.

Biomass energy, which is difficult to evaluate, may represent up to 30% of the national energy assessment, according to some estimates, with a major impact on the country's forest resources.

Environmental context

The majority of the atmospheric pollutants in Morocco come from **thermal electric power stations, industry, transport** - which consumes almost all the coal and the oil products - and **biomass burning.** This last source, which is consumed entirely by the residential and tertiary sectors, also places Moroccan forests in a critical and worrying situation. The 35,000 hectares of forest lost every year will certainly increase if nothing is done to alleviate the extreme poverty of the waterside populations of the forests or to curb demographic pressure.

One other worrying aspect in Morocco is the pollution of marine and continental waters especially by urban and industrial waste. Currently the most worrying case is that of Oued Sebou, which drains over 40% of the country's recoverable rainfall and which irrigates very fertile agricultural zones. The Sebou crosses conurbations and industrial zones from which it receives waste, in particular toxic waste from industry and crafts; add to this the residues from fertilisers and pesticides used in the agricultural zones dissected by the river.

2.2 Greenhouse gases and climate changes in Morocco

Basic facts about climate change in Morocco

Morroco's particular interest in the **climate** came to light following the severe drought between 1979 and 1983. A dendrochronology study has therefore been used to reconstruct the climate history of the past millennium and to attempt to map out the periodicity of the droughts, their length and their magnitude (Bazza and Stockton, 1990).

The second World Climate Conference, held in Geneva in October 1990, clearly raised national awareness of these problems. Since then Morocco has played a regular part in the work of the Intergovernmental Panels on Climate Change (IPCC). Following the UNCED (Rio, June 1992), Morocco has introduced various networks for closely monitoring these problems; in particular, in 1992 it created a *Sous-Secrétariat d'Etat chargé de la protection de l'Environnement* (which became the *Ministère de l'Environnement* in March 1995), interministerial committees for monitoring projects within the *Conseil National de l'Environnement* and a *Comité National du Climat* (CNC). However, public information and awareness campaigns relating to the problems of climate change are still very limited.

The studies and research carried out in Morocco on **climate change with respect to the greenhouse effect** are still very limited. These have mainly involved bibliographical summaries of the development in knowledge of these problems and the most recent results of large climate models (Agoumi et al., 1991).

Moreover, the *Direction de la Météorologie National* has significantly developed its network of measures in recent years. Temperature changes and rainfall in the main regions of the country have been monitored. This has been performed in accordance with the recommendations of the World Meteorological Organization of the United Nations (WMO).

Impacts of climate changes in Morocco

As a result of its geographical location (arid and semi-arid zone) and its policy choices (priority given to agricultural development), Morocco's development is largely conditioned by the climate and by water.

Since the beginning of the nineteen-sixties, Morocco has been implementing a dynamic, ambitious strategy for developing water resources. However, despite its obvious efforts, the results obtained, although highly encouraging, are flimsy in the long term: the challenge of providing a safe water supply for the years 2010-2020 is still a valid one!

The climate of this region can periodically be characterised by frequent, long droughts (several years). Studies and research carried out into this aspect have confirmed the distant origin of this aridity (Agoumi et al., 1991; Stockton, 1985). During the 1980s Morocco experienced a severe drought which had a major impact on the economy. During such periods, the potential in terms of water which can be mobilised (estimated at 21 billion m^3) falls dramatically, sometimes by more than 90% (generally between 50-90%).

Possible effects of warming on water resources

The large climate models, simulating changes in temperature and rainfall in the event of a doubling of the concentration of CO_2 in the atmosphere (envisaged around 2050), despite their inaccuracy, forecast a possible global rise in the average annual temperature of over 4 °C for the Moroccan region, with a very slight variation in rainfall levels (Agoumi et al., 1991). This would involve:

* direct consequences on available water resources (contributions and losses, especially by evapotranspiration) and on their quality;

* consequences on the demand for water for industry, municipalities and agriculture in particular;

* an irreparable fall in hydroelectric capacity;

* indirect consequences on vegetation, the soil and the environment.

Given such assumptions about the level of warming in the area, it was estimated that potential evapotranspiration would increase by more than 200 mm per year, that water requirements for crops would increase from 40 to 150 mm depending on the length of their growing cycle and that the demand for irrigation water would follow the same pattern in zones with fewer than 40 mm rainfall (Benarafa, 1992).

The water supply/demand imbalance would become great, in turn affecting sensitive sectors such as drinking water, agriculture, health, etc..

The **hydric deficit** which could affect the region under such circumstances would have a definite **impact** on **forestry**, as well as on **desertification.**

Possible impacts of warming on the coastline

With an extensive coastline, Morocco is a maritime country which has clearly been expanding this sector for some years now. Today, Morocco's **coastline** represents:

* an exclusive **economic zone** stretching some 200 nautical miles with especially rich waters from a biological point of view (cold water rising to the surface along the Atlantic coast);

* an intensive **maritime transport zone**: 98% of Morocco's contacts with foreign countries take place by sea;

* a seaside **tourist zone** in most of the country's coastal regions.

Much of the population of Morocco lives on the coast: 20% are concentrated purely in the area between Casablanca and Kenitra. Large climate models envisage a possible rise in sea levels, as a result of thermal expansion and the melting of the glaciers, estimated at between 0.3 and 0.5 m by 2050. On a world scale, this would flood millions of kilometres of coast, which would affect coastal ecosystems. Warming would also cause a rise in ocean surface temperatures, affecting both the ecological balance of the sea and interaction between the sea and the atmosphere.

So far, no studies have been carried out into the potential impact of such situations on Morocco. However, the significant role played by the coast in the development of the country - through fishing, tourism and trade exchanges - indicates that this impact could be great.

Departments, institutions and bodies involved in GHGs and the climate in Morocco

The list of institutions involved in the environment in general, and greenhouse gases in particular, is given in Appendix 1 of volume 2; the characteristics and role of these institutions are outlined briefly. We should point out that the *Ministère de l'Environnement*, responsible for coordinating all activities relating to the environment, as well as some other specialist institutions, are of recent origin (since 1992) and have not yet fully demonstrated their abilities. Moreover, the technical departments listed (*Ministère de l'Agriculture, Ministère de l'Industrie, Ministère des Travaux Publics*, etc.) have all set up at least one "environment cell" within their midst. This is a measure of the sensitivity of governmental bodies to environmental problems.

3. SUMMARY OF GHG EMISSIONS IN MOROCCO

3.1 Results of the inventory for 1990

Detailed calculations of emissions for each source of GHGs, for the base year 1990, are given in the worksheets (Appendix 4, volume 2). The global results per emission source and per type of gas are presented in Tables 2 and 3.

The accuracy of the figures obtained varies from 5% (conventional energy) to 30% or more (biomass, forestry), depending on the sector in question. The annual estimate of GHG emissions in Morocco was made following the most recent IPCC directives (1994), recommending that calculations be made for 6 main gases (CO_2, CH_4, CO, N_2O, NO_x and NMVOC) but that only the contributions to the radiative effect of the gases with a direct effect (CO_2, CH_4 and N_2O) be incorporated. This excludes CO, NO_x and NMVOC summations, which are only translated by indirect radiative effects. The GWP values used (24.5 for CH_4 and 320 for N_2O) include the direct and indirect radiative effects of these gases, in accordance with the most recent IPCC directives (1994). The calculations relating to NMVOC have not been performed for any sectors due to a lack of data on the emission factors of these gases.

Comments on the results per sector of activity are given at the end of each chapter; comments on the IPCC/OECD Methodology used are given in Appendix 5, volume 2.

In 1990, Morocco emitted a total of almost **44 million tonnes equivalent CO_2 (E-CO_2)**[1] as a result of its anthropogenic activities, of which almost 75% were CO_2. Consequently, a Moroccan citizen has emitted an average of 1.7 t E-CO_2 per year, 1.3 tonnes of which was CO_2.

Table 1 gives the results for the whole country and per inhabitant.

Table 1: Emissions of GHGs in Morocco in 1990

	CO_2*	CH_4*	CO	N_2O*	NO_x	**E-CO_2**
Total emissions (Gg)	**32,545**	450	500	1.11	74.8	**43,923**
Emissions per inhabitant** (kg/inh.)	**1291**	17.9	19.8	0.04	2.97	**1743**

[1] E-CO_2 = CO_2 + 24.5 CH_4 + 320 N_2O for an integration time of 100 years (IPCC 1994)

* Gas taken into account in calculating $E\text{-}CO_2$
** Population of Morocco in 1990: 25.5 million.

Table 2: Assessment of greenhouse gas emissions per emission source and type of gas in 1990

Emission in Gg	CO_2	CH_4	CO	N_2O	NO_x	E-CO_2	%
1- **ENERGY** Conventional energy (fossil fuels)	19,287	8.8	42	0.57	66.32	19,685	44.8
2- **FOREST** . Biomass energy (Off-site burning)	965	54	455	0.35	8.4	2400	5.5
. Net forest clearing*	1320	-	-	-	-	1320	3.0
. Forest fires	80	0.3	3	0.002	0.06	88	0.2
3- **AGRICULTURE** . Grassland conversion**	8213	-	-	-	-	8213	18.7
. Rice cultivation	-	2.9	-	-	-	71	0.2
. Breeding - Enteric fermentation - Animal manure	- -	231 10	- -	- -	- -	5660 245	13.5
. Chemical fertilisers	-	-	-	0.19	-	61	0.1
4- **INDUSTRY** (processes) . Cement works	2680	-	-	-	-	2680	6.1
5- **WASTE** . Landfills . Municipal wastewater . Industrial wastewater	- - -	138 3.5 1.3		- -	- -	3500	8.0
TOTAL (Gg)	**32,545**	**450**	500	**1.11**	74.8	**43,923**	100
ASSESSMENT PER TYPE OF GAS	CO_2	CH_4	CO	N_2O	NO_x	TOTAL	
TOTAL E-CO_2 (Gg)	32,545	11,025	-	355	-	43,925	
Percentage %	**74.1**	**25.1**	-	**0.8**	-	**100**	
Conversion factors for GHGs into E-CO_2	1	24.5	0	320	0		

* Net clearing = clearing for agriculture - reforestation
** Conversion into cultivated lands (part of the "land use change" module)

Table 3: Proportion of different GHGs in the emissions assessment in 1990

	CO_2		CH_4		CO		N_2O		NO_x	
MOROCCO - 1990	Gg	%	Gg	%	Gg	%	Gg	%	Gg	%
1- **ENERGY** Conventional energy (fossil fuels)	19,287	59.3	8.8	2.0	42	8.4	0.57	51.3	66.32	88.7
2- **FOREST** . Biomass energy (Off-site burning)	965	3.0	54	12.0	455	91.0	0.35	31.5	8.4	11.2
. Net forest clearing*	1320	4.0	-		-		-		-	
. Forest fires	80	0.2	0.3	0.1	3	0.6	0.002	0.2	0.06	0.1
3- **AGRICULTURE** . Grassland conversion**	8213	25.2	-		-		-		-	
. Rice cultivation	-		2.9	0.6	-		-		-	
. Breeding - Enteric fermentation - Animal manure			 231 10	53.6						
. Chemical fertilisers	-		-		-		0.19	17.1	-	
4- **INDUSTRY** (processes) . Cement works	2680	8.3	-		-		-		-	
5- **WASTE** . Landfills . Municipal wastewater . Industrial wastewater	 - - -		 138 3.5 1.3	31.7	 - - -		 - - -		 - - -	
TOTAL (Gg)	**32,545**	100	**450**	100	500	100	**1.11**	100	74.8	100
	CO_2		CH_4		CO		N_2O		NO_x	

* Net clearing = clearing for agriculture - reforestation

** Conversion into cultivated lands (part of land use change)

The activities which consume **conventional energy**, notably transport and industry, have been responsible for **59%** of **CO_2** emissions. Including the biomass, **total energy consumption** accounted for **62%** of emissions of **CO_2**.

Grassland conversion into cultivated lands (which is part of the land use change module in the IPCC/OECD Methodology) was responsible for **25%** of **CO_2** emissions in 1990. **Cement works** come in third place, with **8%** of **CO_2** emissions.

Breeding is the chief source of emissions of **CH_4 (54%)**, followed by **waste (32%)**, then **biomass energy (12%)**.

The main causes of emissions of the other GHGs are:

* off-site burning of biomass in the case of **CO** (91% of the total), followed by fossil fuels (8.4%);

* the burning of fossil fuels (51% of emissions), the biomass (31.5%0 and the use of chemical fertilisers (17%) in the case of **N_2O**;

* the same causes as N_2O for **NO_x** - 88.7% for fossil fuels and 11.2% for the biomass.

As far as all GHGs are concerned, CO_2 takes first place, accounting for 74.1% of total emissions in E-CO_2, followed by CH_4 (25%).

To conclude, we can say that the sectors which are responsible for most GHG emissions in Morocco are the sectors which are major consumers of energy, particularly transport and industry in the case of fossil fuels and the residential and rural sectors in the case of the biomass, as well as land use change in agriculture.

According to the initial preliminary figures available to us, in 1990 Morocco's GHG emission rate was well below that of other countries, as Table 4 below shows.

Table 4: Emissions of GHG per inhabitant in 1990

Country	Morocco	Algeria+	Tunisia+	Libya+	Egypt+
E-CO_2 tonnes/inh.	1.74	7.0	2.1	12.9	1.9

Country	Senegal*	France*	Netherlands*	USA*
E-CO_2 tonnes/inh.	1.9	8.15	14.23	21.24

Sources: + S. AMOUS (1994)

The values given for Tunisia, Libya and Egypt are estimates.
The value given for Algeria was recalculated here with 24.5 as the GWP for CH_4, since N_2O was overlooked in the inventory calculations for the Algerian report (SEI-ACTS).

* National information (1994)

All the values in the table are given for 1990, except those for Senegal, where the value is for 1991.

3.2 Forecast emissions of GHGs for 2010

The theories underlying our forecasts and calculations of GHG emissions for 2010, per emission source and per type of gas, are presented in Chapter 9.

Table 5 below summarises the results obtained for all countries, per inhabitant.

Table 5: Emissions of GHGs in Morocco in 2010

	CO_2*	CH_4*	CO	N_2O*	NO_x	**E-CO_2**
Total emissions (Gg)	**72,837**	599	753	2.23	187.6	**88,222**
Emissions** per inhabitant (kg/inh.)	**2130**	17.5	22.0	0.07	5.49	**2580**

* Gas taken into account for the E-CO_2 calculation
** Population of Morocco in 2010: 34.2 million

In 2010 Morocco would emit over 88 million tonnes of E-CO_2 as a result of its anthropogenic activities, in other words slightly double its emissions in 1990, of which over 82% is CO_2. A Moroccan would therefore emit an average of approximately 2.6 t E-CO_2 in 2010, 2.13 tonnes as CO_2.

In this section, for each of the sectors in question, we analyse the sector and calculate the emissions.

The order of the sectors has been changed with respect to the classification in the IPCC/OECD Methodology, with a view to a more logical reorganisation: emissions of gases other than CO_2 due to biomass burning are therefore calculated in the "Energy" module, while the corresponding CO_2 is in the "Forestry" module. We have therefore placed the "Forestry" module just after the "Energy" module.

The "Grassland conversion into cultivated lands" part was included in the "Forestry and land use change" module. We preferred to included it under "Agriculture" since, in the case of Morocco, the surface areas in question are calculated based on the evolution of the usable agricultural surface (UAS).

The estimate of greenhouse gas emission was compiled using the **IPCC/OECD Methodology**. Although this method poses some application difficulties because it may not be suitable for the African situation or lacks clarity, often as a result of poorly translated original documents, we have adopted it to estimate GHG emissions for the **base year 1990.**

However, the methodology worksheets have been revised and partially transformed with a view to adapting them to the Moroccan situation, and in particular to respect the *Nomenclature marocaine des activités économiques* (Moroccan Nomenclature of Economic Activities - N.M.A.E.)) for the data (oil products, types of coal, industries, etc.), but also with a view to simplifying and condensing these worksheets.

The general conclusions and recommendations concerning the inventory methodology have been included in Chapter 10 (part A); detailed comments per sector are given in Appendix 5 (volume 2).

The second last chapter (9) of part A presents a forecast of GHG emissions for 2010 and strategic options to reduce GHG emissions.

4. ENERGY

The situation in the energy sector is analysed on the basis of the 1990 energy assessment compiled by the *Direction de l'Energie, Ministère de l'Energie et des Mines.*

The other data - for the period 1980-1992 - originate from the *Annuaires Statistiques du Maroc* (1985, 1989 and 1993), with reference to the *Direction de l'Energie* as a data source.

We have observed significant differences for certain data, which can be explained by the fact that the *Annuaire Statistique* does not use the conversion standards of the OECD; so, for example:

	OECD standard	*Annuaire statistique*
1 tonne of crude oil	1 toe	0.93 toe
1 MWh of hydraulic electricity*	0.086 toe	0.26 toe

* 0.26 toe per MWh corresponds to the conversion factor relating to the production of electricity in a thermal electric power station;

* 0.086 toe per MWh is the conversion factor relating to the consumption of electrical energy.

We have applied the OECD standards to our conversions. No accurate data exist for biomass energy because the majority of these fuels are channelled through non-commercial circuits. However, surveys have made it possible to estimate their consumption in 1990 (*Société Nationale des Produits Pétroliers,* 1990).

4.1 Analysis of the energy sector

Supplies

Morocco has some anthracite resources, virtually no hydrocarbons and a considerable hydraulic potential, but this is largely directed towards irrigation and varies widely depending on the rainfall. Energy supplies are therefore based mainly on the biomass and imports of crude oil and coal.

The **production of primary energy** in 1990 was 3940 ktoe, 3480 ktoe from the biomass.

Morocco's **hydroelectric potential** is judged to be 5000 GWh, 40% of which are currently used, representing 22 hydroelectric power stations with a hydroelectric generating **capacity** of around **700 MW**. Despite the high number of thermal electric power stations, hydroelectric electricity as a proportion of total electricity generation remains low and varies widely depending on rainfall: 54% in 1974, 12% in 1990 and 1.6% in 1993!

Table 6: Production of primary energy (ktoe)

ktoe	1980	1984	1988	**1990**	1992
Crude oil*	13.9	16.6	19.9	14.9	10.8
Natural gas	51.8	63.0	63.3	43.3	18.2
Anthracite	380.8	469.0	356.6	294.6	322.4
Hydraulic electricity	131.0	31.0	80.0	105.0	84.0
Total conventional energy	577.4	579.6	519.8	**457.8**	435.4
Biomass	na	na	na	**3480**	na

Source: Annuaires statistiques du Maroc, 1985, 1989, 1994. *na: not available*

** Data modified to take account of OECD conversion factor used here (1 tonne of crude oil = 1 toe).*

Imports of energy products relate mainly to crude oil (82% in 1990) and coal (soft coal and coke: 12% in 1990) and, to a lesser extent, to oil products other than crude oil (6% in 1990).These imports almost doubled between 1980 and 1992, which means a very high oil bill (8.94 billion DH in 1990; 9.12 billion DH in 1992) and a very heavy energy dependence, approximately 90% in 1990.

The amount of **coal** imported is on the increase, partly as a result of the stagnation in national production (only one deposit which produces anthracite) and because of the reconversion of coal by several industries (thermal electric power stations, cement works, sugar refineries), with the aim of reducing dependence on oil, lowering the oil bill and diversifying supply sources under improved cost and security conditions. In the MEM forecasts, by the year 2000 and beyond coal should represent approximately 30% of supplies.

Table 7: Imports of energy products (ktoe)

ktoe	1980		1984	1988	**1990**		1992
Crude oil*	3988.0	96%	4652.9	5050.0	**5681.0**	81.9%	6455.1
Oil products	162.2	3.6%	160.9	194.1	449.0	6.4%	800.5
Coal	18.9	0.4%	143.8	704.9	809.1	11.7%	802.1
Total	4169.1	100%	4959.6	5949.0	**6939.1**	100%	8057.7

Source: *Annuaires statistiques du Maroc,* 1985, 1989, 1994. na: not available
* Data modified to take account of OECD conversion factor used here (1 tonne of crude oil = 1 toe).

As for **exports of energy products**, coal has disappeared from this category since 1990; only naphtha remains, which comes from oil refineries and is almost all exported.

Table 8: Exports of energy products (ktoe)

ktoe	1980	1984	1988	1990	1992
Coal	50.1	36.8	4.9	0	0
Oil products (except naphtha)	82.0	5.2	28.2	0	0
Naphtha	212.2	321.3	307.4	544.2	552.1
Total	344.3	363.3	340.5	544.2	552.1

Source: *Annuaires statistiques du Maroc* 1985, 1989, 1994.

Consumption of **primary commercial energy** in Morocco rose from 4.7 Mtoe in 1981 to 7 Mtoe **in 1990**, in other words **consumption per inhabitant** of approximately **0.26 toe**; if the **biomass** is also taken into account, a total of 10.5 Mtoe, or **0.42 toe per inhabitant** is achieved.

Transformation

Two **refineries** (SAMIR and SCP), with a combined capacity of 7,950,000 tonnes, are also responsible for manufacturing oils and lubricants as well as filling the LPG cylinders.

On top of the 22 hydroelectric stations, on 31 December 1991 there were 29 **thermal electric power stations**, using fuel oil, gas oil or coal, with a total generating **capacity of 1360 MW.**

It can therefore be said that **1 MW out of 3 MW of generating capacity** is **hydraulically generated** in Morocco; however, production can sometimes be as low as in 1993, when only fewer than 1 kWh out of 20 kWh produced were hydraulically generated.

Despite this high number of hydraulic and thermal electric power stations, electricity generation runs a net deficit once a prolonged period of drought starts, as was the case in 1992-93; this led to power cuts affecting many industries. Moreover, the thermal electric power stations are fairly old, hence the current trend for building new power stations and privatising the generation of electricity available before 1994, 90% by ONE (*Office National de l'Electricité*) and 10% by industry.

Electricity generation by thermal electric power stations is the chief consumer of energy in Morocco, consuming 792 ktoe of coal in 1990 (or 66% of the coal consumed in Morocco) and 1200 ktoe of oil products, or 22% of oil products from refineries (chiefly fuel oil).

Finally, the **production of charcoal**, which has a fairly low yield of around 18%, using around 1330 ktoe of fuelwood to obtain 240 kt of charcoal, according to estimates for 1990 (SNPP survey, 1990).

Consumption of final energy

The sectoral analysis of energy consumption for the year 1990 enables the major consumer sectors to be identified and, at the same time, to assess the main stakes linked to this energy consumption.

As far as **conventional final energy** is concerned, the transport sector is the largest consumer, at 1640 ktoe, or 33% of the total. **Industry** takes second place with 32%, or 422 ktoe of coal and 903 ktoe of oil products, which represent 100% and 23% respectively of coal and oil products consumed as final energy. Industry also consumes all the natural gas produced in the country and 41% of the electricity, in other words 263 ktoe.

Finally, the **residential sector** only comes in third place, at 17%. However, one or two specific aspects make it a highly interesting sector: if biomass were included in the assessment, it would be the largest energy-consuming sector, with 41% of the final energy assessment.

In fact, the residential sector is the largest consumer of biomass energy, at 2467 ktoe or 79% of the biomass energy consumed in Morocco. The resulting deforestation is one of the major environmental risks facing Morocco.

Table 9: Consumption of final energy by sector in 1990 (ktoe)

Sectors	Industry	Transport	Agriculture and fishing	Residential	Tertiary	Total
→ (%) Conventional energy ↓ (%)	32.2 **1619** 100	32.8 **1640** 100	11 **566** 100	17 **859** 25.8	7 **321** 33	100 **5005**
Biomass	**0** 0	**0** 0	**0** 0	79 **2467** 74.2	21 **650** 67	100 **3117**
Total	20 **1619** 100	20 **1640** 100	7 **566** 100	41 **3326** 100	12 **971** 100	100 **8122**

Source: *Direction de l'Energie - MEM*

More detailed information about consumption per source of energy and per sector is given in the tables in Appendix 2 (A2-5 to A2-10), volume 2.

Oil products

Table 10 shows the development in the consumption of oil products between 1980 and 1990.

It is noticeable that, over a period of 11 years, consumption of LPG (especially butane) has doubled and that of gas oil has also significantly increased. Consumption of other oil products has, by contrast, changed little.

LPGs were for the most part consumed by the residential sector; the rapid rise in their consumption can be explained by the population growth and urbanisation and by the fact that charcoal is no longer used in the urban context for specific culinary purposes (kebabs, for example). This fall in the consumption of charcoal can also be explained by a change in lifestyles and in urban consumption, prices, etc..

As far as diesel is concerned, the rapid expansion in the fleet of commercial and diesel vehicles accounts for the rapid increase in consumption, as well as the expansion of the national fishing boat fleet.

Table 10: Consumption of oil products (1000 tonnes)

10^3 tonnes	1980	1982	1984	1986	1988	1990	1992
Propane	16.2	20.0	21.0	24.0	38.0	50.1	66.4
Butane	269.6	295.4	332.5	390.9	459.8	542.9	638.7
Total LPG	285.8	315.4	353.5	414.9	497.8	593.0	705.1
Super	234.0	228.9	239.8	234.4	262.9	291.5	314.7
Ordinary	137.3	123.5	110.0	102.3	97.4	90.0	89.1
Total petrol	371.3	352.4	349.8	336.7	360.3	381.5	403.8
Gas oil	1109.7	1190.2	1183.5	1289.1	1483.9	1706.4	1968.2
Fuel oil	1711.6	1944.1	2032.5	1865.5	1873.7	2010.8	2154.1
Jet fuel	244.4	190.4	207.7	204.7	212.1	247.9	215.6
Aviation fuel	1.6	1.4	1.5	1.0	1.7	1.4	
Kerosene	57.2	55.2	59.3	49.3	50.2	47.8	45.0
Special petrol	3.0	2.8	1.7	2.2	0.6	0.8	
Paraffin	14.0	10.8	16.0	16.0	16.7	20.0	
Total bunkers* (fuel + gas oil)	67.2	23.1	13.7	12.2	16.4	20.3	-
Total energy products	**3865.8**	**4085.9**	**4219.0**	**4191.7**	**4513.4**	**5030.0**	
Oils and fats	51.1	47.4	47.5	47.8	54.0	64.3	62.2
White spirit	3.8	3.7	2.5	4.3	4.9	5.5	
Bitumen	62.4	91.2	61.7	73.1	80.0	103.2	119.3
Overall total	**3983.1**	**4228.2**	**4330.8**	**4316.9**	**4652.3**	**5203.0**	

Source: *Annuaires statistiques du Maroc* 1985, 1989, 1994.
(*) not including fishing boats

Electricity consumption

Electrical energy consumption is rising steadily by approximately 10% per year, with an increase in low voltage from 29% in 1980 to 35% in 1990.

Source: *Annuaires statistiques du Maroc* 1985, 1989, 1994.

Between 1989 and 1992, consumption by the industrial sector represented an average of 31.5% of total final consumption of electricity (*Annuaire statistique,* 1994).

In 1992, the number of customers consuming medium and low voltage was almost 900,000, an increase of 8.5% over 1991; of this number, just over 50,000 are customers in rural areas, where numbers have only increased by 6.6% since 1991. The rural population of Morocco is therefore particularly poorly "electrified". The interconnected *Programme national d'extension du réseau* (PNER) comprises several strands:

* PNER I (1980-86): electrification of 286 centres

* PNER II (1990-99): electrification of 600 centres (at the end of 1994 just over 300 centres had been electrified);

* PNER III (being developed) electrification of 700 centres.

Once this programme is completed, 90% of villages (over 28,000) will still not have been connected to the network; this represents 65% of rural families or 1,600,000 homes which will still not have electricity.

The *Programme national d'électrification décentralisée* (PNED) which has just been launched (1993) by the *Centre de développement des énergies renouvelables* (CDER) and the *Office National d'Electricité* (ONE) allows us to be a little more optimistic about rural electrification within a more reasonable period of time.

Strategic options

The permanent feature of Morocco's energy policy has always been the search for diversification of energy sources. Many hopes were thus founded on oil research and then on mining deposits of bituminous shales. However, the results of these two options were unconvincing. The construction of a nuclear power station to generate electricity was also planned; the feasibility study was carried out for the site under consideration but no decision has yet been taken on the adoption of this solution.

Today it seems as if Morocco is definitely going for the **gas option**, taking advantage of the commissioning of the gas pipeline which will transport Algerian gas to Spain via Morocco.

The development of **renewable energy** is also one of the stated options. This solution is planned chiefly for isolated rural areas, far from the electrical network, within the framework of rural electrification programmes.

The problem of the "sustainable" use of **biomass** resources is particularly acute in Morocco. Biomass is the main energy source for a large majority of rural inhabitants and the only one which is "freely" available. Since demand far exceeds the regeneration capacity of the Moroccan forest, the plant cover rapidly deteriorates, which will only accelerate as the population grows (excessive tree felling: 25,000 ha/year; overgrazing, etc.), leading to desertification and erosion as well as a rural exodus. In several rural areas to the south of the country, trees have disappeared completely and the inhabitants have to make do with brush before being forced to leave because of a lack of fuel.

Table 11: Energy assessment for Morocco, 1990

Mtoe	Coal	Crude oil	Oil products	Natural gas	Hydro*	Electricity*	Total 1	NCE 2	Total 1+2
Production	0.3			0.04	0.1		0.5	3.5	4.0
Imports	0.8	5.8	0.5				7.1		7.1
Exports			-0.6				-0.6		-0.6
Bunkers									
Stock variation	0.0		-0.1				-0.1		-0.1
Prim. consumption	1.1	5.8	-0.2	0.04	0.1		**7.0**	**3.5**	**10.5**
Refineries		-5.8	5.4				-0.4		-0.4
Electric power stations	-0.8		-1.2		-0.1	0.7	-1.3		-1.3
Autocons. + losses			-0.1			-0.1	-0.1	-0.4	-0.5
Final consumption	0.4		4.1	0.03		0.6	**5.2**	**3.1**	**8.3**
Of which:									
Industry	0.4		0.9	0.03		0.3	1.6		1.6
(of which, non-energy)			0.1				0.1		0.1
Transport			1.6				1.6		1.6
Agriculture + fishing			0.5				0.5		0.5
Residential + tertiary			0.9			0.3	1.2	3.1	4.3

* 1 kWh = 0.086 toe
** NCE: non-commercial energy

4.2 Calculating GHG emissions for the "energy sector"

The basic data for the "energy sector" (i.e. production, imports, exports, transformation, consumption) provided by the *Ministère de l'Energie et des Mines* are combined into the tables in Appendix 2.

The worksheets in the IPCC/OECD Methodology allow a relatively accurate calculation of the quantities of:

* CO_2 emitted by the consumption of fossil fuels;

* CH_4, CO, N_2O and NO_x emitted by burning biomass energy (wood and brush, charcoal);

* CH_4 emitted during coal, oil and natural gas production, as well as during oil refining.

The corresponding worksheets, completed for the year 1990, are incorporated into Appendix 4 (A4-1 to A4-6) in volume 2 of this document.

Calculations of GHGs other than CO_2, emitted by the consumption of fossil fuels (remainder of a.), are much less accurate, and not without reason. In contrast to emissions of CO_2, which do not depend on the technology used, emissions of CO, CH_4, NO_x, N_2O and NMVOC are strongly linked to both the type of fuel and the level of pollution control exercised in that country.

Calculating these emissions therefore requires data which are difficult to identify and obtain; however, given the contribution this combustion makes to emissions of gases other than CO_2, particularly NO_x and CO, we have tried to apply the IPCC/OECD Methodology, based on certain theories.

The calculation formula is simple:

Volume of gas emitted = energy consumed x gas emission factor
(Gg) (GJ) (Gg/GJ)

Energy consumption per type of fossil fuel and per sector of activity are given in Table 12. The emission factors per type of fuel and per activity, for each of the four gases considered, are given in Table 13; the values have been taken by default from volume 3 of the Methodology.

These factors were chosen by taking the most plausible theories depending on the type of activity:

* the majority of phosphate industries use kilns and dryers fired by fuel oil (gas oil);

* other industries consume fuel oil, charcoal and natural gas primarily in boilers;

* thermal electric power stations consume fuel oil and charcoal in old-fashioned boilers;

* the residential and tertiary sectors use mainly small gas oil boilers;

* in the agriculture and fishing sectors, two-thirds of the consumption of oil products are used in mobile equipment (tractors, harvesters, fishing boats) and the remaining one-third in fixed equipment (generators, motor pumps, compressors, dryers, etc.);

* in the transport sector, vehicles are considered on the basis of average petrol or gas oil consumption of between 10 and 20 litres per 100 km and moderate control; locomotives, boats and aeroplanes produce non-controlled emissions.

The results of these calculations are given in Table 14; they confirm that the transport sector is the main perpetrator of emissions of CO (60%), N_2O (55%) and CH_4 (39%) from fossil fuels.

Agriculture and fishing take second place for CO (21%) and CH_4 (23%) and first place for NO_x (35%); this is chiefly due to the important role played by fossil fuels (two-thirds of the total) used in mobile agricultural gear (tractors) and fishing boats. Thermal electric power stations and industry contribute primarily to NO_x emissions (21% and 18% respectively).

Table 12: Consumption of fossil fuels per type and per sector of activity in 1990

Type of fuel		Oil products		Coal		Natural gas	
Activity		ktoe	10^3 GJ	ktoe	10^3 GJ	ktoe	10^3 GJ
1. Thermal electric power stations		1166	48,818	792	33,160	-	-
2. Phosphate industries		323	13,523	-	-	16	670
3. Other industries		580	24,283	422	17,668	15	628
4. Transport							
- road	• petrol	441	18,464	-	-	-	-
	• gas oil	911	38,142	-	-	-	-
- rail	• gas oil	19	795	-	-	-	-
- maritime	• gas oil	19	795	-	-	-	-
- air	• jet fuel	234	9797	-	-	-	-
5. Agriculture/fishing							
Equipment:	fixed	176	7369	-	-	-	-
	mobile	353	14,779	-	-	-	-
6. Residential		671	28,093	-	-	-	-
7. Tertiary		194	8122	-	-	-	-

The global results of the emissions of GHGs in Morocco, in 1990, by the "energy sector", are given in Table 15.

Table 13: Emission factors for GHGs other than CO_2 during fossil fuel burning (g/GJ)

Fuel	Oil products				Coal				Natural gas			
Activity	CO	CH_4	NO_x	N_2O	CO	CH_4	NO_x	N_2O	CO	CH_4	NO_x	N_2O
1. Thermal electric power stations	15	0.03	68	0.6*	121	1**	326	0.8				
2. Phosphate industries	16	1	168	na					11	1.1	64	na
3. Other industries	15	2.9	161	0.6*	93	2.4	329	1.4*	17	1.4	67	0.1*
4. Transport												
- road petrol (+)	880	11.3	150	13								
gas oil (++)	200	2	170	1.9								
- rail (o)	610	6	1800	2								
- maritime (o)	500	5	1600	2								
- air (o)	120	2	290	na								
5. Agriculture/fishing Equipment - fixed	15	2.9	161	0.6*								
- mobile	600	11	1500	2								
6. Residential	13	5	51	na								
7. Tertiary	16	0.6	64	15.5								

Source: Volume 3 of the IPCC/OECD Methodology

* Table 2.18, p. 2.53 — (o) Table 2.31

** Table 2.17, p. 2.51 — (+) Table 2.21

na: not available — (++) Tables 2.24 and 2.25: average values

Table 14: Emissions of GHGs other than CO_2 as a result of the consumption of fossil fuels in 1990 (tonnes)

GHG	CO		CH_4		NO_x		N_2O	
ACTIVITY	t	%	t	%	t	%	t	%
1. Thermal electric power stations	4744	11.2	**35	4.3	14,130	21.3	56	9.8
2. Phosphate industries	224		14		2315		-	
3. Other industries	2018		114		9765		* 39	
Total industry (2+3)	2242	5.3	128	15.9	12,080	18.2	* 39	6.8
4. Transport								
- road	23,877		285		9254		312	
- rail	485		5		1431		1.6	
- maritime	398		4		1272		1.6	
- air	1176		20		2841		-	
Total transport	25,936	61.2	314	39.0	14,798	22.3	315	55.0
5. Agriculture/fishing	8,978	21.2	184	22.8	23,355	35.2	34	5.9
6. Residential	365	0.9	140	17.4	1433	2.2	-	
7. Tertiary	130	0.3	5	0.6	520	0.8	128	22.5
TOTAL	42,395	100	806	100	66,316	100	572	100

Table 15: Emissions of GHGs by the "energy sector" in 1990

GHG / ACTIVITY	CO_2 kt	%	CH_4 kt	%	CO kt	%	N_2O kt	%	NO_x kt	%	E-CO_2 kt	%
Conventional energy												
- coal production	-		7.1		-		-		-			
- oil production and	-		0.18		-		-		-			
refining	-		0.71		-		-		-			
- natural gas production	19,287		0.81		42.4		0.57		66.3			
- consumption (all sectors)												
TOTAL 1	19,287	-	8.8	14	42.4	8.5	0.57	62	66.3	88.8	19,685	93
Biomass energy												
- direct fuelwood burning	See		38.5		403.7		0.31		7.48			
- production of charcoal	"forestry		15.1		25.2		0.02		0.47			
- charcoal burning	sector"		0.35		25.7		0.02		0.47			
TOTAL 2			54	86	454.6	91.5	0.35	38	8.42	11.2	1435	7
TOTAL 1 + 2	19,287*	-	62.8	100	49.7	100	0.92	100	74.7	100	21,120	100

* This total does not include the CO_2 emitted by the consumption of biomass energy calculated in Chapter 5.

The results of the emissions of GHGs other than CO_2 attributable to the "energy sector" reveal that:

* biomass energy is the main source of emissions of CH_4 (86%) and CO (91.5%); the major sources of emission of these gases would therefore seem to be the residential sector and, to a lesser extent, the tertiary sector;

* the burning of fossil fuels is the main source of emission of N_2O (by transport in particular, at almost 35% out of 62%); it is also the largest source of emission of NO_x (89%), at 31% for agriculture and fishing, 20% for transport, 20% for thermal electric power stations and 16% (of the 89%) for industry.

We can therefore note that the residential sector (biomass) and the transport sector (fossil fuels) account for a large proportion of emissions of GHGs by the "energy" sector.

5. FORESTRY

The main source for the data used here on Moroccan forests is the *Direction des Eaux et Forêts et de la Conservation des Sols (DEFCS)* of the *Ministère de l'Agriculture et de la Mise en Valeur Agricole*. Furthermore, the same data feature in the *Annuaires Statistiques du Maroc* (1993 and 1994).

Generally speaking, most of the available documents are old: the most recent repeat the data produced by the *Plan National de Lutte contre la Désertification (FAO/MARA)* dating from 1986.

The most recent information about forestry resources dates from 1991; the *Inventaire Forestier National*, launched in 1990, should conclude in June 1995.

Certain selective studies are currently underway, concerning the consumption of fuelwood; they differ in terms of survey methodology, level of accuracy and year of completion, which means that their results are difficult to compare or extrapolate at national level. A national survey of the consumption of wood energy is currently underway (03/95) at the *Direction des Eaux et Forêts* (with financing from the World Bank). The results of this survey should quantify, for each region of Morocco and each consumption sector, needs in terms of wood energy.

The study carried out in parallel to this one within the framework of this project, involving monitoring the development of forests and UAS in Morocco using remote sensing(*), has provided results which provide additional and very useful information, even if it has not been possible to use them in this project; this will enable data on land use change to be provided and improved in the future.

5.1 Presentation of the sector

The exact surface area of forests in Morocco is not known because, so far, forestry inventories have only involved 15% of forests and 73% of areas covered with esparto (alfa) grass. In anticipation of the results of the current inventory, we will therefore have to make do with estimates, which vary according to source: a figure of **4177 thousand hectares of natural forest** can be adopted if we exclude the Saharan acacias as a result of their weak plant cover and 505 thousand reforested hectares (or an approximate forestation rate of 9%) (Appendix 2-12, volume 2). The grassland expanses cover 3160 thousand hectares (DEFCS, 1993).

We should point out that the study carried out by the CRTS(*) gives the following estimates of Moroccan forests:

4,220,000 ha in 1987
4,004,400 ha in 1993.

(*) Part of the UNEP Project no. GF/0103-92-34 undertaken by the *Centre Royal de télédétection spatiale* (MOROCCO).

If we consider that the fluctuation in this surface area during the 7-year period in question was linear, this gives a value of **4,122,000 hectares** for the forest surface area in 1990; the value of 4,682,000 ha given by the MAMVA is therefore well within the estimate range generated on the basis of the CRTS study.

The reforested surface areas have regularly increased: 4000 hectares in 1950, 20,000 in 1986, 17,000 in 1987, 27,000 in 1988, 19,000 in 1989 and 46,000 in 1990 (Benazzou, 1993). These surface area estimates are still approximations, given the average success rate of reforestation, which is allegedly below 50%.

Average productivity of Moroccan forests varies, in terms of wet matter, between 0.3 and 8 m^3 per hectare and per year, which corresponds to 0.19 to 5.1 tonnes/ha/year (1 m^3 = 0.64 tonnes: Popp, C., 1995). Using the data in Table 2-20 of Appendix A2-12, we have established an average value of 1.15 tonnes/ha/year, which corresponds to 0.63 tonnes of dry matter per hectare and per year (at the DEFCS average humidity of the biomass is taken to be 45%). Since this productivity is particularly important in the first 50 years, we have estimated the average biomass volume per hectare at approximately 30 tonnes of dry matter per hectare (0.63 x 50). We can consider this value as a good average, given the results put forward by the CRTS study, which are summarised in Table 16 below.

Table 16: Average value of biomass of Moroccan forest, per zone

Forest in the zone of	Total biomass* t/ha (TB)		Aboveground biomass t/ha (AB=TB/2)	
	FOREST	REFORESTATION	FOREST	REFORESTATION
Oujda	50	80	25	40
Tanger/ Tetouan	90	80	45	40
Gharb/Saïs	80	90	40	45
Rabat	80	60	40	30
Chaouia	-	30	-	15
Doukkala	60	-	30	-
Tensift	70	-	35	-

* this term also includes the root biomass (RB), TB = AB + RB = 2AB (OECD)
Source: CRTS study, Volume 6 (1995)

The forest plays an important economic and social role through the income it provides for the population: grassland, fuelwood, food produced. However, a very clear reduction in wooded cover is noticeable, particularly afforestation of holm oak, cork oak and thuja. For the 1990s, annual **losses** of forest are estimated by the DEFCS at approximately **35,000 ha/year** (MAMVA, *Acts du Séminaire* June 1993). The results of the study by the CRTS have confirmed these estimates: the loss of 216,000 hectares between 1987 and 1993 does correspond to 36,000 hectares per year.

The causes of such losses can be attributed, according to the MAMVA, as follows:

* 25,000 ha/year due to excessive wood extraction (71%)

* 6000 ha/year due to clearing for agriculture (17%)

* 1000 ha/year due to land use (2.8%)

* 2700 ha/year due to forest fires (7.7%).

The heavy impact of fuelwood collection on forest reduction (25,000 ha/year) is striking, while fires only account for 2700 ha/year, thanks to the tidiness of the undergrowth (intensive grazing, collection of dead wood and brush).

In global terms, wood used for direct burning and the production of charcoal is estimated at between 10 and 11 million m^3 per year, of which apparently only 3 million are adapted to the ecological capacity of forest renewal (Popp C., 1995).

In a great many rural areas, charcoal is the main source of energy, both for cooking and heating. Wood is burned in open or closed stoves at a very low yield, possibly as low as 5-12% (Popp C., 1995)! Add to this that kitchens in rural areas do not have a ventilation shaft, which means a concentration of particles suspended in the air (which can reach 16-19 times the maximum value permitted by the World Health Organization (World Bank, 1992)), and the harmful effects on the health of women and children are clear.

Despite the inaccuracy of the statistics, we can therefore conclude that the Moroccan forest is in a critical position. The current deficit between the demand for fuelwood and its production can only increase, given demographic pressure and the disappearance of the forest.

The average annual loss of forest is predicted to rise from 35,000 hectares to 50,000 by the year 2010. Using the same distribution, this would give:

* 35,000 hectares: excessive wood extraction

* 8500 hectares: clearing for agriculture

* 1400 hectares: land use

* 3900 hectares: fires.

The above estimated forest losses are global and no indications have been found relating to these losses per type of forest. Thus, in the estimated emissions of GHGs resulting from forestry development, we have had to consider the Moroccan forest, represented by an "average" area with average ecological characteristics: we have had to adopt an approximation for want of specific facts about the forest ecosystems and their ecological dynamics.

The facts available do not correspond to the entries on the IPCC/OECD Methodology worksheets; we have had to modify and adapt these worksheets to our situation.

5.2 Calculation of GHG emissions

In accordance with the IPCC/OECD Methodology, GHG emissions have been estimated for 1990, resulting from:

* biomass burning on-site and off-site;

* clearing for agriculture (long-term emissions).

The tables showing the calculations of these emissions are those in Appendices A4-7 and A4-8 (volume 2).

The results of these calculations are summarised in Table 17 below.

This reveals that of the 3808 Gg equivalent CO_2 emitted, the chief perpetrators of emissions are fuelwood (off-site burning) and clearing for agriculture (63% and 34.7% respectively). Forest fires, by contrast, have a very limited impact on GHG emissions.

Table 17: GHG emissions by the "forestry sector" in 1990

GHG	CO_2		CH_4		CO		N_2O		NO_x		E-CO_2	
Activity	Gg	%	Gg	%	Gg	%	Gg	%	Gg	%	Gg	%
Off-site burning (biomass energy)	965	40.8	54	99.4	455	99.3	0.35	99.4	8.4	99.3	2400	63.0
Clearing for agriculture (long-term emissions)	1320	55.8	-	-	-	-	-	-	-	-	1320	34.7
Fires	80	3.4	0.3	0.6	3	0.7	0.002	0.6	0.06	0.7	88	2.3
TOTAL	**2365**	100	54.3	100	458	100	0.352	100	8.46	100	**3808**	100

5.3 Assessment of uptake and forest emissions

The calculations were made using modified Methodology worksheets (5.5A, 5.5B and 5.5C) (Appendix A4-9, volume 2). In **1990**, the increase in the biomass was allegedly 2810 kt of dry matter, which corresponds to a **carbon uptake** of approximately **1260 kt** (or 4620 Gg of CO_2).

During the same period, **2320 kt of carbon** were apparently extracted from the forest (the equivalent of 8500 Gg of CO_2), in other words 1.8 times more than the amount taken up.

This represents an **assessment deficit of 1060 kt of carbon** (the equivalent of 3880 Gg of CO_2).

This result confirms **the critical situation affecting the Moroccan forest**, which is no longer playing the role of "lung", even with respect to itself.

6. AGRICULTURE

The main source for the data used is the *Ministère de l'Agriculture et de la Mise en Valeur Agricole (Rapports des Directions de la Production Végétale, de l'Elevage et de DEFCS)*. Most of the information used has also been checked in the *Annuaires Statistiques du Maroc* (1984 to 1994). The results of the CRTS study on the development of the UAS have provided additional information which has been analysed.

6.1 Presentation of the sector

The chief **limiting factors** in the development of agriculture are the **climate hazard**, on the one hand, and the **land structures** on the other hand. A major qualitative leap was made during the period 1986-1990, thanks to a return to more favourable climate conditions (compared to the drought of the first half of the 1980s) and to a certain number of encouraging measures (agricultural credit, investment subsidies, taxation, etc.). We have thus seen a very clear improvement in yields, an increase in cultivated surface area and in production, as well as wider diversification in agricultural production (greenhouse crops, new varieties of fruit and vegetables, etc.).

During this period (1986-1990) **agricultural GDP** reached an average of almost 18 billion DH per year (**18% of national GDP**); its average annual growth rate was around 6% (4% for national GDP during the same period).

Agricultural exports represent 30-35% of total exports from the country. Food products represent almost 90% of agricultural exports. These are essentially citrus fruits and early fruit and vegetables (fresh tomatoes, potatoes, etc.). Agricultural imports represent 20-25% of total imports to the country. Wheat, sugar, vegetable oils and dairy products make up two-thirds of food imports and over one-third of the total of agricultural imports. The agricultural sector employs almost 40% of the country's workforce.

The main agricultural activities which could contribute to GHG emissions in Morocco are land use change, rice cultivation, domestic animal breeding and the use of nitrogenous fertilisers. Residue burning is a practice which has virtually died out.

6.2 Land use change (grassland conversion)

In Morocco, the usable agricultural surface area (UAS) has grown from 7.6 million hectares during the 1970s to 9.2 million in the 1990s, in other words an annual average increase of 65,000 ha and a total of 1.6 million hectares over 25 years (Appendix 2-13). This expansion seems to be fairly steady over a 25-year timescale. Clearing of land for agriculture only accounts for a small proportion (less than 10%) of this increase in UAS; the remainder is due to the transformation of grassland into agricultural land following incentives to do so (extension of irrigated areas, subsidies for rock removal or for sinking wells, etc.) or to demographic and economic pressures in particular (the number of persons in the propertied family increases, new needs arise, etc.).

Between 1990 and 2010, expansion is likely to be even more rapid: agricultural modernisation, the development of large farms, economic liberalisation. Moreover, the data given in the table in Appendix 2-13 (volume 2) reveal that:

* between 1970 and 1980 UAS expansion was 2.3%

* between 1981 and 1990 UAS expansion was 12%.

Therefore, on the basis of the trend of the curve in Figure 5 below, expansion in UAS of 30% has been considered for the 25 years leading up to 2010, or a total of 2.42 million hectares between 1985 and 2010.

Source: *Annuaires Statistiques du Maroc* (1975 to 1994)

The CRTS study provided UAS estimates for 1987 and 1993. Since the figures put forward do not confirm those of the MAMVA, on the one hand, and do not cover the 25-year period required by the IPCC/OECD Methodology on the other hand, we decided not to use them at this stage in our investigations.

6.3 Rice cultivation

This is a very limited activity in Morocco, concentrated in the Gharb region. The surface area occupied by the paddy fields depends to a large extent on the climate - it varies greatly from one year to the next: 5900 ha in 1979-80, 600 ha in 1984-85, 10,700 ha in 1992-93 (Appendix 2-13, volume 2). In order to calculate GHG emissions, we used an average value of 6000 hectares for 1990 and 13,000 hectares for extrapolation to 2010 (forecast permitted by the *Direction de la Production Végétale* of *MAMVA*).

6.4 Breeding

Livestock depend very heavily on variations in climate. Before the drought of the 1980s there were 3.4 million cattle, 16.5 million sheep and 6.1 million goats. During the drought (1982-85), livestock numbers fell by approximately 30% and only reached their 1979 level in 1990 (Table 18 below and Appendix A2-14, volume 2).

The livestock estimate must therefore be treated with great caution. However, as far as cattle, sheep and camels are concerned, efforts made by the State should bring about an increase in livestock numbers of about 20% by 2010. For the year 2010, the same numbers will be used as for 1990 with the exception of cattle (3.5 million), sheep (16.5 million) and camels (42,000).

Table 18: Domestic animals in 1990 (10^3 units)

Cattle	Sheep	Goats	Donkeys and mules	Horses	Camels	Poultry
3350	13,500	5300	1435	194	34	100,000

Source: *Annuaire statistique du Maroc*, 1993.

6.5 Use of nitrogenous fertilisers

In 1990 fertiliser consumption was around 31,000 fertilising units, or **740,000 tonnes per year** (Appendix 2-14, volume 2, Fertima, 1994).The global quantities consumed can be divided as follows: 45% nitrogen, 40% phosphate and 15% potassium. The use of fertiliser was 14 times greater during the 1990s than in the 1960s. This translates into an increase in fertiliser use of about 9500 tonnes per years. Assuming that this increase stabilises over the next 20 years, Morocco would use 940,000 tonnes of fertiliser in 2010.

6.6 Calculation of GHG emissions

Calculations of emissions of GHGs linked to the activities of the agricultural sector have been made using the IPCC/OECD Methodology and are given in Appendices A4-10 and A4-11 (volume 2 of this document). Emissions due to the consumption of fossil fuels in agricultural activities are not included; these are accounted for in Chapter 4, dealing with the Energy sector.

A summary of the results of these calculations is given in Table 19 below.

It is noticeable that of the **14,249 Gg E-CO_2 emitted by agriculture, breeding and grassland conversion into cultivated lands** represent **99%**; by contrast, the use of fertilisers and rice cultivation in Morocco make only a negligible contribution.

Table 19: GHG emissions by the "agriculture sector" in 1990

	CO_2		CH_4		N_2O		E-CO_2	
	Gg	%	Gg	%	Gg	%	Gg	%
Grassland conversion into cultivated lands	8213	100	-	-	na		8213	57.6
Rice cultivation	-	-	2.9	1.2	-		71	0.5
Breeding	-	-	241	98.8	-		5904.5	41.4
Fertilisers	-	-	-	-	0.19	100	60.8	0.5
Total	**8213**	100	**243.9**	100	**0.19**	100	**14,249**	100

na: not available (1 Gg = 1 kt)

7. INDUSTRIAL PROCESSES

7.1 Presentation of the industrial sector

The industrial share of GDP is stable at around 16-18%, depending on the year. Between 1980 and 1990, the growth rate for the industrial sector, in real terms for added value, was 3.8% per year on average (Benazzou, 1993).The manufacturing industries employed 27% of the urban working population in 1990.

The contribution of the industrial sector to exports from Morocco reached 68% in 1990, as opposed to 38% in 1980. This progress confirms the tendency of industrial policy towards increased exports; this results in a series of activities to reinforce the industrial fabric and improve the quality of products.Industry makes a significant contribution to GHG emissions through its consumption of energy (100% of coal, 23% of oil products and 41% of electrical energy) (Appendix 2-7, volume 2). These emissions have been calculated in Chapter 4, dealing with the Energy sector. The industries which are major consumers of energy include cement works, the phosphate industry, sugar refineries and construction material manufacturing for buildings and public works.

Furthermore, some industries contribute to GHG emissions not only through their consumption of energy but also as a result of the industrial process, which involves chemical reactions which release CO_2.

Cement production is the major industrial source of CO_2, which is generated during clinker production.

No method of calculating CO_2 emitted exists for the other industrial processes which produce CO_2 (production of lime, bricks, paper, pulp and print, consumption of limestone), since the national data for evaluating the emission factors are still being collected.

Moroccan cement production (Portland cement) rose from 3570 kt in 1984 to 6220 kt in 1992, or an average annual increase of 8.5% per year; however, within the trade this increase is expected to stabilise at 4% per year for the next 20 years (Appendix 2-15, volume 2).
Available capacity is currently 8800 kt, divided among 10 units. Clinker has been entirely locally produced since 1994 (until 1993 imports amounted to 7%).

Source: *Annuaires Statistiques du Maroc*, 1989 and 1993

7.2 Calculation of emissions

The Methodology for cement concerns Portland cement, which is the type produced in Morocco (content: 60-67% lime by weight).
CO_2 is calculated using the following formula:

Volume of gas emitted = volume of cement produced x emission factor

The calculation was performed for 1990 and for 2010 on the same worksheet (Appendix A4-12, volume 2).

Results:

* **1990: 2680 Gg of CO_2 emitted**

* **2010: 5997 Gg of CO_2** would be emitted by cement production, or an increase of 123%.

8. WASTE

8.1 Study of the sector

The source of data for household refuse is the *Direction de l'Eau et de l'Assainissement (DGCL, MII)*. Like most developing countries, Morocco regularly records an increase in **municipal solid waste**, both as a result of the increase in the urban population and the increase in consumption needs of the population in question, particularly in terms of perishable products. However, the annual variations in waste and their characteristics are still not fully known and statistics are rare.

In 1992, the production of household waste at national level was estimated at over 8000 tonnes per day (Aït Ouadi 1992). The amounts produced per inhabitant and per day vary from town to town, even from district to district, from 0.4 to 0.7 kg.

No study has been performed on the composition of waste since 1980; the one performed then by a consultancy, on Moroccan refuse, reports the following composition given in Aït Ouadi (1992):

* paper, board: 18 to 20%
* textiles, fabric: 2 to 4%
* glass: 0.5 to 1%
* vegetables, perishables: 70 to 65%
* metal: 1 to 3%
* plastic: 2 to 3%
* inert materials (sand, earth): 5 to 7%

These results, which have to be updated, refer to the composition of the refuse produced which differs somewhat from the refuse which is dumped. Currently it is assumed that 80% of solid waste is found in non-controlled landfills, with a perishable fraction amounting to around 67% (Darley, 1994). With respect to refuse collection, no studies have been performed on the systems used by the municipalities. It can be said that this varies from collection on a donkey's back and by carts and vans to refuse collection vehicles. Sorting takes place secretly at the level of dustbins or in the landfills.

In 1990 Morocco had a population of 25.2 million, 11.73 million in an urban environment (Appendix 2-1, volume 2. CERED, 1991 and 1993). Supposing that the average waste **per inhabitant** in an urban environment is **0.6 kg/day**, advanced by Darley (1994), in 1990 the country's waste would have been approximately 2,750,000 tonnes (or 7040 t/day); it would therefore reach 4,380,000 tonnes by 2010, when the urban population is approximately 20 million (58% of the total population).

As far as **municipal wastewater** is concerned, Morocco currently has 37 urban water purification plants, only 17 of which are in working order. The other urban centres inland discharge their wastewater in its raw state into rivers and water tables and those on the coast into the sea. Thus, the largest cities in Morocco (Casablanca, Rabat, Fez, Marrakech) do not currently have purification plants. Furthermore, only 9% of urban centres have a sewer system. This means that the quality of water resources is seriously compromised which in turn implies that the ONEP (*Office National de l'Eau Potable*) has to treat increasing quantities of water in order to make it suitable for drinking.

The Tadla region (in the centre of the country) was chosen as a pilot zone for studying the BOD (biochemical oxygen demand) load of urban wastewater. Table 20, compiled by the *Conseil Supérieur de l'Eau* (CSE, 1988) gives the BOD_5 levels for waste in urban centres in the region for 1986. The BOD_5 generation rates can be derived from it, varying from 0.0095 to 0.017 Gg BOD_5/1000 persons/year, with an average of 0.013, very close to the value of 0.0135 suggested in volume 2 of the Methodology.

We have therefore calculated methane emissions from municipal wastewater by the urban population (25.2 million in 1990) and the BOD_5 generation rate in volume 2 of the Methodology.

Finally, the data relating to **industrial wastewater** are taken from the results of the survey report on industrial discharges by the *Ministère du Commerce et de l'Industrie* (August 1994, Appendix 2-16, volume 2).

It would seem that we are heading towards the creation of an *Agence Nationale d'Assainissement*, which would be responsible for problems relating to discharges.

Table 20: Domestic pollution in the Tadla area in 1986

Urban centre	No. of inhabitants 1986	% inh. connected to network	Quantity of effluent (1000 m^3/year)	Pollution (t/year)			BOD_5 generation rate BOD_5/1000 pers./year Gg*
				BOD_5	N	P	
KHENIFRA	54,000	59	856	511	86	10	0.0095
Z. CHEIKH	14,000	67	480	195	33	4	0.014
EL KBAB	6900	89	148	121	20	2	0.017
K. TADLA	33,000	65	632	423	71	9	0.013
BNI MELLAL	110,000	70	2658	1516	4	31	0.013
AFOURAR	5500	60	137	65	11	1	0.012
D.O.ZIDOUH	5800	60	150	69	12	1	0.012
F.B.SALEH	55,000	75	806	813	137	17	0.014

Source: *Conseil Supérieur de l'Eau* (1988)
* Values calculated in the present study
N = nitrogen P = phosphorous

8.2 Calculating emissions

In refuse landfills, like those for wastewater, methane is produced by the anaerobic decomposition of organic matter. CO_2 is also produced, but is compensated by the CO_2 which was absorbed during production of the organic matter; it is therefore not included in the inventory.

CH_4 emissions were calculated on the IPCC/OECD Methodology worksheets (Appendices A4-13 and A4-14 of volume 2 of this document). The values for the different conversion factors and emission factors, as well as their origins, are given in Appendix 3 (A3-4) as well as on the worksheets. The results are shown in Table 21 below.

Table 21: GHG emissions from waste in 1990 (in Gg)

	CH_4	
	Gg	%
Landfills	138	96.6
Municipal wastewater	3.5	2.5
Industrial wastewater	1.3	0.9
TOTAL	142.8	100

It is clear that landfills form the main source of methane emissions, with almost 97% of CH_4 emissions generated by waste.

9. FORECAST FOR 2010 AND STRATEGIC OPTIONS TO REDUCE GHG EMISSIONS

9.1 Forecast GHG emissions in Morocco for 2010

The estimate of GHG emissions expected in Morocco in 2010 was made using data and results from 1990; we have however retained the same values for all the coefficients and emission factors and formulated **theories** which we give below, sector by sector.

ENERGY

The current distribution (1990) of primary energy consumption (82% crude oil, 16% coal, 1.5% hydraulic electricity and 0.5% natural gas) would be completely different if Algerian natural gas were introduced. The stated objective of the heads of the *Département de l'Energie,* during their meeting with the GERERE on 31 May 1994, would then be to achieve the following approximate distribution for the country's supply of **primary energy in 2010**: **30% oil, 30% coal, 30% natural gas** and 10% renewable energy sources.

The **scenario** envisaged in this study implies an **increase in consumption** of primary energy of **5% per year** (Table 22).

Table 22: Consumption of primary energy in Morocco in 1990 and 2010

Total consumption of primary energy (ktoe)		Consumption per inhabitant (toe/ca)	Coal (ktoe)	Oil (ktoe)	Natural gas (ktoe)	Renewable energy sources (ktoe)
1990	7039	0.28	1126	5765	43	105*
2010	18,600	0.54	5580	5580	5580	1860

* Hydraulic electricity

In order to **calculate CO_2** we have determined the "global emission factors", based on the results from 1990, for each type of fuel; this enabled us to calculate the emissions given in Table 23.

Table 23: Emissions of CO_2 in 2010 from fossil fuels

Fuel	Consumption 10^6 GJ	Emission factor Gg $CO_2/10^6$GJ	Volume of CO_2 emitted Gg
Oil	234	70.7	16,544
Coal	234	92.7	21,692
Natural gas	234	55.0	12,870
TOTAL	702	-	51,106

For **gases other than CO_2** it is difficult to forecast the state of technology by the year 2010. We have therefore assumed that technology will be at the same global level as in 1990 (some sectors will modernise while others will become obsolete). Furthermore, since the distribution in the consumption of the various fuels by sector of activity is difficult to predict for 2010, we have assumed that the relationship (CO_2/other gases) will have the same value as in 1990. The results of this calculation are given in Table 24 below.

Table 24: Emissions of GHGs other than CO_2 in 2010 from the burning of fossil fuels

GHG	CH_4*	CO	N_2O	NO_x	E-CO_2
Volume of gas emitted Gg	2.14	112.3	1.5	175.7	539

Methane CH_4 emitted by the **production** of coal, oil and natural gas, as well as oil **refining**, has been estimated at 8.0 Gg, or the same value as in 1990. Total CH_4 emitted by the energy sector is therefore 10.14 Gg (2.14 + 8 Gg).

FORESTRY

The DEFCS predicts an annual increase in losses of forests between 1990 and 2010 of 40% (35,000 ha in 1990 and 50,000 ha in 2010). We are supposing that the respective shares accounted for by the various causes of these losses remain constant; this allows us to calculate the corresponding GHG emissions in 2010 simply by increasing 1990's values by 40%. We thus obtain the results given below in Table 25.

Table 25: Emissions of GHGs in 2010 from the "forestry sector" (Gg)

GHG Activity	CO_2	CH_4	CO	N_2O	NO_x	E-CO_2	%
Off-site burning (biomass energy or fuelwood)	1351	75.6	63 7	0.49	11.8	3360	63
Forest clearing (clearing for agriculture)	1848	-	-	-	-	1848	34. 7
Forest fires	112	0.42	4.2	0.003	0.084	123	2.3
					TOTAL	**5331**	100

The **assessment** of the uptake of emissions of **carbon from forests**, calculated for **2010** (Appendix A4-9) is even **more negative than for 1990:** 1085 kt of carbon taken up for 3250 kt of carbon emitted, in other words 3 times more.

If no specific measures are taken to redress the balance, the situation will worsen, leading to greater ecological imbalance.

AGRICULTURE

Land use change

The increase in UAS between 1990 and 2010 could be greater than during the period 1970-1990 as a result of agricultural modernisation, the development of large agricultural businesses and economic liberalisation. We have therefore assumed a 30% increase in UAS during the 25 years leading up to 2010, or a total of 2.42 million hectares.

Rice cultivation

For the same reasons as for UAS, we have forecast an increase in rice cultivation, which would occupy a surface area of 13,000 hectares by 2010.

Breeding

In Chapter 6 we saw that livestock numbers remained relatively stable, except in the case of cattle, sheep and camels; in these cases the Government agreed to make efforts to lead to an increase in numbers of about 20%.

Nitrogenous fertilisers

Using the same increase in fertiliser consumption as before 1990, the total for 2010 is 940,000 tonnes. Calculations made on the basis of these hypotheses produced the results shown in Table 26.

Table 26: Emissions of in 2010 by the "agriculture sector" (Gg)

GHG / Activity	CO_2	CH_4	N_2O	E-CO_2	%
Land use change	12,423	-	-	12,423	65.1
Rice cultivation	-	6.2	-	153	0.8
Breeding:	-				
- Enteric fermentation		251	-	6150	33.7
- Animal manure		11	-	270	
Chemical fertilisers	-	-	0.24	77	0.4
			TOTAL	19,073	100

INDUSTRIAL PROCESSES

At an average annual cement production increase of 4%, production would reach 12,042 kilotonnes of cement by 2010, in other words emission of **5997 Gg of CO_2**.

WASTE

Emissions of CH_4 from **landfills**, like those from **municipal wastewater**, were calculated in 1990 on the basis of the urban population.

For extrapolation to the year 2010, we retained the same generation levels for waste and BOD and assumed an urban population of 20 million inhabitants, according to forecasts by the CERED (Appendix 2-1, volume 2).

Since no accurate data on the development of the various branches of industry and their discharges are available for **industrial wastewater**, we have applied the same progression as used for the energy sector (5%), in other words a ratio of emissions in 2010 and 1990 of 2.67.

Emissions of CH_4 in 2010 from waste:

landfills:	235 Gg
municipal wastewater:	5.9 Gg
industrial wastewater:	3.4 Gg
Total: 244.3 Gg CH_4, or 5986 Gg E-CO_2	

The global results per emission source and per type of gas are given in Tables 27 and 28.

Table 27: Assessment of greenhouse gas emissions per emission source and per type of gas; forecast for 2010

Emission in Gg	CO_2	CH_4	CO	N_2O	NO_x	E-CO_2	%
1- **ENERGY** Conventional energy	51,106	10.14	112.3	1.5	175.7	51,834	58.8
2- **FORESTRY** . Biomass energy (Off-site burning)	1351	75.6	637	0.49	11.8	3360	3.8
. Net forest clearing*	1848	-	-	-	-	1848	2.1
. Forest fires	112	0.42	4.2	0.003	0.084	123	0.1
3- **AGRICULTURE** . Grassland conversion**	12,423	-	-	-	-	12,423	14.1
. Rice cultivation	-	6.2	-	-	-	153	0.2
. Breeding - Enteric fermentation - Animal manure	 - -	 251 11	 - -	 - -	 - -	 6150 270	7.3
. Chemical fertilisers	-	-	-	0.24	-	77	-
4- **INDUSTRY** (processes) . Cement works	5997	-	-	-	-	5997	6.8
5- **WASTE** . Residues and residual industrial water . Household refuse and wastewater	 - -	 3.4 241		 - -	 - -	 83 5904	6.8
TOTAL (Gg)	**72,837**	**599**	753	**2.23**	187.6	**88,222**	100
ASSESSMENT PER TYPE OF GAS	CO_2	CH_4	CO	N_2O	NO_x	TOTAL	
TOTAL E-CO_2 (Gg)	72,837	14,676	-	714	-	88,226	
Percentage %	82.6	16.6	-	0.8	-	100	
Conversion factors for GHGs into E-CO_2	1	24.5	0	320	0		

* Net clearing = clearing for agriculture - reforestation
** Conversion into cultivated lands (part of land use change)

Table 28: Proportion of different GHGs in the assessment of emissions for 2010 (Gg)

Morocco - 2010	CO_2		CH_4		CO		N_2O		NO_x	
	Gg	%	Gg	%	Gg	%	Gg	%	Gg	%
1- **ENERGY** Conventional energy	51,106	70.2	10.1	1.7	112	14.9	1.5	67.3	175.7	93.7
2- **FORESTRY** . Biomass energy (Off-site burning)	1351	1.9	75.6	12.5	637	84.6	0.49	22.0	11.8	6.3
. Net forest clearing*	1848	2.5	-	-	-	-	-	-	-	-
. Forest fires	112	0.1	0.42	0.1	4.2	0.5	0.003	-	0.084	-
3- **AGRICULTURE** . Grassland conversion**	12,423	17.1	-	-	-	-	-	-	-	-
. Rice cultivation	-	-	6.2	1.0	-	-	-	-	-	-
. Breeding - Enteric fermentation - Animal manure	-	-	262	43.7	-	-	-	-	-	-
. Chemical fertilisers	-	-	-	-	-	-	0.24	10.7	-	-
4- **INDUSTRY** (processes) . Cement works	5997	8.2	-	-	-	-	-	-	-	-
5- **WASTE** . Residues and residual industrial water . Household refuse and wastewater	-	-	3.4 241	40.8	-	-	-	-	-	-
TOTAL (Gg)	**72,837**	100	**599**	100	753	100	**2.23**	100	187.6	100
	CO_2		CH_4		CO		N_2O		NO_x	

* Net clearing = clearing for agriculture - reforestation
** Conversion into cultivated lands (part of land use change)

9.2 Strategic options

In signing the Framework Convention on Climate Change, Morocco subscribed to the commitments it prescribes for developing countries. Specifically, it must formulate, implement and publish national programmes to limit climate change and adapt to its effects. As a member state of the Conference of the Parties (COP) - after ratification of the Convention - Morocco has until 21 March 1997 to submit information about its programmes; this information must include, in particular, a national inventory of anthropogenic GHG emissions and a description of the measures taken or planned to implement the Convention.

Morocco must develop a national policy on climate change. The facts we present in this report could form the basis for a debate on this policy.

The structure of the assessment of GHG emissions in Morocco gives some indication of the actions to be taken to stabilise - even to reduce - these emissions by 2010.

Technical options have been identified and chosen on the basis of their potential impact on reducing GHG emissions. Analysis of the results obtained in 1990 reveals that 45% of GHG emissions in Morocco can be attributed to the consumption of conventional energy (electricity generation, industry, transport) and 5.5% to biomass energy consumption (Table 2). Efforts must therefore be concentrated on this "**energy sector**", which is responsible for over 50% of emissions.

Land use change takes second place (19% of total emissions), followed by breeding (13.5% of emissions). But action in this sector is difficult, since it is linked to agricultural development and therefore to the country's food supplies. Given that agriculture is a strategic sector in both economic and social terms, any action in this sphere can only be undertaken with the greatest of caution. However, the intensification policy should be pursued in order to limit land clearing for agricultural purposes.

In all cases, any option aimed at stabilising or reducing GHG emissions must be examined with respect to the sustainable development strategy of the country, and its cost (economic, financial, social and ecological) must be evaluated.

The technical options for reducing GHG emissions which seem to us most suited to the situation in Morocco can be summed up as follows:

* the use of natural gas, especially in thermal electric power stations;

* the control of energy and the use of clean technologies in industry;

* more intense use of renewable energy in rural areas;

* the introduction and spread of improved stoves in rural areas;

* improvement in carbonisation yields;

* reforestation for energy uses;

* action at the level of urban transport.

It should be noted that implementation of the first three options has already been undertaken by the *Ministère de l'Energie et des Mines* or bodies under its auspices (*Office National de l'Electricité, Projet de Gestion de l'Energie dans les entreprises marocaines, Centre de Développement des Energies Renouvelables*). We will now briefly describe the options chosen.

9.2.1 The use of natural gas in thermal electric power stations

As we have already indicated, Morocco's thermal electric power stations are old and can no longer meet the demand for electricity, particularly during drought years when the supply from hydroelectricity is insufficient. The current policy of the MEM therefore envisages the construction of new thermal electric power stations within the context of the privatisation of electricity production, which has until now been 90% managed by the ONE.

Moreover, the gas pipeline which will take Algerian gas to Spain, via Morocco, will provide the country with natural gas. The MEM therefore forecasts that this gas will supply 30% of energy needs by 2010. In the knowledge that **natural gas is much less of a pollutant than coal and oil**, particularly in new gas turbine power stations with a combined cycle (higher yield and lower emissions than conventional power stations), this option will certainly have a major effect on limiting the increase in GHG emissions.

9.2.2 The control of energy and the use of clean technologies in industry

The *Gestion de l'Energie au Maroc* (GEM) project, which has been running in Rabat since 1989 and is managed by the MEM with funding from USAID, has already performed several energy audits in the industrial and tertiary sectors.

It has thus been demonstrated, in several cases, that the savings made in energy spending largely make up for the investment required to implement the technical solutions put forward; generally speaking, the payoff periods for these investments are currently between a few months and two years. Much has still to be done therefore in this sector, corresponding to a considerable **deposit of energy savings** which has not yet been evaluated. The initial targets should be those industries which are major energy consumers and which have been clearly identified (Appendix A2-8, volume 2).

Alongside the control of energy, the use of natural gas instead of coal and oil products can also be advocated, together with the use of specific antipollution equipment for the type of technology used.

9.2.3 More intense use of renewable energy in rural areas

Over 28,000 villages (90% of the total) have still to be electrified as the *Programme national d'extension du réseau électrique* (PNER) draws to a close. Renewable energy, in particular photovoltaic panels, is already in use in rural areas (1 MW capacity by 1994) in the form of individual equipment (for lighting and television) or shared equipment (for pumping water). Moreover, the PPER (*Programme pilote d'électrification rurale*) which involves approximately 200 villages, is currently at the stage of equipping the 30 villages in the first phase and the PNED is poised to take over.

Recent measures (February 1994) to reduce the tax on all equipment used in conjunction with renewable energy should bring about a fall in prices and thus encourage investment in this sector. It is expected that the **MEM and the DGCL will continue their voluntarist policy of rural electrification by renewable energy** provided the required funding can be obtained. The stated objective of those in charge is to achieve the decentralised electrification of at least 50% - possibly 75% - of the rural population by the year 2000. Electrification is an essential aspect of improving living conditions in rural areas; however, on its own it is not enough and other equipment supplying thermal electric energy, which could replace charcoal, also has to be introduced: solar water heaters, ovens and cookers, solar distillers and dryers, biogas.

9.2.4 Introduction and spread of improved stoves in rural areas

Wood and brush form the main source of energy for most of the Moroccan rural population. This leads to deforestation, placing an even heavier burden on wood. The spread of improved stoves, for both wood and charcoal, while **increasing the combustion yield**, would bring about substantial fuel savings. An evaluation of these savings can therefore be suggested, on the basis of the following theories: replacing one third of ranges by 2010 with improved ranges producing a combustion yield of 30% (rather than the average of 10% for ordinary ranges). This operation would involve 80% of the biomass, which represents 67.5 Gg of CO_2 or 0.1% of total CO_2 emitted in 2010.

Alongside this action, it would be a good idea to propagate techniques for building ventilation shafts for kitchens, where women and children are currently living under conditions which are extremely damaging to their health.

One other option would be to **intensify the use of LPG in rural areas**, in order to replace fuelwood. The more well-off families currently use small gas cylinders for lighting or to make tea for guests, but still use wood or charcoal for cooking food. This option has the disadvantage that it is expensive, since on top of the costs of transport and the cylinders, families with limited financial means also have to buy gas stoves. However, it offers the advantage of having a major impact on reducing GHG emissions and on deforestation.

9.2.5 Improving carbonisation yields

Charcoal has traditionally be used chiefly in rural areas for cooking food. Despite the widespread use of LPG in rural areas, coal is still used for specific applications. Carbonisation produces a very poor yield. Improved carbonisation techniques should therefore be publicised via a programme of training for coal merchants.

The spread of these techniques would on the one hand reduce specific clearing for agriculture and, on the other hand, reduce GHG emissions. This reduction has been estimated for 2010 on the basis of an improvement in carbonisation yield from 18% to 25%. This would thus reduce the total amount of biomass energy by 4.3%, which corresponds to a reduction in CO_2 emitted of 58 Gg, or approximately 0.08% of total CO_2 emitted in 2010.

9.2.6 Reforestation for energy purposes

In view of the worrying shrinking of Moroccan forests and the demand for fuelwood from rural populations, one of the obvious solutions would be reforestation for energy purposes which would have the effect of reducing net emissions of CO_2 by recreating a CO_2 sink. This reforestation must be carried out under conditions which guarantee its success (choice of varieties, plantation period, etc.) and, here too, lessons must be learned from the past by identifying the reasons why previous reforestation has not been very successful.

It would also be desirable, in addition to this action, to **manage the forest resources more efficiently**, particularly by involving rural communities more closely in the Government's efforts to reforest the country.

9.2.7 Action at the level of urban transport

As has already been indicated, road transport is the chief culprit in terms of GHG emissions due to transport, especially diesel vehicles. Commercial vehicles represent over 30% of Morocco's vehicle fleet and are heavy consumers of diesel fuel (Appendix A2-11, volume 2). Action must therefore be directed towards this category of vehicle in order to limit GHG emissions.

Several types of action are to be taken in parallel. Since the mechanical and technical condition of vehicles is very average, even mediocre, **compulsory technical inspections should be imposed.** Currently, these inspections only apply to vehicles over 10 years old but they do not involve any monitoring of fuel consumption nor of GHG emissions.

Modernising the vehicle fleet: action is currently underway aimed at providing the country with a **fuel-efficient car**. It would desirable to extend this to commercial vehicles.

Urban transport: Casablanca, which accounts for over 40% of the vehicle fleet and has high atmospheric pollution, should target its efforts towards reducing GHG emissions. In addition, the bus fleet, despite its partial privatisation, barely meets demand and the vehicles are in a disgraceful technical condition.

Action therefore needs to be taken at the level of public transport by replacing buses and taxis, which are heavy consumers of diesel fuel, by **electric vehicles** (trams or trolleybuses) or by an **elevated railway** which would serve the entire conurbation.

A metro project is underway in Casablanca but the funding required for its implementation has yet to be raised. This metro would replace 50% of buses and taxis in the city, leading to a reduction in GHGs emitted by national road transport of around 5%.

Conclusion

To conclude, we can say that action on the level of conventional energy and an intensification of the use of renewable energy would have a significant economic impact (reduced imports of oil, reduced spending on energy, etc.) as well as restricting GHG emissions.
The other options relate more to the natural environment (management of the forest resources).

No evaluation of the costs and benefits of these options has been carried out due to a lack of technical and economic information on the one hand and methodology on the other hand. Nonetheless, these proposals remain interesting as **guiding elements for a national strategy to be prepared within the context of the Framework Convention on Climate Change.**

Like all African countries, the development of Morocco must of necessity be accompanied by an increase in energy consumption; naturally, GHG emissions will rise. At a given rate of economic growth, the risk in any development strategy of this kind is knowing at precisely what rate GHG emissions will rise. Stabilising, even reducing emissions means making a choice of investment projects based on a comparison of costs, technologies and their impact on the environment and on development.

The formulation of a development strategy including the aspects of GHG reduction and its implementation requires human resources and adequate funding.
Although the Framework Agreement on Climate Change envisages industrialised countries making a contribution to the financing of projects within such a strategy, the finance mechanisms are far from clear.

Negotiations between northern and southern countries will still be necessary, especially to define a joint methodology for evaluating the costs of reducing GHG emissions, as well as a platform for the joint implementation of programmes, and to clarify the conditions for the acquisition and transfer of high-performance technologies. Morocco would like to make a positive contribution to this debate. In the mean time, the first task which it must address is the training of national experts in all aspects concerning the environment. It is also the main activity where international cooperation must prove effective and prompt.

At domestic level, the Government must outline the main features of a policy aimed at redirecting current trends and at achieving a certain number of objectives. Generally speaking, this should produce specific measures, particularly regarding transport, industry and forestry.

A town and country planning policy, for example, should encourage local communities and the population generally to favour public transport, electrical energy systems, low-consumption vehicles, etc..

The objective of reducing consumption due to transport by 15-20% before the year 2000, compared to the laissez-faire scenario, seems entirely reasonable. Simulations can be made for each of the sectors under consideration, to evaluate the impact of the planned options and thus confirm the need for the measures to be undertaken.

10. CONCLUSIONS AND RECOMMENDATIONS REGARDING THE INVENTORY METHODOLOGY

On first reading the 3 volumes of the IPCC/OECD Methodology, 1994 version, it is easy to become lost and to be struck by their sheer size. The current version would benefit from being simplified and modified in terms of its presentation along the following lines:

* produce a simplified, condensed version of the methodology;
* group together the tables showing coefficients and emission factors in an appendix;
* combine the worksheets into a separate section;
* modify the worksheets to simplify and correct them.

It would therefore be a good idea to design documents which are simpler and better adapted, capable of being used at regional or even national level, and which could be created within the framework of inventory projects.

The French version contains many errors and incorrect or inaccurate terms, a few of which are listed below.

Readers familiar with the Methodology will notice that the wording of the column headings or of worksheet lines have been changed because they were vague or inconsistent, or not suitable for Moroccan data. Therefore, in the Methodology, the wording of the column headings changes from one sheet to another, for the same concept. We have used:

"Masse de gaz émis" (volume of gas emitted) for the last columns, instead of
"Emission réelle de ..." (actual emissions) (sheet 1-1 C)

"Emission de CH_4 générée par la combustion de la biomasse" (CH_4 emissions from biomass burned) (sheet 1.3A)

"Emission de méthane" (Methane emissions) (sheets 1.4A and 1.5A)

"CO_2 emis" (CO_2 emitted) (sheet 2-1)
see also worksheets (4.1A, columns C, E), (4.2A, column E), etc..

"Fraction de carbone émis sous forme de X" (carbon fraction emitted in the form of X) instead of *"Rapport X-C"* (Report X-C) or *"Rapport d'émission de gaz trace X"* (Emission report on trace gas X).

"Emission potentielle de carbone" (Potential carbon emission) instead of *"fraction de carbone"* (carbon fraction) (worksheet 1-1B).

"Surface cultivée" (cultivated surface area) instead of *"zone de récolte"* (harvested area) (worksheet 4-2A).

The term *"gaz de trace"* (trace gas), used in the Methodology worksheets (e.g. sheet 5-2A) is not correct in French. In fact, this refers to CO, CH_4, N_2O and NO_x, which are present in the atmosphere in very small quantities = in traces!

Furthermore, the worksheet titles have been simplified in order to make them clearer and easier to read (omission of module, submodule).

It is very important to check that the emission calculations have been made after correcting volume 2 of the Methodology, page by page, using the Errata for volume 2. In fact, the differences between the value in the original version of the Methodology and that of the Errata are sometimes huge. For example, the emission factor for methane from municipal wastewater was 22 Gg of CH_4/Gg of BOD_5 (page 6.11); the corrected value is 100 times smaller - 0.22.

However, we would also point out that the Errata itself contains errors: the numbers of the pages to be corrected in volume 2 of the French version of the Errata do not correspond to the page numbers of the French version of volume 2.

At the end of the Errata, a part is missing concerning the corrections to pages 6.13 and 6.14, about industrial wastewater, particularly the correction of the methane emission factor (0.22 instead of 22). We have corrected it by analogy with municipal wastewater.

The non-corrected errors are:

* in Table 6-2 (page 6.9): *aérobie* instead of *anaérobie* and vice versa;

* in Table 6-1 (page 6.5): the coefficients in the last 2 lines (0.85 instead of 85, 0.8 instead of 80, 0.175 instead of 17.5, 0.15 instead of 15).

The unit in the last column of this table is incorrect:

* rather than Gg/1000 pers/year, these are Gg/10^6 pers/year.

The **biomass** section appears in the Energy chapter and in the Forestry chapter, which causes some confusion; in addition, it lacks accurate information:
solid biomass (worksheet 1-1A): does this mean only primary fuels or charcoal as well? Dry or wet matter?

Fuel which goes via commercial circuits or the total biomass consumed?

Despite the diagram on page 5.4, the Forestry chapter would benefit from being simplified and better explained.

In particular, the calculation of CO_2 emission or removal in worksheets 5.5A, B and C surely duplicates worksheets 5-1A, B and C?

The commercial harvest is entered in worksheet 5-5B, to which fuelwood and other uses of wood are added, then wood removed from forest clearing is subtracted. This calculation process is not at all clear; it seems as if the same thing is being counted several times. Furthermore, wood which is not burned (joinery, timber, posts) should not be included in emissions since it represents stored carbon (cf. energy: non-energy oil products).
We have combined detailed comments on the IPCC/OECD Methodology, sector by sector, into Appendix 5 of volume 2 of this document.

B. DATABASE

11. PRINCIPLES OF COMPILATION

The objective of this study is to compile a specific program to create a database (or information system) relating to all the GHG emission sources. The ultimate aim of the development of this information system is to provide researchers, administrators and others with an improved management tool and an official source of information, suited to the Moroccan context on the one hand and easy to re-update on the other hand.

An information system is a complex thing, evolving in an equally complex environment. In order to control this complexity, we used a phased development method, as described below:

1. Evaluation of demand

The objective of this phase was to clarify the demand, evaluate the feasibility and prepare an evaluation report on the demand.

2. Detailed analysis

The chief objectives of the detailed analysis were:

* to understand the problems with the information system under study;

* to determine the genuine causes of these problems;

* to identify the demands and constraints imposed on the current system (Minergg software based on IPCC/OECD Methodology to draw up GHG balance sheets);

* to define the objectives which the new information system should achieve.

3. Logical design

This task involved determining all the logical components of an information system which enable the problems of the current system to be excluded and the objectives of the previous phase to be achieved. Logical design involved the following activities:

* designing the database (files and links between files, cf. Appendix 6, volume 2);

* designing processes;

* designing entry flows (inputs).

4. External physical design

The main tasks of external physical design were:

* detailed design of interfaces (inputs and outputs);

* design of mode of interaction with computerised section;

* design of manual procedures.

5. Technical implementation

The main activities of technical implementation were:

* the choice of programming language; developments were performed using the Clipper tool.

We chose this tool firstly because it is compatible with the dBase tool, which in turn means that data can be exported and imported to and from other programs and, secondly, for functional reasons. In fact, the Clipper tool enables feasible programs to be produced which can be installed on any type of hardware (PC or compatible from 8086 to 80486);

* internal physical design;

* programming;

* tests;

* preparation of documentation.

Although it forms a separate phase, technical implementation is closely linked to external physical design.

6. Installation and operation

In order for the information system to be installed smoothly, the following activities should be undertaken:

* training in its use;

* operation and maintenance;

* evaluation.

12. POSSIBILITIES AND LIMITATIONS

The information system which has been installed encompasses all the factors (currently permitted by the IPCC/OECD Methodology) responsible for emissions of greenhouse gases. The data storage capacities of the program are only limited by the available capacity of the hard disk. The limitations of the GHG software are listed below, together with their expansion possibilities:

* the program has been designed to run on the DOS operating system; this choice was discussed, given that most computers operate under DOS. However, the limitations of DOS in no way alter the operation of the software since the latter only requires 512 kb of conventional memory;

* the production of reports is impeded by the fact that the compiler does not have a powerful request optimiser. In order to alleviate this problem, simply recompile the program with a new, more powerful version of the compiler (note that a new version has just been launched on the market);

* the GHG program is incompatible with the DOS6 MEMMAKER option; this option should be deactivated before running the program.

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ANNEXE 1

A1-1- Liste des institutions concernées par les gaz à effet de serre et le climat

A1-2- Eléments sur les gaz à effet de serre

ANNEXE 1

Liste des institutions concernées par les gaz à effet de serre et le climat

Institution	Attribution et rôle en la matière
Ministère de l'Environnement	Département chargé de la coordination du secteur dans le pays
Conseil National de l'Environnement	Conseil associant les différents départements concernés par les problèmes de l'environnement qui suit et oriente la stratégie Nationale en la matière
Comité National du Climat	Comité présidé par le Directeur de la Météorologie Nationale et regroupant des représentants des différents départements ministériels : animation et suivi des aspects climatiques au niveau national et international
Ministère des Travaux Publics	**Administration de l'Hydraulique** : chargé de la gestion de l'eau et pouvant être concernée par l'impact des changements climatiques. **Direction des Ports** : chargée de la gestion du Domaine Public Maritime et pouvant être concernée par l'impact des changements climatiques. **Direction de la Météorologie Nationale** : direction en charge du suivi du climat du pays.
Ministère du Transport	Département ayant la tutelle du transport terrestre, aérien, ferroviaire et maritime : influence au niveau des émissions de gaz à effet de serre.
Ministère de l'Energie et des Mines	Département ayant la tutelle des organes de production de l'énergie au Maroc notamment l'Office National de l'Electricité : impact au niveau des émissions de gaz à effet de serre lors de la production d'énergie.
Ministère de l'Industrie	Département ayant la tutelle du secteur industriel : impact au niveau des émissions lors de l'activité industrielle
Ministère de l'Agriculture et de la Mise en valeur Agricole	Ministère ayant pour tutelle la forêt, l'agriculture, l'élevage ... : action directe de ces activités sur le bilan en gaz à effet de serre
Ministère d'Etat à l'Intérieur	**Collectivités locales** (Direction de l'Eau et de l'Assainissement) en charge de la gestion des ordures et des eaux usées : impact relatif au rejet des ordures et des eaux usées.
Ministère de l'Information	**Information** : action de sensibilisation et d'information en particulier sur les gaz à effet de serre et le climat

Ministère de l'Education Nationale	Ministère ayant la tutelle de l'enseignement primaire et secondaire. Ce ministère pourrait promouvoir la formation en relation avec ces aspects
Ministère de l'Enseignement Supérieur, de la Recherche Scientifique et de la Formation des Cadres	Promotion de la formation et de la recherche en relation avec ces aspects.
Ministère de la Santé Publique	Direction de l'épidémiologie: impact sur la santé des différents polluants en particulier les gaz à effet de serre.
Centre Royal de Télédétection Spatiale	organe visant à promouvoir, à coordonner et à développer l'utilisation de la télédétection spatiale dans les différents secteurs. Contribution aux études pouvant être menées sur les changements climatiques dans la région.
Centre National de Recherche Scientifique	Centre chargé de l'animation et de la coordination du secteur de la recherche scientifique dans le pays
Ecoles d'Ingénieurs	* Institut Agronomique et Vétérinaire Hassan II : agriculture, forêts, sols, écologie ... * Ecole Hassania des Travaux Publics : eau, climatologie, littoral, énergie, environnement. * Ecole Mohammadia des Ingénieurs : eau, climatologie, littoral, énergie, environnement. * Ecole Nationale de l'Industrie Minérale : mines, énergie, environnement.
Organisations Non Gouvernementales	* Association Marocaine de protection de la nature * Groupe d'Etudes et de Recherches sur les Energies Renouvelables et l'Environnement. * Société Marocaine du Droit de l'Environnement * Comité Inter associations sur l'Environnement * Association Marocaine pour la Protection de l'Environnement * Association Marocaine pour la Mer * Forum Maghrébin pour l'Environnement et le Développement * Mouvement Ecologique Marocain * Mouvement National pour l'Environnement

Eléments sur les gaz à effet de serre

L'effet de serre naturel de certains gaz de l'atmosphère (dont la vapeur d'eau) rend la température de la Terre assez élevée pour permettre la vie sur la planète.

Cependant, depuis la fin du 19ème siècle, en raison de l'augmentation de la population et de l'industrialisation, la concentration de certains GES a beaucoup augmenté, provoquant une amplification de l'effet de serre et rendant probable un réchauffement climatique.

Afin de mieux comprendre les causes et les conséquences du réchauffement climatique, et de juger de l'opportunité d'élaborer une stratégie mondiale de limitation des émissions de GES, il est nécessaire d'améliorer la connaissance des facteurs anthropiques responsables de ces émissions.

Principales activités anthropiques contribuant à l'effet de serre additionnel

Les principales activités humaines responsables de l'effet de serre "additionnel" sont :
- la production, la consommation, le stockage et la distribution des énergies fossiles ;
- l'exploitation de la forêt, le changement d'affectation des sols et la combustion de la biomasse ;
- l'agriculture (et l'élevage) ;
- certains procédés industriels (cimenteries) ;
- les déchets urbains et industriels ;
- l'utilisation des CFC.

Les principaux gaz émis par les activités précisées ci-dessus (en dehors des CFC pris en compte dans le Protocole de Montréal) sont :
- le dioxyde de carbone (CO_2) ;
- le monoxyde de carbone (CO) ;
- le méthane (CH_4) ;
- l'oxyde nitreux (N_2O) ;
- les oxydes d'azote (NOx) ;
- les composés organiques volatils non méthaniques (COVNM, en anglais: NMVOC).

L'impact d'une quantité d'un gaz donné, en terme de réchauffement climatique, est appelé **potentiel de réchauffement global** (PRG, en anglais: global warming potential ou GWP). Le PRG dépend de la nature du gaz et, pour un gaz donné, de l'efficacité thermique de ce gaz, de divers paramètres physico-chimiques complexes, ainsi que de sa durée de vie dans l'atmosphère.
Le PRG du CO_2 étant pris comme référence, égal à 1, celui des gaz autres que CO_2 dépend de la durée d'intégration choisie (20 ans, 100 ans ou 500 ans).
20 ans est une durée trop courte pour juger des phénomènes

climatologiques, à forte inertie ; de plus, la durée de vie de CO_2 et N_2O (120 ans) est bien supérieure à 20 ans. Une durée d'intégration de 500 ans est attrayante mais nous ne disposons pas de modèles prospectifs à un tel horizon.
Aussi, la durée intermédiaire, 100 ans, est-elle adoptée actuellement.
Le PRG permet ainsi d'exprimer dans une unité homogène (en équivalent CO_2), à des fins d'agrégation et de comparaison, les émissions globales d'une activité, d'un secteur, d'un pays.
Ainsi, pour une durée d'intégration de 100 ans, le méthane a un PRG égal à 24.5 fois celui de CO_2 et N_2O a un PRG égal à 320 fois celui de CO_2. On multipliera donc la masse de CH_4 émis par 24.5 et celle de N_2O par 320 afin d'obtenir des E-CO_2 (équivalent - CO_2).

Le tableau ci-dessous regroupe les caractéristiques des GES autres que les CFC.
La méthodologie IPCC/OCDE ne prend en compte que les GES à effet direct, qui agissent directement sur l'effet de serre.
Le PRG du méthane inclut son effet direct et ses effets indirects dûs à la production d'ozone troposphérique et de vapeur d'eau stratosphérique.
L'effet indirect dû à la production de CO_2 n'est pas inclus
NO_x et CO n'ayant pas d'effet direct significatif sur l'effet de serre, aucune valeur du PRG n'est indiquée pour ces deux GES. Ils influencent indirectement la concentration d'autres GES (ex : ozone troposphérique) à travers la chimie atmosphérique. Leurs effets indirects sont complexes et dépendent de où et quand ils sont émis.
De nouvelles techniques doivent être développées pour évaluer leur influence sur l'effet de serre.

Caractéristiques des principaux gaz à effet de serre (sauf les CFC)

Gaz	Durée de vie (année)	Effet direct sur une période de			Effet indirect
		20 ans	100 ans	500 ans	
CO_2	120	1	1	1	Nul
CH_4	14.5 ± 2.5	62	24.5	7.5	Positif
CO	qq mois	-	-	-	Positif
N_2O	120	290	320	180	Inconnu
NO_x	qq jours	-	-	-	Positif
COVNM	qq jours à qq mois	-	-	-	Inconnu

* Source : Radiative forcing of climate change, the 1994 report of the scientific assessment working group of IPCC (Summary for policymakers), IPCC/WMO/UNEP.

ANNEXE 2

Données de base sur les secteurs d'activité économique

Tableau 2-1 : Evolution de la population du Maroc
en millions d'habitants

Année	1982	1990	1994	2000	2010	2020
Sources d'information	Recensement général	CERED-91	Recensement général	<------- CERED 92 ------->		
Pop. rurale (%)	11.68 (57.4)	13.47 (53.5)	13.41 (51.4)	13.63 (46)	14.3 (41.8)	14.90 (38.7)
Pop. urbaine (%)	8.67 (42.6)	11.73 (46.5)	12.66 (48.6)	16.00 (54)	19.9 (58.2)	23.56 (61.3)
Pop. totale (%)	20.35 (100)	25.20 (100)	26.07 (100)	29.63 (100)	34.2 (100)	38.46 (100)

CERED : Centre d'Etudes et de Recherches Démographiques

Source : CERED, 1993.

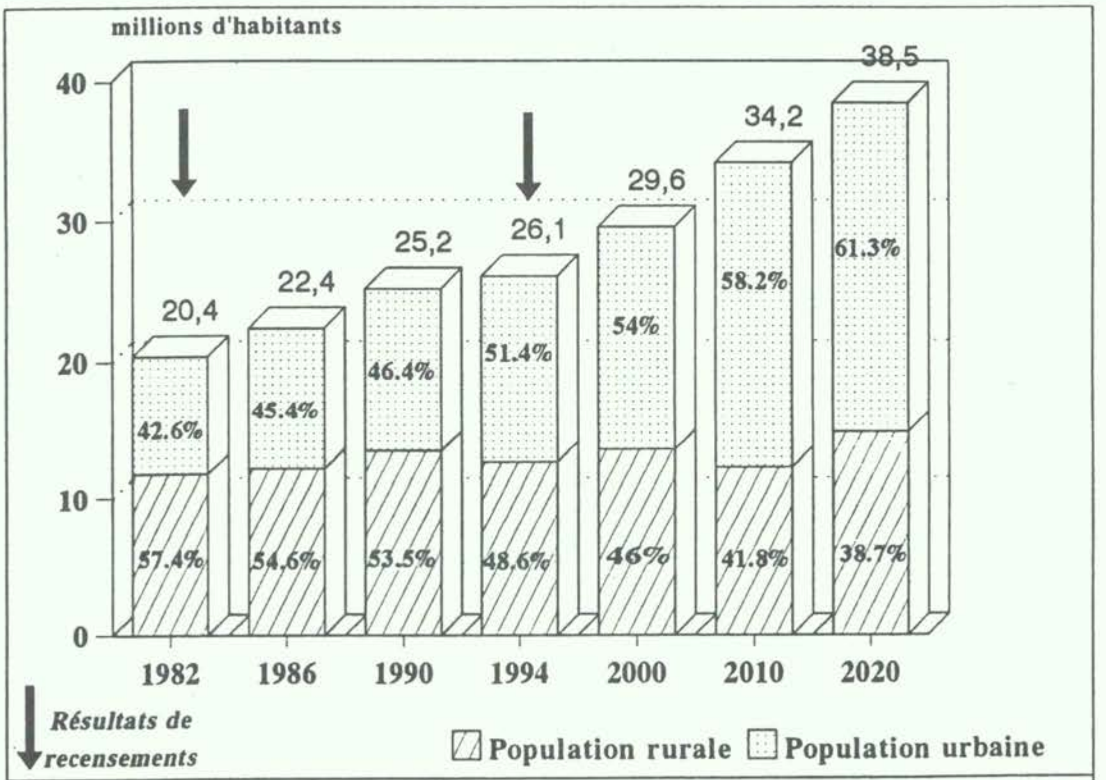

Figure 7: Evolution de la population du Maroc

Tableau 2-2 : Production d'énergie primaire

	1980	1982	1984	1986	1988	1990	1992
Pétrole brut (10^3 tonnes)	14	16	16	23	20	15	11
Gaz naturel (millions de m^3)	68	79	83	91	83	57	24
Anthracite (10^3 tonnes)	680.0	735.0	837.5	775.0	636.7	526.0	575.8
Electricité hydraulique (millions de kWh)	1486.7	555.2	351.9	625.2	915.1	1195.9	963.8

Source : Annuaires statistiques du Maroc 1985, 1989, 1994
Bois de feu (combustion directe) : 7360 kt en 1990
Bois pour produire du charbon de bois : 1330 kt en 1990.

Tableau 2-3 : Importations de produits énergétiques (10^3 tonnes)

10^3 tonnes	1980	1982	1984	1986	1988	1990	1992
Pétrole brut	3988	4468	4644	4149	5050	5681	6455
Produits pétroliers	245	188	180	272	205	464	
dont prod. énerg.	162	122	161	259	194	449	
non énerg.	83	66	19	13	11	15	
Coke et charbon gras	28.6	64.5	218.0	817.2	1067.8	1225.9	1215.2

Source : Annuaires statistiques du Maroc 1985, 1989, 1994

Tableau 2-4 : Exportations de produits énergétiques (10^3 tonnes)

10^3 tonnes	1980	1982	1984	1986	1988	1990	1992
Produits pétroliers (sauf naphta)	81.6	6.7	5.2	0	28.1	0	0
Naphta	197.4	200.3	298.8	248.7	286.0	506.2	513.6
Charbon	89.5	28.3	65.7	50.0	8.8	-	-

Source : Annuaires statistiques du Maroc 1985, 1989, 1994

Tableau 2-5 : Importations de produits pétroliers (sauf brut) (10³ tonnes)

10³ tonnes	1980	1982	1984	1986	1988	1990	1992
Butane et propane	107.2	109.1	125.8	235.8	185.7	280.0	474.3
Gasoil	41.6	-	-	5.9	-	24.7	112.1
Fueloil	-	-	17.2	-	-	125.6	-
Essences spéciales	3.2	2.7	3.3	2.9	0.9	1.9	
Essences avion	1.9	1.4	1.4	0.8	1.6	1.0	
Paraffine	2.5	7.5	16.0	13.7	5.8	15.9	7.5
White spirit	3.7	3.7	4.7	4.3	3.1	5.2	
Huiles de base	48.3	34.7	7.9	3.5	0.05	2.5	
Lubrifiants et graisses	3.2	2.7	2.9	2.3	4.1	2.7	
Additifs	1.6	3.7	3.3	2.4	3.5	4.2	
Bitumes	12.7	21.5	-	-	-	-	
Total	225.9	187.0	182.5	271.6	204.8	463.6	

Source : Annuaires statistiques du Maroc 1985, 1989, 1994

Tableau 2-6 : Soutes internationales (10³ tonnes)

10³ tonnes	1980	1982	1984	1986	1988	1990
maritimes :						
Fuel oil	25.5	5.1	1.6	0.2	0.3	0.5
Gasoil	11.3	5.9	3.1	4.0	2.8	5.4
aériennes : ATK	91.7	59.7	61.9	57.2	57.2	68.8

Source : Annuaires statistiques du Maroc 1985, 1989, 1994

Tableau 2-7 : Soutes nationales (10³ tonnes)

	1980	1982	1984	1986	1988	1990
maritimes :*						
Fuel oil	13.1	3.8	0.5	0.07	0.2	0.7
Gasoil	40.8	105.1	40.2	60.9	115.7	175.6
aériennes : ATK**	154.3	133.4	145.4	149.7	158.4	180.0

Source : Annuaires statistiques du Maroc 1985, 1989, 1994

** Navires et bateaux de pêche* *** Carburéacteur + essences aviation*

Tableau 2-8 : Transformation ; raffineries de pétrole (10^3 tonnes)

10^3 tonnes	1980	1982	1984	1986	1988	1990	1992
Mise en oeuvre	4215	4316	4728	4292	5144	5657	6230
dont SAMIR	3295	3292	3752	3276	3952	4438	5016
S.C.P	920	1024	976	1016	1192	1219	1214
Production des raffineries	4002	4115	4333	4139	4632	5274	5654
dont SAMIR	3111	3116	3367	3140	3469	4093	4485
S.C.P	891	999	966	999	1163	1181	1169
Livraison des raffineries	4052	4211	4372	4193	4567	5275	5779
dont SAMIR	3119	3218	3436	3181	3407	4092	4496
S.C.P	933	993	936	1012	1160	1183	1283

Source : Annuaires statistiques du Maroc 1985, 1989, 1994

Tableau 2-9 : Transformation ; combustibles entrant dans les centrales thermiques de l'ONE (10^3 tonnes)

10^3 tonnes	1980	1982	1984	1986	1988	1990	1992
Charbon	594.6	649.6	861.1	952.0	1186.6	1199.2	1059.6
Fuel-oil	570.3	905.3	1116.8	1002.4	988.8	1204.6	1418.0
Gasoil	3.2	4.4	11.6	4.9	6.5	9.2	37.1

Source : Annuaires statistiques du Maroc 1985, 1989, 1994

Tableau 2-10 : Production des raffineries de pétrole (10^3 tonnes)

10^3 tonnes	1980	1982	1984	1986	1988	1990	1992
Propane	32.4	25.5	31.1	32.4	46.3	51.2	60.0
Butane	161.2	162.5	176.0	171.9	213.1	181.9	173.6
Kérosène	68.2	57.5	59.5	48.3	45.7	45.2	45.3
Essence ordinaire	135.3	128.1	109.0	97.9	98.6	89.4	86.8
Essence super	226.4	230.3	232.7	220.9	265.7	302.2	316.5
Gasoil	1124.9	1229.2	1142.6	1192.5	1543.6	1785.8	2079.5
Fuel-oil	1756.8	1820.9	2063.4	1923.7	1901.8	2046.5	2143.4
Carburéacteur	250.5	179.5	197.7	204.2	215.8	250.0	206.4
Naphta	174.6	196.7	310.4	241.0	295.1	521.6	542.3
Paraffine	5.1	3.0	2.8	2.8	10.4	5.1	9.8
Huiles de base	45.6	42.7	45.8	44.3	90.2	81.1	97.8
Graisses	2.2	1.8	1.5		1.6	2.2	
Bitumes	45.7	74.7	61.7	71.8	86.9	99.1	115.6

Source : Annuaires statistiques du Maroc 1985, 1989, 1994

Tableau 2-11 : Puissance installée, production et consommation d'électricité

	1980	1982	1984	1986	1988	1990	1992
Puissance installée MW	1466.4	1814.8	1947.8	2056.6	2257.4	2278.8	2544.0
Production nette (millions de kWh)	4936.7	5691.2	6400.6	7105.4	8326.2	9267.9	9719.9
dont. ONE Total	4428.9	5042.4	5628.6	6404.2	6999.7	8024.9	8395.6
thermique	2942.2	4487.2	5276.7	5779.0	6084.6	6829.0	7431.8
hydraulique	1486.7	555.2	351.9	625.2	915.1	1195.9	963.8
. Indust.autoprod.	492.2	626.1	748.3	677.4	1301.1	1228.4	1314.4
. Petites distributions isolées	15.6	22.7	23.7	23.8	25.4	14.6	9.9
Consommation (millions de kWh)	4433.9	5047.9	5706.5	6342.4	7516.3	8518.6	9546.6

Source : Annuaires statistiques du Maroc 1985, 1989, 1994

Tableau 2-12 : Consommation finale d'énergie électrique par branches d'activité économique (millions de kWh)

GWh	1980	1982	1984	1986	1988	1990
HAUTE ET MOYENNE TENSION	**2824.6**	**3071.7**	**3441.1**	**3894.8**	**4250.6**	**4744.0**
Agriculture, pêche	163.5	246.4	226.4	347.1	364.1	430.6
Distribution d'eau	188.1	201.3	294.7	250.1	253.9	298.9
Mines	482.0	529.1	578.8	584.0	701.5	721.0
Industries	1439.8	1477.9	1681.9	1907.8	2047.0	2329.9
Transports et communications	160.0	168.7	186.5	242.7	258.0	285.0
Commerce, hôtellerie, services	203.4	239.5	223.3	276.2	192.4	226.5
Radio, TV, administration	187.8	208.8	249.5	286.9	433.7	452.1
BASSE TENSION	**1130.4**	**1362.5**	**1514.1**	**1788.0**	**2154.1**	**2598.9**
Force motrice	67.3	72.9	77.4	93.9	92.9	113.5
Eclairage public	79.6	92.4	111.4	139.3	168.5	217.6
Eclairage privé, administratif et usages domestiques	983.5	1197.2	1325.4	1554.8	1892.7	2267.8
CONSOMMATION TOTALE	**3955.0**	**4434.2**	**4955.2**	**5682.8**	**6404.7**	**7342.9**

Source : Annuaires statistiques du Maroc 1985, 1989, 1994

N.B. La consommation correspond aux ventes moins les pertes dans les réseaux de transformation et de distribution.

Tableau 2-13 : Consommation d'énergie primaire en 1990

Sources d'énergie	ktep	% total énergies conventionnelles	% total énergie
. Pétrole	5 765	82	55
. Charbon	1 126	16	11
. Gaz naturel	43	0.5	0.4
. Electricité hydraulique	105	1.5	1
Total énergies conventionnelles	**7 039**	**100**	**67**
. Biomasse	**3 480**	-	**33**
Total	**10 519**	-	**100**

Source : Annuaires statistiques du Maroc 1985, 1989, 1994

Tableau 2-14 : Consommation d'énergie finale en 1990

Sources d'énergie	ktep	% total énergies conventionnelles	% total énergie
. Produits pétroliers	3 920	78	48.3
. Charbon	422	9	5.2
. Gaz naturel	31	0.6	0.4
. Electricité	632	12.4	8
Total énergies conventionnelles	**5 005**	**100**	**62**
. Biomasse	**3 117**	-	**38**
Total	**8 122**	-	**100**

Source : Annuaires statistiques du Maroc 1985, 1989, 1990

Tableau 2-15 : Consommation d'énergie finale par secteur en 1990 (ktep)

ktep	Produits pétroliers	Charbon	Gaz naturel	Electricité	Total énergie conventionnelle	Biomasse	Total
→(%) Industrie ↓(%)	56 **903** 23	26 **422** 100	2 **31** 100	16 **263** 41	(100) **1619** 32.2	**0**	100 **1619** 20
Transport	99 **1623** 41.5	**0**	**0**	1 **17** 3	(100) **1640** 32.8	**0**	100 **1640** 20
Agriculture et pêche	93.5 **529** 13.5	**0**	**0**	6.5 **37** 6	(100) **566** 11	**0**	100 **566** 7
Résidentiel	20.2 **671** 17	**0**	**0**	5.6 **188** 30	(25.8) **859** 17	(74.2) **2467** 79	100 **3326** 41
Tertiaire	20 **194** 5	**0**	**0**	13 **127** 20	(33) **321** 7	(67) **650** 21	100 **971** 12
Total	48.3 **3920*** 100	5.2 **422** 100	0.4 **31** 100	7.7 **632** 100	(61.6) **5005** 100	(38.4) **3117** 100	100 **8122** 100

* A ce total, il faut ajouter 173 ktep de produits pétroliers destinés à des usages non énergétiques.
→(%) pourcentages de consommation de chaque type d'énergie, pour un secteur donné.
↓(%) pourcentages de consommation de chaque secteur, pour un type d'énergie donné.

Tableau 2-16 : Consommation d'énergie finale dans l'industrie en 1990 (ktep)

ktep	Charbon	Fuel-oil	Gasoil	Gaz naturel	Electricité	Total
IGCE						
1. Phosphates		230	36	16	19	301
2. Acide phosphorique et engrais		50	7		16	73
3. Ciment	360	44	3		47	454
4. Papier		20	1	15	5	41
5. Pâte à papier		21			9	30
6. Sucre	26	136	1		9	172
Total IGCE	**386**	**501**	**48**	**31**	**105**	**1 071**
Industries légères (IL)						
1. IAA		3	21		24	48
2. TC		64	3		50	117
3. AMC + BTP	15	167	51		15	248
4. CP		6	4		25	35
5. IMME	21	12	4		17	54
6. Divers		18	2		27	47
Total IL	**36**	**270**	**85**	**0**	**158**	**549**
Total Industrie	**422**	**771**	**133**	**31**	**263**	**1 620**
%	26.1	47.6	8.2	1.9	16.2	100

Source : Direction de l'Energie, Ministère de l'Energie et des Mines

IGCE	*: Industries grosses consommatrices d'énergie*
IAA	*: Industries agricoles et alimentaires*
TC	*: Industries du textile et du cuir*
AMC+BTP	*: Industries des matériaux de construction, du bâtiment et travaux publics*
CP	*: industries du carton et papier*
IMME	*: Industries mécaniques, métallurgiques et électriques*

Tableau 2-17 : Consommation d'énergie finale dans le secteur résidentiel en 1990 (ktep)

ktep	Electricité	GPL	Gasoil	Pétrole lampant	Paraffine	**Total énergies fossiles**	Bois de feu	Charbon de bois	**Total**	%
Eclairage	77.0	-	-	48	20	**145.0**	-	-	**145.0**	4
Cuisson	-	463.0	-	-	-	**463.0**	1881	125	**2469.2**	74
Chauffage	3.2	39.0	15.0	-	-	**57.2**	227	22	**306.2**	9
Eau chaude sanitaire	21.2	86.0	-	-	-	**107.2**	192	20	**319.2**	9
Téléviseurs	11.4	-	-	-	-	**11.4**	-	-	**11.4**	0
Réfrigérateurs	46.5	-	-	-	-	**46.5**	-	-	**46.5**	1
Divers	28.8	-	-	-	-	**28.8**	-	-	**28.8**	0
TOTAL	**188**	**588**	**15**	**48**	**20**	**859**	**2300**	**167**	**3326**	10
% du total énergies fossiles	21.9	68.5	1.7	5.6	2.3	100	268	19	387	
% du total énergie	5.7	17.7	0.4	1.4	0.6	25.8	69.2	5.0	100	

Source : Direction de l'Energie, Ministère de l'Energie et des Mines

Tableau 2-18 : Consommation d'énergie finale dans les transports en 1990 (ktep)

ktep	essence	gasoil	électricité	ATK	Total	%
Transport routier	**441**	**911**	-	-	**1352**	**82.4**
dont						
véhicules tourisme	248	75	-	-	323	19.7
motocyclettes	2	-	-	-	2	
véhicules utilitaires	191	467	-	-	658	40.1
transport public voyag.	-	59	-	-	59	3.6
transport marchandises	-	310	-	-	310	18.9
Transport ferroviaire	-	**19**	**17**	-	**36**	**2.2**
Transport maritime	-	**19**	-	-	**19**	**1.2**
Transport aérien	-	-	-	**234**	**234**	**14.2**
Total transports	**441**	**949**	**17**	**234**	**1641**	**100**

Source : Direction de l'Energie, Ministère de l'Energie et des Mines

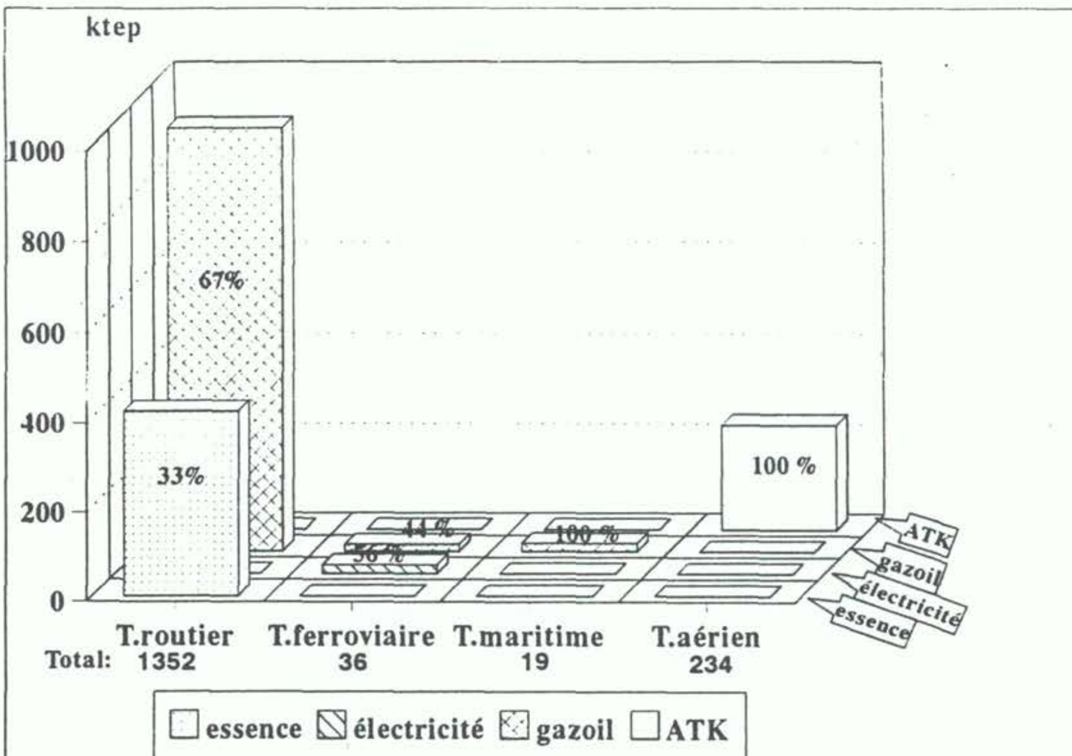

Figure 8: Consommation d'énergie finale dans les transports en 1990

Tableau 2-19 : Transport, évolution des parcs

Transport routier

	1980	1982	1984	1986	1988	1990	1992
Motocyclettes	-	-	18 736	19 015	19 201	19 409	19 592
Voitures de tourisme							
- essence	411 822	433 770	452 704	472 200	496 098	534 020	577 976
- gasoil	17 784	28 796	38 440	55 237	92 797	135 617	200 904
TOTAL 1	429 606	462 566	491 144	527 437	588 895	669 636	778 880
Véhicules utilitaires							
- essence	80 614	82 997	85 551	87 022	87 763	88 877	89 855
- gasoil	119 945	134 526	147 138	160 700	175 326	194 068	217 495
TOTAL 2	200 559	217 523	232 689	247 722	263 089	282 945	307 350

Transport ferroviaire

	1980	1982	1984	1986	1988	1990	1992
Matériel moteur *							
- électrique	80	88	102	108	108	108	112
- diesel	122	122	151	136	136	148	145
TOTAL	202	210	253	244	244	256	257

* locomotives et automotrices

Source : Annuaires statistiques du Maroc 1985, 1989, 1994

Tableau 2.20 : Potentialités de production annuelle de la forêt marocaine

Essence	Superficie 1000 ha	Possibilités de production m³/ha/an	Possibilités totales 1000 m³				TOTAL 1000 m³	
Forêt naturelle			BO	BT	BI	BF	Bois rond	BF
Cèdre	143.2	1.3	170	-	-	33	170	33
Pin d'Alep	64.8	1.0	40	-	20	11	60	11
Pin maritime	15.8	1.5	15	-	5	3	20	3
Chêne vert	1298.2	0.6	20	-	-	760	20	760
Chêne liège	274.8	1.5	-	-	-	450	-	450
Chêne zeen	13.4	1.5	5	-	-	17	5	17
Arganier	820.9	0.3 à 1.5	-	-	-	270	-	270
Genévrier	295.1	0.3	-	-	8	89	8	89
Thuya	543.5	0.5	-	-	20	277	20	277
Essences secondaires	707.7	0.3	-	-	22	190	22	190
Sous total	4177.4		250	-	75	2100	325	2100
Reboisements								
Eucalyptus zone 1	145	3 à 8	15	400	145	145	560	145
Eucalyptus zone 2	67	2 à 6	27	40	100	114	167	114
Autres feuillus	55	0.3 à 5	-	-	30	260	30	260
Résineux	238	2.5 à 5	59	-	476	120	535	120
Sous total	505		101	440	751	639	1292	639
TOTAL	**4682.4**		351	440	826	2739	**1617**	**2739**

Source : DEFCS, 1993 - La filière bois au Maroc

BO : bois d'oeuvre — BT : bois de trituration

BF : bois de feu — BI : bois d'industrie

Tableau 2-21 : Evolution de la SAU et des Rizières

Campagnes	RIZICULTURE			SAU 1000 ha
	Superficies 1000 ha	Rendements Qx/ha	Productions 1000 Qx	
70-71	1.0	27.0	27.0	7621.2
71-72	3.1	44.8	139.0	7579.5
72-73	2.7	38.7	104.4	7506.9
73-74	3.8	32.2	122.5	7460.3
74-75	6.2	47.1	292.0	7540.5
75-76	5.3	33.9	179.6	7833.4
76-77	6.2	38.4	238.1	7908.9
77-78	2.3	31.5	72.4	7887.3
78-79	5.7	32.9	187.6	7663.1
79-80	5.9	48.7	287.5	7795.1
80-81	5.2	37.3	193.7	7919.2
81-82	1.0	36.4	36.4	7918.3
82-83	1.7	23.4	39.8	8005.5
83-84	1.8	25.2	45.4	8021.3
84-85	0.6	28.8	17.3	8037.4
85-86	4.5	45.5	204.8	8061.5
86-87	8.9	55.0	489.5	8246.3
87-88	7.5	44.5	333.8	8328.4
88-89	0.7	63.0	44.1	8661.3
89-90	0.8	41.8	33.4	8889.2
90-91	6.4	38.4	245.8	8944.1
91-92	7.2	30.7	221.0	9195.3
92-93	10.7	50.0	535.0	9255.5

Source : Annuaires statistiques du Maroc 1975, 1980, 1985, 1989, 1994

SAU : superficie agricole utile

Tableau 2-22 : Elevage, évolution du cheptel

Cheptel	1988	1989	1990	1991	1992
Bovins	3 136 926	3 324 240	3 346 258	3 182 916	3 004 833
Ovins	12 733 345	13 761 368	13 514 426	13 307 557	14 153 746
Caprins	5 030 495	5 281 310	5 335 093	4 560 995	4 673 676
Chevaux	197 600	184 082	193 545	188 115	185 622
Mulets	511 262	515 122	522 831	528 253	528 426
Anes	904 109	918 239	911 892	896 245	981 593
Chameaux	35 597	-	33 775	32 563	38 845

Source : Annuaires statistiques du Maroc 1993 et 1994

Tableau 2-23 : Evolution de la consommation des engrais chimiques

Campagne	1985-86		1986-87		1987-88		1988-89		1989-90		1990-91		1991-92	
	Tonnes	%	Tonnes	%	Tonnes	%	Tonnes	%	Tonnes	%	Tonnes	%	Tonnes	%
Importations	282532	39.3	298638	40.7	308541	41.4	292082	39.9	312093	42.3	324450	43.8	315614	40.1
Production locale	435869	60.7	435117	59.3	436028	58.6	439330	60.1	426568	57.7	416397	56.2	472033	59.9
Total	718401	100	733755	100	744569	100	731412	100	738661	100	740847	100	787647	100
Unités fertilisants	304245	100	314785	100	321118	100	315278	100	320732	100	310247	100	338057	100

Source : FERTIMA 1994

PRODUCTION DE CIMENT

Unités de production en 1994

Cimenteries	Nombre d'unités	Capacité de production (1000 tonnes)
CINOUCA	1	1200
CIOR	2	1400 + nd
CIMAR	2	nd
ASMAR	1	450
CADEM	1	620
ASMENT	1	625
TANGER	1	220
TETOUAN	1	220
TOTAL	10	-

Source : Annuaire statistique du Maroc 1994.

Tableau 2-24 : Evolution de la production et de la consommation nationale de ciment et de clinker (1000 tonnes)

Année	1984	1985	1986	1987	1988	1989	1990	1991	1992
Production									
- ciment	3573	3704	3709	3879	4263	4641	5381	5777	6223
- clinker	-	-	2974	-	3355	3187	3758	3858	3936
Consommation de ciment	3596	3627	3690	3982	4230	4605	5384	5763	6361

Source : Annuaires Statistiques du Maroc 1989 et 1993.

Tableau 2-25 : Caractéristiques des eaux usées industrielles

Secteur	Quantité annuelle d'eaux usées m^3	Quantité totale de DBO_5 Gg	Concentration de la DBO_5 * Gg/m^3
Sucreries et raffineries de sucre	$6.6\ 10^6$	6.4	$0.97\ 10^6$
Conserves de fruits et légumes	$3.5\ 10^6$	3.4	$0.97\ 10^{-6}$
Produits laitiers	$1.5\ 10^6$	1.7	$1.13\ 10^{-6}$
Corps gras d'origine végétale	$1.4\ 10^6$	19.5	$13.93\ 10^{-6}$
Conserves de poissons	$2.0\ 10^6$	1.0	$0.5\ 10^{-6}$
Boissons et tabacs	$2.0\ 10^6$	1.7	$0.85\ 10^{-6}$
Textiles et bonneterie	$8.6\ 10^6$	15.0	$1.74\ 10^{-6}$
Cuir et chaussures en cuir	$1.4\ 10^6$	0.5	$0.36\ 10^{-6}$
Industries chimiques et parachimiques	$931\ 10^6$	4.3	$0.005\ 10^{-6}$
Papier, carton et imprimerie	$7.0\ 10^6$	1.6	$0.23\ 10^{-6}$
TOTAL	$965\ 10^6$	55.1	

Source : Rapport : Situation des rejets industriels, Ministère du Commerce et de l'Industrie, août 1994.

* *Valeurs calculées*

ANNEXE 3

Données pour le calcul des émissions de gaz à effet de serre

Données pour le calcul des émissions de GES

ENERGIE

Combustion des énergies fossiles

Facteurs de conversion (tonnes, Mm^3 et MWh en Gj ou ktep)

Combustible	$GJ/10^3$ tonnes	$ktep/10^3$ tonnes
Charbon		
. local (anthracite)	23446	0.5
. importé (coke et charbon gras)	27633	0.6
Pétrole brut	41868	1.0
GPL	47310	1.1
Kérosène	44750	1.0
Essence	44800	1.0
Gasoil	43330	1.03
Fuel oil	40190	0.9
Carburéacteur	44590	1.06
Naphta	45010	1.07
Paraffine	40190	0.9
Huiles de base	40190	0.9
Graisses et lubrifiants	40190	0.9
Bitumes	40190	0.9
White spirit	40190	0.9
Bois de feu	16747	0.4
Charbon de bois	29308	0.7
Gaz naturel	31820 GJ/Mm^3	0.76 ktep/Mm
Electricité	3.6 GJ/MWh	0.086 ktep/GW

peta P 10^{15}	Mega M 10^6	déca da 10^1
tera T 10^{12}	kilo k 10^3	
giga G 10^9	hecto h 10^2	

Données pour le calcul des émissions de GES

ENERGIE

Combustion des énergies fossiles

Masses volumiques moyennes des produits pétroliers au Maroc
(en tonnes par métre cube)

Essence super	0.750
Essence ordinaire	0.725
Kérosène (pétrole lampant)	0.790
Gasoil	0.840
Carburéacteur	0.790

Facteurs d'émission de carbone

Pétrole brut : 20.0 kg de carbone/GJ
Produits pétroliers : de 17.2 pour les GPL à 22 pour le bitume
Charbon : 25.8 kg de C/GJ
Gaz naturel : 15.3 kg de C/GJ

Fraction de carbone oxydée (combustion incomplète)

Pétrole et produits pétroliers : 0.99
Charbon : 0.98
Gaz naturel : 0.995

Fraction de carbone stocké

Lubrifiants : 0.50
Bitume : 1.0

Données pour le calcul des émissions de GES

ENERGIE

Mines de charbon

. Facteur d'émission moyen de CH_4

Pendant l'extraction : 18 m^3 de CH_4/t de charbon
Après l'extraction : 2.4m^3 de CH_4/t de charbon

. Facteur de conversion : 0.67 Gg de $CH_4/10^6m^3$ de CH_4

Production et raffinage du pétrole
Production du gaz naturel

. Facteur d'émission moyen de CH_4

Production de pétrole	:	2650 kg de CH_4/PJ
Raffinage du pétrole	:	745 kg de CH_4/PJ
Production de gaz	:	68000 kg de CH_4/PJ
Traitement, transport et distribution de gaz	:	228500 kg de CH_4/PJ

Combustion du bois de feu

	Bois de feu et broussailles (combustion directe)	Bois pour la production de charbon de bois	Charbon de bois
Consommation (1990)*	7370 kt	1330 kt	240 kt
Efficacité de la combustion	0.87	0.30	0.88
Fraction de carbone de la biomasse	0.45	0.45	0.87
Fraction de carbone émis sous forme de CH_4	0.01	0.063	0.0014
Fraction de carbone émis sous forme de CO	0.06	0.06	0.06
Rapport azote/carbone	0.01	0.01	0.01
Fraction d'azote émis sous forme de N_2O	0.007	0.007	0.007
Fraction d'azote émis sous forme de NO_x	0.121	0.121	0.121

Source : Méthodologie IPCC/OCDE
*Source : Enquête SNPP (1990)

FORETS

. *Production moyenne de la forêt :*
1.15 tonnes de biomasse/ha x an
soit 0.64 tonnes de matière sèche/ha x an
. Contenu moyen en biomasse par hectare de forêt : 30 tonnes/ha
. Efficacité de la combustion : 0.9
. Fraction de carbone de la biomasse aérienne incinérée : 0.45
. Teneur en carbone des sols des terres défrichées : 120 t/ha
. Fraction de carbone émis par les sols des terres défrichées : 0.5

DECHETS

Décharges

. Taux de génération de déchets : 219 Gg de DSM/10^6 personnes/an
. Fraction mise en décharge : 0.8
. Fraction de carbone organique dégradable
des déchets solides municipaux : 0.15 Gg de COD/Gg de DSM
. Fraction qui se dégrade réellement : 0.67
. Fraction de CH_4 dans le biogaz : 0.50

Eaux usées municipales et industrielles

. Taux de génération de DBO des eaux usées municipales :
0.0135 Gg de DBO/1000 personnes /an
. Fraction traitée en anaérobiose : 0.10 Gg de DBO
. Fraction d'émission de méthane : 0.22 Gg de CH_4/Gg DBO_5

DBO = demande biologique d'oxygène
COD = carbone organique dégradable
DSM = déchets solides municipaux

INDUSTRIE

Production de ciment

. Facteur d'émission : 0.498 kt de CO_2/kt de ciment produite

AGRICULTURE

Changement d'exploitation des sols

. Teneur en carbone des sols des prairies : 70 tonnes de carbone par hectare
. Taux annuel d'émission de carbone à partir des sols : 0.02

Riziculture

. Facteur d'émission : 3.48 kg de CH_4 par hectare - jour

Elevage

Type de bétail	Bovins	Ovins	Caprins	Anes et mulets	Chevaux	Chameaux	Volaille
Facteur d'émission de la fermentation entérique kg de CH_4/tête/an	35	5	5	10	18	46	-
Facteur d'émission du fumier kg de CH_4/tête/an	1	0.16	0.17	0.9	1.6	1.9	0.018

Engrais chimiques

. Proportion d'engrais azotés : 0.45
. Proportion d'azote : 0.30
. Fraction d'azote émis sous forme de N_2O : 0.0012

ANNEXE 4

Feuilles de calcul des émissions de GES selon la méthodologie IPCC/OCDE (version 1994)

ENERGIE — Feuille de calcul 1-1 A

ENERGIES FOSSILES : consommation apparente

Unité : kt = 10³t			A Production	B Importations	C Exportations	D Mouvements de stock	E Consommation apparente
Type de combustibles							E = A + B - C - D
FOSSILES LIQUIDES kt	primaires	Pétrole brut	15	5681	0	-30	5726
	secondaires	GPL		280	0	5	275
		Kérosène		0	0	2	-2
		Essence		2	0	34	-32
		Gasoil		25	0	107	-82
		Fuel oil		126	0	118	8
		Carburéacteur		1	0	12	-11
		Naphta		0	506	41	-547
		Paraffine		16	0	1	15
		Huiles de base		3	0	2	1
		Graisses et lubrifiants		3	0	1	2
		Bitumes		0	0	15	-15
		White spirit		5	0	0	5
	TOTAL		15	6142	506	308	5345
FOSSILES SOLIDES kt	primaires	Charbon vapeur	0	1194	0	370	824
		Coke	0	32	0	0	32
		Anthracite	526	0	0	0	526
	TOTAL		526	1226	0	370	1382
FOSSILES GAZEUX 10³ tep		Gaz naturel (sec)	43	0	0	0	43
SOUTES kt		Gasoil + Fuel oil					23
		Carburéacteur					313
		Total en soutes					336
BIOMASSE kt		Bois de feu et broussailles	7370				7370
		Bois pour produire du charbon de bois	1330				1330
		TOTAL	8700				8700

ENERGIE — Feuille de calcul 1-1 B

ENERGIES FOSSILES : émissions de CO_2

			F Facteur de conversion $GJ/10^3t$	G Consommation apparente 10^6 GJ	H Facteur d'émission * kg de C/GJ	I Emission potentielle de carbone Gg de C	J Carbone stocké Gg de C
Type de combustibles				$G = (ExF)10^{-6}$		I = G x H	
FOSSILES LIQUIDES	primaires	Pétrole brut	41868	240	20.0	4800	
	secondaires	GPL	47310	13	17.2	223.6	
		Kérosène	44750	-0.09	19.6	-1.8	
		Essence	44800	-1.43	18.9	-27	
		Gasoil	40190	-3.30	20.2	-66.6	
		Fuel oil	40190	0.32	21.1	6.8	
		Carburéacteur	44590	-0.50	19.5	-9.8	
		Naphta	45010	-24.6	20.0	-492	
		Paraffine	40190	0.60	20.0	12	
		Huiles de base	40190	0.04	20.0	0.8	
		Graisses et lubrifiants	40190	0.08	20.0	1.6	
		Bitumes	40190	-0.60	22.0	-13.2	72
		White spirit	40190	0.20	20.0	4.0	
	TOTAL		-	224	-	4438	
FOSSILES SOLIDES	primaires	Charbon vapeur	27633	22.8			
		Coke	27633	0.9			
		Anthracite	23446	12.3			
	TOTAL		-	36.0	25.8	929	
FOSSILES GAZEUX		Gaz naturel (sec)	41868	1.8	15.3	28	
TOTAL ENERGIES FOSSILES			-	261.8			
SOUTES		Gasoil + Fuel oil	40190	0.92	20.2	19	
		Carburéacteur	44590	14	19.5	273	
		Total en soutes		15		292	
BIOMASSE		Bois de feu et broussailles	16747	123	25.8	3173	
		Bois pour produire du charbon de bois	16747	23	25.8	593	
		TOTAL	-	146		3766	

* *Source : Méthodologie IPCC/OCDE, Vol. 2, Tableau 1-3, page 1.9*

ENERGIE

Feuille de calcul 1-1 C

ENERGIES FOSSILES : émissions de CO_2

CO_2

			K Emission nette de carbone Gg de C	L Fraction de carbone oxydé *	M Carbone émis sous forme de CO_2 Gg de C	N Masse de gaz émis **Gg de CO_2**
Type de combustibles			K = I - J		M = K x L	N = M x 44/12
FOSSILES LIQUIDES	primaires	Pétrole brut	4800			
	secondaires	GPL	223.6			
		Kérosène	-1.8			
		Essence	-27			
		Gasoil	-66.6			
		Fuel oil	6.8			
		Carburéacteur	-9.8			
		Naphta	-492			
		Paraffine	12			
		Huiles de base	0.8			
		Graisses et lubrifiants	-79.6			
		Bitumes				
		White spirit				
	TOTAL		4366	0.99	4323	**15850**
FOSSILES SOLIDES	primaires	Charbon vapeur				
		Coke				
		Anthracite				
	TOTAL		929	0.98	910	**3338**
FOSSILES GAZEUX			28	0.995	27	**99**
TOTAL ENERGIES FOSSILES						**19287**
SOUTES			292	0.99	289	1060
BIOMASSE			3766	0.90	3389	12428

* *Source : Méthodologie IPCC/OCDE, Vol. 2, Tableau 1-4, page 1-10*

ENERGIE — Feuille de calcul auxiliaire 1-1 A

Estimation du carbone stocké dans les produits pétroliers à usage non énergétique

	A Quantité consommée ktep	B Facteur de conversion * GJ/ktep	C Quantité consommée GJ	D Facteur d'émission * kg de C/GJ	E Emission potentielle de carbone Gg de C	G Fraction de carbone stocké *	H Carbone stocké Gg de C
			C = A x B		$E = CxDx10^{-6}$		H = E x G
Lubrifiants + Bitume	173	41868	$7.2\ 10^{6}$	20.0	145	0.50	72.5

* *Source : Méthodologie IPCC/OCDE, Vol. 2, tableau 1-3, page 1.9*

ENERGIE — Feuille de calcul 1-4 A

MINES DE CHARBON : émissions de CH_4 — CH_4

Activité minière		A Quantité de charbon produite millions t	B Facteur d'émission moyen* m^3 de CH_4/t	C Emission de méthane millions m^3	D Facteur de conversion * Gg de $CH_4/10^6m^3$	E Masse de gaz émis **Gg de CH_4**
				C = A x B		E= C x D
Mine souterraine (Anthracite)	Pendant l'extraction	0.526	18	9.5	0.67	6.3
	Après l'extraction	0.526	2.4	1.3	0.67	0.8
					TOTAL	**7.1**

* Source : Méthodologie IPCC / OCDE, Vol. 2, tableau 1-7, page 1.21.

ENERGIE **Feuille de calcul 1-5 A**

PRODUCTION ET RAFFINAGE DU PETROLE : émissions de CH_4

PRODUCTION DE GAZ NATUREL : émissions de CH_4

	A Activité PJ	B Facteur d'émission * kg de CH_4/PJ	Masse de gaz émis C kg de CH_4	D Gg de CH_4
PETROLE			C = A x B	
Production	0.6	2650	1590	0.002
Raffinage	240	745	178 800	0.179
			Total Pétrole	**0.181**
GAZ NATUREL				
Production	1.8	68 000	122 400	0.122
Traitement, transport et distribution	1.8	228 500	411 300	0.411
			Total Gaz naturel	**0.533**
			Total Général	**0.714**

* *Source : Méthodologie IPCC/OCDE, Vol. 2, Valeurs moyennes Table 1.8, page 1.26.*

ENERGIE — Feuille de calcul 1-3 A

BIOMASSE-ENERGIE : émissions de CH_4

	A Consommation totale de biomasse kt de ms	B Fraction de la biomasse qui s'oxyde (efficacité de la combustion)*	C Quantité de biomasse oxydée kt de ms	D Fraction de carbone de la biomasse *	E Quantité totale de carbone émise par combustion de la biomasse kt de C	F Fraction de carbone émis sous forme de CH_4 *	G Carbone émis sous forme de CH_4 kt de C	H Masse de gaz émis Gg de CH_4
			C = A x B		E = C x D		G = E x F	H=Gx16/12
Bois de feu et broussailles (combustion directe)	7370	0.87	6412	0.45	2885	0.01	28.9	38.5
Bois pour la production de charbon de bois	1330	0.30	399	0.45	180	0.063	11.3	15.1
Charbon de bois	240	0.88	211	0.87	184	0.0014	0.26	0.35
				TOTAL	3249	-	40.5	54

* *Source : Méthodologie IPCC/OCDE, Vol. 2, Tableaux 1-5, 1-6, pages*

ENERGIE — Feuilles de calcul 1-3 B et C

BIOMASSE-ENERGIE : émissions de CO, N_2O, NO_x

	I Carbone émis sous forme de CO kt de C	J CO émis Gg de CO	K Quantité totale d'azote émise kt de N	L Azote émis sous forme de N_2O kt de N	M N_2O émis Gg de N_2O	N Azote émis sous forme de NOx kt de N	O NO_x émis Gg de NOx
	I=Ex0.06*	J=I x28/12	K= E x0.01*	L=K x0.007*	M=L x44/28	N=Kx0.121*	O=Nx 30/14
Bois de feu et broussailles (combustion directe)	173	403.7	28.85	0.20	0.31	3.49	7.48
Bois pour production de charbon de bois	10.8	25.2	1.80	0.013	0.02	0.22	0.47
Charbon de bois	11.0	25.7	1.84	0.013	0.02	0.22	0.47
	TOTAL	454.6	32.5	TOTAL	0.35	TOTAL	8.42

* *Source : Méthodologie IPCC/OCDE, Vol. 2, tableau 1-6 page 1-17.*

0.06 : fraction de C émis sous forme de CO

0.01 : rapport de combustibles azote-carbone

0.007 : fraction de N émis sous forme de N_2O

0.121 : fraction de N émis sous forme de NO_x

FORETS — Feuilles de calcul 5-1 A, B et C

Emissions de CO_2 par combustion de la biomasse sur et hors site — CO_2

	A Superficie éclaircie chaque année kha	B Biomasse avant l'éclaircissement t de ms/ha	C Biomasse après l'éclaircissement t de ms/ha	D Changement net dans la biomasse t de ms/ha	E Perte annuelle de biomasse kt de ms	F Quantité de biomasse oxydée kt de ms	G Quantité de carbone émis sous forme de CO_2 (à partir de la biomasse incinérée) kt de C	H Masse de gaz émis Gg de CO_2
				D=B-C	E=AxD	F=Ex0.9*	G=Fx0.45*	H=Gx44/12
Prélèvements abusifs de bois	25	30	10	20	500	450	202.5	742.5
Défrichements	6	30	10	20	120	108	48.6	178.2
Occupation des sols	1	30	0	30	30	27	12.1	44.4
Incendies de forêts **	2.7	30	10	20	54	48.6	21.8	79.9
						TOTAL	285	1045

** Source : Méthodologie IPCC/OCDE, volume 2, page 5.9.*
0.9 : efficacité de la combustion
0.45 : fraction de carbone de la biomasse
*** seuls les "Incendies de forêts" correspondent à une combustion sur site*

FORETS — Feuille de calcul 5-1 E

DEFRICHEMENTS : émissions de CO_2 à long terme des sols — CO_2

A Superficie moyenne des forêts éclaircies (moyenne sur 25 ans) kha	B Teneur en carbone des sols sur les terres défrichées t/ha	C Perte annuelle potentielle totale de carbone des sols kt de C	D Fraction de carbone émis	E Quantité de carbone émis sous forme de CO_2 kt de C	F Masse de gaz émis Gg de CO_2
		C=AxB		E=CxD	F=Ex44/12
6	120	720	0.5	360	1320

Source : Méthodologie IPCC/OCDE, Vol. 2, pages 5.11 et 5.12.

FORETS	Feuille de calcul 5-1 F
TOTAL DES EMISSIONS DE CO_2	CO_2
	Masse de gaz émis **Gg de CO_2**
Combustion de biomasse sur et hors site	1045
Défrichements (émissions à long terme)	1320
TOTAL	**2365**

FORETS — **Feuille de calcul 5-2 A**

INCENDIES DE FORETS : émissions de CH_4, CO, N_2O, NOx

A Carbone émis kt de C	B Rapport (N/C) *	C Total d'azote émis kt de N		D Fraction de C ou de N émis sous forme de gaz **	E Quantité de C ou N émis sous forme de gaz kt de C	F Facteurs de conversion	G Masses de gaz émis **Gg de CH_4,CO**
					E=AxD		G=ExF
21.8	-	-	**CH_4**	0.01	0.22	16/12	**0.29**
21.8	-	-	**CO**	0.06	1.31	28/12	**3.05**
					kt de N		**Gg de N_2O,NO_x**
		C=AxB			E=CxD		G=ExF
21.8	0.01	0.22	**N_2O**	0.007	0.001	44/28	**0.0016**
21.8	0.01	0.22	**NO_x**	0.121	0.026	30/14	**0.06**

** Source : Méthodologie IPCC/OCDE, volume 2*
** Page 5-13*
*** Tableau 5-4, page 5.14.*

FORETS				Feuille de calcul 5-5 A
Forêts exploitées				**Bilan des captages et des émissions de carbone**
Forêt marocaine	A Superficie totale kha	B Taux de croissance annuel kt de ms/kha	C Augmentation annuelle de la biomasse kt de ms	D Augmentation totale du carbone par an kt de C
			C = A x B	D = C x 0.45
1990	4682.4	0.6	2809.4	**1264.3**
2010	4020	0.6	2412	**1085.4**

0.45 = teneur en carbone de la matière sèche

FORETS						Feuilles de calcul 5-5 B et C
Forêts exploitées						**Bilan des captages et des émissions de CO_2**
	E Bois récolté** km^3	F Biomasse totale récoltée * kt de ms	G Bois ramassé lors de l'éclaircissement des forêts kt de ms	H Consommation totale de biomasse dans les forêts exploitées kt de ms	I Emission annuelle de carbone kt de C	J Emissions ou suppressions annuelles réelles de CO_2 Gg de CO_2
		F = E x0.5	à partir de la colonne E de A4-7	H = F - G	I = H x 0.45	J = (D-I)44/12
1990	11617	5808.5	650	5158.5	**2321.3**	- 3876
2010	16263	8131.5	910	7221.5	**3249.6**	-7936

* 0.5 : facteur d'expansion de la biomasse en t de ms/m^3

Source : Méthodologie IPCC/OCDE, vol.2, page 5.25

** Bois total récolté : 11617 km^3 = 10000 km^3 de bois de feu + 1617 km^3 de bois rond

AGRICULTURE — Feuille de calcul 5-3 A

CHANGEMENT D'EXPLOITATION DES SOLS — CO_2

	A Surface totale des prairies converties en zones de culture sur 25 ans kha	B Teneur en carbone des sols des prairies * t de C/ha	C Taux annuel d'émission de carbone à partir des sols *	D Carbone émis sous forme de CO_2 kt de C	E Masse de gaz émis Gg de CO_2
Année				D = AxBxC	E = Dx44/12
1990	1600	70	0.02	2240	**8213**
2010	2420	70	0.02	3388	**12423**

* *Source : Méthodologie IPCC/OCDE, Vol. 2, page 5-15.*

AGRICULTURE — N_2O

ENGRAIS CHIMIQUES : émissions de N_2O

	A Consommation d'engrais kt/an	B Proportion d'engrais azotés	C Proportion d'azote *	D Quantité d'azote kt de N	E Azote émis sous forme de N_2O kt de N	F Masse de gaz émis Gg de N_2O
Année				D = AxBxC	E = Dx0.0012*	F = Ex44/28
1990	740	0.45	0.3	100	0.120	**0.19**
2010	940	0.45	0.3	126.9	0.152	**0.24**

* *0.0012 : fraction d'azote émis sous forme de N_2O*
Source : Colloque de Bamako (1992, ENDA-TM et CRES)

AGRICULTURE — Feuille de calcul 4-1 A

ELEVAGE : émissions de méthane — CH_4

	A Nombre d'animaux ** 1000	B Facteur d'émission de la fermentation entérique* kg de CH_4/tête/an	C Emissions de la fermentation entérique Mg de CH_4	D Facteur d'émission pour le fumier * kg de CH_4/tête/an	E Emissions du fumier Mg de CH_4	F Masse de gaz émis **Gg de CH_4**
			C=AxB		E=AxD	F=(C+E)10⁻³
Bovins	3350	35	117250	1	3350	120.6
Ovins	13500	5	67500	0.16	2160	69.7
Caprins	5300	5	26500	0.17	901	27.4
Anes et Mulets	1435	10	14350	0.9	1292	15.6
Chameaux	34	46	1564	1.9	65	1.6
Chevaux	194	18	3492	1.6	310	3.8
Volaille	100000	-	-	0.018	1800	1.8
		TOTAUX	230656	-	9878	**241**

** Source : Méthodologie IPCC/OCDE, Vol. 2, tableaux 4-2 et 4-3, pages 4.6 et 4.8.*
*** Source : Annuaire statistique du Maroc 1993 (chiffres de 1990)*

AGRICULTURE — Feuille de calcul 4-2 A

RIZICULTURE : émissions de méthane — CH_4

Régime de gestion des eaux	A Surface cultivée Mha	B Durée de la saison * jours	C Mégahectares -jours Mha-jours	D Facteur d'émission * kg de CH_4/ha-jour	E Masse de gaz émis **Gg de CH_4**
			C=AxB		E=CxD
Inondation constante	0.006	138	0.828	3.48	**2.88**

** Source : Méthodologie IPCC/OCDE, Vol. 2, tableau 4-6, page 4.14.*

INDUSTRIE **Feuille de calcul 2-1**

PRODUCTION DE CIMENT : émissions de CO_2

Année	A Quantité de ciment produite kt	B Facteur d'émission * kt de CO_2/kt de ciment produite	C Masse de gaz émis **Gg de CO_2**
			C = A x B
1990	5381	0.498	**2680**
2010	12042	0.498	**5997**

* *Source : Méthodologie IPCC/OCDE*

DECHETS — Feuille de calcul 6-1 I

DECHARGES : émissions de méthane — CH_4

Année	A Population urbaine 10^6 pers	B Quantité de déchets générée Gg de DSM	C Déchets solides municipaux mis en décharge Gg de DSM	D Quantité annuelle de COD mis en décharge Gg de COD	E Quantité annuelle de carbone émis sous forme de biogaz Gg de C	F Carbone émis sous forme de CH_4 Gg de C	G Masse de gaz émis **Gg de CH_4**
		B=Ax219*	C=Bx0.8 *	D=Cx0.15**	E=Dx0.67*	F=Ex0.5**	G=Fx16/12
1990	11.73	2569	2055	308	206	103	**138**
2010	20.00	4380	3504	526	352	176	**235**

COD : carbone organique dégradable DSM : déchets solides municipaux

* 219 Gg de DSM/10^6 personnes/an = taux de génération de déchets. Cette valeur correspond à 0.6 kg de déchets solides produits par personne et par jour en milieu urbain.
0.8 : *fraction mise en décharge*
0.67 : fraction de COD qui se dégrade réellement
Source : Direction de l'eau et de l'assainissement, (DEA) , Ministère de l'Intérieur et de l'Information, Rabat.

** 0.15 : fraction de COD en Gg de COD/Gg de DSM (tableau 6-1, page 6.5)
0.5 : fraction de CH_4 dans le biogaz (page 6.7).
Source : Méthodologie IPCC/OCDE, volume 2.

DECHETS — Feuille de calcul 6-2 I

EAUX USEES MUNICIPALES : émissions de méthane — CH_4

Années	A Population urbaine 1000 pers.	B Taux de génération de DBO Gg de DBO_5/ 1000personnes/an*	C DBO générée Gg de DBO_5	D Quantité de DBO traitée en anaérobiose Gg de DBO_5	E Masse de gaz émis **Gg de CH_4**
			C = A x B	D= C x 0.1*	E = D x 0.22*
1990	11730	0.0135	158	16	**3.5**
2010	20000	0.0135	270	27	**5.9**

DBO : demande biologique d'oxygène
* 0.10 : fraction d'eaux usées traitée en anaérobiose (tableau 6-4, page 6.10)
0.22 Gg de CH_4/Gg de DBO_5 : facteur d'émission de méthane (page 6.11).
Source : Méthodologie IPCC/OCDE, volume 2.

DECHETS — Feuilles de calcul 6-3 A et B

EAUX USEES INDUSTRIELLES : émissions de méthane

		A Décharge annuelle d'eaux usées m^3 *	B Taux de concentration de la DBO Gg/m^3 *	C DBO totale générée * Gg de DBO	D Quantité de DBO traitée en anaérobiose Gg de DBO	E Masse de gaz émis **Gg de CH_4**
				C = A x B	D = C x 0.1**	E = D x 0.22**
INDUSTRIES ALIMENTAIRES	Sucreries et raffineries de sucre	$6.6\ 10^6$	$0.96\ 10^{-6}$	6.4	0.64	0.14
	Conserves fruits et légumes	$3.5\ 10^6$	$0.97\ 10^{-6}$	3.4	0.34	0.07
	Produits laitiers	$1.5\ 10^6$	$1.13\ 10^{-6}$	1.7	0.17	0.04
	Corps gras d'origine végétale	$1.4\ 10^6$	$19.0\ 10^{-6}$	26.6	2.66	0.59
	Conserves de poisson	$2.0\ 10^6$	$0.5\ 10^{-6}$	1.0	0.10	0.02
Boissons et tabacs		$2.0\ 10^6$	$0.85\ 10^{-6}$	1.7	0.17	0.04
Produits textiles et bonneterie		$8.6\ 10^6$	$1.74\ 10^{-6}$	15.0	1.50	0.33
Cuir, articles et chaussures en cuir		$1.4\ 10^6$	$0.36\ 10^{-6}$	0.5	0.05	0.01
Papier et carton-imprimerie		$7.0\ 10^6$	$0.23\ 10^{-6}$	1.6	0.16	0.03
					TOTAL	**1.27**

DBO : demande biologique d'oxygène

* *Source : Situation des rejets industriels - rapport du M.C.I.- Août 1994.*

** 0.10 : fraction d'eaux usées traitée en anaérobiose (tableau 6-4, page 6.10)

0.22 Gg de CH_4/Gg de DBO_5 : facteur d'émission de méthane (page 6.11)

Source : Méthodologie IPCC/OCDE, volume 2.

ANNEXE 5

Commentaires par secteur sur la Méthodologie IPCC/OCDE (version 1994)

ANNEXE 5

Commentaires par secteur sur la Méthodologie IPCC/OCDE (version 1994)

1. Energie

Les colonnes indiquées ci-après sont celles des tableaux de l'annexe 4 qui ne coincident pas toujours avec celles des feuilles de calcul de la Méthodologie.

Feuille de calcul 1-1A (annexe A4-1)

. Le calcul proposé par la Méthodologie ne fait intervenir pour les produits pétroliers issus du raffinage du pétrole brut que les quantités importées, exportées, et les mouvements de stock (colonnes B, C, D). La majeure partie des émissions de CO_2 est donc calculée à partir du pétrole brut (avec un facteur d'émission de 20 kg de C/GJ) alors qu'en fait, ce sont les produits pétroliers autres que le brut qui, en s'oxydant, émettent du CO_2, avec des facteurs d'émission différents de celui du pétrole brut.
Il serait plus réaliste de donner, dans la colonne E "consommation apparente", les produits pétroliers issus des raffineries en ne laissant sur la première ligne que la quantité de pétrole brut perdue pendant le raffinage.

. L'ordre adopté pour les produits pétroliers est celui de l'Annuaire Statistique du Maroc, pour éviter les erreurs ; cet ordre est différent de celui de la Méthodologie.

. Nous avons modifié les entrées pour les combustibles fossiles solides afin de les adapter aux données marocaines.

. Il y a une imprécision en ce qui concerne les soutes.
Faut-il porter uniquement les soutes internationales ?
Faut-il faire intervenir soutes maritimes et aériennes ?
Dans les soutes nationales, faut-il inclure les bateaux de pêche ?
La Méthodologie n'apporte pas de réponse à ces questions.

Feuille de calcul 1.1B (annexe A4-2)

. On peut faire l'économie d'une colonne en calculant directement le carbone en Gg.

. Le titre des colonnes I et J a été modifié :
"Emission potentielle de carbone" au lieu de "Fraction de carbone".

. Les facteurs de conversion (GJ/10^3 t) de la colonne F n'existent pas pour tous les combustibles dans la Méthodologie. Aussi avons-nous refait un tableau donnant ces facteurs pour tous les combustibles fossiles et pour la biomasse en GJ/kt et en ktep/kt (annexe A 3-1). Les valeurs données pour le charbon, le gaz naturel, le bois de feu et le charbon de bois, sont celles utilisées au Maroc.

. Colonne H : facteurs d'émission en kg de C/GJ
Les valeurs retenues sont celles du tableau 1-3, p 1-8 de la Méthodologie.

Feuille de calcul 1-1C (annexe A4-3)

. Les titres des colonnes M et N ont été modifiés :
M : "Carbone émis sous forme de CO_2" au lieu de "Emission réelle de carbone"
N : "Masse de gaz émis" au lieu de "Emission réelle de CO_2".

. Du fait que la fraction de carbone oxydé est la même pour chaque catégorie de combustibles, les calculs ont été réalisés sur les totaux seulement, dans un but de simplification.

Feuille de calcul auxiliaire 1-1A (annexe A4-4)

. Les produits pétroliers à usage non énergétique, produits et utilisés dans le pays, sont les graisses, les lubrifiants et les bitumes. La quantité totale consommée en 1990 est estimée à 173 ktep.

. La colonne E a été supprimée et le calcul fait directement en Gg.

. Le titre de la colonne F (devenue E) a été modifié :
"Emission potentielle de carbone" au lieu de "Fraction de carbone".

Feuille de calcul 1-3A (annexe A 4-6)

. Titres des colonnes C, E, F, H modifiés :
C : "Quantité de biomasse oxydée" au lieu de "Combustion de la biomasse"
E : "Quantité totale de carbone émise par combustion de la biomasse" au lieu de "Quantité totale de carbone émise par les combustibles de la biomasse"
F : "Fraction de carbone émis sous forme de CH_4" au lieu de "Rapport CH_4-C".
H : "Masse de gaz émis" au lieu de "Emissions de CH_4 générées par combustion de la biomasse".

. Le libellé des lignes a été modifié également :
"Bois de feu (combustion directe)" au lieu de "Bois de feu"
"Bois pour la production de charbon de bois" au lieu de "Production de charbon de bois".
"Charbon de bois" au lieu de "Consommation de charbon de bois".
En effet, il s'agit ici de quantités consommées et non de l'activité concernée.

. Colonne B : Fraction de la biomasse qui s'oxyde
Valeurs du tableau 1-5 page 1-16 de la Méthodologie.

. Colonne D : Fraction de carbone de la biomasse
Valeurs du tableau 1-5, page 1-16.

. Colonne F :
Valeurs du tableau 1-6, page 1-17.

Feuilles de calcul 1-3 B et 1-3C (annexe A4-6)

Ces deux feuilles de calcul ont été compactées en un seul tableau, du fait que les coefficients des colonnes I, L, N, Q étaient identiques pour toutes les lignes.
Les noms de ces coefficients ont été modifiés :
"Fraction de C émis sous forme de CO" au lieu de "Rapport d'émission de gaz trace CO-C";
Même chose pour N_2O et NO_x.
Les valeurs de ces coefficients proviennent du tableau 1-6 page 1-17.

Remarques sur le calcul de la quantité totale de carbone émise par combustion de la biomasse-énergie.

Ce calcul est fait deux fois : en bas des feuilles de calcul 1-1 A, B, C et dans la feuille de calcul 1-3A, par deux méthodes différentes.

Feuilles de calcul 1-1 A, B, C :

Quantité totale de carbone émis par combustion de biomasse = Q = quantité de biomasse consommée Q_1 (en GJ) x facteur d'émission (25.8) x fraction de carbone oxydée (0.9).

Feuille de calcul 1-3 A :

Quantité totale de carbone émis par combustion de la biomasse = Q = quantité de biomasse consommée Q'_1 (en kt de matière sèche) x efficacité de la combustion x fraction de carbone de la biomasse (0.45 pour le bois et 0.87 pour charbon de bois).

Quantité de biomasse consommée :
Dans le premier calcul (feuille 1-1A), il semble qu'il s'agit de matière humide alors que dans le second, il s'agit de matière sèche.

Dans le premier calcul, il semble que ne doivent figurer que les combustibles primaires (ici le bois) comme pour les combustibles fossiles, alors que dans le second calcul figure aussi le charbon de bois (combustible secondaire).
Logiquement, on devrait trouver le même résultat à la fin des calculs. Ceci se vérifie à condition de prendre la matière humide des deux côtés.
Il serait bon d'homogénéiser ces deux méthodes de calcul en précisant bien les entrées, ainsi que les coefficients utilisés (la fraction de carbone oxydée est-elle différente de l'efficacité de la combustion ?).

Feuille de calcul 1-4 A (annexe A4-4)

Il existe une seule mine de charbon au Maroc, celle de Jerada : elle est souterraine et produit de l'anthracite.
Les facteurs d'émission sont des valeurs moyennes des données du tableau 1-7.
Le facteur de conversion (Gg de $CH_4/10^6m^3$) est également la valeur par défaut de la Méthodologie.

Feuille de calcul 1-5A (annexe A4-5)

Colonne B : Fractions d'émission
Ce sont les valeurs moyennes des fourchettes de valeurs du tableau 1-8 page 1-26, dans la colonne "Reste du monde".

2. Forêt

Les colonnes indiquées ci-dessous sont celles des tableaux des annexes A4-7, A4-8, A4-9.

Feuilles de calcul 5-1 A, B, C (annexe A 4-7)

Les 3 feuilles de calcul de la Méthodologie ont été compactées en une seule car nous avons traité simultanément la combustion sur site (incendies de forêts) et la combustion hors site qui correspond, pour le Maroc, aux rubriques : prélèvements abusifs de bois, défrichements, occupation des sols.
Comme nous ne disposons pas d'informations détaillées sur les superficies éclaircies chaque année par type de forêts, nous avons modifié le libellé des lignes des feuilles de calcul en fonction des données disponibles sur la déforestation au Maroc : les surfaces déboisées chaque année par prélèvements abusifs de bois, défrichements, occupation des sols, incendies de forêts.

. Colonne B
La valeur de la biomasse avant éclaircissement a été prise égale à 30 t de matière sèche/ha (donnée présentée au chapitre 5-1 de ce rapport).

. Colonne C
Biomasse après éclaircissement = 10 t de m s/ha. C'est une valeur par défaut proposée par la Méthodologie (volume 2, page 5-7). Pour la rubrique "occupation des sols", ce paramètre est nul.

. Colonne F
Efficacité de la combustion = 0.9 (Méthodologie vol.2, page 5.9).

. Colonne G
Fraction de carbone de la biomasse = 0.45 (Méthodologie, vol 2, page 5.9).

Feuille de calcul 5-1D

Cette feuille de calcul n'a pas été utilisée car il n'y a pratiquement pas de décomposition de la biomasse, le sous-bois étant parfaitement propre au Maroc à cause du surpâturage et des prélèvements de broussailles.

Feuille de calcul 5-1E (annexe A4-7)

Ne disposant pas de données sur les défrichements par type de forêt, le calcul a été effectué pour la totalité de la surface défrichée pendant l'année.

. Colonne F
Contrairement à la feuille de calcul 5-1E où l'on ne calcule que la quantité de carbone émis sous forme de CO_2, nous avons ajouté cette colonne F pour en déduire la masse de CO_2 émis.

. Colonnes B et D
Teneur moyenne du sol en carbone = 120 t/ha
Fraction de carbone émis = 0.5.
Ces valeurs proviennent de la Méthodologie (vol 2, pages 5.11 et 5.12).

Feuille de calcul 5-1F (annexe 4-8)

Au lieu de sommer la quantité de carbone, c'est la masse de CO_2 émis par combustion de la biomasse sur et hors site et par les émissions à long terme des défrichements qui est calculée.

Feuille de calcul 5-2A (annexe 4-8)

La feuille de calcul a été utilisée telle que proposée dans la Méthodologie. Seuls ont été modifiés les libellés des titres des colonnes D, E et G.

Les coefficients retenus sont ceux de la Méthodologie (vol II, page 5-13 et tableau 5-4, page 5.14).

L'expression "gaz de trace" (colonnes D et E) ne nous semble pas çorrecte du point de vue langue. On peut parler de "traces de gaz" mais non de "gaz de trace"!!.

Feuilles de calcul 5-5A, B et C (annexe 4-9)

- Sur la feuille de calcul 5-5A l'estimation est faite pour la forêt marocaine de façon globale.
Nous n'avons pas pu disposer de donées par type de forêt.

. Colonne A (feuille 5-5A)
Il s'agit là de l'estimation globale de la superficie des forêts gérées (KHATTABI, 1993).

. Colonne B
Le taux de croissance retenu, 0.6 t de ms/ha, est celui estimé partir des données statistiques (cf chapitre 5.1).

. Colonne D
La teneur en carbone de la matière est prise égale à 0.45 (valeur par défaut, IPCC/OCDE, volume 2, page 5-24).

. Colonne F (feuille 5-5B) - colonne E en annexe 4-9
La récolte commerciale considérée ici regroupe : le bois de feu (10 000 km^3) et le bois utilisé pour d'autres usages, estimé par KHATTABI (1993) à 1 617 km^3.

. Colonne G
Le facteur d'expansion de la biomasse utilisé est de 0.45 (valeur par défaut de la Méthodologie, volume 2, p.5-25).

. Colonne I
Quantité de biomasse exposée à une combustion hors site prise égale à 650 kt de ms ; ce chiffre a été déduit de la colonne E de l'annexe 4-7.

En conclusion, on constate que les données disponibles sur la forêt marocaine sont très globales et limitées alors que celles demandées par la Méthodologie sont très détaillées.
Il a été fait appel pour tous les calculs aux paramètres "par défaut" de la Méthodologie. Mais l'on peut se demander jusqu'à quel point ces paramètres sont fiables et adaptés au Maroc.

3. Agriculture

Feuille de calcul 5-3A (annexe A4-10)

Cette feuille de calcul 5-3A était incluse dans le module "Forêts et changement d'exploitation des sols" dans le volume 2 de la Méthodologie. Nous avons préféré l'inclure dans "Agriculture" puisque, dans le cas du Maroc, les superficies concernées sont calculées à partir de l'évolution de la SAU (surface agricole utile) : 1600 kha de surface de prairies converties en zones de cultures sur les 25 ans précédant 1990 et 2420 kha pour 2010 (colonne A).

. Colonne B
Teneur en carbone des sols des prairies : 70 t de C/ha (valeur par défaut, Méthodologie, Vol 2, page 5-15).

. Colonne C
Taux annuel d'émission de carbone généré par les sols : 0.02 (valeur par défaut, Méthodologie, vol 2, page 5.15).

Feuille de calcul 4-1A (annexe A4-11)
Elevage

. Dans la feuille de calcul 4-1A, les chevaux sont regroupés avec les mulets alors que dans le tableau 4-2 (page 4.6 du vol. 2 de la Méthodologie) les mulets sont regroupés avec les ânes car ils ont le même facteur d'émission alors que le facteur d'émission des chevaux est très différent.
Dans le tableau de l'annexe A4-11, nous avons donc modifié la classification des animaux en fonction des facteurs d'émission.
Nous avons également modifié le libellé des titres des lignes :
bovins au lieu de vaches
ovins au lieu de moutons
caprins au lieu de chèvres.

. Facteurs d'émission de méthane
Valeurs par défaut de la Méthodologie (vol 2, tableau 4-2, page 4.6 et 4-5, page 4.8).

Feuille de calcul 4-2A (annexe A4-11)
Riziculture

Régime de gestion des eaux : inondation constante
Durée de la saison : 138 jours
Facteur d'émission : 3.48 kg de CH_4/ha-jour.
Ces données sont des valeurs par défaut de la Méthodologie (vol.2, tableau 4-6, page 4.14).
Pour le facteur d'émission, nous avons considéré une température moyenne de 18°C car la zone où se fait la riziculture se trouve au nord du Maroc.

Annexe A4-10
Engrais chimiques

La Méthodologie IPCC/OCDE ne propose pas de feuille de calcul des émissions de N_2O dues à l'utilisation des engrais chimiques, dans le volume2. Cependant, dans les tableaux récapitulatifs du volume 1, le module III D (Agriculture ; terres agricoles) correspond, malgré son appellation, aux GES émis suite à l'utilisation des engrais azotés.
Nous avons donc fait le calcul du N_2O émis à partir de la méthode proposée par le colloque de Bamako (1992, ENDA-TM et CRES).

Colonne B
Les quantités totales d'engrais consommés au Maroc se répartissent à raison de 45 % pour l'azote, 40 % pour le phosphate et 15 % pour le potassium (source : FERTIMA 1994).

Colonne C
La proportion d'azote fluctue entre 15 et 82 % avec une moyenne de 30%, adoptée pour le calcul (source : colloque de Bamako, 1992).

Colonne E
Fraction d'azote émis sous forme de N_2O = 0.0012 ; c'est la moyenne des valeurs extrêmes de la fourchette de variation : 0.03 % et 1.63 % (colloque de Bamako, 1992).

En conclusion, nous avons été amenés dans la majorité des cas à adopter les valeurs par défaut de la Méthodologie IPCC/OCDE, par manque de valeurs spécifiques au Maroc, surtout pour les facteurs d'émission des GES.

Par ailleurs, lorsque l'on entreprend de réaliser des projections à l'an 2010, on se heurte également au problème du manque de données précises sur l'évolution des différents secteurs étudiés.

4. Procédés industriels

Feuille de calcul 2-1 (annexe A4-12)

Le calcul a été fait à partir de la quantité de ciment produit pendant l'année et non à partir du clinker.
Le facteur d'émission utilisé alors est de 0.498 kt de CO_2/kt de ciment produit.

On a supprimé la colonne C de la feuille de calcul 2-1 de la Méthodologie; en travaillant directement sur des kilotonnes de ciment, on obtient alors des gigagrammes de CO_2 et non des tonnes qu'il faut ensuite convertir en Gg.

5. Déchets

Les feuilles de calcul de la Méthodologie ont été modifiées en supprimant les colonnes correspondant aux coefficents.

Feuilles de calcul 6-1 1 et supplémentaire (annexe A4-13)

Ces deux feuilles ont été compactées en une seule en en supprimant les colonnes B, D, F, H, I, et J (il n'y a pas de récupération de méthane au Maroc).

La quantité de déchets solides municipaux mis en décharge est obtenue à partir de la population urbaine et du taux de génération de déchets.

Le taux de génération de déchets solides (0.6 kg de déchets solides produits par personne et par jour, en milieu urbain soit 219 Gg de déchets solides municipaux par an et par millions de personnes) a été fourni par la Direction de l 'eau et de l'assainissement, au Ministère de l'Intérieur et de l'Information.
La fraction mise en décharge (0.8) et la fraction de carbone organique qui se dégrade réellement (0.67) proviennent de la même source (DEA, MII).
La fraction de carbone organique dégradable (0.15) et la fraction de CH_4 dans le biogaz (0.5) ont été pris dans la Méthodologie (volume 2, pages 6.5 et 6.7).

Les calculs ont été effectués pour 1990 et 2010.

Feuille de calcul 6.2.1. (annexe A4-13)

Les colonnes H et I ont été supprimées car il n'y a pas de récupération de méthane au Maroc.
Le calcul de la DBO a été réalisé à partir de la population urbaine.
Remarquons que BOD en anglais devient DBO en français, nous avons donc corrigé les feuilles de calcul.

Les colonnes D et F ont été également supprimées car elles contiennent un simple coefficient.
Le taux de génération de DBO (0.0135) a été pris dans le volume 2 de la Méthodologie (tableau 6-3, page 6.10).
La fraction traitée en anaérobiose (0.10) dans le tableau 6-4, page 6.10 et le facteur d'émission de méthane à la page 6.11.

Les calculs ont été faits pour 1990 et 2010.

Remarque : dans la colonne D de la feuille de calcul 6-21 (page 6.17), la fraction traitée en anaérobiose est donnée en Gg de BOD_5 alors que c'est un nombre sans dimension et donc sans unité.

Feuilles de calcul 6-3 A et B (annexe A4-14)

Les feuilles de calcul 6-3 A et B ont été regroupées en une seule ; les colonnes H et I supprimées car il n'y a pas de récupération de méthane au Maroc.
Nous avons également supprimé les colonnes D et F qui contiennent un simple coefficient.
Les unités des colonnes A et B ont été modifiées :
colonne A : m^3 au lieu de Mlitres
colonne B : Gg/m^3 au lieu de kg/litre.

En fait, nous disposons directement des données de la colonne C, mais nous avons calculé le taux de concentration de la DBO (colonne B) à des fins de comparaison avec les valeurs par défaut de la Méthodologie (volume 2, tableau 6-6, page 6.13).
La fraction traitée en anaérobiose et le facteur d'émission de méthane sont les valeurs déjà utilisées pour les eaux usées municipales.

ANNEXE 6

Base de données GES

ANNEXE 6

• Entrées de la base de données GES

Energie

Produits pétroliers (Production, Importation, Exportation et Mouvement de stock) (Kt)
- Pétrole brut - GPL - Pétrole lampant - Essences - Gasoil - Fuel-oil - ATK[1] - Naphta - Paraffine - Huiles de base - Graisses et lubrifiants - Bitumes - White spirit

Charbon (Production, Importation, Exportation et Mouvement de stock) (kt)
- Charbon vapeur - Coke - Anthracite

Gaz naturel (Production, Importation, Exportation et Mouvement de stock) (10^3m^3)
- Gaz naturel

Biomasse-énergie (Production, Importation, Exportation et Mouvement de stock) (kt)
- Bois de broussaille: combustion directe - Bois pour produire du charbon de bois - Charbon de bois - Résidus Agricoles

Electricité (Production) (GWh)
- Thermique - Hydraulique - D'importation - Eolienne - Solaire

[1]Carburéacteur et essences aviation

Transports

Consommation d'énergie en ktep	Parc véhicule
- Transport routier - Véhicules de tourisme - Motocyclettes - Véhicules utilitaires - Transports publics voyageurs - Transport de marchandises - Transport ferroviaire - Transport maritime - Transport aérien	

Forêts

Forêts
- Productivité moyenne de la forêt (t/ha) - Biomasse moyenne après éclaircissement (t/ha) - Proportion de biomasse incinéré lors d'un incendie (%) - Proportion de biomasse incinéré dans les autres formes de pertes en forêt (%)
- Incendies (ha) - Prélèvements abusif de bois (ha) - Défrichements (ha) - Occupation du domaine (ha) - Reboisement (ha) - Superficie globale de la forêt (ha)

Agriculture

Elevage (milliers d'unités)
- Bovins - Ovins - Caprins - Anes et mulets - Chevaux - Chameaux - Volaille

Riziculture
- Superficie (ha) - Production (Qx)
- durée de cycle (jours)

Evolution de la SAU (Superficie Agricole Utile)
- Surfaces de prairies converties en terres cultivées pendant les 25 années avant l'année de référence (ha)
- Teneur en carbone des sols concerné (kt C /ha)

Engrais
- Consommation annuelle (kt) - Proportion d'engrais azotés dans le total - Proportion moyenne d'azote dans les engrais utilisés

Industrie

Cimenterie
- Production (kt)

Déchets

Décharges
- Quantité de déchets urbains produites (Gg) - Proportion de déchets organique (%) - Proportion de ces déchets qui se retrouvent dans des décharges incontrôlées (%) - Proportion de déchets dégradables (%)

Eaux usées municipales
- Production par habitant (kg/jour) - DBO5
- Population urbaine (million d'habitants)

Eaux Usées industrielles
- Groupe d'industrie
- Quantité annuelle d'eaux usées par groupe (Millions de litres)

Configuration matérielle

Minimum : Processeur 8086, 512 K de mémoire conventionnelle DOS disponible, 1 Moctet d'espace libre sur le disque dur (1 000 000 octets), DOS version 3.1.

Recommandée : Processeur 80386, 2 Moctets de mémoire vive étendue libre (2 000 000 d'octets), 2 Moctets d'espace libre sur le disque dur (2 000 000 d'octets), DOS version 5.0.

Installation du logiciel GES

Pour installer GES, insérer la disquette installation dans le lecteur a: (ou b:). Taper A:INSTALL (ou B:INSTALL) pour lancer l'installation. Le système crée alors un répertoire par défaut (C:\GES) et copie dans celui-ci tous les fichiers de programme et de données. L'installation effectuée, il faut se positionner dans ce répertoire (au moyen de DOS cd) pour pouvoir lancer GES.

Pour installer GES, sous WINDOWS vous devez l'installer au préalable sous DOS. Se placer ensuite sous l'environnement WINDOWS. Sélectionner dans le menu "Fichier" l'option "Nouveau", ensuite "Programme". Une fenêtre est alors affichée dans laquelle il faut remplir les informations suivantes avant de cliquer sur le bouton "OK" :

1. Nom : "GES"

2. Ligne de commande : "GES"

3. Répertoire de travail : "C:\GES"

• Utilisation de GES

Pour lancer le logiciel GES

Sous DOS, placez-vous dans le répertoire dans lequel est installé GES (si GES est installé dans le répertoire C:\GES, vous devez taper cd\GES), puis taper GES.

Sous WINDOWS, sélectionnez l'icône GES et cliquez deux fois avec la souris.

Le programme GES déterminera si votre ordinateur est équipé d'un écran couleur ou d'un écran noir et blanc, et s'adaptera en conséquence. Ensuite il vous demandera le mot de passe, ce mot de passe à l'installation est "GES", vous pouvez le modifier à votre guise en appelant le menu "système" et en sélectionnant l'option "changement de mot de passe".

Utilisation du clavier

Avant de sélectionner une option quelconque dans GES, il faut d'abord que le curseur soit positionné de manière à mettre en évidence l'élément voulu sur l'écran. Utilisez les touches de déplacement droite, pour vous déplacer à droite, et gauche, pour vous déplacer à gauche.

Pour activer une option quelconque, après que celle-ci ait été mise en évidence, appuyer sur la touche "ENTREE".

Durant la saisie des données les touches accessibles sont :

. "ENTREE", "Pg Up" et "Pg Down" pour confirmer la rentré des données.

. "ESC" pour annuler les modifications.

Menu principal

Le menu principal de GES indique la structure du programme. Chaque élément mentionné dans la barre de menu en haut de l'écran donne accès à une zone différente du programme. La sélection de chacun des éléments du menu donne accès à un sous-menu.

Veuillez noter la ligne d'information dans le bas de l'écran. Cette ligne indique les touches de fonctions disponibles ainsi que l'action qu'engendre leur activation.

Déplacement d'un élément à l'autre du menu

Lorsque tous les éléments du menu sont désactivés, vous pouvez vous déplacer d'un élément de menu à l'autre au moyen des touches de curseur "Flèche droite" ou "Flèche gauche" du clavier. Pour ouvrir une option de menu et faire apparaître le sous-menu, vous devez appuyer sur la touche "ENTREE". Pour refermer le sous-menu, appuyer sur la touche "ECHAPPEMENT".

- **Base de données : alimentation en informations et leur source**

Source	**Données**
Ministère de l'Energie et des Mines	. Importation, production et consommation d'énergie . Bilan énergétique national . Projections de production et de consommation
Ministère de l'Agriculture et de la Mise en Valeur Agricole	. S A U . Changements d'affectation des Sols . Déboisements-reboisements . Riziculture . Elevage (cheptel)
Ministère des Transports	. Parc de véhicules par catégorie et par âge . Consommation par type de transport
Ministère de l'Industrie	. Consommation d'énergie par branche, par région . Rejets industriels (G.L.S) . Nombre d'établissements par branche, par région . Production
Ministère des Travaux Publics	. Données sur les eaux . Données météo
Ministère de l'Intérieur	. Données sur les ordures ménagères (urbaines et rurales) . Données sur les eaux usées municipales . Données sur la population

• Dictionnaire de la base de données

Nom du tableau	CHAMPS						
TAB1: Dénomination des éléments énergétique	GROUPE	ORDRE	ELEMENT	ENERGIE	UNITE	FACT_CONV	PUISSANCE
	Groupe d'élément énergétique	Type d'élément énergétique	dénomination	Si l'élément est énergétique	Unité	Facteur de conversion	Puissance
TAB2: Données sur l'énergie	GROUPE	ORDRE	ANNEE	PRODUCTION	IMPORT	EXPORT	STOCK
	Groupe dans TAB2=Groupe dans TAB1	Ordre dans TAB2=Ordre dans TAB1			Importation	Exportation	
TAB3: Mode de transports	NIVEAU	LIAISON	ORDRE	SECTEUR			
	Interne[2]	Interne	Type de transport	Dénomination du type de transport			
TAB4: Consommation d'énergie par secteur d'activité	ORDSECTEUR	ORDELEMENT	GROUPE	ANNEE	CONSOM		
	Secteur d'activité	Ordelement dans TAB4=Ordre dans TAB1	Groupe dans TAB4=Groupe dans TAB1		Consommation d'énergie		
TAB5: Production de ciment	ORDRE		ANNEE		PRODUCTION		
	Interne						
TAB6: Réservé	ORDRE			NOM			
TAB7: Agriculture, élevage	ORDRE			NOM			
	Numéro du cheptel			Race			
TAB8: Agriculture, élevage	ANNEE		ORDRE		QUANTITE		
			Ordre dans TAB8=Ordre dans TAB7		Taille du cheptel		
TAB9: Agriculture, riziculture	ANNEE	CYCLE	SUPERFICIE	PRODUCTION			
		Durée du cycle de la culture du riz dans les conditions locale					
TAB10: Agriculture, évolution de la SAU	ANNEE			SAU			
				Surface Agricole Utile			
TAB11: Agriculture, engrais	ANNEE			CONSOM			
				Consommation			
TAB12: Données sur la forêts	ORDRE			CAUSE			
	Code de la cause			Causes des pertes dans la forêt			

[2]Utilisation interne

Nom du tableau	CHAMPS					
TAB13:	ANNEE		ORDRE		SUPERFICIE	
Pertes annuelles en forêt			Ordre dans TAB13=Ordre dans TAB12			
TAB14:	ANNEE	DECHETS_P	DECHETS_O	INCONTROLE	FRAC_DEGRA	
Déchets urbains produits		Déchets produits	% de déchets organiques	% de déchets qui se retrouvent dans les décharges incontrôlées	Fraction dégradables	
TAB15:	ANNEE		POPU_URB		POPU_RUR	
Eaux usées municipales			Population urbaine		Population rurale	
TAB16:	ORDRE			GROUPE		
Groupes d'industries	Numéro du groupe d'industrie			Groupe d'industrie		
TAB17:	ANNEE		ORDRE		QUANTITE	
Eaux usées industrielles			Ordre dans TAB17=Ordre dans TAB16		Volume d'eau déversé par chaque industrie	
TAB18:	ORDSECTEUR	ORDELEMENT	GROUPE	ANNEE	PARC	CONSOM
Transport	Interne	Ordelement dans TAB18=Ordre dans TAB1	Groupe dans TAB18=Groupe dans TAB1			Consommation par type d carburant
TAB19:	ANNEE	ORIGINE	FUEL_OIL	GASOIL	ATK	
Soutes maritimes et aérienne nationales et internationales		Nationale ou Internationale			Carburéacteur et essences aviation	
TAB20:	ANNEE		ORDRE		QUANTITE	
Production d'électricité et pertes			Interne		Quantité produite	
TAB21:	ANNEE	TENSION	ORDRE	QUANTITE		
Transformation d'énergie électrique par branche d'activité		Interne	Interne	Quantité consommée		
TAB22:	ANNEE		ORDRE		QUANTITE	
Mise en oeuvre et production des raffineries de pétroles			Interne			

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