CARBON-DI-OXIDE EMISSIONS AND THE PROSPECTS OF NON-CONVENTIONAL ENERGY FOR SUSTAINABLE DEVELOPMENT

A dissertation submitted in partial fulfillment of the degree of

Master of Philosophy

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CERTIFICATE

This is to certify that the dissertation entitled "**Carbon-di-oxide Emissions and the Prospects of Non-Conventional Energy for Sustainable Development**" submitted by Madhurima Mitra, in partial fulfillment of the requirements for the award of the degree of Master of Philosophy of this University, is her original work and has not been submitted for the award of any other degree of this University or any other University.

We recommend that this dissertation be placed before the examiners for evaluation.

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LIST OF ABBREVIATIONS

ACCF CPR	:	*American Council for Capital Formation Centre for Policy Research*
APM	:	*Administered Pricing Mechanism*
ASEAN	:	*Association of South East Asian Nations*
BOV	:	*Battery Operated Vehicles*
CASE	:	*Commission for Additional Sources of Energy*
CDM	:	*Clean Development Mechanism*
CNG	:	*Compressed Natural Gas*
CO_2	:	*Carbon-di-oxide*
COP	:	*Conference of Parties*
CPCB	:	*Central Pollution Control Board*
DSS/IPC	:	*Decision Support System for Integrated Pollution Control*
DTC	:	*Delhi Transport Corporation*
GDP	:	*Gross Domestic Product*
GEF	:	*Global Environment Facility*
GHG	:	*Green House Gases*
GW	:	*Gigawatts*
HSD	:	*High Speed Diesel*
IPCC	:	*Intergovernmental Panel on Climate Change*
IREDA	:	*Indian Renewable Energy Development Agency*
Kcal	:	*Kilocalories*
kWh	:	*Kilo Watt Hour*
LDO	:	*Light Diesel Oil*
LSD	:	*Low Sulphur Diesel*
LSHS	:	*Low Sulphur Heavy Stock*
Mha	:	*Million Hectares*
MNES	:	*Ministry of Non-conventional Energy Sources*
MOA	:	*Ministry of Agriculture*

MoEF	:	*Ministry of Environment and Forests*
MREP	:	*Mexico Renewable Energy Programme*
MT	:	*Million Tonnes*
MW	:	*Mega Watts*
NDP	:	*Net Domestic Product*
ODS	:	*Ozone Depleting Substances*
OECD	:	*Organisation for Economic Co-operation and Development*
PAHO	:	*Pan American Health Organisation*
PC	:	*Peta Calories*
R&D	:	*Research and Development*
SEB	:	*State Electricity Board*
SPV	:	*Solar Photovoltaic*
T&D	:	*Transmission and Distribution*
TEDDY	:	*Tata Energy Data Directory and Yearbook*
TERI	:	*Tata Energy Research Institute*
TJ	:	*Tera Joules*
TOE	:	*Tonnes of Oil Equivalent*
UNCED	:	*United Nations Conference on Environment and Development*
UNDP	:	*United Nations Development Programme*
UNEP	:	*United Nations Environment Programme*
UNFCCC	:	*United Nations Framework Convention on Climate Change*
WHO	:	*World Health Organisation*

Chapter 1

INTRODUCTION

1.1 INTRODUCTION

A major problem facing developing countries today is that while energy is necessary for development, it is a major source of environmental degradation. Economic growth necessitates the use of energy, while policies aimed at safeguarding the environment call for limitations on energy use. Expanding the productive base of an economy often implies an increase in energy use, and many developing countries cannot afford the expensive technology required for environmental restoration or efficient use of energy.

The environment is an example of a public good that is overused due to an inability to regulate its use. While developed countries are attempting to introduce ways and means to limit and rationalise environmental use in an efficient way, for most developing countries such efforts are secondary in importance to meeting the basic needs of the population. In terms of priority, economic development comes first, often at the expense of the environment.

Complicating the issue further is the widely held view in the developing world that environmental degradation (especially the thinning of the ozone layer and the climatic warming trend) is a problem precipitated by the developed world. Certainly with regard to carbon energy use, the developed countries consume the bulk of fossil fuel and are thus the major contributors to global environmental degradation.

In 1994, fossil fuel consumption for the developed countries totalled nearly 5 billion tonnes of oil equivalent (TOE) compared with 2,280 million TOE consumed by the developing countries (British Petroleum, 1989-95). Per capita energy consumption of primary, commercially traded energy in North America during 1994 was greater than 6 TOE, slightly above 3 TOE in Europe and a little above 0.5 TOE in the rest of the world. Indeed, the importance of environment and energy policies in developing countries lies in the potential adverse effects of energy use on the environment. Growth of worldwide energy demand will occur as developing countries prosper and grow in the coming century and as their populations increase.

Although often dismissed as far less efficient than fossil fuels and other conventional energy sources, non-conventional energy sources are being reconsidered, especially for rural areas. One recent study concludes that if the environment health related costs of burning fossil fuels are included in their price, renewable sources actually less expensive than fossil fuels per unit of energy delivered (Hohmeyer, 1992). Another study notes that the widespread adoption of renewable energy sources is hampered by a lack of institutional framework; the infrastructure available in most developing countries favours a centralised, capital intensive energy supply (Hulscher and Hommes, 1992). In the long term, renewable energy may be a solution to present-day environmental problems caused by the use of fossil fuels.

The different types of energy can be broadly classified into two groups: non-renewable and renewable. Non-renewable energy is defined as energy from sources which are not being regenerated. In contrast the renewable type of energy comes from sources which are either constantly renewed or not used up or transformed in the production of energy.

Table 1: Different Sources of Energy

Non-renewable types		Renewable types	
Petroleum, Natural gas and its derivatives	10.94%	Hydroelectricity (including small hydel)	25.83%
Coal, lignite, peat	58.99%	Biomass	0.27%
Nuclear fission	2.68%	Wind	1.23%
		Tidal	0.00%
		Solar	0.05%
		Waste	0.01%

Note: Figures are as on March 31, 2001.
Technical advances may produce other sources of energy in the future. Recent experimental studies show that sugar could possibly be an energy source in the future.

In theory, the non-renewable sources of energy could be replenished, but their formation is so slow that on a human time scale they can be taken as spent. At present, about 90 per cent of the total energy consumed comes from oil, coal and natural gas, with oil meeting more than a third of global energy demand. It is estimated (World Resources Institute, 1994) that the contribution of oil and natural gas will be severely diminished in the twenty-first century, being replaced by currently considered non-conventional sources of energy.

1.2 OBJECTIVE OF THE STUDY

The main objective of this study is to suggest a proposition on how India will cope with the changing global scenario regarding energy use and environmental degradation. Awareness of the effects of greenhouse gas emissions on global climate change has led to several international conferences, starting with COP 1 (Conference of Parties) in Berlin, Germany in 1995 and ending with the recent COP 6 in Hague, Netherlands in November 2000. In 1992, the leaders of the world's nations met at the Earth Summit in Rio to set out an ambitious agenda to address the environmental, economic, and social challenges facing the international community. In 1997, Governments took a further step and agreed on the Kyoto Protocol (COP 3) that establishes targets for reduction of greenhouse gases emitted by industrialised countries. The Kyoto Protocol has set the target reduction to 7 per cent below 1990 levels for the OECD countries.

Agriculture is the driving force of the Indian economy with nearly three-fourths of the population engaged in it. It is also a substantial contributor of carbon-di-oxide, the main greenhouse gas. The use of non-conventional energy sources is suited to agriculture as they have spatial and other requirements not ideal for industry. The MNES has already adopted the task of expanding the use of such energy, but there is still scope for greater realisation of potential. The main deterrent in this regard is the huge financial investment that is required by the government, which is why that is an important part of this study. I have attempted to compare the government subsidy bill going to non-conventional energy sources and how much can be recovered if farmers were involved in the process.

The Kyoto Protocol has championed the idea of global emissions trading between countries. This means that countries with lower costs of pollution abatement abate more than is required by them and sell the tradable permits for emissions to other countries at a suitable international price. Studies also show that the Asian region will have the highest sales of permits under such a regime (F. Smith, 1997). Cutting down the use of fossil fuels and energy intensity may have serious fallouts for a developing country, leading to a slowdown of its growth process. It may harm domestic industry leading to closure as emissions levels are reduced to more than 50 per cent of their present volume. The purchasing power of such permits would obviously lie with the developed countries, who under this regime, will not have to compromise that much on their emissions levels.

Given proper incentives, farmers can actively participate in changing over to non-conventional energy sources, after which instead of inter-country, intra-country trade in emissions permits can take place between agriculture and industry sectors. The permits can be sold to industry by agriculture, which would give agriculture added financial benefits. In a real situation, the government can act as the supervisor, buying the permits from the farmer and selling it to industry at a premium. This calls for a proper policy and incentive structure which has been dealt with later in this study. Such trading would give industry that much extra capacity for energy consumption, keeping within the limits of the Protocol. Thus, this is one of the ways in which a country can function in the national interest without compromising the health of the global environment.

1.3 A REVIEW OF LITERATURE

Tradable Permits

One of the first composite literatures written on the theory of tradable permits for emissions was by **T. H. Tietenberg** (1985) in which he discusses in detail its various aspects. The permits model is comprehensive and has been applied to both uniformly mixed assimilative pollutants and non-uniformly mixed assimilative pollutants. The conceptual framework of the model has been discussed in this study. Other approaches to economic modelling of marketable permits have been done by **Manne and Rutherford** (general equilibrium model, 1994) and **Nagurney and Dhanda** (multi-product, multi-pollutant market pollution permit model, 1997).

In a more recent study by **C. D. Kolstad** (2000), issues that complicate the use of tradable permits have been dealt with. These include the spatial problem (pollution transport depends on location), the problem of time and accumulation of pollutants over time, and the problem of imperfect competition.

The concept of tradable permits has been applied in the case of the steel industry in India in a study by **R. Pandey** (2000). She has also suggested trade between several emission points within an industrial unit depending on the varying cost of abatement between those points.

Tradable permits have been prescribed at the international level by the Kyoto Protocol in 1997. Several studies have analysed the impact of such a regime on different groups of countries. A book by **Kleindorfer, Kunreuther and Hong** (1996) derives the regionwise global sales and purchases of emissions permits.

The Theory of Environmental Policy by **Baumol and Oates** (1988) explores the theory of marketable emissions permits and the role of the government in sharing the burden of the polluters. The taxes versus subsidies problem has also been dealt with. It has also formulated a model for pricing of exhaustible resources, analysing response to various scenarios and conditions.

International Effort

There is a lot of literature on the different **Conferences of Parties (COP 1-6)** of the United Nations Framework Convention on Climate Change (UNFCCC), their agendas and outcomes. The UNFCCC official website gives details of the **Kyoto Protocol** (1997), which followed the **Montreal Protocol** (1987) on substances that deplete the ozone layer and the

Earth Summit (1992) developments, and the stands taken by the different countries regarding the issues of climate change.

Of interest is the United States' withdrawal from the Protocol. A comprehensive analysis of the US agricultural scenario and how it will be affected by the Protocol has been conducted by **Francl, Nadler and Bast** (1998). They have analysed the increase in costs for the farmer for different increases in gasoline taxes and its effects on US agricultural input demand and production.

Decision Support System for Integrated Pollution Control (DSS/IPC), a World Bank publication (1999), details a software package that was developed by the World Bank in collaboration with the World Health Organisation (WHO) and the Pan American Health Organisation (PAHO) to analyse the alternative pollution control strategies and policies. It builds on a WHO method for estimating pollution loads in a study area, such as a metropolitan area or water basin, by applying standard emissions factors to data on economic activity, by industry or sector. The load estimates are then used to compute annual average concentrations of pollutants in an area or water body and the outcomes of selected pollution controls. The DSS/IPC extends this approach, allowing users to calculate the costs of controls and outline a cost-effective abatement strategy.

Another book by the World Bank Group called **Pollution Prevention and Abatement Handbook** (1998) gives various models applicable to estimate the changes in ambient air quality, both local and at a distance, caused by a particular set of emissions. It introduces the reader to Screening Models, Refined Models, Industrial Source Complex Models and their uses.

Alternative Solutions

An alternative system for dealing with the problem of sustainable agriculture has been explored by the **University of Kansas**. The system is known as Carbon Farming in which carbon sequestration is accomplished through a variety of methods, including no till or low-till cultivation, creating composts of small grains, adding hay and legumes to crop rotations, and incorporating trees into farming operations. But Carbon Farming requires new equipment that is very expensive and there is not enough financial incentive for the farmer to use these practices.

Carbon Taxes is another area which has been explored in detail by many as an effective solution to the emissions problem. But in every study which compares the effectiveness of taxes and permits side by side, permits have shown up to be the more efficient option.

Environmental Policy and Market Structure (1996) edited by **Carraro, Katsoulacos and Xepapadeas**, is a book which deals with carbon taxes in detail. It explains the effect of emissions taxes under various market structures such as monopoly, oligopoly and perfect competition. It also gives the pricing strategies and environmental taxes under international price competition, that is if the output of the international duopoly is for a third-country market. In the second part of the book, there is a model which describes trade and environmental policy, deriving equilibrium tax rates both in a non-cooperative and a cooperative game.

India

In the Indian case, the option of harnessing the potential of non-conventional energy sources is being actively explored by the **Ministry of Non-conventional Energy Sources** (MNES). Their annual reports give updates of the various programmes and undertakings in this sector. It gives indepth information about the progress in the rural renewable energy sector, the activities of the **Indian Renewable Energy Development Agency** (IREDA), and the various policy decisions and implementations in this area.

Parivesh, a publication of the Central Pollution Control Board (CPCB), also gives an insight into the programmes of pollution abatement and their problems. The non-conventional energy scenario has been addressed in centre for Science and environment's **Fifth Citizen's Report**, which gives data and information on the scope for development in this area.

The energy scene for India has been addressed in depth in ***Asia Energy Vision 2020: Sustainable Energy Supply*** (1996). The paper by **K. S. Narasimhan** projects future energy demand trends till 2020. Every form of renewable energy source, their advantages and potential has been explored by **D. K. Sharma and D. P. Kothari**. **P. P. Dua and S. B. Rao** has done an empirical study on rural Uttar Pradesh, what are the principal domestic energy sources and how a sustainable system of energy use may be developed. **A. K. Jain's** *Development of Alternative Energy Sources* shows how dependence on commercial energy sources has escalated during the last decade. He also addresses the energy crunch and the potential energy conservation in the country. He suggests alternative fuel substitution to petroleum fuels and methods of improving their efficiency. **S. S. Ahluwalia's** *Bridging the Energy Gap in India* talks about the financial crunch facing the energy sector and how it can be tackled.

The Report of the Task Force to Evaluate Market-Based Instruments (1997), submitted to the Ministry of Environment and Forests, gives details of all the market-based instruments and which should be chosen when. In this context it compares taxes to permits and concludes in favour of permits, as they allow the regulatory authority to control the quantity of emissions instead of letting the polluters determine level of emissions in response to an emissions tax. The report details environmental laws in India and analyses the choice of market-based instruments in India and the lessons to be learnt from international experience.

The Special Millennium Issue of PowerLine magazine (January 2000), is a collection of articles giving the current status and development of renewable energy sources in India. Although the focus of this issue is on long-term planning and fundamental reforms in the power sector, it reveals several interesting facts and estimates which gives an overall idea of the present situation. Its projections say that by 2015 India will be producing SO_2, NO_x, particulate emissions and ash at three times the current levels. Certain relevant graphs and trends from their analyses is given in the Annexures.

Policy

The **World Energy Council**, of which India is a member, in its **Statement 2000** gives the international developments that have evolved in the sustainable energy area since 1993. This includes the energy challenge that we are facing and the international environmental agenda in response to it. It also advocates ten policy guidelines for the energy sector which cover the important issues in sustainable energy development like poverty, information, research and ethics in governance.

The Greening of Economic Policy Reform (1997), edited by **Cruz, Munasinghe and Warford** of the World Bank, gives several case studies and the experience of countries in framing and application of environmental policy. Of interest is the energy sector policy of Sri Lanka which addresses electricity pricing reform, greenhouse gas reduction issues and the options available such as wind energy, reducing transmission and distribution (T&D) losses, demand management, clean coal technology and others.

In case of India, the shortcomings of our environmental legislations and what weaknesses prevent their effective application has been pointed out in **Bandyopadhyay, Jayal, Schoettli and Singh** edited *India's Environment: Crises and Responses* as early as 1985. It has also dealt with the options of pollution control laws. *Innovation in Environmental Policy* (1992), a collection of articles edited by **Tietenberg and Oates**, gives in depth analysis of the avenues of enforcement of environmental laws and the loopholes that they may suffer from.

Fiscal Policy and Environmental Welfare (1998) by **Thorsten Bayindir-Upmann** gives a game theoretic model with firms and consumers and conducts a welfare analysis for Nash emission tax rates against cooperative tax rates. A study by **R. Pandey** on Economic Policy Instruments for Controlling Vehicular Air Pollution (2000) gives an overview of the different economic approaches as well as command-and-control regulations which are the policy options for air pollution control. It also gives the various laws and approaches adopted in Delhi for controlling emissions.

Jepma and Munasinghe have authored a book called Climate Change Policy (1998), which deals specifically with the issues of climate change. The present status and future changes of global climate, its impact on ecological and social systems and equity, all provide the foundation for developing the policy framework for decision-making. It suggests equitable allocation of emission rights, different response strategies and an overview of current international developments and policies.

Accounting and Data Application

The Measurement of Environmental and Resource Values (1993) by **A. Myrick Freeman III**, gives the complete collection of models and methodologies for valuation of environmental assets. It addresses welfare measures, public policy and how environmental value can be measured and interpreted in economic terms.

Accounting and Valuation of Environment (1997), a United Nations publication, illustrates various methods of accounting for environmental degradation, the trade-offs involved and the rationale behind such accounting. It gives an idea of "Green NDP" and how it can be calculated, and the concept of Environmental impact Assessment. A model for environmental and economic accounting of Indian industry has been developed and tested by **Murty and Kumar** (2001), which is part of a World Bank funded project for environmentally corrected GDP.

The main data bank for the calculation of subsidies going to non-conventional sources of energy are the **Finance Accounts** published by the State and Central Governments of India. They give detailed financial statements and help in calculating the subsidy bill of the government separately for every accounting head or category. Another important source of energy related data is the **Tata Energy Data Directory and Yearbook** (TEDDY), published annually by the Tata Energy Research Institute (TERI).

The data from the finance accounts has been applied to the methodology given in the book called *Government Subsidies in India* by **Srivastava and Sen** (1997). This book focuses explicit and implicit subsidies given by the central and state governments in both merit and non-merit goods. TEDDY data has been used for deriving trends in fuel consumption and projecting future use. It has also been used in the regressions determining future carbon-di-oxide emissions from the sector.

1.4 THE INDIAN AGRICULTURE SECTOR

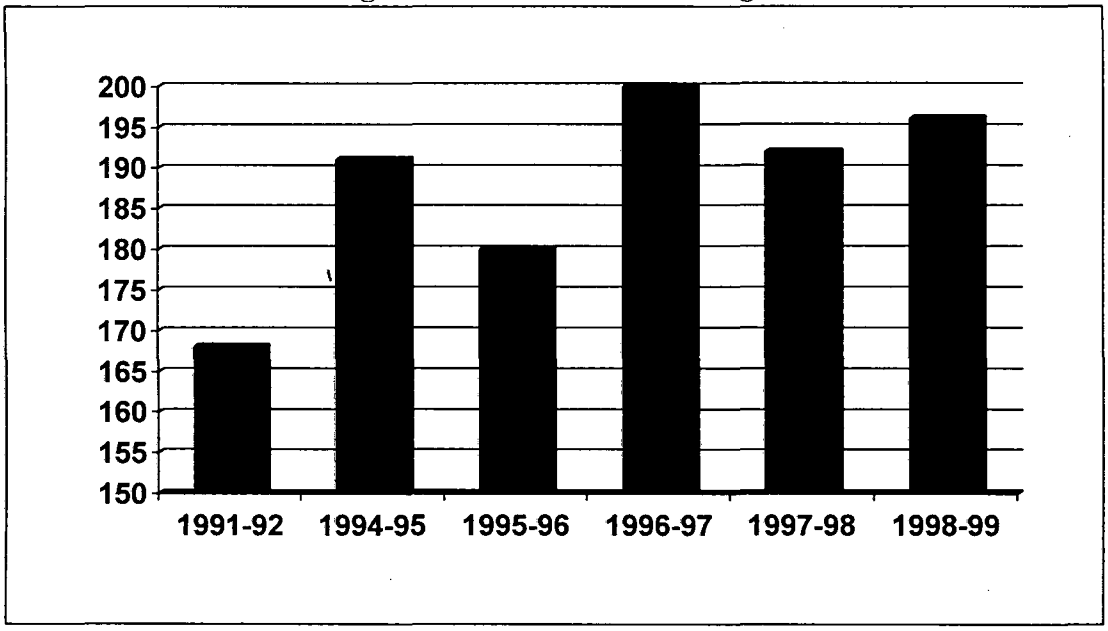
Agriculture is the largest sector of economic activity and gives maximum employment in India. It is estimated that 68 per cent of the workforce was employed in agriculture in 1991. In fact, the Ninth Five-Year Plan (1997-2002) has accorded priority to agriculture and rural development so as to generate adequate productive employment and eradicate poverty. Agriculture's share in the gross domestic product (GDP) decreased from 50 per cent in 1950-51 to 27.6 per cent in 1996-97 (at 1980/81 prices). However, during the Eighth Five–Year Plan, agricultural production increased by about 3.9 per cent a year and the foodgrain output grew at 3 per cent per annum.

The total foodgrain production in India increased from 51 MT (million tonnes) in 1950-51 to 191 MT in 1994-95. During the next four years, it fluctuated from 180 MT in 1995-96 to 199 MT in 1996-97, to 192 MT in 1997-98, to 195.2 MT in 1998-99.

The Ninth Five Year Plan projects foodgrain production to increase from 199 MT in 1996-97 to 304 MT in 2011-12 and consumption to increase from 195MT to 298 MT during the same period. Yield is expected to grow at the rate of 2.9 per cent a year over the entire Ninth Plan perspective period.

According to the Ministry of Agriculture, agricultural production during 1996-97 registered about 6 per cent growth, mainly due to the increase in production of wheat (10 per cent), coarse cereals (16 per cent), pulses (10 per cent), oilseeds (12 per cent), and cotton (9 per cent).

Figure 1 : Production of Foodgrain



Source: Agricultural Statistics at a Glance, MOA, New Delhi (1998)

1.4.1 Distribution of Crops

Rice, wheat, and coarse foodgrains such as maize, bajra, and jowar occupy more than 90 per cent of the area under foodgrains and 82 per cent of the net sown area. The share of rice and wheat in total foodgrain production increased from 53 per cent in 1950 to 76 per cent in 1994. Rice accounts for 43 per cent of the total foodgrain production and is cultivated on 43 million hectares, which is about 30 per cent of the net sown area. The demand for rice is expected to increase to 95-100 MT in the next five years and can reach 120-125 MT a decade beyond. This demand can be met if the productivity of crops increases from the present level of 1.9 tonnes per hectare to 2.47 tonnes per hectare by 2000 and 3.5 tonnes per hectare by 2010.

Wheat accounts for one-third of the total foodgrain production. The high-yielding varieties now cover about 87per cent of the area under wheat cultivation and this is increasing at the rate of 1.7 per cent a year compared to 0.5 per cent a year for rice. The annual production of 60 MT and a low growth rate of wheat in the past seven years (1.5 per cent) indicates that the yield plateau of wheat has been reached. Demand for wheat is expected to increase to 95 MT by 2020.

Progress in Indian agriculture can be attributed to several factors. First, the development and adoption of improved agricultural techniques and improved seed/crop varieties. Secondly, the development of an efficient input production and delivery system. Thirdly, progress being made in agrarian reforms along with development of rural infrastructure, banking and credit, input and output pricing policies, and marketing arrangements.

1.4.2 Agricultural Inputs

a. Land

Of the total geographical area of 329 Mha (million hectares), only 305 Mha is the area suitable for land utilization. The net sown areas increased from 119 Mha in 1950-51 to 143 Mha in 1994-95, mostly through reclamation of old fallow and cultivable wastelands, and this is expected to remain more or less constant throughout the Ninth Plan perspective period. However, cropping intensity is projected to rise from 134.2 per cent in 1996-97 to 150.35 per cent in 2011-12.

b. Water

The distribution of rainfall in India is not uniform over space and time. The annual average rainfall is 1150 mm, of which 73 per cent is received from the south west monsoon. The country has been receiving normal rainfall for the sixth year in succession since 1993. As only a small part of the cultivated area is irrigated, agriculture in India depends mostly on monsoons.

The area under irrigation has increased over time. Irrigation potential has been developed largely through minor irrigation projects. Till 1992, 120 major and medium irrigation projects had been completed, and in the Eighth Five-Year Plan (1992-97), 158 projects were ongoing. It is estimated that the country has an irrigation potential of 140 Mha of which 58.5 Mha can be served by major and medium irrigation schemes, about 17 Mha by minor surface water schemes, and about 64.5 Mha by groundwater.

Net irrigated area increased from 31.11 Mha in 1970-71 to 53 Mha in 1994-95. This represents an increase from 22.1 per cent to 37.1 per cent, where irrigated area is taken as a percentage of the net sown area.

c. High-Yielding Varieties

Good-quality certified seeds are the basic and crucial inputs for enhancing agricultural production. High-yielding varieties have been contributing significantly to increased yield of different crops. The total area under high-yielding varieties of different crops increased from 15.38 Mha in 1970-71 to 72.11 Mha in 1995-96[2][3]. Simultaneously, the use of certified/quality seeds increased from 0.2 MT in 1970-71 to 0.7 MT in 1996-97. However, high-yielding varieties are generally highly susceptible to pests and diseases and, as such, need adequate care and plant protection measures.

d. Fertilizer Use

India is the fourth largest fertilizer consumer in the world. The consumption increased from 0.29 MT in 1960-61 to 14.31 MT in 1996-97. Prior to the introduction of high-yielding varieties in 1966, most of the cultivated area in India was under traditional varieties, which are low-yielding and less responsive to the addition of nutrients. Since then, fertilizer consumption has increased steadily, as high-yielding varieties are highly responsive to the addition of nutrients.

Chemical fertilizer consumption was 80 kg/ha in 1994-95, and is estimated to increase to 185.81 kg/ha in 2011-1/12. Since high level of consumption of chemical fertilizers may not be environment-friendly, it seems prudent to substitute them with bio-fertilizers to some extent. As such the Ninth Plan encourages greater use of bio-fertilizers and biotechnological research.

The consumption of fertilizers in gross cropped area in 1996-97 was 76.75[2] kg/ha. Consumption increased there-fold from 5.5 MT in 1980-81 to 14.3 MT in 1996-97, and is anticipated to increase to 16.4 MT in 1997-98. Consumption of nitrogenous fertilizers increased by 0.4 MT during 1995-96 and 1996-97. Over the same period, consumption of phosphatic fertilizers increased while that of potash fertilizers declined marginally.

e. Pesticides

Use of pesticides, commonly accepted as formulations that attack, repel, sterilize, or destroy any insect, fungus, bacterium, rodent, etc., is on the increase. In India, 133 pesticides have been registered for regular use, of which 34 are either banned or restricted in other countries. The main thrust of plant protection activities during the Ninth Plan is the promotion of integrated pest management for all crops and throughout the country.

Indiscriminate use of pesticides can adversely affect both human and animal health, besides polluting air, water, and soil. Since the use of safer pesticides, including neem-based and bio-pesticides, is being encouraged, the consumption of chemical pesticides decreased from 75,000 tonnes during 1990-91 to around 56,000 tonnes during 1996-97. As of date, Andhra Pradesh has the maximum share of pesticide consumption (16.11 per cent), followed by Uttar Pradesh (13.63 per cent).

f. Energy

Land preparation and irrigation are the two major agricultural operations that consume energy (both direct and indirect). Since land is more or less a fixed resources, agricultural productivity can be related directly to the energy inputs. Agriculture is a seasonal industry, and, therefore, the demand for energy fluctuates with season. In certain months of the year, agriculture demands more energy for sowing, transplantation, harvesting, and threshing.

Oil and electricity are extensively consumed in this sector. Although the quantum of both oil and electricity consumed increased in absolute terms between 1970/71 and 1987/8, their relative share remained unchanged (Table 2).

Table 2: Consumption of oil and electricity in agricultural sector (peta-calories)

Year	Oil	Electricity	Total
1970/71	6.88 (64.15)	3.84(35.85)	10.72 (100)
1975/76	14.23 (65.49)	7.50 (34.51)	21.73 (100)
1980/81	27.94(69.16)	12.46 (30.84)	40.40 (100)
1984/85	29.65 (68.75)	18.03 (31.25)	57.68 (100)
1987/88	47.05 (64.44)	25.96 (35.56)	73.01 (100)

Source: Sectoral Energy Demand in India, Planning Commission, GOI (1993).

Land preparation and harvesting account for the bulk of diesel consumption whereas electricity is largely used for irrigation purposes. All activities put together, paddy and wheat consume approximately 1.55 MT of diesel, which is a little over 10 per cent of the total diesel consumption in the country in 1985-86. The total electricity consumption is 21.13 TWh, which is approximately 90 per cent of the reported electricity consumption by this sector. As a typical example, energy consumption in wheat and rice is given in Table2.

Table 3: Energy consumption in wheat and paddy

Activity	Energy source	Estimated consumption Wheat	Paddy
Land preparation	Diesel	0.32 MT	0.15 MT
Irrigation	Diesel	0.11 MT	0.24 MT
	Electricity	6.15 TWh	14.73 TWh
Harvesting, collection, threshing	Diesel	0.43 MT	0.13 MT
	Electricity	0.24 TWh	-
All activities	Diesel	1.01 MT	0.54 MT
	Electricity	6.40 TWh	14.73 TWh

Source: Agricultural Energy Requirement in India, TERI, 1998.

i) Land Preparation

Traditionally, human labour and livestock have been the main sources of energy for Indian agriculture, and they continue to be so despite substantial mechanization in this sector. Farm operations like digging, transplantation, weeding, harvesting, and paddy threshing are largely performed manually.

India has about 200 million agricultural workers providing 43 000 TJ (terajoules) of human energy and 80 million draught animals providing 81 000 TJ of animal energy. Together they provide about 0.298 kW/ha of farm power. Draught animal power, by and large, continues to be a major power source for filed operations.

Energy consumption has evolved over time. The recent trends show the changes in the number of mechanized and traditional means of cultivation. The mechanization process in the agricultural sector accelerated with the introduction of high-yielding varieties in the 1960s.

The rapid rise in the number of tractors during the 1970s was accompanied by a fall in the working animal stock, from 81 million in 1971-72 to 73 million in 1982-83. However, there was no change in the working animal stock in the next decade.

Table 4: Time variation of mechanised and traditional cultivation

	Tractors	Power tillers	Pumps	Bovines
	thousands	Thousands	Millions	Millions
1971-72	75	-	5	81
1981-82	486	249	11	73
1991-92	1,363	513	16	13

Source: Agricultural Energy Requirement in India, TERI, 1998.

Mechanization of agriculture has progressed at disparate rates in different states of the country. In 1991-92, Punjab, Haryana and Uttar Pradesh recorded the highest tractor-to-operated area ratio. In Haryana and Gujarat, the number of working animals per 100 hectare increased during 1970s, despite a rise in the number of tractors per 10,000 ha.

It is estimated that more than 55 per cent of land is cultivated by draught animal power (with a command area of 2 ha per pair). Paddy, which is grown on 23 per cent of the total cropped area (1992-93), use 35.6 per cent of the total draught animal power. The use of animal energy per hectare for jute, potato, onion, and paddy crops is comparatively high. These crops are largely known grown in states with higher draught animal power density and lower levels of mechanization. However, the share of draught animal power in the total farm power is declining.

Table 5: Energy source: contribution by source

Energy source	Contribution (%)
Male	7.32
Female	2.08
Animals	25.76
Tractors	23.8
Power tiller	0.44
Diesel engine	14.04
Electric motor	25.32
Combines	1.24

Source: Tata Energy Data Directory and Yearbook, TERI, 2001.

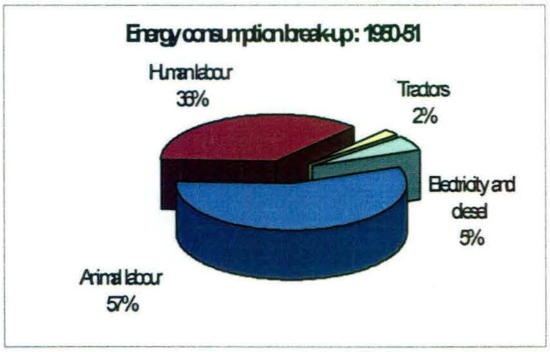
The share of human energy in the total farm power decreased from 35 per cent in 1950-51 to 8 per cent in 1995-96. Similarly, the average use of animal energy per hectare decreased from 159 animal pair per hour per hectare in 1971-72 to 109 animal pair per hour per hectare in 1990-91, registering a decline of 1.5% a year. The total power availability from draught animal power in 1995-96 was estimated at 16.8 million kW. This was 12.3 per cent of the total farm power consumption in 1995-96. The share of draught animal power in agriculture decreased from 55 per cent in 1950-51 to 12 per cent in 1995-96. With limited landmass and increasing human population, India cannot afford to have more draught animals. For a desirable level of agricultural activity (200 per cent cropping intensity), the farm power requirement is estimated at 0.746 kW/ha.

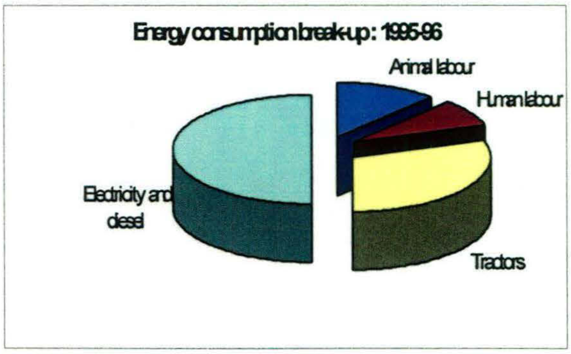
Human resources are surplus, leading to mass unemployment problems during off-season. In peak periods, however, draught animal power cannot sufficiently cope with the heavy loads. Therefore, the deficit in farm energy availability has to be met from mechanized sources. To a large extent, draught animal power has been supplemented by tractors, power tillers, diesel engines, and electric motors.

The use of tractors has increased at a compound growth rate of more than 13 per cent a year, which may stabilize around 10 per cent by the next decade. With an estimated total tractor population of 1.8 million, the country has a potential to cover 16 per cent-17 per cent of the cultivated area (15-16 ha of operational area per tractor).

In spite of the phenomenal growth in the number of tractors in the past two decades, Indian agriculture continues to depend to a great extent (about 25 per cent) on an animate energy for various operations. Further, human labour accounts for almost eight per cent of the energy used for farm operations. The relative share of electricity and diesel power, as against human and animal power, is shown in Figure 2 corresponding to 1950/51 and 1995/96 respectively.

Figure 2: Energy consumption break-up





Source: Tata energy data directory and yearbook, TERI, 2001.

Though farm mechanization is increasing, the yield increase does not reflect the proper use of energy in Indian agriculture. The output-to-input ratio has gone down considerably over the years. Distortion of data has also to be considered as energy consumption is measured merely in terms of the number of pump sets energized.

Irrigation is largely done using diesel and electrical energy. The number of electric pumps increased from 1.6 million in 1970-71 to 10.3 million in 1993-94. The number of diesel pumps increased from 1.5 million to 4.9 million during the same period. Consequently, the share of farm sector in the electrical energy consumption increased from 3.9 per cent in 1950-51 to 28.7 per cent in 1992-93. Diesel consumption by the farm sector is a little over 10 per cent of the total diesel consumption. Electricity and diesel power contributed almost 50 per cent of the total farm power consumed for irrigation in 1995-96.

The decision of most of the state governments to have a subsidized flat-rate tariff on electric pump sets based on horsepower rating is one of the factors that led to an increase in the number and use of irrigation pump sets.

ii) Electricity Use

Electricity is an essential input for agricultural development. The availability of farm power per unit area (kWh/ha) has been considered one of the parameters of the level of mechanization. The total power availability from all the sources increased from 0.18 kWh/ha in 1950-51 to 0.7 kWh-ha in 1995-96 at a compound annual growth rate of 3.06 per cent. The kWh consumption of electricity in pump sets and lift irrigation is given in Table 6.

Table 6: Electricity consumption in agriculture (kWhs)

	Pumpsets/Tubewells	Lift irrigation
1993-94	69,886	873
1994-95	77,774	925
1995-96	84,839	947
1996-97	82,824	1,474
1997-98	89,803	1,538
1998-99	95,759	2,163
1999-00	102,099	2,988
2000-01	107,162	3,837
2001-02	112,515	4,541

Source: 16^{th} Annual power survey, (CEA), Ministry of Power, GOI, New Delhi, 2001

In 1997/98, the average electricity tariff for agriculture was only 22 paise/kWh. With most of the state governments either refusing to even nominally raise the tariff for the farm sector, the power subsidy to agriculture has gone up sharply in recent years. Effective subsidy for agricultural consumers increased from 73.34 billion rupees in 1992-93 to 174.91 billion rupees in 1997-98. This has increased the use of electricity as compared to diesel. The share of mechanical power in total farm power increased from 3.6 per cent in 1950-51 to 80 per cent in 1995-96. The government has been adopting policies to encourage the use of electricity for farming and pump set operation supplying cheap electricity.

Groundwater source contributed nearly 53 per cent of the total area irrigated in 1992-93. Since the 1960s, rural electrification and a substantial increase in the number of energized pump sets have led to a dramatic increase in the utilization of groundwater. The Ninth Plan has provisions for much more energized of pump sets.

However, the groundwater resource is getting depleted due to increased levels of extraction. Surface water sources like rivers, canals, tanks, and rivulets have also been affected considerably due to degradation and siltation of riverbeds.

The usage of energy has increased manifold, but over a very small area with little yield increments. Thus, with the groundwater table going down, electricity consumption per kilowatt-hour should increase. To get an actual picture and take remedial action, such consumption should be properly metered and not merely estimated. There is a need for drastic energy savings while maintaining yields by water conservation and by shifting to energy-efficient tilling and fertilizer consumption.

1.5 THE NINTH FIVE-YEAR PLAN

The Ninth Plan targets a growth rate of 4.5 per cent a year in agricultural output and production of 234 MT foodgrains by 2001-02. Agricultural development would be centered on achieving the objectives of sustainability of employment generation, food and nutrition security, equity, and poverty alleviation.

The various targets to be achieved are as follows.

- High productivity zone: The high productivity zones in the north-western regions are to promote diversification to high-value crops and to strengthen linkages with agro-processing industries and exports.
- Low productivity-high potential zone: Eastern region with abundant water to exploit the productivity potential through flood control, drainage management, improvement of irrigation facilities, and improved input delivery systems.
- Low productivity zone: water-scarce peninsular region, including Rajasthan, is to focus on efficient water harvesting and conservation method and technologies based on watershed approach and appropriate farming system.

- Ecological fragile regions: Ecologically fragile regions, including the Himalaya and desert areas, are to concentrate on eco-friendly agriculture.

For achieving the objective of sustainable agricultural development greater emphasis would be laid on (1) conservation of land, water, and biological resources; (2) development of rural infrastructure; (3) development of rain-fed agriculture; (4) development of minor irrigation schemes/projects; (5) timely and adequate availability of inputs; (6) increasing flow of credit; (7) enhancing public sector investment; (8) enhancing support for research; (9) effective transfer of technology and; (10) marketing infrastructure support and export promotion.

1.6 NON-CONVENTIONAL ENERGY AND GREENHOUSE GASES

A lot of emphasis is being laid on renewable energy sources today. It is being thought of as the world's best energy option for the future. The World Renewable Energy Congress VII is coming up in Cologne, Germany in June, 2002. The aims of the Congress are given in the Annexures.

During the next five-year plan, the one major focus would be the increase the energy supply. In view of the limited sources of conventional energy, there is likely to be more emphasis on the renewable energy technologies in the agriculture sector. This will on the one hand decrease pressure on the conventional sources of energy and on the other hand reduce the greenhouse gas emissions. Consumption of these energy sources causes a huge amount of GHG emissions. To reduce these emissions the efficiency of the farm equipment needs to be increased and more and more renewable energy techniques need to be employed.

1.6.1 GHG Emissions and CDM

Clean development mechanism or CDM as it is commonly called is one of the several "flexibility mechanisms" authorised in the December 1997 Kyoto Protocol to the 1992 United Nations Framework on Climate Change (UNFCC). The Kyoto Protocol specified legally binding commitments by most industrialised countries to reduce their collective green house gas (GHG) emissions by at least 5 per cent compared to 1990 levels by the period 2008-2012.

With the goal of reaching these targets at the lowest possible costs for countries that committed to reductions, the protocol created two flexibility mechanisms – GHG emissions trading and CDM. The CDM is also intended to be an opportunity for the developing countries that did not accept binding emissions reductions at the protocol.

Article 12 of the Kyoto Protocol provides for a clean development mechanism whereby developed countries are able to invest in emissions reducing projects developing countries to obtain credits to assist in meeting their assigned targets.

1.6.2 Benefits of CDM

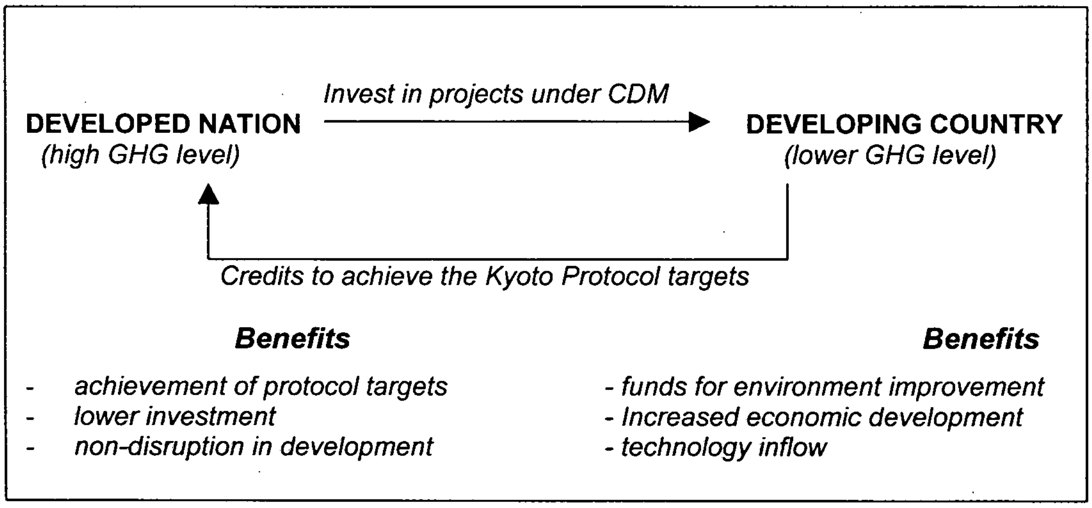
The CDM was created as a successor to "Joint Implementation" (JI). JI consists of a bilateral agreement between two entities to achieve a GH mitigation project. The investor is from the industrialised country that must reduce its emissions under the framework convention. JI can provide credits for emissions abatement to the investor at a lower cost than domestic abatement. In other words JI is a form of "emissions trading". At the same time, a developing country host can benefit from the new investment that increases economic productivity and reduction in local environmental problems.

The three specific goals for CDM are:

- to assist in the achievement of sustainable development
- to contribute to the attainment of the environmental goals of the framework convention
- to assist developed nations in complying with their emissions reduction commitments

The details of CDM have yet to be negotiated at an international level. However, it does allow countries to use credits obtained from the year 2000 for the purpose of meeting their assigned amounts. Participation is voluntary, and open to private and public entities.

Figure 3: Benefits of CDM



1.7 RATIONALE FOR THE STUDY

The study is necessitated due to the following factors:

- Government subsidies have been continued and have gone on increasing over time even after they have served their purpose, due to political pressures. This has proved counterproductive by creating artificial demand for subsidised inputs and increasing environmental degradation.

- The need for a solution to the trade-off between controlling environmental pollution and staying on the growth path for developing nations.

- Conservation of energy has become essential in view of increasing pressure on the fossil fuel reserves in the country and perpetual demand-supply gap in the area of energy.

- Since the electrical energy is subsidised in the agricultural sector, there is rampant non-optimal use of electricity. The pump sets used in the rural sector are grossly inefficient and waste useful energy.

- There are increasing environmental and financial pressures due to fossil fuels being used in the agriculture sector and increasing application of inputs like fertilizers going into the sector.

- In view of the emission norms laid down by the Kyoto Protocol, there is an increased opportunity of such projects being funded by the developing countries. This would be beneficial to both the parties.

Chapter 2 of this study gives an overview of the global efforts being made in the renewable energy scene. It also gives details of the Indian scenario and its prospects. Chapter 3 deals with CO_2 emissions and projects emissions levels for 2005. It also gives the marketable permits framework and how it can lead to efficient energy generation. Chapter 4 estimates the financial ability of the large and medium farmers to changeover to the new technology and the current cost to the government in this sector. This chapter thus assesses the feasibility of the policy recommendation. Chapter 5 gives an overview of policy decisions so far and the prescribed policy framework.

1.8 LIMITATIONS OF THE STUDY

- Any study on policy and economics requires extensive and reliable data, which in case of India is not available. The information regarding the income, crop production, prices, households, energy consumed, etc. are not well documented. The data, if available, is always dated.

- The study is based on a number of assumptions, which has compromised the true picture. The policy solution to the trade-off is a concept, the success of which can only be determined after implementation. More powerful empirical work is possible in this area by collecting and applying primary data to get a realistic idea about the costs and benefits of inter-sectoral trade in emissions.

- Parallel studies need to be done in agriculture and industry to explore if a non-cooperative game theoretic model can be supported and to develop proper incentive structure for the sectors to participate.

Chapter 2

NON-CONVENTIONAL SOURCES OF ENERGY: GLOBAL AND INDIAN INITIATIVES

NON-CONVENTIONAL SOURCES OF ENERGY

2.1 INTRODUCTION

Energy supplies in many countries are not commensurate with their development needs and are wrongly priced and unstable. In rural areas of the developing countries, the chief sources of energy are fuelwood, crop residues and manure, together with animal and human energy. More intensive energy inputs are required for increased productivity of human labour and for income generation. To this end, rural energy policies and technology should promote a mix of cost effective fossil and renewable energy sources that is itself sustainable and ensures sustainable agricultural development. Rural areas provide energy supplies in the form of wood. The full potential of agriculture and agroforestry, as well as common property resources, as sources of renewable energy, is far from being realised.

The objectives of the Earth Summit programme were:

a. not later than year 2000, to initiate and encourage a process of environmentally sound energy transition in rural communities, from unsustainable energy sources, to structured and diversified energy sources by making available alternative new and renewable sources of energy.

b. To increase the energy inputs available for rural household and agro-industrial needs through planning and appropriate technology transfer and development.

c. To implement self-reliant rural programmes favouring sustainable development of renewable energy sources and improved energy efficiency.

Long term sustainable development in all countries requires a gradual move towards renewable energy sources that are more equitably distributed and less environmentally destructive than current fossil fuel sources. Aggressive development of renewable energy sources offers developing nations the prospect of increasing energy self-reliance,, both nationally and locally, and reaping the attendant economic and security benefits. And, because of their ability to function independently of utility grids, renewable such as solar photovoltaic arrays and wind turbines could be particularly important in providing power in remote areas. The prospect of such decentralized installations is particularly attractive in light of the limited success of current rural electrification programmes.

2.2 THE NEED

The threat posed to sustainable development by GHG (greenhouse gas) emissions and deterioration of the natural resources base has caused worldwide concern. The natural resource base has deteriorated considerably due to the rapid growth in population, urbanization and fossil fuel consumption. The objectives of natural resource conservation and environmental protection need to be integrated with the overall development process, as articulated in Agenda 21 of the United Nations Conference on Environment and Development (UNCED).

Two strategies need to be adopted concurrently for the conservation of the natural resource base. The first strategy pertains to the appropriate pricing of exhaustible or non-renewable resources by moving away from the APM (administered pricing mechanism). The APM does not reflect the true cost and tends to significantly under price resources. Moving towards the true costs would encourage fuel efficiency and prevent wasteful energy use.

The second strategy is that of developing and promoting appropriate technologies using renewable natural resources such as biomass, water, wind, and solar energy. Recourse to renewable sources of energy has become necessary with growing concerns about climate change and dwindling fossil fuel reserves. Though the developed nations have contributed the most to global warming, the share of developing countries is increasing at an alarming rate.

Recognizing the importance of the renewable sources of energy, the government of India set up CASE (Commission for Additional Sources of Energy), in 1981. The next year, the Department of Non-conventional Energy Source was created, which was upgraded to the MNES (Ministry of Non-conventional Energy Sources) in 1992. IREDA (Indian Renewable Energy Development Agency Limited) was established in March 1987 as a public sector enterprise for the promotion, development, and financing of new renewable sources of energy technologies.

2.3 INTERNATIONAL EFFORT

The attainment of sustainable rural development is intimately linked with energy demand and supply patterns. The world demand for energy is expected to grow well into the next century in both developed and developing countries. The following table shows recent demand forecasts to the year 2010.

Energy demand is expected to increase by an average annual rate of 3.1 per cent during the first decade of the 21st century, which, although not as high as growth in the 1970's, represents an increase over the world growth in energy demand during the 1980's and the 1990's. Growth in energy demand in the developed countries has steadily decreased since the 1970's and is expected to increase only slightly in the first decade of the 21st century. Developed countries' share of world consumption is expected to fall from 55 per cent in 1992 to 51 per cent in 2010.

Table 7: Carbon-di-oxide emissions (per capita) from industrial processes: 1991

Countries	Per capita carbon-di-oxide emissions (tonnes)
Africa	1.0
Nigeria	0.8
South Africa	7.2
China	2.2
Japan	8.8
Canada	15.2
United States	19.5
Argentina	3.6
Brazil	1.4
Germany	12.1
United Kingdom	10.0

Source: World Resources 1994-95: A report by the World resource Institute in collaboration with UNEP and UNDP.

The largest increases in energy demand are expected to occur in the developing countries as economic growth occurs and populations increase. Energy use for the 1990's in Asia is estimated to be growing at a rate of 6.8 per cent per year and is forecasted at 5.5 per cent per year between the years 2000 and 2010. Although lower than growth during the 1980's, this still represents a significant increase, especially given Asia's relative economic importance in the world.

Table 8: Actual and projected energy demand growth rates (avg. annual change in %)

	1970-1980	1980-1990	1990-2000	2000-2010
OECD (including Turkey)	3.3	2.8	2.3	2.4
Eastern Europe and former Soviet Union	3.3	1.6	-2.7	4.1
Non-OECD Asia	6.0	7.2	6.8	5.5
Middle East	5.2	0.9	4.0	3.7
Africa	4.2	1.4	2.6	2.9
Central and South America	5.6	1.1	3.7	3.6
Total	3.6	2.7	2.3	3.1

Source: F. Smith (ed), Environmental Sustainability: Practical Global Implications, 1997.

The supply of energy in a given developing country often reflects traditional energy demand patterns and the types of energy available within its boundaries. The following table shows the types of fuels used worldwide and by developed and developing countries in 1990 and forecast to 2010. While total energy use is projected to grow over the 20-year period, fuel composition is not expected to change significantly. Although oil and natural gas use will almost double during this period, their share in total fuel used is expected to increase only slightly.

The use of oil and natural gas by developing countries is forecast to grow by 2 and 1.8 per cent respectively, while that of renewables is projected to increase by 2.5 per cent on an annual average basis. Coal use is expected to increase by 1.6 per cent per year. All growth rates are higher than those of developed countries except for natural gas use, which in developed countries is expected to increase by 2.2 per cent per year during the 20-year period. While energy use will increase considerably in both developed and developing countries, the table shows that the bulk of the increase is expected to originate in developing countries. It is important to note, however, that energy use in developing countries will still be not even half that used by developed countries by 2010.

Table 9: Actual and forecasted energy supply in million tonnes of oil equivalent (TOE), 1990-2010 (percentages in parentheses)

	1990	2000	2010
World			
Oil	3302.4 (39.2)	3817.1 (38.9)	4422.0 (38.4)
Natural gas	1756.1 (20.8)	2175.6 (22.2)	2600.0 (22.6)
Coal	2241.5 (26.6)	2451.2 (25.0)	2878.0 (25.0)
Nuclear	495.1 (5.9)	578.0 (5.9)	595.1 (5.2)
Renewables	639.0 (7.6)	685.4 (7.0)	1002.4 (8.7)
Total	8429.3 (100.0)	9819.5 (100.0)	11504.9 (100.0)
Developed countries			
Oil	2456.1 (39.0)	2497.6 (36.8)	2863.4 (37.4)
Natural gas	1502.4 (23.9)	1822.0 (26.9)	2126.8 (27.8)
Coal	1419.6 (22.5)	1363.4 (20.1)	1439.0 (18.8)
Nuclear	468.3 (7.4)	541.5 (8.0)	536.6 (7.0)
Renewables	456.1 (7.2)	558.5 (8.2)	6787.0 (8.9)
Total	6295.1 (100.0)	6782.9 (100.0)	7651.2 (100.0)
Developing countries			
Oil	846.3 (39.7)	1319.5 (43.5)	1558.5 (40.4)
Natural gas	253.7 (11.9)	353.7 (11.6)	473.2 (12.3)
Coal	822.0 (38.5)	1087.8 (35.8)	1439.0 (37.3)
Nuclear	26.8 (1.3)	36.6 (1.2)	58.5 (1.5)
Renewables	182.9 (8.6)	239.0 (7.9)	324.4 (8.4)
Total	2134.1 (100.0)	3036.6 (100.0)	3853.7 (100.0)

Source: F. Smith (ed), Environmental Sustainability: Practical Global Implications, 1997.

Table 10: Actual and forecasted regional shares of world energy supply (percentages)

	1992	2010
OECD	54.7	50.7
Eastern Europe and former Soviet Union	18.2	15.8
Non-OECD Asia	16.3	22.1
Middle East	3.5	3.9
Africa	3.1	3.1
Central and South America	4.1	4.4

Source: F. Smith (ed), Environmental Sustainability: Practical Global Implications, 1997.

2.3.1 United States

The share of the Nation's total energy supply provided by renewable energy resources increased to 7.6 percent in 1995, up from 7.1 percent the previous year. But, non-hydroelectric renewable energy was essentially unchanged from 1994 levels.

Table 11: U.S. Renewable Energy Consumption by Source, 1991-1995

(Quadrillion Btu)

Energy Source	1991	1992	1993	1994	1995
Geothermal Energy	0.347	0.367	0.381	0.381	0.325
Biomass	2.642	2.788	2.784	2.852	2.941
Solar Energy	0.068	0.068	0.069	R0.068	0.073
Wind Energy	0.027	0.030	0.031	0.036	0.033
Total	6.265	6.106	6.403	6.296	6.832

Source: Energy Information Administration (EIA), Annual Energy Review 1995.

Biomass energy consumption increased by 3.1 percent from 1994 to 1995, a little more than the 2.6-percent annual growth rate from 1991 to 1994. Excluding hydropower, biomass accounted for 87 percent of the remaining renewable energy consumption in 1995. Production of energy from municipal solid waste (MSW) supplies, which grew rapidly during the 1980s as a result of waste-to-energy (WTE) facilities, has been curtailed during the 1990s. With the construction of new geothermal power facilities stalled, the most significant event in the U.S. geothermal industry in 1996 was the startup of a new 40-megawatt power plant in California, Salton Sea Unit IV.

The domestic wind energy market has remained stable, even as market uncertainty increases with electric utility deregulation and restructuring. Wind-powered electricity generation totaled 3.2 million kWh in 1995, down from 3.5 million kWh in 1994. California has, by far, more wind-powered generating capacity and electricity generation than any other

State. In 1996, California had 95 percent of the operational wind capacity in the country. Minnesota, however, has 61 percent of the planned capacity. Wind turbine performance continues to improve, and costs (both capital and operations and maintenance) continue to decline as wind energy projects are becoming increasingly geographically dispersed.

Solar energy consumption rose by 7 percent in 1995, mostly as a result of increased use of solar panels for heating in the residential/commercial sector. Shipments of photovoltaic modules and cells totaled 31.1 MW in 1995, an increase of 19 percent over 1994 shipments.

2.3.2 China

China is already the third largest energy consumer in the world after the United States and the former Soviet Union and ranks fourth in electricity use. The country's total energy consumption (commercial and non-commercial) in 1990 accounted for nearly 11 per cent of global carbon-di-oxide (CO2) emissions. Coal, of which China has 11 per cent of world reserves, forms the backbone of its energy system, supplying over 75 per cent of all commercial energy. But China's coal reserves have dramatically fallen. Whereas in 1987, China's proved recoverable coal reserves were assessed at 730 million tonnes, 1995 World Resources estimates reserves of 114 mt, just 15 per cent of the previous estimate.

China's interest in renewables, especially to meet rural energy needs, is growing. Substantial progress has already been made in applying solar, wind, and even tidal technology to electricity production. For example, 12 Chinese factories now produce photovoltaic modules and small 20-50 watt PV kits have becpome popular in remote sites. A 20 kW system has been completed. About 100,000 microwind units have been installed in northern and western provinces. About 10,000 wind pumps extract groundwater in northern and surface water in the south and east. Six wind farms with a capacity of over 4 MW have been connected to electric grids in various parts of the country.

2.3.2 Mexico

In Mexico, as part of the Mexico Renewable Energy Programme (MREP) team lead by Sandia National Laboratories, Winrock is helping to promote expanded use of renewable energy for agricultre, including the effective incorporation of renewable energy into the Mexican Government's agricultural investments programmes. This programme has resulted in the installation of over 140 solar PV water pumping systems for livestock, irrigation, and potable water supply.

The Renewable Energy Agriculture Project was approved by the Global Environment Facility (GEF) in 1999, with final World Bank and Mexican Government agreement in early 2000. The project, which began in fall of 2000, is valued at approximately $ 31 million. It is expected to support approximately thousand projects, including PV water pumping projects, over 50 wind electric projects, and 24 milk refrigeration projects.

2.3.3 Others

Several countries are launching programs to bring PV systems to rural areas. One of the most successful is the Dominican Republic. About 1500 systems have been installed since 1985. It is estimated that 20 per cent of rural households who lack electricity could afford a 35-40 watt PV system to satisfy their basic needs. Similar programmes using PV systems are under way in Sri Lanka and Indonesia. Biomass/cogeneration is also supposed to come up in a big way. The following table shows biomass energy consumption in developing countries.

Table 12: Biomass energy consumption (PJ)

Country	1981	1986	1991
Bangladesh	243	262	277
Bhutan	7	9	12
China	1541	1820	2018
India	2165	2441	2824
Indonesia	1181	1320	1465
Malaysia	69	78	90
Myanmar	156	175	193
Nepal	113	197	206
Pakistan	192	233	296
Philippines	308	327	382
Sri Lanka	70	78	89
Thailand	484	546	526
Vietnam	197	222	251
Total	**6755**	**7742**	**8666**

Source:Asia Energy Vision 2020: Sustainable Energy Supply, World Energy Council,1996.

World additions to installed wind turbine capacity reached their single-year high in 1995—a total of 1,289 megawatts—bringing the worldwide cumulative total to 4,900 MW. In the past 10 years, sales of photovoltaics worldwide have more than quadrupled, while installed costs have dropped by more than half. The rapid decline in the cost of photovoltaics and the development of niche markets have increased demand at a rate of 25 percent per year. In developing countries, demand has risen significantly. Manufacturers of photovoltaic cells and modules in the United States are currently exporting about two-thirds of their annual production.

The Philippines is now the second-largest producer of geothermal electricity, after the United States, with a 1994 installed capacity of 1,191 megawatts. Total installed capacity was expected to reach 1,945 megawatts by 1998. As of mid-1996, the World Bank and its Global Environmental Facility had a combined 41 renewable energy projects in several stages of development, from appraisal to ongoing.

2.4 NON-CONVENTIONAL ENERGY IN INDIAN AGRICULTURE

During the Eighth Five Year Plan, commercial renewable energy sources contributed to nearly seven per cent of total power capacity (including hydro power). It is estimated that nearly 3500 MW power can come from bagasse based cogeneration in the 430 sugar mills in India. Till July 2000, 1704 biomass gasifiers with an aggregate capacity of 34.36 MW had been installed. Biomass based power plants are ideal for decentralized application in rural areas. India is among the largest markets and manufacturers or solar PV modules in the world. The country has installed 58 MWp of Solar PV systems for various end uses and exported about 6 MWp PV. With an installed capacity of over 1175 MW, India ranks fifth in wind power generation in the world. India's wind power potential is estimated at 45,000 MW. Till 31 march 2000, 3 million biogas plants had been set up, indicating nearly 25 per cent coverage of potential. The estimated potential for deployment of solar water heaters is around 30 million square metres of collector area. However, so far, only about 500,000 square metres has been installed.

Over the next 15 years, renewable energy supplies could increase by more than seven times, and their share in the country's total power generation capacity could nearly triple. At roughly 1,378 MW, renewable energy technologies currently account for about 1.5 per cent of the total power generation capacity (MNES, 1999), of which wind power accounts for about 72 per cent (992 MW) and small hydro roughly 13 per cent. Biomass and solar energy account for the rest. MNES has estimated that 126 gigawatts of power generation capacity is available for renewable energy sources in the long run. Although the technical potential for the use of renewable energy sources in India is vast, the prospects for expansion may be limited because of technological, institutional, infrastructural and financial constraints.

Table 13: Potential contribution of renewable energy technologies (gigawatts)

Installed Capacity (gigawatts)	2001-2002	2006-2007	2011-2012
With govt. financial incentives	4.5 (3.4 %)	7.1 (3.5 %)	11.0 (3.8 %)
Without govt. financial incentives	3.1 (2.3 %)	4.9 (2.4 %)	6.7 (2.3 %)

Note: Percentages of the totals for India are in parentheses
Source: Special Millennium Issue, PowerLine magazine, 2000.

2.4.1 Wind Pumps

In the early 1950s, about 100 Australian "Yellowtail' machines were imported by the Public Health Department, Government of India, and installed under a project for providing drinking water. During the 1970s and 1980s, several new wind pump models such as the NAL-MP series, CEZARI, ANILA, POGHIL, and SAMIR were developed and tested. In the early 1980s, the 'Apoly 12PU500' was designed and fabricated at the Institute of Engineering Technology, Allahabad with Dutch assistance. This wind pump designed had a 12-bladed rotor of 5 metre diameter directly connected to a piston pump. It was selected by the MNES for large-scale propagation all over India and more than 3000 12PU500 wind pumps were subsidized by the MNES and installed under the demonstration programmes.

The performance of a majority of these wind pumps in the field was not satisfactory mainly due to implementation problems such as improper siting and installation, lack of user awareness and training and poor maintenance. However, the 12PU500 continues to operate successfully in several pockets in Bihar and Gujarat where the site conditions are suited to the wind pump (wind speeds are low and the water table is high), and the users have learnt to take care of routine maintenance.

Since 1993, the MNES has also been supporting the 3-m diameter geared-type deep-well wind pumps under its demonstration programme. This is a first generation wind pump that has a proven performance record for unattended operation in Argentina, Australia, Canada, and USA.

Another wind pump supported by the MNES under its subsidy schemes is the 'AV-55' wind pump developed by the Centre for Scientific Research, Auroville (5.5 m diameter, 18-bladed, direct-drive).

The MNES currently provides subsidy on these models. It is likely that these subsidy levels will be maintained during 2000/01. A state wise list of wind pumps supported by the MNES since 1993 is given in Table 14.

Table 14: State-wise wind pump installations

	Windmills installed							Total
	1993-94	1994/95	1995/96	1996/97	1997/98	1998/99	1999/00	
Andhra Pradesh	0	0	0	0	0	1	1	2
A & N	0	0	0	0	0	0	2	2
Assam	0	0	0	3	0	0	0	3
Bihar	0	0	30	0	12	0	0	42
Gujarat	0	3	32	36	57	6	86	220
Karnataka	0	0	3	0	11	0	6	20
Kerala	0	10	14	20	11	0	12	67
Maharashtra	0	3	1	0	7	0	7	18
Rajasthan	0	032	8	32	100	50	0	222
Tamil Nadu	0	8	2	7	7	5	12	41
Total	0	56	90	98	205	62	126	637

Source: Annual report:1999-2000, MNES, GOI, New Delhi (2000)

The wind pumps are mainly popular in the coastal regions and some of the hilly states since these places have adequate wind speed through out the year. A normal wind pumping system normally needs a cut-in wind speed of around 10kmph and can efficiently draw water from up to 20 metres depth.

2.4.2 Biogas

The National Project on Biogas Development was launched in 1981-82 for the promotion of family type biogas plants. The project aims at providing a clean and inexpensive energy source, producing enriched manure and improving sanitation in rural areas.

Against a target of setting up nearly 68,000 family type biogas plants in 1999-2000, about 60,000 plants were in stalled till December 1999. The Ninth Plan has set a target of installing at least 1.2 million family type biogas plants. Biogas generated in such plants can also be used to power pumping systems in the rural areas. Around 25 kg of wet dung is enough to generate 1 m^3 of biogas in such plants. Besides pumping, the gas can be used for other thermal and mechanical applications.

The other main benefit of the biogas based system is the generation of manure. Such manure can replace the fertilizers and thereby save on pollution and the energy consumption on production of chemical fertilizers.

2.4.3 Biomass Gasifiers for Thermal Applications

The techno-economic feasibility of utilizing biomass gasifiers for a variety of thermal applications has been well established. The capacity rating of these gasifiers is up to 150kg of biomass per hour (equivalent to 400,000 kcal). The lower capacity gasifiers are used in small-scale industries like silk reeling, textile dyeing, drying, and for community cooking. Commonly available biomass gasifiers for thermal applications have inherently low payback periods. Moreover, the use of gasifiers offers substantial reductions in fuel consumption and harmful emissions.

Biomass gasifier based systems for power generation and a variety of thermal and shaft power applications are gaining popularity in India. For example, 3k W-500kW biomass gasifier based power generation systems are commercially available in India. Small size gasifiers coupled to diesel engine pumpsets are also being considered for irrigation pumping. Five HP (3.75kW) and ten HP (7.5kW) systems are now commercially available and so far, about 500 biomass gasifier based pumpsets have been installed in the country. With respect to the vast potential of water pumping applications, financial incentives (up to 60% of the capital cost in 1996-1997) are provided by the Government of India to encourage the use of biomass gasifiers for water pumping in rural areas.

A biomass based water pumping system consists of a biomass gasifier with cooling and cleaning system and a dual-fuel diesel engine coupled with a centrifugal type pump. Gasification of biomass in presence of restricted amount of air produce a combustible gas. This medium calorific value gas (1100 kcal/kg) known as producer gas can be used in diesel engines in dual fuel mode replacing about 65-70 per cent.

Direct combustion of biomass resources such as agricultural residues and firewood as fuel for domestic as well as industrial applications has been a traditional practice. Biomass fuels have found place for boiler applications in rice mills, sugar industries and several other agro-processing industries. However, in many of these applications, the efficiency of utilisation is rather low and it is necessary to develop energy efficient technologies for bio-fuel utilisation.

Table 15: Biomass potential (million tonnes)

Biomass	1980/81	1985/86	1990/91	1991/92	1992/93	1993/94	1994/95	1995/96
Rich husk	26.8	31.9	37.1	37.3	36.5	40.2	40.9	39.8
Wheat straw	48.4	62.7	73.5	74.3	76.3	79.6	87.5	83.3
Maize cobs	2.1	2.0	2.7	2.4	3.0	2.9	2.7	2.8
Millet straw	8.9	6.1	11.4	7.8	14.8	8.3	12.0	9.0
Bagasse	51.4	56.9	80.4	84.7	75.8	90.9	93.4	na
Coconut shell	0.8	0.9	1.3	1.4	1.5	1.6	1.8	1.9
Coconut fibre	0.9	1.1	1.6	1.7	1.9	2.0	2.2	2.3
Coconut pith	1.4	1.7	2.4	2.5	2.8	2.9	3.3	3.4
Grndnut. shell	1.7	1.7	2.5	2.4	2.9	2.6	2.7	2.6
Cotton stalks	23.5	22.6	22.3	23.0	22.6	22.0	23.7	27.3
Jute sticks	3.9	4.5	3.1	3.3	2.8	2.7	2.7	2.7

Source: Tata energy data directory and yearbook, TERI, New Delhi (2001)

A variety of incentives are being given by the Government of India to encourage the use of biomass gasifier technology. During the year 1996-97 the financial support provided under the biomass gasifier demonstration programme was 30 per cent of the cost of gasifiers for thermal applications and 60 per cent for the mechanical and electrical applications. In the same year there was a special scheme for providing financial support to the extent of about 50-75 per cent of the capital cost of gasifiers for thermal applications at community level.

Table 16: Biomass power statistics (1999)

Project Status	Biomass power		Cogeneration		Total	
	MW	Numbers	MW	Numbers	MW	Numbers
Commissioned	38	9	174	30	212	39
Under implementation	61.5	15	218.7	28	280.2	43
Pipeline	263	37	303	22	566	59

Source: Special Millennium Issue, PowerLine magazine, 2000.

2.4.4 Improved Cookstoves

The National Programme on Chulhas was launched in 1984-85 with the objectives of fuel conservation, reduction of smoke and conservation of forests and the environment. Improved chulhas can have thermal efficiencies in the range 20 per cent-35 per cent. About 800,000 improved chulhas were installed during April-December 1999.

2.4.5 Solar Thermal Systems

In India, solar thermal systems have two major applications: domestic and industrial. In the industrial sector, solar thermal energy is utilized for preheating boiler feed water and also for supplying direct process heat. The resultant savings are mainly in terms of boiler fuel. Moreover, solar water heating systems are used to meet hot water requirements in hotels, hospitals, and hostels. In the domestic sector, since solar water heating systems primarily replace electric geysers, it saves electrical energy. The small capacity systems (capacity up to 2000 litres per day work on natural circulation or the thermo-siphon principle. However, for larger capacity systems, pump with necessary controls is required for circulation of water and such systems are designated as 'forced flow' systems. According to a conservative estimate, the potential for the deployment of solar water heaters is around 30 million square metres of collector area, of which 500,000 square metres have already been installed.

Considering the vast potential and resource availability, the Government of India, through the MNES provided various incentives in terms of subsidy and other fiscal benefits for the promotion of solar water heating systems. These subsidies were abolished in July 1993 when the technology attained a certain level of commercialization. Instead, provisions were made for soft loans through IREDA and some other designated banks.

2.4.6 Solar Cooking

In an ordinary household in the country, a major part of the energy is spent on cooking. In urban households, there is a gradual shift from fuel wood to LPG (liquefied petroleum gas) for cooking. Therefore, cooking with solar energy appears to be a viable option in the domestic sector. At the micro level, solar cooker facilitates financial savings for the consumer; at the macro level, it helps in the conservation of LPG and fuelwood. Cooking through solar cookers also helps in abating the greenhouse effect. Of the different types of solar cookers, indirect heating type solar cookers (with or without heat storage), and hybrid type solar cookers, the box type solar cookers have reached the commercialization stage. Nearly 480,000 cookers have been sold since the inception of the MNES. In April 1994, the subsidy provided by the MNES on solar cookers was replaced by financial support for promotional activities such as publicity, cooking demonstrations and competitions, and training. Soft loans are presently available for purchase of solar cookers through some designated nationalized banks.

2.4.7 Non-Conventional Fuels for Surface Transport

The MNES promotes the substitution of petrol-driven vehicles by BOVs (battery-operated vehicles) and of diesel by alcohols like ethanol and methanol. To facilitate the implementation of BOVs and alcohol-operated vehicles, CASE offers subsidies and has approved the operation of the state road transport corporation buses on dual fuel mode, namely diesel alcohol, in five states. In Delhi, the state is successfully implementing the running of DTC (Delhi Transport Corporation) buses and auto-rickshaws on CNG (compressed natural gas) which has substantially reduced carbon-dioxide (CO_2) emissions in the city.

The use of BOVs, however, has been constrained by inadequate infrastructure support for charging/replacement of batteries, poor performance, high maintenance cost, failure of components etc.

2.4.8 SPV Pumping

Solar energy offers several features that make its utilisation for irrigation pumping quite attractive. First, the greatest need for the pumping occurs in the summer season when the solar radiation availability is maximum. Secondly, pumping can be intermittent to an extent. During periods of low solar radiation, evaporation losses from crops are also low.

Despite efficient operation and mature technology, the SPV based pumping has not become very popular, primarily due to prohibitive costs. However, with further advances in the technology, the costs are likely to come down.

2.4.9 Solar Drying

Besides pumping, solar energy can also be used extensively for crop drying. Drying is necessary as the crops usually carry more moisture and this needs to be removed after the crops are harvested. As against conventional fuels being used for the drying purpose, solar energy can be used efficiently. This is especially suitable since crop drying does not require very high temperatures.

In India, such systems can be used for drying of cash crops and foodgrains and are in operation in quite a few tea and coffee estates.

2.4.10 Solar Greenhouse

A solar greenhouse offers possibility of year-round plant production. Greenhouses provide crop cultivation in a controlled environment. A greenhouse is basically a structure covered with transparent material that uses solar energy to grow plants that may not otherwise grow due to harsh winter conditions. A typical greenhouse is equipped with temperature control equipment for heating, cooling, ventilation etc.

A winter green house is especially suitable for very cold climates where otherwise it would be impossible for any kind of vegetation to grow. These can be employed in India especially in hilly states like the north-east, Himachal Pradesh, Uttaranchal and Jammu and Kashmir.

Chapter 3

CARBON-DI-OXIDE EMISSIONS FROM AGRICULTURE AND INTER-SECTORAL EMISSIONS TRADING

CO_2 EMISSIONS FROM AGRICULTURE

3.1 INTRODUCTION

The gross CO_2 emissions attributable to the agriculture sector comprise the direct emissions and the indirect emissions. The direct emissions can be directly linked to the fuel use in the agriculture sector. This may include fuel consumption in irrigation, drying, harvesting, transportation, etc. The indirect emissions are the energy embodied in the common inputs used in the agriculture sector like fertilizers, pesticides and other chemical compounds. The emissions caused due to production of various farm equipment may also be included as indirect emissions. Tables 17 and 18 show the direct and indirect emissions from the agriculture sector.

Table 17: Direct emissions

Year		Natural gas (m. m^3)	HSD (m. tonne)	LSD (m. tonne)	Fuel oil (m. tonne)	Power (GWh)	CO_2 (m. tonnes)
1996-97	1	163.40	0.55	0.04	0.28	98,880	49.44
1997-98	2	128.38	0.55	0.04	0.30	103,800	51.90
1998-99	3	163.40	0.57	0.04	0.35	103,920	51.96
1999-00*	4	163.40	0.59	0.04	0.38	104,400	52.20

**Estimated figures*

Source: Tata energy data directory and yearbook, TERI, New Delhi (2001)

Table 18: Indirect emissions due to fuel consumption in fertilizer production

Year		Naphtha (m. tonnes)	Furnace oil (m. tonnes)	LSHS (m. tonnes)	HSD/LDO (m. tonnes)	Electricity (GWh)	CO_2 (m.tonnes)
1990-91	1	1.84	1.06	1.18	0.02	4,906	15.24
1991-92	2	1.77	1.40	1.05	0.03	5,013	15.74
1992-93	3	1.68	1.35	1.00	0.02	5469	15.35
1993-94	4	2.17	1.16	1.05	0.01	5700	16.62
1994-95	5	2.50	1.51	1.00	0.02	6203	18.87
1995-96	6	2.67	1.77	1.11	0.03	5946	20.46
1996-97	7	2.73	1.37	1.35	0.03	7213	20.81
1998-99*	8	3.19	1.49	1.55	0.04	7,536	23.40

**Estimated figures*

Source: Tata energy data directory and yearbook, TERI, New Delhi (2001)

It may be noted that during 1998-99, the direct and indirect emissions attributable to the agriculture sector were 52.2 million tonnes and 23.4 million tonnes respectively.

3.2 TREND ANALYSIS

The basic assumption in potential estimation using trend analysis is that the historical trend will continue in the future. The methodology involved collation of historical figures (for the last four years) for fuel consumption in the agriculture sector. The direct fuel consumption comprised the fuels used to power the farm equipment, tractors, pumps etc.

In this scenario, the historical values for fuel and fertilizer consumption for the last four years was extrapolated using the regression time-series approach and the CO_2 emissions were projected for the next 5 years.

The methodology followed was as follows:

- For the last four years, the consumption of various fuels directly used in agriculture was noted.

- For each of these fuels, a time-series curve fitting approach was used and the equation of best-fit was obtained. This equation was used to project the consumption of these fuels in the agriculture sector for the next five years.

- The consumption of fertilizer was noted in the agriculture sector. The fuels used in fertlizer, hence indirectly contributing to the CO_2 emissions in the agriculture sector were estimated.

- Similar curve-fitting approach was used for each of these fuels to project their consumption in the next five years.

- Corresponding carbon emission directly and indirectly caused by the agriculture sector were calculated.

3.3 EQUATIONS OF TREND FOR FUEL CONSUMPTION

3.3.1 Direct consumption of fuel:

High speed diesel consumption (C_{hsd}):

$$C_{hsd} = 0.005\, y^2 - 0.011\, y + 0.555 \quad (1)$$

Fuel Oil (C_{fo}):

$$C_{fo} = 0.0025\, y^2 + 0.0225\, y + 0.2525 \quad (2)$$

Power (C_p):

$$C_P = 1668\, y + 98580 \quad (3)$$

Natural Gas (C_{ng}):

$$C_{ng} = 3.502\, y + 145.89 \quad (4)$$

3.3.2 Indirect consumption of fuel (inputs in fertilizers):

Naphtha ($IC_{naphtha}$):

$$IC_{naphtha} = 0.0197\, y^2 + 0.0316\, y + 1.6741 \quad (5)$$

Fuel Oil (IC_{fo}):

$$IC_{fo} = 0.0124\, y^2 + 0.1652\, y - 0.9627 \quad (6)$$

LSHS (IC_{lshs}):

$$IC_{lsha} = 0.0293\, y^2 - 0.2121\, y + 1.3673 \quad (7)$$

HSD/LDO ($IC_{hsd/ldo}$):

$$IC_{hsd/ldo} = 0.0011\, y^2 - 0.0075\, y + 0.0314 \quad (8)$$

Power (IC_{power}):

$$IC_{power} = 33.095\, y^2 + 75.286\, y + 4815.5 \quad (9)$$

where:

C = direct consumption of fuel

IC = indirect consumption of fuel

y = year number (1,2,3…) with y=1 for 1996-97

Table 19: Fuel consumption projections for 2005

Type of fuel	Projected 2005 levels of fuel consumption
Natural gas	180.91 mm^3
High speed diesel	0.945 mt
Low sulphur diesel	0.04 mt
Fuel oil (direct)	0.7275 mt
Power (direct)	115260 GWh
Naphtha	6.5806 mt
Fuel oil (indirect)	4.3053 mt
Low sulphur heavy stock	4.7783 mt
HSD/LDO (indirect)	0.1664 mt
Power (indirect)	13391.17 GWh

3.4 REGRESSION RESULTS OF CARBON-DI-OXIDE EMISSIONS

The basic assumption in this potential estimation is that the historical trend will continue in the future. The historical figures for fuel consumption in the agriculture sector were collated. The regression of CO_2 emission on the direct fuel consumption in agriculture was done using the historical data for consumption as well as the projected consumption figures. It gave an R square value of 1. It was observed that the direct CO_2 emission in 2005 stands at 53.44 million tonnes.

Table 20: Direct CO_2 emission

Year		Natural gas (m. m^3)	HSD (m. tonne)	LSD (m. tonne)	Fuel oil (m. tonne)	Power (GWh)	CO2 (m. tonnes)
1996-97	1	163.40	0.55	0.04	0.28	98,880	49.44
1997-98	2	128.38	0.55	0.04	0.30	103,800	51.90
1998-99	3	163.40	0.57	0.04	0.35	103,920	51.96
1999-00*	4	163.40	0.59	0.04	0.38	104,400	52.20
2000-01	5	163.40	0.62	0.04	0.43	106,920	53.28
2001-02	6	166.90	0.67	0.04	0.48	108,588	53.43
2002-03	7	170.40	0.72	0.04	0.53	110,256	53.59
2003-04	8	173.91	0.78	0.04	0.59	111,924	53.68
2004-05	9	177.41	0.86	0.04	0.66	113,592	53.44

For analysing the consumption of fuel indirectly used in agriculture, the fuel consumption in production of fertilizers was collated for the last four years and again by using the regression analysis, these numbers were projected till 2005. The R square value achieved was 0.99. The CO_2 emissions which can be indirectly attributed to the agriculture sector were thus calculated.

Table 21: Emissions due to indirect fuel consumption

Year		Naphtha (m. tonnes)	Furnace oil (m. tonnes)	LSHS (m. tonnes)	HSD/LDO (m. tonnes)	Electricity (GWh)	CO_2 (m.tonnes)
1990-91	1	1.84	1.06	1.18	0.02	4,906	15.24
1991-92	2	1.77	1.40	1.05	0.03	5,013	15.74
1992-93	3	1.68	1.35	1.00	0.02	5,469	15.35
1993-94	4	2.17	1.16	1.05	0.01	5,700	16.62
1994-95	5	2.50	1.51	1.00	0.02	6,203	18.87
1995-96	6	2.67	1.77	1.11	0.03	5,946	20.46
1996-97	7	2.73	1.37	1.35	0.03	7,213	20.81
1998-99*	8	3.19	1.49	1.55	0.04	7,536	23.40
1999-00	9	3.55	1.53	1.83	0.05	8,173	25.89
2000-01	10	3.96	1.93	2.18	0.07	8,877	29.90
2001-02	11	4.40	2.35	2.58	0.08	9,648	34.24
2002-03	12	4.89	2.81	3.04	0.10	10,484	39.09
2003-04	13	5.41	3.28	3.56	0.12	11,387	44.28
2004-05	14	5.98	3.78	4.14	0.14	12,356	49.94

Finally it emerges that the total emissions in the year 2005 would reach ***103 million tonnes*** according to this approach.

Table 22: Direct and indirect emissions

Year	CO_2 emissions (million tonnes)
1998-99*	75.43
1999-00	78.14
2000-01	83.17
2001-02	87.67
2002-03	92.68
2003-04	97.96
2004-05	103.38

Graphs showing pattern of carbon-di-oxide emissions from direct and indirect agricultural sources and total carbon-di-oxide emissions are given in the Annexures.

INTER-SECTORAL EMISSIONS TRADING

3.5 INTRODUCTION

At the United Nations Conference on Environment and Development held in Rio de Jeneiro in June of 1992, 154 countries and the European community formally signed the Global Framework Climate Change Convention (GFCCC). The stated objective of the convention was 'stabilization of greenhouse gas concentrations in the atmosphere at a level which would prevent dangerous anthropogenic interference with the climate system'.

CO_2 is the principal greenhouse gas. According to the 1990 scientific assessment by the inter-governmental panel on climate change, stabilisation of CO_2 concentrations in the atmosphere at present day levels would require reductions in annual emissions from human sources of more than 60 per cent. The less onerous scenario of maintaining atmospheric emissions at 1990 levels would lead to an eventual increase in atmospheric concentration of about 50 per cent.

In an ACCF Special Report by M. H. Novak, studies show that the required reduction in carbon emissions from the energy sector is very large. Even though each country is gaining in energy and carbon efficiency, they are pessimistic about the prospects for the United States, Canada, Japan, Australia, and New Zealand meeting their Kyoto targets without relying on extraordinary measures (such as carbon fees) or trading. The studies stress that carbon dioxide emissions are related to all facets of energy use in the economy, that energy is fundamental to improving economic performance, and that energy and carbon efficiency are difficult to improve further in the short- to mid-term due to the cost and longevity of energy-using capital equipment.

3.6 THE UNITED STATES' ARGUMENT AGAINST THE PROTOCOL

President Bush recently announced that the United States Government will not honour its commitments under the 1997 Kyoto Protocol to reduce greenhouse gases. The United States produces 25% of the world's carbondioxide, a gas that is believed to be the main contributor to global warming.

Because U.S. agriculture accounts for nearly one-fifth of U.S. greenhouse gas emissions, compliance with the Kyoto Protocol can increase U.S. farm production expenses by $ 10 billion to $ 20 billion annually and depress annual farm income by 24 per cent to 48 per cent. Higher fuel oil, motor oil, fertiliser and other farm operating costs would also mean higher consumer food prices, greater demand for public assistance with higher costs, a decline in agricultural exports and a wave of farm consolidations. At the negotiating session in December, 1997, U.S. administration officials agreed to reduce U.S. greenhouse emissions to 7 per cent below 1990 levels by 2010. The U.S. Senate, however, has indicated that it will not approve any treaty that causes economic harm to the United States.

U.S. farming is very energy intensive. Fuel and oil costs represent only about 30 per cent of the total energy bill farmers pay. The remaining 70 per cent is hidden in the prices of manufactured inputs, fertilisers, pesticides and other chemicals. the American Petroleum Institute (API) reports that gasoline, diesel fuel and electricity prices would need to rise, through use of a carbon tax, by 50 per cent or more – or about $ 0.50 per gallon - to cap U.S. greenhouse emissions at 1990 levels.

The U.S. department of commerce has estimated the tax necessary to cap emissions at $ 0.25 per gallon, on the assumption that the administration will get other nations to agree to a highly efficient international emissions trading regime, while finding a way to boost domestic economic activity by shifting taxes away from capital. A 1998 paper by Francl, Nadler and Bast, presented at the ACCF Centre for Policy Research, studies how taxes likely to result from the Kyoto Protocol will affect farmers and the U.S. economy.

An energy price increase of $ 0.25 per gallon of fuel is likely to cause the cost of agricultural inputs to rise from 5–25 per cent; a $0.50 per gallon fuel cost hike would increase the prices of inputs by 10-50 per cent. It has been estimated that the Protocol would cause a 0.7 per cent decline in domestic demand for food which would depress food prices. The higher energy costs together with reduced domestic and export demand, could lead to a decline in investment in agriculture and a sharp increase in farm consolidation.

Table 23: Farm income impacts as a result of the Kyoto Proposal

Item	1998	Impact	Adjusted	Change
		billion $		(pct)
Farm receipts	214	-5.3	209	-2.3
Direct govt. payments	7		7	0.0
Gross cash income	221		216	-2.3
Gross farm income	231		226	-2.3
Cash expenses	165	16.2	181	9.6
Total expenses	186	16.2	202	8.6
Net cash income	56	21.5	35	-38.9
Net farm income	46	21.5	24	-52.8

Source: ACCF CPR, Impact of the Kyoto Protocol on Agriculture (Special Report), 1998.

Both emissions taxes and tradable permits provide price incentives for emitters to abate without dictating how that abatement is to occur. Emitters within each country are left free to choose the most cost effective means of reducing emissions.

3.7 TRADABLE PERMITS

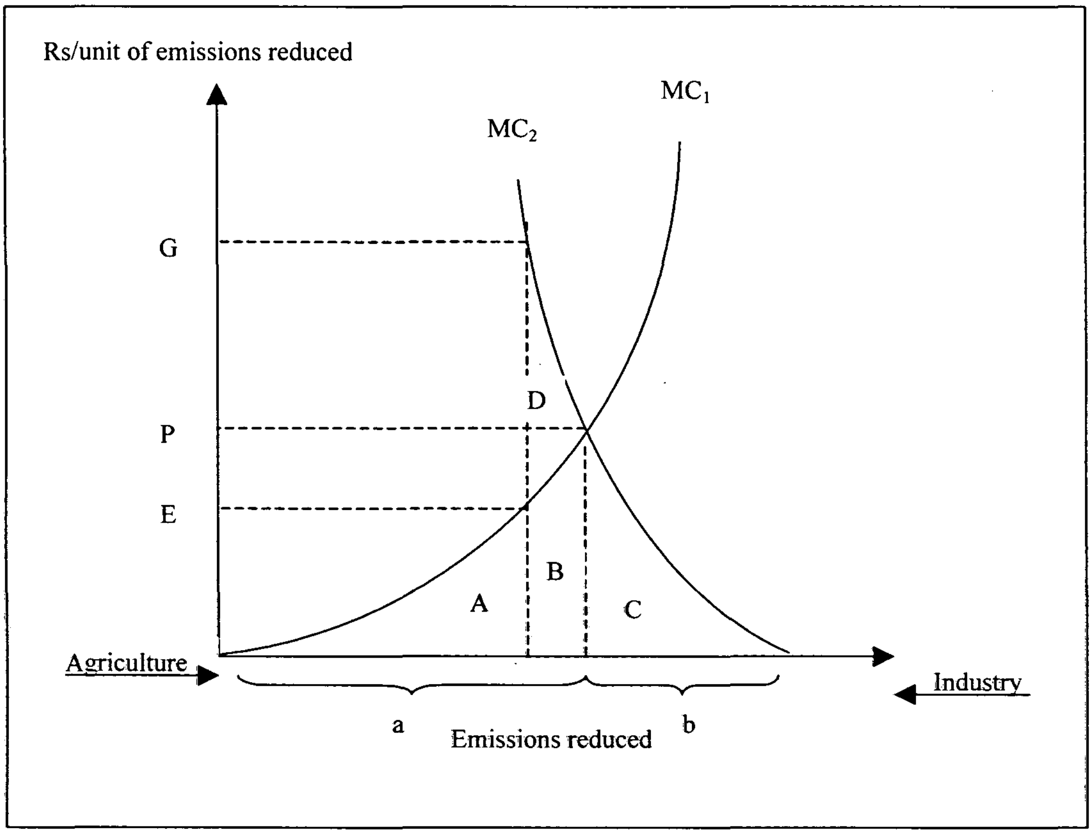
To improve global efficiency, a system of tradable emission permits has been proposed. In this scheme, a country which has a high marginal cost of emission reduction can lower it by purchasing emission permits from another country which has a lower marginal cost. Moreover, if the permits are allocated in an appropriate manner, fair burden sharing can be realised through money transfer associated with permit trade. Permit trade is theoretically expected to have a potential to be an efficient and equitable institutional scheme for controlling CO_2 emissions.

Under a system of internationally traded emission permits, countries would receive a quota of emissions 'permits' entitling firms and industries in each country to emit CO_2. The sum of the emissions allowed under a permit system would be equal to a predetermined level, for example, 80 per cent of a country's current emissions. The permits would then be traded in the open market both within and across national borders. Countries wishing to increase their emissions beyond their initial permit allocation would need to buy permits from other countries. Those nations with a high cost of emissions abatement would be able to purchase emissions credits from countries with a low cost of abatement under an agreed set of international protocols.

International trading of emissions permits could result in substantial transfers of wealth between buyers and sellers. Thus, the initial allocation of permits would create winners and losers within a context of an overall efficient outcome. In an unequal world such as ours, it is difficult to rely on perfect international co-operation and efficiency. We are already in a position where the developed countries are responsible for the largest share of GHG emissions. In an open market, the ability to purchase emissions permits will also rest in the hands of a few affluent nations. In trying to curb emissions, a country's development and economic progress may be hampered, which is something the developed countries did not have to deal with. Trading in emissions permits between different sectors within the national boundary is an effective way of controlling emissions and at the same time catering to the national interest.

3.8 THE EMISSIONS TRADING CONCEPT

Figure 4: Inter-sectoral allocation of emissions reduction



Source: T. H. Tietenberg,, Emissions Trading, Resources of the Future, 1985.

Here, MC_1 is the marginal cost of abatement function for agriculture and MC_2 is the marginal cost of abatement function for industry. The figure is drawn assuming that there are only two sectors which are sources of pollution. For achieving the target reduction in emissions, (a+b) amount of emissions needs to be reduced. The origin of MC_1 is the left-hand axis and the origin of MC_2 is the right-hand axis. The desired a+b units of emissions reduction is achieved at every point on this graph. Drawn in this manner, the diagram represents all possible allocations of the a+b reduction between the two sectors.

In a cost effective allocation of the control responsibility between these two sources, agriculture cleans up "a" units while industry cleans up "b" units. The total variable control cost of this particular assignment of responsibility of reduction is represented by the area A+B+C. Area A+B is the cost of control for agriculture while area C is the cost of control for industry. Any other allocation would result in a higher total control cost. As shown in the figure, an arbitrary alternative allocation would result in a total control cost of A+B+C+D, which is greater than A+B+C.

If this was the starting point, then both sectors will have the incentive to trade, since the marginal cost of control for industry is substantially higher than that of agriculture. This is generally the case as industry, being the major pollutant, is responsible for the bulk of the control. Industry would lower its cost as long as it could buy emission reduction credits from agriculture at a price lower than "G". Because the marginal cost curves cross at the cost effective allocation, they must be equal at that point. Given the presumed shape of the curves, marginal control costs are not equal at any other allocation. Therefore, the costs of achieving a given reduction in emissions will be minimized if and only if the marginal costs of control are equalized across all emitters.

In the present scenario, non-conventional sources of energy are more applicable to agriculture than to industry. Switching over to non-conventional sources of energy would imply a substantial reduction in CO_2 emissions in the agricultural sector. This reduction can foster growth in the industrial sector by allowing for that much of additional emissions as is reduced by the agricultural sector and at the same time adhering to the FCCC norms. This kind of inter-sectoral trade in emissions permits seems more plausible as it will be executed in the national interest with a common aim for both parties involved.

The following tables and diagram of Energy, Environment and the Economy: Asian Perspectives by Kleindorfer, Kunreuther and Hong (1996) show how the international scene will look after implementation of the permits regime.

Table 24: Estimated macroeconomic effects of an emissions trading system where OECD countries stabilize their own emissions or purchase emissions credits from other countries

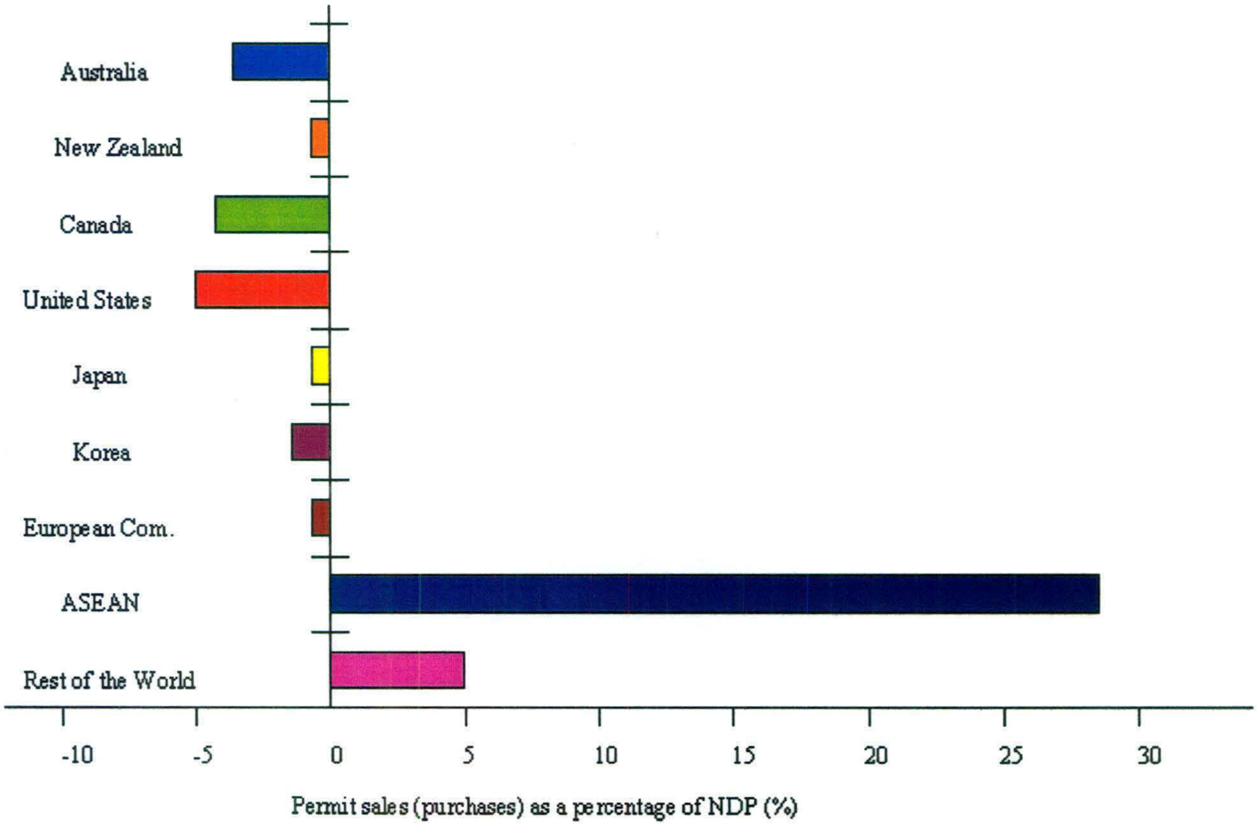
	Annual percentage change in real national consumption	Permit price per tonne of CO_2 (US $ 1988)	Percentage change in emissions levels	Sale of permits (MT of CO_2)
Japan	-0.04	$ 5	-4	-195
Korea	-0.06	$ 5	-2	6
ASEAN	-0.13	$ 5	-3	8
Australia	-0.29	$ 5	-5	-46
New Zealand	-0.11	$ 5	-2	-3
Canada	-0.01	$ 5	-4	-10
United States	-0.11	$ 5	-10	-96
European Union	-0.04	$ 5	-2	-145
Rest of the World	0.03	$ 5	-3	480

Table 25: Estimated macroeconomic effects of an emissions trading system where permits are allocated on a per capita basis and global emissions are stabilized at 1990 levels in the year 2000

	Annual percentage change in real national consumption	Permit price per tonne of CO_2 (US $ 1988)	Percentage change in emissions levels	Sale of permits (MT of CO_2)
Japan	-1.07	$ 49	-20	-297
Korea	-2.95	$ 49	-15	-32
ASEAN	31.24	$ 49	-8	1245
Australia	-5.31	$ 49	-26	-139
New Zealand	-1.42	$ 49	-13	-7
Canada	-5.15	$ 49	-25	-353
United States	-7.92	$ 49	-33	-4342
European Union	-1.66	$ 49	-15	-712
Rest of the World	4.52	$ 49	-14	4637

The following diagram shows ASEAN countries to be the net sellers of the emissions permits. This gives an optimistic scenario for agriculture and industry to work together in meeting the 1990 standard of emissions imposed by the FCCC.

Figure 5: Permit sales as a percentage of NDP for various countries



As is implied by the two tables and the diagram, ASEAN countries stand to gain from a permit regime, being net sellers of permits to the developed nations. But it also implies that emissions will be largely restricted by these countries leading to a possible slowdown of growth. To combat this dual problem, working within a country to exploit the comparative advantages of different sectors for pollution abatement (not only cost effectiveness), and the feasibility of such abatement keeping in mind the objective of economic growth, seems to be a solution.

Many countries are now making efforts to stabilize greenhouse gas emissions at the levels realised in 1990. Although it is a significant first step, greenhouse gas emissions must be further reduced in order to stabilize greenhouse gas concentrations in the atmosphere, which is the target set in the Framework Convention on Climate Change.

Carbon taxes have been introduced in some countries, and other countries are now considering the possibility. A carbon tax theoretically minimizes the national cost of reducing CO_2 emissions because marginal costs are set equal to the tax rate in all sectors. However, since the marginal cost to achieve each country's reduction target differs from one to another, global efficiency in controlling emissions is generally not maximized by the national carbon taxes.

Over the next 20 years, energy use in the Asian region is anticipated to grow by about 5 per cent annually. This is among the highest rates of growth of any world region. Restricting the growth in fossil-fuel use in Asia would severely hamper the region's ability to benefit from the sort of economic growth developed nations have already enjoyed. The 1992 GFCCC recognised the costs developing nations would incur if they were obliged to reduce rates of growth in the use of fossil fuels. Consequently, the Convention only committed OECD countries to reducing their emissions of greenhouse gas. Nevertheless, OECD-wide reductions in emissions will still have spillover effects into the Asian region through reduced demand for fossil fuels and a general decline in world-wide economic activity.

Chapter 4

ABILITY TO PAY AND THE BURDEN OF SUBSIDIES TO NON-CONVENTIONAL ENERGY SOURCES

THE FARMER'S ABILITY TO PAY

4.1 INTRODUCTION

The Intergovernmental Panel on Climate Change (IPCC) jointly established by the World Meteorological Organization and the United Nations Environment Programme, concluded in 1995 that "the balance of evidence suggests that there is a discernible human influence on global climate." Current concentrations of carbon dioxide, methane, nitrous oxide, and the other greenhouse gases have reached levels well above those of pre-industrial times. Of these, carbon dioxide (CO_2) is the most important: net cumulative CO_2 emissions resulting from the burning of fossil fuels and deforestation account for about two-thirds of potential warming from changes in greenhouse gas concentrations related to human activity.

If growth in global emissions continues unabated, the atmospheric concentration of CO_2 is likely to double relative to its pre-industrial level by midway through the next century and continue to rise thereafter. As a result of the increased concentration of CO_2, the IPCC estimates that global temperatures will increase by between 2 to 6 degrees Fahrenheit in the next 100 years, with a best guess of about 3.5 degrees Fahrenheit. While scientists believe that human activities are leading to a gradual warming of the average temperature of the earth, the change in temperature in a given region at a given time may differ substantially from this average. Indeed, models predict warming will be greater in high latitudes than in the tropics, and greater over land than ocean.

Potential consequences associated with this shift in climate include a rise in sea levels, greater frequency of severe weather events, shifts in agricultural growing conditions from changing weather patterns, threats to human health from increased range and incidence of diseases, changes in availability of freshwater supplies, and damage to ecosystems and biodiversity.

Thus, there is a growing importance of applying non-conventional energy sources to agriculture where it is feasible. Since introduction of these energy applications, be it water pumping systems or gasifiers or solar drying, require considerable amount of investment, therefore, it is imperative that for any kind of potential estimation of such technologies the starting point has to be the affordability.

4.2 METHODOLOGY

The following methodology was adopted for estimating the affordability level of the farmers:

- The production in million tonnes for each crop and the corresponding area in million hectares under cultivation for that crop were tabulated. This gave the yield of the production per unit hectare for each crop in each state. This also gave the proportion of area under cultivation for each crop in each state.

- The yield per hectare was adjusted for the crop consumption by the household for food and feed to the cattle. For the category of farmers that are most likely to buy the renewable energy technologies, it has been assumed that 5 per cent of the yield is retained by the households for food and fodder to the animals.

- It was assumed that a share (50 per cent) of this net yield is sold at the market price and the balance, the remaining 50 per cent, is sold at the government-administered price. The government-administered prices are documented and are widely available. The market prices of the crops were taken to be 20 per cent higher than the government administered prices.

- Using the yield figure, the sales figure and the price data, income per hectare of a particular crop in one particular state was calculated. Then to arrive at the average figure for all the crops for each state, percentage area under cultivation for each crop was used as weight.

- This average income figure was multiplied by the land holding to arrive at the gross income of each household corresponding to the land owned by the household. The area under each crop in a state is taken as representative weight to arrive at the average income in that state.[1]

The cash inflow per hectare has been estimated using the following expression:

$$I = \sum_{l=1}^{M} \{ \sum_{i=1}^{N} [S_{ai} (P_{ci}/A_{ci}) P_{rai} + S_{mi} (P_{ci}/A_{ci}) P_{rmi}] R_{ai} \} H_l \qquad (10)$$

where:

I = average income per annum for a farmer in India (Rs)

S_{ai} = % net sales of crop i made by a farmer at the government administered price

P_{ci} = gross production of crop i in million tonnes per annum available for sale net of the crop by the farmer for food and feed

A_{ci} = area under cultivation of crop i in million hectares

P_{rai} = administered price in Rs per quintal of crop i

S_{mi} = % net sales of crop i made by a farmer in the market

P_{rmi} = estimated average selling price in Rs per quintal of crop i directly sold in the market

R_{ai} = ratio of area under cultivation for crop i to the total area under cultivation in the state

H_l = land holding in hectares

i =1 to N for all the crops cultivated in the state

l =1 to M for all the states in the country

[1] *This methodology has been adopted in S. Puri (2000)*

4.3 LAND HOLDING PATTERN

The income level of the farmers can be directly linked to the crops that they produce and the land holding pattern in the country. The land holding pattern in the country clearly brings out that around one-third of the total land holding in the country comprises marginal, small or subsistence farmers. Most of these farmers produce only enough for their own consumption, and hence are not able to add much to the national agricultural income. Another 50 per cent holding is in the 4 hectare to 10 hectare category. Average holding of the country is just 1.55 hectare. The land holding pattern is given in Table 26.

Table 26: Land holding pattern in India

	Size	Area	Percentage area	Average holding
	Hectare	Hectare	(%)	Hectare
Marginal	<1ha	24,894,000	15	0.39
Small	1ha-2ha	28,827,000	17	1.43
Semi medium	2ha-4ha	38,375,000	23	2.76
Medium	4ha-10ha	44,752,000	27	5.9
Large	>10ha	28,659,000	17	17.33
Total		165,507,000	100	1.55

Source: Agricultural Statistics at a Glance, MOA, New Delhi (1998)

Of the total number of households in the country, over 80 per cent are marginal and small farmers. The average land holding for marginal farmers is only 0.39 hectare and that of small farmers is 1.43 hectare. These two categories that comprise the majority of the households may not be the potential households for the implementation of the renewable energy technologies on their farmlands.

Of the total of 106 million households, only 9 million comprise the medium and larger farmers. These 9 per cent farmers control a substantial portion of the total agricultural land, that is 44 per cent of the total cultivated land area. In fact, in the "over-10" hectare category the average land holding is 17.33 hectares. On preliminary analysis, this is the category (medium and large farmers) that will be the most receptive to installation of renewable energy technologies on their farmlands as they can well afford these systems. Number of households (in thousands) under each category are given in Table 27.

Table 27: Number of households (in 1000's) in various landholding categories

	Marginal	Small	Semi medium	Medium	Large	Total
Andhra Pradesh	5,211	1,972	1,345	644	118	9,290
Arunachal Pradesh	16	17	30	26	5	94
Assam	1,521	560	343	95	5	2,524
Bihar	10,193	1,438	945	351	39	12,966
Goa	58	8	4	2	1	73
Gujarat	924	915	890	669	118	3,516
Haryana	622	304	336	222	46	1,530
Himachal Pradesh	532	166	94	36	6	834
Jammu & Kashmir	902	197	98	20	1	1,218
Karnataka	2,262	1,586	1,163	636	129	5,776
Kerala	5,016	280	98	21	3	5,418
Madhya Pradesh	3,136	1,917	1,738	1,287	323	8,401
Maharashtra	3,275	2,728	2,126	1,171	171	9,471
Manipur	69	49	21	3	-	142
Meghalaya	59	51	46	13	1	170
Mizoram	29	23	9	1	-	62
Nagaland	13	21	26	47	33	140
Orissa	2,118	1,035	594	186	15	3,948
Punjab	296	204	289	261	67	1,117
Rajasthan	1,517	1,019	1,061	1,017	493	5,107
Sikkim	26	11	9	5	1	52
Tamil Nadu	5,848	1,275	618	228	31	8,000
Tripura	217	69	28	4	-	318
Uttar Pradesh	14,819	3,118	1,543	548	45	20,073
West Bengal	4,639	1,107	457	79	1	6,283
Total	63,318	20,070	13,911	7,572	1,652	106,523

Source: Agricultural Statistics at a Glance, MOA, New Delhi (1998)

4.4 INCOME OF THE FARMERS AND AFFORDABILITY

To estimate the income of a farmer per hectare it is necessary to study the pattern of crop production and the corresponding area under cultivation. The ratio of these two terms gives the yield in kg per hectare of a particular crop. In terms of yield, sugarcane has the highest. Which is followed by coconut. A crop with a high yield improves the cash inflow situation of a farmer. Pulses usually have a low yield. Table 28 gives the yield figures for various crops.

Table 28: Yields of various crops

Crop	**Food grains**	**Rice**	**Wheat**	**Coarse Cereals**	**Jowar**
Yield (Kg/hectare)	1,551	1,895	2,469	1,002	727
Crop	**Sunflower**	**Cotton***	**Jute***	**Sugarcane**	**Tobacco**
Yield (Kg/hectare)	550	213	1,795	69,584	1,391
Crop	**Arhar**	**Oilseeds**	**Groundnut**	**Rapeseed**	**Soyabean**
Yield (Kg/hectare)	564	840	1,078	667	1,126
Crop	**Maize**	**Pulses**	**Gram**	**Bajra**	**Coconut***
Yield (Kg/hectare)	1,719	572	813	792	6,888

Production of coconut : 100 million nuts
Production of cotton : million bales of 170 kg
Production of jute : million bales of 180 kg each

The yield of the crops needs to be viewed in conjunction with the prices of the crops. The government, year-to-year announces the administered prices of various crops. However, some part of the yield also sells directly in the market. In this analysis, market sale price has been assumed to be 20 per cent more than the administered price. In actual practice, the market price may be even higher, but it has been assumed that only 20 per cent percolates to the farmers and the incremental profits are retained by the middlemen. The prices (both administered and market selling prices) are given in Table 25.

Table 29: Price of crops

	Rice	Wheat	Coarse Cereals	Jowar	Bajra	Copra
Administered	415	510	360	360	360	2,700
Market price	498	612	432	432	432	3,240
	Maize	**Pulses**	**Gram**	**Groundnut**	**Rapeseed**	**Arhar**
Administered	360	900	815	980	940	900
Market price	432	1,080	978	1,176	1,128	1080
	Soyabean	**Sunflower**	**Cotton**	**Jute**	**Sugarcane**	**Tobacco**
Administered	750	1,000	1,500	570	48	23
Market price	900	1,200	1,800	684	58	27

Market price =1.20 administered price

Assuming an average renewable energy technology may require a capital expenditure of around Rs 50,000 – Rs 75,000. The interest there on the loans is low if the equipment is financed on a long-term basis by agencies like IREDA. Assuming that the farmer has to pay back the amount in a duration of 10 years. Then his per annum cash outflow on this investment will be Rs 5,000 to Rs 7,500 plus interest accrued thereon. We have further assumed that the farmers may not be willing to pay more than 20 per cent of the annual income on these capital expenditures. Hence only the farmers that have an annual income of more than 30,000 will be willing to invest on these technologies.

Sample calculations:

- Production of rice (million tonnes per annum) : 82.30
- Area under rice cultivation in the state (million hectares) : 43.42
- Yield of rice (kg per hectare) = 82.30 x 1000/43.42 : 1,895
- Administered price of rice (Rs per 100 kgs) : 415
- Market price of rice (Rs per 100 kg) = 415 x 1.20 : 498

- Assuming 5 per cent of the crop is retained for food and feed and of the rest 50 per cent is sold at the market price and the balance is sold at the administered price
- Income from rice (Rs per hectare) = 1895 x 0.95 x (0.5 x 415 + 0.5 x 498) : 8,220
- Percentage area under rice cultivation (%) : 22 %
- Weighted average income from rice (Rs per hectare) = 0.22 x 8220 : 1,800

In terms of income per hectare, sugarcane and coconut are two most profitable crops. It is due to this high-income opportunity that many farmers in recent times have shifted to sugarcane. Bajra and Jowar have the lowest income per hectare. Income for crops are detailed in Table 30.

Table 30: Income from various crops (Rs per hectare)

	Rice	Wheat	Coarse Cereals	Jowar	Bajra	Maize
Income	8,220	13,161	3,768	2,734	2,979	6,469
	Pulses	**Gram**	**Arhar**	**Groundnut**	**Rapeseed**	**Soyabean**
Income	5,380	6,924	5,301	11,043	6,553	8,824
	Sunflower	**Cotton**	**Jute**	**Sugarcane**	**Tobacco**	**Coconut**
Income	5,744	3,335	10,693	35,231	32,713	29,154

This income for each state and for various land holding sizes is given in Table 31. The states of Haryana, Punjab, Kerala, Tamil Nadu and UP show maximum income levels. The southern states have a high income primarily due to vast areas dedicated to coconut, which has a high market price and the northern region of UP and Punjab is mainly wheat and sugarcane oriented. On the other hand states like Maharashtra, Rajasthan and Assam register the lowest income per hectare.

Table 31: Income for various landholding sizes ('000 Rs per annum)

Land holding (hectares)	1	3	4	5	5.9	7	9	10	15	17
Andhra Pradesh	7.73	23.18	30.91	38.63	45.59	54.09	69.54	77.27	115.91	131.36
Assam	5.96	17.89	23.85	29.82	35.18	41.74	53.67	59.63	89.45	101.37
Bihar	7.14	21.43	28.58	35.72	42.15	50.01	64.30	71.44	107.16	121.45
Gujarat	8.54	25.62	34.15	42.69	50.38	59.77	76.85	85.39	128.09	145.16
Haryana	11.41	34.24	45.66	57.07	67.35	79.90	102.73	114.15	171.23	194.06
Himachal Pradesh	7.45	22.36	29.82	37.27	43.98	52.18	67.09	74.54	111.81	126.72
Jammu & Kashmir	6.78	20.33	27.10	33.88	39.97	47.43	60.98	67.75	101.63	115.18
Karnataka	6.54	19.61	26.14	32.68	38.56	45.75	58.82	65.35	98.03	111.10
Kerala	19.63	58.90	78.53	98.17	115.83	137.43	176.70	196.33	294.50	333.76
Madhya Pradesh	6.16	18.48	24.64	30.80	36.34	43.12	55.44	61.60	92.40	104.72
Maharashtra	3.97	11.92	15.90	19.87	23.45	27.82	35.77	39.75	59.63	67.58
Orissa	5.70	17.11	22.82	28.52	33.65	39.93	51.34	57.04	85.56	96.97
Punjab	16.03	48.09	64.12	80.15	94.58	112.21	144.27	160.30	240.45	272.51
Rajasthan	5.30	15.91	21.22	26.52	31.29	37.13	47.74	53.04	79.56	90.17
Tamil Nadu	13.65	40.95	54.61	68.26	80.54	95.56	122.86	136.51	204.77	232.07
Uttar Pradesh	11.01	33.02	44.03	55.04	64.95	77.06	99.07	110.08	165.12	187.14
West Bengal	9.73	29.20	38.93	48.66	57.42	68.13	87.60	97.33	146.00	165.46
Others	6.61	19.82	26.42	33.03	38.97	46.24	59.45	66.05	99.08	112.29
Total	7.72	23.16	30.88	38.60	45.55	54.05	69.49	77.21	115.82	131.26

After considering the income levels on all-India basis for various land holdings, it is clear that farmers or households with small landholdings (<3 hectare) may not be able to afford any incremental expenditure on renewable energy technologies. According to our analysis only farmers with over 5 hectare land holdings may be in a position to invest on renewable energy technologies. For optimistic estimates we have considered landholdings of over 4 hectares for arriving at the potential figures of various renewable technologies. By our previous analysis also, we have arrived at the farmers with a land holding of over 4 hectares (net annual income of Rs 30,000 and above) as the target population.

Taking the average land holding of the medium sized and large farmers to be 5.9 and 17 hectares, the average annual income of medium farmers comes to about Rs 45 thousand and that of the large farmer comes to about Rs 131 thousand. According to our assumption, the amount that the farmers might be willing to spend on such capital expenditure as setting up renewable energy applications is 20 per cent of this amount, that is about Rs 9 thousand and Rs 26 thousand for the medium and large farmer respectively. Considering the population of large and medium farmers, the aggregate amount comes to about Rs 6,898 crore for medium sized farmers, and about Rs 4,337 crore for large farmers. Thus, the total amount which Indian farmers might be able to allocate to non-conventional energy sources is to the tune of Rs 11,235 crore.

There are, of course, several reasons why a farmer may not want to change over to such technology, even though he may possess the disposable income to do so. With certain farming techniques and energy sources already in place, farmers may not be willing to invest in new technology in spite of having full knowledge of the benefits that can be derived from such applications. Therefore, a conservative estimate may be, when, given availability and affordability, proportion of farmers actually willing to shift over to non-conventional energy is 10 per cent. A liberal estimate may be reached when that proportion is raised to 50 per cent.

Thus, we arrive at two estimates of the amount which farmers are willing to invest in non-conventional applications, giving us an estimate of the demand for such technology and how much of it can be afforded by the farming community. The conservative estimate comes to about ***Rs 1123.5 crore*** and the liberal estimate comes to about ***Rs 5617.5 crore***.

THE GOVERNMENT'S SUBSIDY BILL

4.5 INTRODUCTION

The United States included in this year's budget an aggressive, $6.3 billion program of tax cuts and R&D investments. The goal is both to stimulate the development of new energy-saving and carbon-saving technologies and to encourage the dissemination of those that exist already. The proposed package contains $3.6 billion over the next 5 years in tax cuts for energy efficient purchases and non-conventional energy, including tax credits of $3,000 to $4,000 for consumers who purchase highly fuel efficient vehicles, a 15 percent credit (up to $2,000) for purchases of rooftop solar equipment, a 20 percent credit for purchasing energy-efficient building equipment, a credit up to $2,000 for purchasing energy-efficient new homes, an extension of the wind and biomass tax credit, and a 10 percent investment credit for the purchase of combined heat and power systems. The package also contains $2.7 billion over the next 5 years in additional research and development investments -- covering the four major carbon-emitting sectors of the economy (buildings, industry, transportation, and electricity), plus carbon removal and sequestration, Federal facilities, and cross-cutting analyses and research.

In the volume on Government Subsidies in India (Srivastava and Sen, et. al., 1997), on which the Discussion Paper on Government Subsidies in India brought out by the Ministry of Finance in May 1997 was based, the Central subsidies were estimated at Rs. 43089 crore in 1994-95. For the States, the aggregate amount of subsidies, at Rs. 93754 crore, was more than twice that at the Centre. Together, these amount to Rs. 136844 crore constituting 14.35 percent of GDP in 1994-95. If we take subsidies net of surplus (Centre and all States) it comes to 13.36 percent of GDP in 1994-95. The estimates of subsidies in social and economic services are more or less in line with the division of expenditure responsibilities in this area. In the provision of social services, the Centre has had a limited role, and its subsidies in this sector are only a small fraction of the total subsidies given by the government as a whole. Nearly 90 percent of the subsidies in social services and a little more than 55 percent of subsidies in economic services are State government subsidies.

The disaggregated picture had shown large subsidies in the areas of agriculture, irrigation, industries, power (excluding petroleum), transport and higher education. In these cases, the services involved can be priced in varying degrees. There is scope for augmenting cost recovery in these areas. A substantial reduction in subsidies in the six sectors noted above would make a real dent on the problem of rising government expenditures. This would need to be done both by reducing expenditure in non-priority areas within these sectors and by ensuring better recoveries. Some of the subsidies, as discussed earlier, may need to be reduced for efficiency reasons also (e.g., irrigation and power).

4.6 DEFINITION AND METHODOLOGY

Subsidies are measured as unrecovered costs of governmental provision of goods and services that are not classified as public goods. The unrecovered costs are measured as the excess of aggregate costs over receipts from the concerned budgetary head. The methodology, described in detail in Srivastava and Sen (1997) and Srivastava and Amarnath (2001), has been followed. The main elements of the methodology are described below.

Measurement of subsidy requires (i) estimation of costs, and (ii) estimation of receipts. Costs themselves have two components: current or variable costs and annualised capital costs. The current (revenue) expenditure on a budgetary head is taken as the variable cost. The capital cost is worked out as the expected annual return on the stock of capital in the form of equity, loans or ownership of capital assets.

Costs:

Aggregate costs may be written as:

$C = RX + (i+d^*) K_0 + iZ_0$

Here, RX = Revenue expenditure

i = Effective interest rate

d^* = Depreciation rate

K_0 = Aggregate capital expenditure at the beginning of the period pertaining to the budgetary head

Z_0 = Sum of loans and equity investment at the beginning of the period pertaining to the budgetary head

Receipts:

Aggregate receipts may be written as:

$R = RR + (I + D)$

Here, RR = Revenue Receipts

I = Interest receipts

D = Dividends

Subsidy is defined as:

$S = C - R$ where S is the calculated subsidy.

Estimation of Capital Cost:

Since estimates are made with respect to a financial year, annualised cost of capital needs to be estimated. In this context, two rates are important, namely: the depreciation rate and the effective interest rate.

We have followed the methodology described in Srivastava and Amarnath (2001) for estimating the depreciation rate. The average life of a capital asset is taken to be 50 years. The depreciation rate is worked out as a function of the parameters, viz., the rate of growth of nominal investment (z) and the long-term rate of inflation (p). This methodology is relevant in the case of investment data given in Finance Accounts which are accumulated as stock in the terms of the nominal values prevalent in the year of acquisition of the asset. The depreciation rate is given by d* as indicated below.

$$d^* = 1/50.\frac{\{1 + w + w^2 + \dots\dots\dots + w^{49}\}.(1 + p)}{\{1 + x + x^2 + \dots\dots\dots\dots + x^{49}\}}$$

with $w = (1+p)/(1+z)$

and $x = 1/(1+z)$

Here, p is the long-term rate of inflation and z is the growth rate of investment. 'p' has been taken to be ***7.98%*** and 'z' has been calculated to be ***12.35%***. d*, the depreciation rate, was calculated to be 0.05247, that is ***5.25%***, by the above method.

Apart from depreciation, we also require the effective interest rate to indicate the opportunity cost of funds. This is to be used in the case of all categories of capital expenditure, i.e. loans and advances, equity investment and own capital expenditure on the functional head.

The effective interest rates, calculated as interest payments as percentage of total borrowing by the concerned government (Centre/State), were obtained state-wise and year-wise from the interest and loans data given in the *Finance Accounts.*

4.7 ANALYSIS OF RESULTS

The subsidy calculations for the states and the Union government, details of which are in Table 28, show that there is a huge amount of unrecovered assistance going to this sector, with recovery rates marginally positive in most cases. Some of the states show zero recovery due to complete lack of receipts. Again some states show up as aberrants and record very high recovery. Typical is the case of Uttar Pradesh in 1995-96. In that year it records 176 per cent recovery. But, on exploring we find that in that year, there was no revenue expenditure recorded. Thus, even though revenue receipts were low and there was substantial capital expenditure, but in accounting, it showed up as a negative subsidy bill.

In the case of Jammu and Kashmir (1994-95), in spite of having no revenue receipts, in accounting the subsidy shows up as negative because of negative interest calculation on loans and investment. This may be due to transfer of funds to other sectors or governments. It thus distorts the actual level of non-conventional energy in the state. Another interesting case is that of Mizoram (1995-96), which gives an absurd negative recovery rate. This again is due to an apparently impossible negative depreciation and interest on capital, which actually shows an outflow of funds to other heads/areas and is reflected in this negative value.

From these calculations we find that the total government subsidy bill for the sector of non-conventional energy sources is more than ***Rs 200 crore per annum*** on an average. Therefore, the burden of the government's implicit subsidy is quite large and can only be partially supplemented by farmer support, considering the substantial amount of time that has to be invested in a non-conventional energy project. There is, however, scope for agriculture to ease this burden to an extent, and release funds for reallocation.

Table 32: Details of subsidy calculations for non-conventional sources of energy

(Units in Rs lakh and Recvy. rate in %)

States	Year	Eff. rate of Int.	Rev. Rec.	Rev. Exp.	Int.on loans	Annualised Cost of Cap.	Imputed Ret. on Inv.	Total Costs	Total Rec.	Subsidy	Recy rat
ANDHRA PRADESH	94-95	11.34	0.02	75.00		151.58		76.52	0.02	76.50	0.0
	95-96	11.75	0.00	202.22		155.29		203.77	0.00	203.77	0.0
	96-97	12.12	0.00	85.00		158.67		86.59	0.00	86.58	0.0
ARUNACHAL PRADESH	94-95	12.28	2.49	101.03		144.55		102.47	2.49	99.99	2.4
	95-96	11.91	1.19	109.43		141.49		110.85	1.19	109.66	1.0
	96-97	12.77	1.41	109.29		148.54		110.78	1.41	109.37	1.2
ASSAM	94-95	14.01	2.70	45.05		1.40		45.06	2.70	42.36	5.9
	95-96	9.82	0.00	48.29		1.09		48.30	0.00	48.30	0.0
	96-97	10.51		11.84		1.14		11.85		11.85	
BIHAR	94-95	11.96		315.52				315.52		315.52	
	95-96	11.17		155.04				155.04		155.04	
	96-97	11.49	0.00	284.87				284.87	0.00	284.86	0.0
DELHI	94-95			104.88				104.88		104.88	
	95-96	14.98		148.60				148.60		148.60	
	96-97	14.03		146.63				146.63		146.63	
GOA	94-95	6.38		11.83				11.83		11.83	
	95-96	7.81		2.82		222.02		5.04		5.04	
	96-97	8.08		6.62		227.01		8.89		8.89	
GUJARAT	94-95	11.42		426.00			373.99	427.14		427.14	
	95-96	11.40		327.22			99.74	328.22		328.22	
	96-97	12.15		163.02	0.86		91.11	163.93	0.86	163.07	0.5
HARYANA	94-95	11.56		46.65				46.65		46.65	
	95-96	11.52		100.98				100.98		100.98	
	96-97	12.18		33.21				33.21		33.21	
HIMACHAL PRADESH	94-95	11.50	0.25	164.91				164.91	0.25	164.67	0.1
	95-96	11.64	0.01	340.36				340.36	0.01	340.35	0.0
	96-97	9.85	0.33	328.99				328.99	0.33	328.65	0.1
JAMMU AND KASHMIR	94-95	15.12					-3.02	-0.03		-0.03	
	95-96	8.68									
	96-97	4.04									
KARNATAKA	94-95	11.59	1.19	1930.91				1930.91	1.19	1929.72	0.0
	95-96	11.93	3.65	1330.13				1330.13	3.65	1326.48	0.2
	96-97	12.21	0.15	1509.01				1509.01	0.15	1508.87	0.0
KERALA	94-95	11.39		579.52				579.52		579.52	
	95-96	10.70		716.80				716.80		716.80	
	96-97	11.14		1458.08		99.75		1461.19		1461.19	
MADHYA PRADESH	94-95	10.14		106.45				106.45		106.45	
	95-96	10.37		0.26				0.26		0.26	
	96-97	10.59	0.14						0.14	-0.14	

States	Year	Eff. rate of Int.	Rev. Rec.	Rev. Exp.	Int.on loans	Annualised Cost of Cap.	Imputed Ret. on Inv.	Total Costs	Total Rec.	Subsidy	Recy Rat
MAHARASH-TRA	94-95	12.36	25.16	1047.77				1047.77	25.16	1022.61	2.4
	95-96	12.70	54.49	897.63				897.63	54.49	843.14	6.0
	96-97	13.39	26.36	741.37				741.37	26.36	715.01	3.5
MANIPUR	94-95	10.51	1.60	42.83				42.83	1.60	41.23	3.7
	95-96	15.89	5.38	52.95				52.95	5.38	47.58	10.1
	96-97	11.22	9.23	59.46				59.46	9.23	50.23	15.5
MEGHALAYA	94-95	13.83	0.27	35.00				35.00	0.27	34.73	0.7
	95-96	12.47	0.08	24.70				24.70	0.08	24.62	0.3
	96-97	12.78	0.03	44.35				44.35	0.03	44.32	0.0
MIZORAM	94-95	8.77									
	95-96	8.93	0.03			-152.70		-1.53	0.03	-1.56	-2.0
	96-97	9.99		0.40		405.17		4.45		4.45	
NAGALAND	94-95	12.00		6.72				6.72		6.72	
	95-96	12.91		7.00				7.00		7.00	
	96-97	11.01		21.40				21.40		21.40	
ORISSA	94-95	11.22		267.72		23.02		267.95		267.95	
	95-96	11.67		169.91		23.66		170.15		170.15	
	96-97	11.50		173.68		23.41		173.91		173.91	
PUNJAB	94-95	11.84		85.55		906.83		94.62		94.62	
	95-96	12.25		101.20		928.93		110.49		110.49	
	96-97	11.98		65.47		914.63		74.62		74.62	
RAJASTHAN	94-95	11.64		357.06				357.06		357.06	
	95-96	11.86		421.88				421.88		421.88	
	96-97	12.38		167.39				167.39		167.39	
SIKKIM	94-95	12.16	3.62	35.51				35.51	3.62	31.89	10.2
	95-96	11.90	2.89	69.17				69.17	2.89	66.29	4.1
	96-97	11.92	1.08	49.36				49.36	1.08	48.28	2.1
TAMIL NADU	94-95	14.61		417.36				417.36		417.36	
	95-96	11.28	0.00	479.09				479.09	0.00	479.09	0.0
	96-97	11.46		253.20				253.20		253.20	
TRIPURA	94-95	11.13	0.10	18.44		7321.71		91.66	0.10	91.56	0.1
	95-96	11.68		19.08		8650.08		105.58		105.58	
	96-97	12.97	0.00	18.03		9813.01		116.16	0.00	116.16	0.0
UTTAR PRADESH	94-95	12.26	0.23	0.36		16.01		0.52	0.23	0.29	44.3
	95-96	11.31	0.27			15.14		0.15	0.27	-0.12	176.5
	96-97	12.32	0.02			16.06		0.16	0.02	0.14	11.3
WEST BENGAL	94-95	11.23		82.13				82.13		82.13	
	95-96	11.81		50.92				50.92		50.92	
	96-97	12.11	0.05	137.15				137.15	0.05	137.10	0.0
CENTRE	94-95	11.42	1.24	13837.1		89832.84		14735.50	1.24	14734.26	0.0
	95-96	17.09	3.79	11822.0		154467.39		13366.73	3.79	13362.94	0.0
	96-97	12.19	8.56	12813.7		121959.51	91995.79	14953.31	729.62	14223.69	4.8

Source: Finance Accounts of States and Union Government (1994-95 to 1996-97).

CHAPTER 5

POLICY AND CONCLUSION

5.1 POLICY HISTORY

Awareness of pollution and environmental degradation has led to several laws and acts being passed by the Indian government. These include **The Water Acts** of 1974, 1975, 1977 and 1978, **The Forest Conservation Act** of 1980, **The Air Acts** of 1981 and 1982, **The Environment Protection Act** of 1986 and **The Hazardous Waste Rules** of 1989 and 1994. In the 90s, **The Public Liability Insurance Act** of 1991, **Coastal Regulation Zone Rules** of 1991/1997, **Environmental Statements, Standards and Clearance** of 1992, 1993 and 1994, **The National Environment Tribunal Act** of 1995, **National Environment Appellate Authority Act** of 1997 and **Bio-Medical Waste Rules**, 1998 were framed.

The government of India has entrusted work relating to ozone layer protection to the MoEF (Ozone Cell), which has established a Steering Committee responsible for implementation of the provisions, review of the various policies and implementation options, project approval, project monitoring etc. The Draft Ozone Depleting Substances Rules was issued by the MoEF in 1998 which specified rules of import, purchase, sale and use of Ozone depleting substances (ODS).

The Indian government offers a number of incentives for renewable energy technology projects. These include soft loans, reduced customs duties on imported material and equipment, 100 per cent depreciation allowance, exemptions from excise and sales tax, large capital subsidies, etc. In Maharashtra, up to 30 per cent capital subsidy is being offered to private developers of wind power projects. For biomass, a capital subsidy of up to 50 per cent of the cost of projects, subject to a maximum of Rs 2.5 crore per MW, is being offered. In the north east, small hydro projects are being promoted with capital subsidy of up to Rs 3 crore per MW or 50 per cent of the project cost. The solar thermal power plant in Rajasthan would be supported by grants from the Central government of up to Rs 50 crores and from the Global Environment Facility of $ 49 million, including a technical assistance component of $ 4 million. MNES provides two-thirds of the project cost for SPV (subject to a maximum of Rs 2 crore per 100 kW).

The Central government has taken several initiatives to promote wind power. It has set up over 20 demonstration projects in 8 states aggregating about 50 MW. The government has also aggressively courted private sector involvement. It has given tax holidays, soft loans, customs and excise duty relief and liberalised foreign investment procedures.[1]

The MNES has issued guidelines to all the states on general policies and facilities for banking and purchase of power from such projects. It proposes that states consider purchasing such power at Rs 2.25 per kW. Nine states have come forward and announced attractive policies for private sector wind power projects while Gujarat, Madhya Pradesh and Maharashtra have also introduced sales tax exemption or deferment policies for wind power projects.

To encourage small investors, joint sector "wind energy estates" was mooted to reduce the gestation period, provide infrastructural facilities and bring down costs to these investors. The first such project with a capacity of 14 MW has begun operations near Indore in Madhya Pradesh. Funds at low interest rates are available from IREDA, which provides loans up to 75 per cent of project cost at 14 per cent interest and repayment period of 10 years. Interest rates for certain categories of commercial projects are as low as 8 per cent.

Commercial projects have so far developed a capacity of 950 MW, mainly in Tamil Nadu, Gujarat and Andhra Pradesh. The largest installation of wind turbines in the country is Muppandal-Perungady area near Kanyakumari with a capacity of about 400 MW.

So far solar power systems with an aggregate capacity of 45 MW have been deployed. The potential, however, is much higher. To make solar photovoltaics (SPV) more popular, the central government offers two-thirds of the project cost. There are financial and fiscal incentives offered to developers of solar power in the form of soft loans from IREDA, which provides 85 per cent of the project cost at concessional rates between 2.5 per cent and 8.3 per compared to other captive plants. Some states offer capital cost subsidies and exemption from generation taxes. Banking charges vary from as low as 2 per cent in Andhra Pradesh to a high of 20 per cent in Maharashtra. IREDA and MNES provide subsidies, low-cost loans and technical assistance. [2]

5.2 FRAMEWORK

Efforts on the part of the Indian government tell us that the importance of renewable energy sources has been realised and progress is being made towards sustainable future energy production. The government is already investing a large sum in renewable energy development. At the same time, electricity for agriculture is very highly subsidised, free of cost in many states. There has been some effort by some of the states to raise the electricity tariff, but it has not been easy due to political reasons. A lot of work has been going on to cut agricultural input subsidies which are believed to have outlived their purpose of promoting use of HYVs in Indian agriculture. It is a difficult task, but correct pricing of conventional electricity for large and medium farmers is the first step that has to be taken by the government in order to induce them to switch to renewables.

The present policy regime has failed to exploit the full potential of non-conventional energy due to obstacles like high costs and a conventional power generation system being already in place. For example, the current potential of cogeneration in India is estimated to be between 17,000 MW and 20,000 MW. The capacity in operation or under construction is less than 500 MW. Again, against the technically exploitable wind power potential of about 45,000 MW, India has achieved a capacity of only about 1,000 MW. Policies till date have also not been able to reduce environmental pollution and degradation effectively, which has rendered economic development unsustainable in the long run.

[2] *PowerLine, Special Millennium Issue, January 2000.*

Table 33: Renewable energy: potential and achievement

Source/System	Potential	Achievement
Biogas plants (million)	12	3.128
Biomass energy (MW)	19,500	273
Solar energy	20 MW/km^2	47 MW
Wind energy (MW)	45,000	1,267
Small hydro power (MW)	15,000	1,341
Waste to energy (MW)	1,700	15.15

Note: Figures are for 31.12.2000
Source: Sector Focus: Power, Indian Infrastructure, June, 2001.

Analysis of results of this study direct us to certain guidelines that the government can initiate to strike a balance between its twin objectives of development and emissions reduction. What is required is an effective incentive structure for farmers to change over to the new technology. Farmers are not bothered about the state of the environment or the level of CO_2 emissions as long as it does not affect their production or profits. Therefore, to induce farmers to take up the change, ample financial incentive has to be given. A lot of steps have to be taken to phase out present government participation and bring in private entrepreneurship and market efficiency.

Large and medium farmers today are not resource constrained. The quality of electricity that is supplied by the government at highly subsidised rates is poor. It is erratic and comes at odd hours, which makes it undependable. Due to such inefficiencies, prosperous farmers of Punjab and other states are actively using personal diesel pumps for irrigation, which come at a cost. Therefore, administered prices of electricity do not reflect the true cost of irrigation borne by the large farmer. Consequently, once the scarcity value of non-renewable energy sources is incorporated, price of conventional electricity will reflect its true cost to society.

This is the first step that has to be achieved for the target farming population for bringing in market based instruments into non-conventional power generation. This may involve price discrimination on the part of the government so that the sustenance of the small farmer is not severely affected by the price change. In the Kyoto Protocol, global emissions trading has been advocated to be the most efficient means of GHG pollution control. This, as has been shown in Chapter 3, will lead to developing countries being net sellers of permits and the developed countries the net buyers. What this means is that developed countries, who presently emit the bulk of GHGs, will not be restricting their emissions to the extent required, which will be offset by massive emissions reductions in the developing world. This will have serious consequences for economic and industrial development in ASEAN countries. If the same model, which has been shown to be globally efficient, can be applied within the national boundary between industry and agriculture, then given a proper incentive structure, a permits regime might be an ideal solution.

Although this study does not address the industry perspective, but it can be gathered that if industry starts buying permits from agriculture for its emissions, then industry costs for pollution will go up. This will induce industry to reduce CO_2 emissions, and even shift to cleaner technology if that proves to be cost effective.

Phasing out of the government will have to take place simultaneously with the government adopting a changed role of supervision and reallocation. The government would buy the permits from the farmers, that is it would measure how much below benchmark levels the farmer is operating and pay an adequate, demand-supply determined sum for that reduction. The government would sell these permits to the industry at the market determined price and thus recover its costs. Effective supervision and correct estimation of emissions levels could thus lead to an efficient general equilibrium solution.

The most important aspect of this formulation that has to be carefully dealt with is the incentive to the farmer to actually take the initiative and make the changeover. What has to be kept in mind is that the farmer already has an established system of irrigation, which may be a combination of government subsidised electricity and personal diesel pumps. To change over to non-conventional energy, he will have to bear a certain expenditure and effort, even after the numerous credit facilities that are already extended by the government. The farmer will not be personally concerned about greenhouse gas emissions and global warming, or any other benefits that may accrue to society from his investment in non-conventional energy.

Therefore, what are the sources of gain for the farmer from this entrepreneurship that he will consider? First, he will consider the increased cost of electricity which he will have to bear when actual pricing of non-renewable sources of energy is done. Thus, a changeover will mean that that amount of expenditure is saved. Secondly, he will consider his earnings from his sale of permits to the government. That being a guaranteed source of income, he will want to maximize his profits by installing larger capacities of production and achieving maximum reduction of emissions. This will lead to an additional third source of income, when the large farmer will be able to sell electricity to the rest of the farming community and thereby complete the changeover.

This is thus a macro versus micro concept, where the government adopts a less active role of supervision and buying and selling, as is done for foodgrains, and gives way to farmer entrepreneurship in commercial projects, supplementing it with its present banking and credit facilities and other fiscal incentives. Non-conventional energy like SPVs, is also a micro concept with local electricity generation, especially in remote rural areas. Efforts have already begun, and farmers are actively encouraged to switch to cleaner technologies for health and other reasons. For establishing the affordability of the rural households with low incomes, the various financing schemes should be taken into account. Low cost financing and attractive leasing and hire-purchase options are widely available in the market to suit the needs of even the low-income-group farmers. Hence net affordability should be worked out by further fine-tuning the cash outflow situation keeping in mind the available financing options available.

5.3 CONCLUSION

The derivation of quantitative or monetary estimates of the damages from such a change in the climate is extremely difficult given the capacity of today's models. Estimates of the economic damages from climate change fall into the following broad areas: agriculture, sea-level rise, air conditioning and heating, water supply, human life and health, air pollution, and other costs (hurricanes, relocation costs, human amenity, construction, leisure activities, urban infrastructure, and ecological damages such as forest loss and species loss). Although the quantification of these effects is quite demanding, researchers have developed estimates that prompt substantial concern. The IPCC reports that a doubling of carbon dioxide levels would lead to approximately 10,000 estimated additional deaths per year for the current U.S. population from higher summer temperatures, even after netting out the effects of warmer winters and assuming acclimatization. Other researchers have predicted sea level increases of about 20 inches by 2100, with greater increases in subsequent years.

Despite the difficulties, researchers have developed estimates of the monetary damages expected from an average worldwide temperature increase. For example, William Cline, of the Institute for International Economics, estimated that a temperature change of 4.5 degrees Fahrenheit would impose annual damages of about 1.1 percent of GDP per year on the U.S. economy. That amounts to $89 billion in today's terms. William Nordhaus of Yale University has likewise computed estimates of the dollar loss attributable to a doubling of greenhouse gas concentrations. Although he uses methods that differ from Cline's in several respects, Nordhuas estimates that a slightly larger temperature change of 5.4 degrees Fahrenheit would impose losses equal to about 1 percent of GDP. It must be noted, however, that the forecasts of the damages from given increases in global warming are estimates based on extrapolations from current and past experience, and may not fully incorporate effects that will unfortunately become apparent only with future experience.

The grim power scenario in India, manifested by shortfall in generation, increase in demand and huge losses by SEBs (estimated at about Rs 27,000 crore plus) has not yet been able to persuade a change from conventional energy sources, which leaves the vast potential of renewables untapped. The role that renewables can play is most evident in Third World countries like India, where a chronic power deficit exists in the face of continuing need to install generating capacities. Non-conventional energy technologies have a set of operating and financial attributes – modularity and flexibility, very low operating costs and ability to create strateguc options for the future that is considerably different from those of traditional, fossil fuel based technologies whose attributes include investment shortfalls and operating cost uncertainties, especially regarding future fuel outlays.

Energy needs of our rural population (75 per cent of the country) could be met using bioenergy and other options. Additionally, they make significant impact/contribution in alleviating the stress on forests and the national electricity grid. They also offer an opportunity for sustainable, self-reliant and equitable development and provide tangible benefits of land reclamation, local employment and reduction of greenhouse gas emissions. A beginning in the use of non-conventional energy sources has been made. An optimal mix of power generated by using different sources may ultimately help in meeting the demand for power in India in the twenty-first century.

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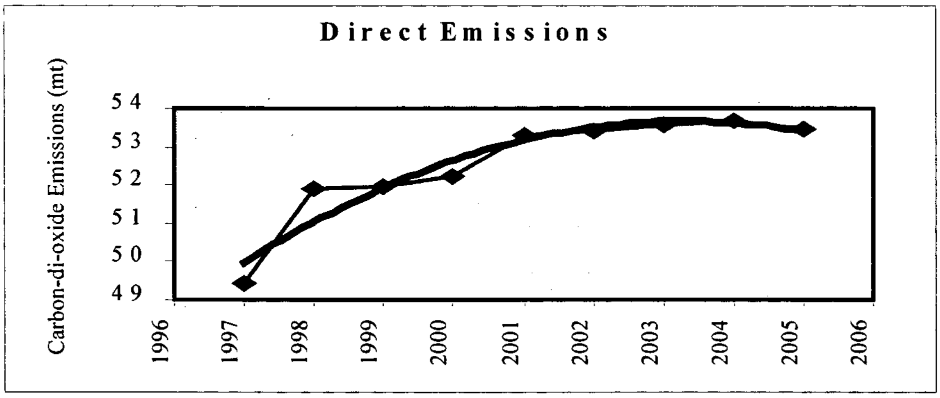
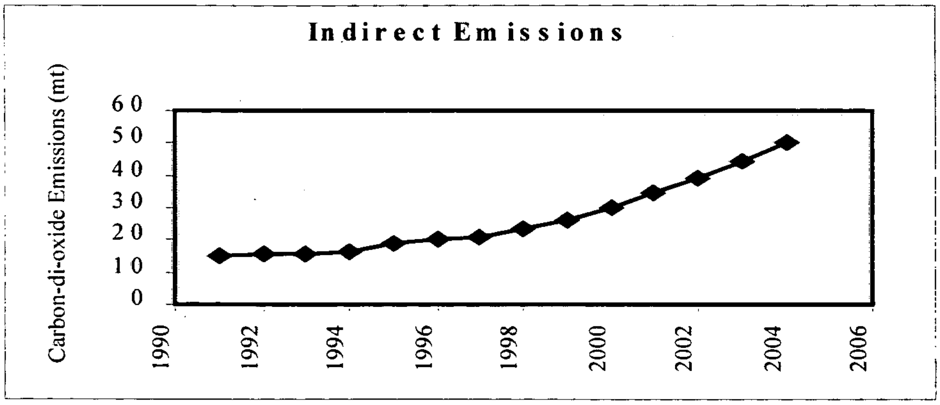
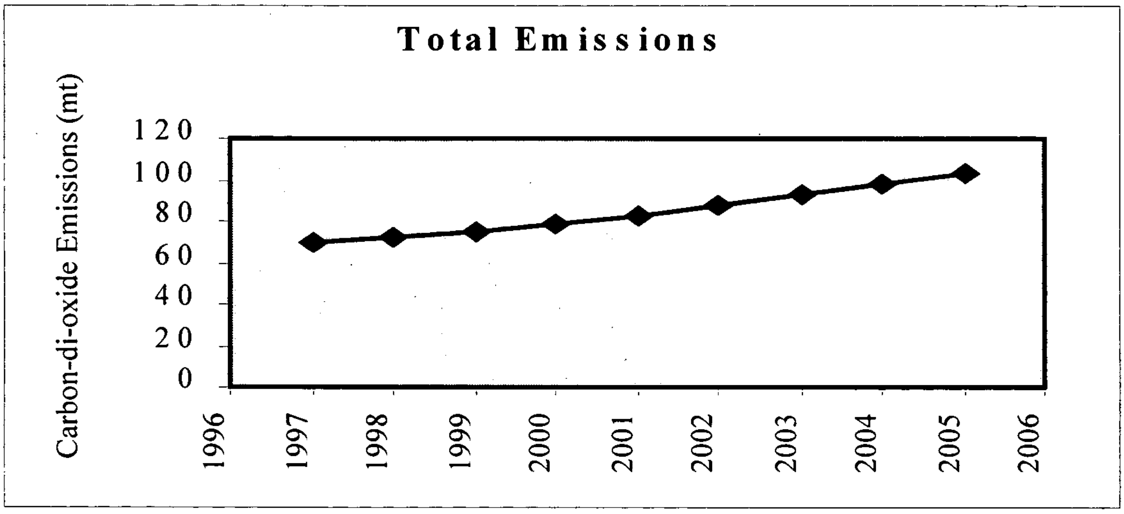
ANNEXURES

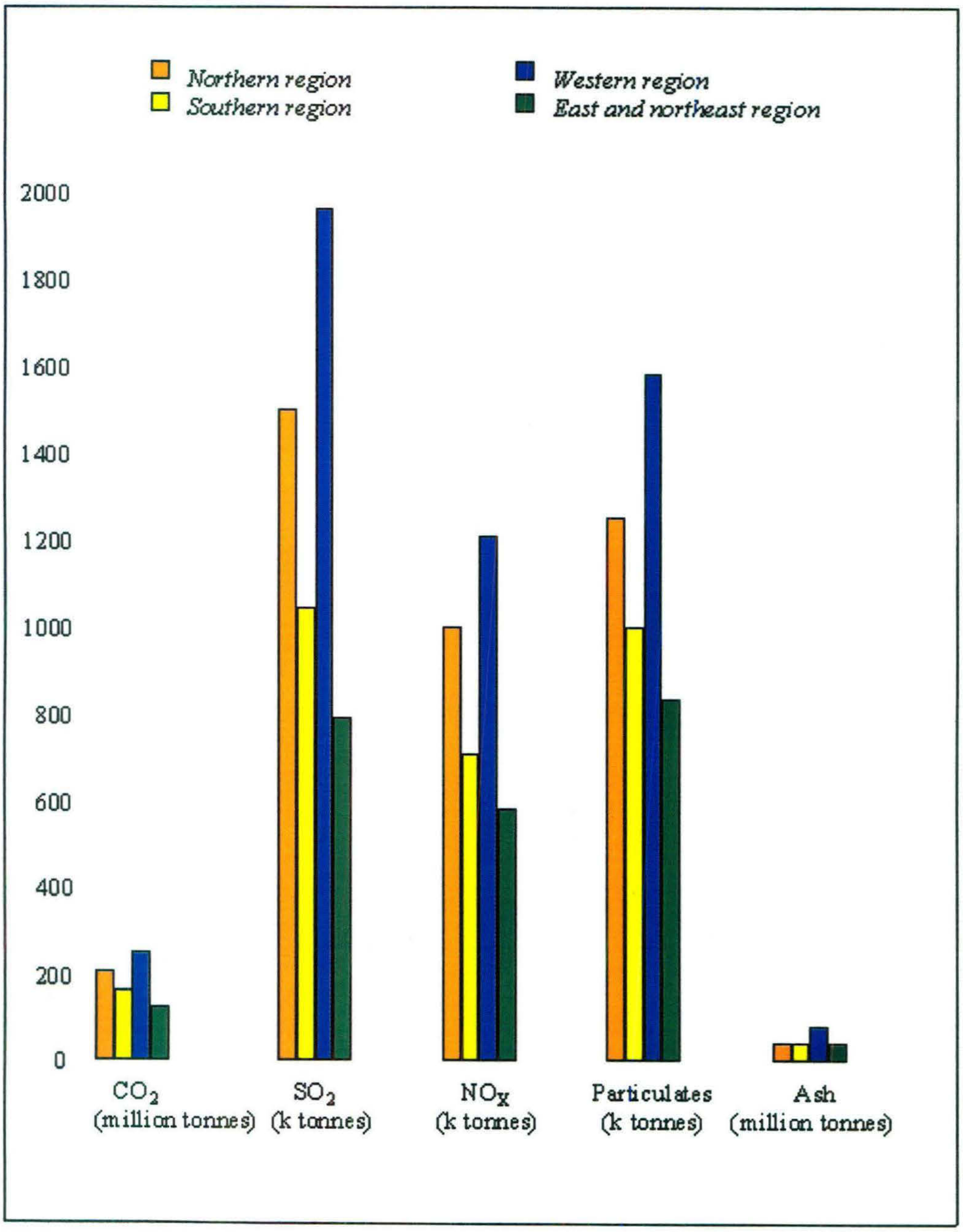
Annexure 1: Trends in carbon-di-oxide emissions in agriculture







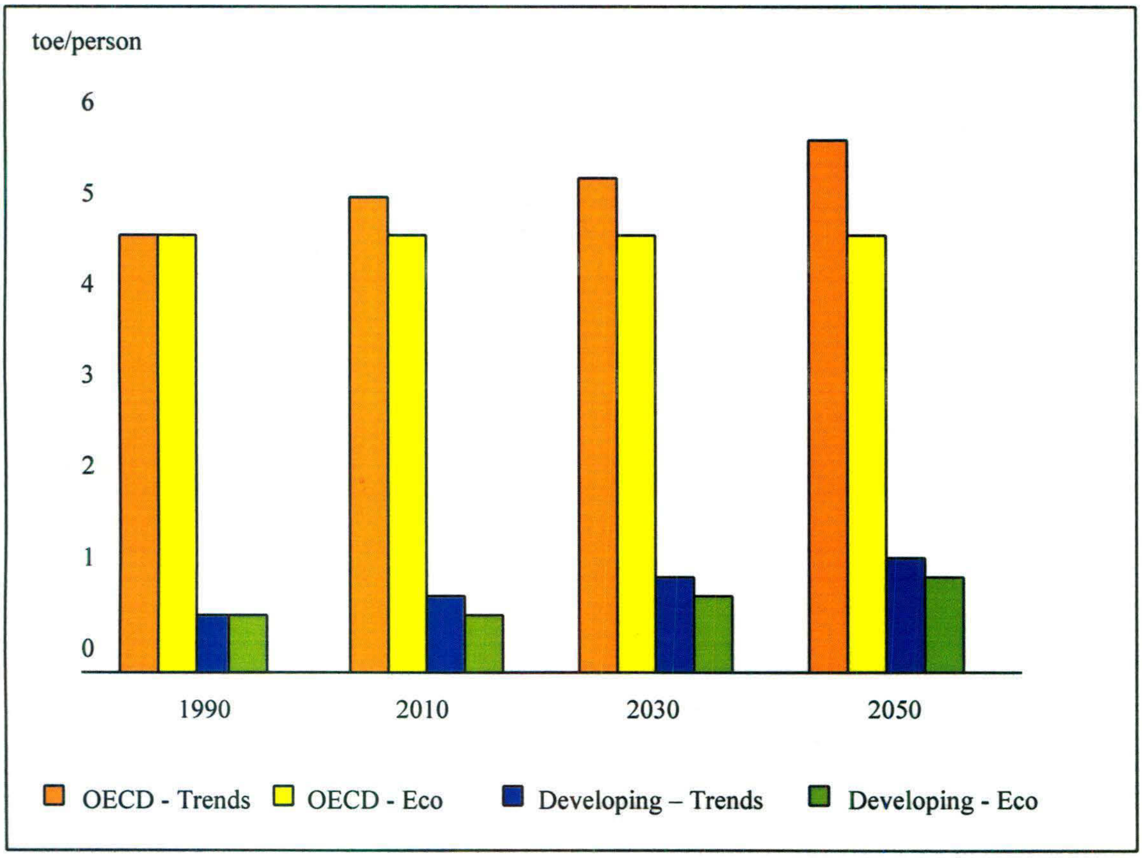
Annexure 2: All India emissions by region in 2015



Source: Special Millennium Issue, PowerLine magazine, 2000.

Annexure 3

Per capita energy consumption in OECD and developing countries, 1990-2050 according to ecologically driven (Eco) and current trends (Trends) scenarios



Source: Special Millennium Issue, PowerLine magazine, 2000.

Annexure 4

Aims of the World renewable Energy Congress, Germany, June 2002.

- Ensuring renewable energy takes its proper place in the sustainable supply and use of energy for greatest benefit of all, taking due account of research requirements, energy efficiency, conservation, and cost criteria.
- Assisting and promoting the real local, regional and global environmental benefits of renewable energy.
- Promoting the innovation, diffusion and efficient application of economic renewable energy technologies.
- Enhancing supply security and reducing important dependence on fossil fuels.
- Widening energy availability, especially in developing countries and rural areas.
- Promoting business opportunities for renewable energy projects and their successful implementation.
- Ensuring the financing of, and institutional support for, economic renewable energy projects.
- Encouraging improved information and education on renewable energy.
- Involving young people in information and education on renewable energy with a parallel, closely integrated programme.
- Providing a technical exhibition where manufacturers and others can display their products and services.
- Strengthen and expand the effectiveness of The World Renewable Energy Network (WREN) in all the above objectives.
- Providing a forum within which participants can network.

Annexure 5.1: Area of production of various crops in India
(Area: million hectares Production: million tonnes)

	Rice		Wheat		Maize		Coarse Cereals	
States	Area	Production	Area	Production	Area	Production	Area	Production
Andhra Pradesh	4.32	11.88			1.46	2.19	0.4	1.38
Arunachal Pradesh								
Assam	2.42	3.25						
Bihar	5.09	6.77	2.12	4.4	0.86	1.66	0.71	1.53
Goa								
Gujarat	0.62	1.02	0.7	1.7	1.72	2.21	0.41	0.7
Haryana	1.08	2.43	2.19	8.57	0.79	0.78		
Himachal Pradesh			0.38	0.64	0.35	0.72	0.31	0.67
Jammu & Kashmir	0.27	0.59	0.24	0.37	0.34	0.54	0.31	0.53
Karnataka	1.43	3.66			3.9	5.37	0.51	1.67
Kerala	0.35	0.73						
Madhya Pradesh	5.48	5.06	4.66	8.33	2.71	2.49	0.85	1.23
Maharashtra	1.48	2.47	1.02	1.31	7.1	6.72	0.28	0.51
Manipur								
Meghalaya								
Mizoram								
Nagaland								
Orissa	4.45	5.39			0.2	0.15	0.05	0.07
Punjab	2.52	7.94	3.34	14.46	0.19	0.46	0.15	0.35
Rajasthan			2.77	6.88	5.9	3.41	0.95	1.03
Sikkim								
Tamil Nadu	2.27	8.14			0.76	0.97		
Tripura								
Uttar Pradesh	5.88	11.39	9.32	23.47	2.77	3.24	1	1.01
West Bengal	5.9	13.32	0.37	0.78	0.06	0.15	0.04	0.12
Others	1.24	2.04	0.41	0.38	0.23	0.28	0.23	0.35
All India	44.8	86.08	27.52	71.29	29.34	31.34	6.2	11.15

Annexure 5.2: Area of production of various crops in India .....continued
(Area: million hectares Production: million tonnes)

	Gram		Arhar		Oilseeds		Groundnut	
States	Area	Production	Area	Production	Area	Production	Area	Production
Andhra Pradesh	0.12	0.09	0.31	0.06	2.51	1.50	1.81	1.18
Arunachal Pradesh								
Assam					0.32	0.17		
Bihar	0.13	0.09	0.06	0.07	0.22	0.17		
Goa								
Gujarat	0.12	0.10	0.40	0.30	2.92	3.83	1.93	2.62
Haryana	0.36	0.31	0.04	0.04	0.59	0.42		
Himachal Pradesh								
Jammu & Kashmir								
Karnataka	0.34	0.12	0.42	0.09	2.16	1.26	1.02	0.75
Kerala								
Madhya Pradesh	2.59	2.42	0.41	0.26	6.09	5.77	0.25	0.26
Maharashtra	0.72	0.29	1.01	0.41	2.62	1.73	0.55	0.62
Manipur								
Meghalaya								
Mizoram								
Nagaland								
Orissa	0.04	0.02	0.16	0.08	0.41	0.21	0.09	0.09
Punjab	0.01	0.01			0.19	0.22		
Rajasthan	2.21	1.93			4.42	3.30	0.33	0.37
Sikkim								
Tamil Nadu			0.11	0.10	1.31	1.88	1.08	1.76
Tripura								
Uttar Pradesh	0.87	0.73	0.48	0.48	1.73	1.01	0.15	0.13
West Bengal	0.03	0.02			0.51	0.39		
Others			0.06	0.06	0.21	0.16	0.07	0.07
All India	7.54	6.13	3.46	1.95	26.21	22.02	7.28	7.85

Annexure 5.3: Area of production of various crops in India .....continued
(Area: million hectares Production: million tonnes)

	Rapeseed & Mustard		**Soyabean**		**Sunflower**		**Cotton**	
States	Area	Production	Area	Production	Area	Production	Area	Production
Andhra Pradesh					0.34	0.22	0.90	1.30
Arunachal Pradesh								
Assam	0.28	0.15						
Bihar	0.10	0.09						
Goa								
Gujarat	0.35	0.35					1.52	3.18
Haryana	0.56	0.37			0.03	0.05	0.64	1.13
Himachal Pradesh								
Jammu & Kashmir								
Karnataka			0.07	0.05	0.74	0.29	0.52	0.99
Kerala								
Madhya Pradesh	0.74	0.42	4.28	4.92			0.52	0.50
Maharashtra			0.86	0.85	0.41	0.14	3.14	1.75
Manipur								
Meghalaya								
Mizoram								
Nagaland								
Orissa								
Punjab	0.07	0.06			0.10	0.14	0.73	0.94
Rajasthan	3.28	2.19	0.50	0.63			0.64	0.87
Sikkim								
Tamil Nadu					0.03	0.03	0.25	0.40
Tripura								
Uttar Pradesh	1.20	0.71	0.05	0.05	0.02	0.03		
West Bengal	0.33	0.25						
Others	0.15	0.12	0.04	0.03	0.04	0.04	0.04	0.08
All India	7.06	4.71	5.80	6.53	1.71	0.94	8.90	11.14

Annexure 5.4: Area of production of various crops in India .....continued
(Area: million hectares Production: million tonnes)

	Jute		Sugarcane		Potato		Onion	
States	Area	Production	Area	Production	Area	Production	Area	Production
Andhra Pradesh	0.09	0.59	0.19	13.73			0.02	0.33
Arunachal Pradesh								
Assam	0.10	0.92	0.03	1.29	0.08	0.67		
Bihar	0.19	1.58	0.11	5.04	0.17	1.46	0.02	0.14
Goa								
Gujarat			0.17	11.84	0.03	0.62	0.02	0.62
Haryana			0.14	7.55	0.01	0.18		
Himachal Pradesh					0.01	0.16		
Jammu & Kashmir								
Karnataka			0.31	28.33	0.03	0.38	0.06	0.36
Kerala								
Madhya Pradesh			0.06	2.11	0.05	0.67	0.02	0.26
Maharashtra	0.03	0.05	0.46	38.18			0.06	0.57
Manipur								
Meghalaya	0.01	0.05						
Mizoram								
Nagaland								
Orissa	0.04	0.24	0.02	1.14	0.01	0.09	0.05	0.16
Punjab			0.13	7.33	0.05	0.85	0.03	0.24
Rajasthan			0.02	1.16				
Sikkim								
Tamil Nadu			0.32	35.68				
Tripura								
Uttar Pradesh			1.96	119.97	0.41	6.07	0.03	0.25
West Bengal	0.65	7.64	0.03	1.83	0.29	5.95		
Others			0.02	1.07	0.07	0.51	0.03	0.21
All India	1.11	11.07	3.97	276.25	1.21	17.61	0.34	3.14

Annexure 5.5: Area of production of various crops in India .....continued
(Area: million hectares Production: million tonnes)

	Tobacco		Coconut	
States	Area	Production	Area	Production
Andhra Pradesh	0.20	0.20	0.10	7.80
Arunachal Pradesh				
Assam				
Bihar	0.02	0.01		
Goa				
Gujarat	0.11	0.18		
Haryana				
Himachal Pradesh				
Jammu & Kashmir				
Karnataka	0.07	0.06	0.29	14.93
Kerala			1.02	59.11
Madhya Pradesh				
Maharashtra	0.01	0.01		
Manipur				
Meghalaya				
Mizoram				
Nagaland				
Orissa	0.01	0.01	0.05	2.72
Punjab				
Rajasthan				
Sikkim				
Tamil Nadu	0.01	0.01	0.32	37.16
Tripura				
Uttar Pradesh	0.02	0.15		
West Bengal	0.01	0.01	0.02	3.06
Others			0.10	6.10
All India	0.46	0.64	1.90	130.88

Annexure 6.1: Yield (Kgs per hectare)

	Food grains	Rice	Wheat	Coarse Cereals	Jowar	Bajra	Maize	Pulses
Andhra Pradesh	1,712	2,431		1,312	724	778	2,700	395
Arunachal Pradesh								
Assam	1,316	1,357						
Bihar	1,461	1,359	2,000	1,535			1,696	707
Goa								
Gujarat	1,400	1,552	2,391	1,324	821	1,364	1,650	678
Haryana	2,717	2,802	3,665	1,103		1,155		881
Himachal Pradesh	1,602		1,472	1,914			2,000	
Jammu & Kashmir	1,593	1,964	1,654	1,353			1,419	
Karnataka	1,245	2,413		1,285	858	467	2,982	291
Kerala	1,581	1,650						
Madhya Pradesh	977	831	1,626	808	833	1,000	1,325	646
Maharashtra	738	1,615	907	704	687	671	1,250	379
Manipur								
Meghalaya								
Mizoram								
Nagaland								
Orissa	1,207	1,378		737			1,200	346
Punjab	3,597	3,465	3,855	2,238			2,059	
Rajasthan	1,021		2,500	693	482	534	1,271	599
Sikkim								
Tamil Nadu	2,101	2,987		1,093	736	1,182		443
Tripura								
Uttar Pradesh	2,027	2,150	2,499	1,466	895	1,432	1,551	826
West Bengal	2,191	2,244	2,189	2,143			3,250	682
Others	1,603	1,683	725	1,087	235	667	1,393	686
All India	1,551	1,895	2,469	1,002	727	792	1,719	572

Annexure 6.2: Yield (Kgs per hectare)....continued

	Gram	Arhar	Oilseeds	Groundnut	Rapeseed	Soyabean	Sunflower
Andhra Pradesh	750	194	598	652			647
Arunachal Pradesh							
Assam			531		536		
Bihar	692	1,167	773		900		
Goa							
Gujarat	833	750	1,312	1,358	1,000		
Haryana	861	1,000	712		661		1,667
Himachal Pradesh							
Jammu & Kashmir							
Karnataka	353	214	583	735		714	392
Kerala							
Madhya Pradesh	934	634	947	1,040	568	1,150	
Maharashtra	403	406	660	1,127		988	341
Manipur							
Meghalaya							
Mizoram							
Nagaland							
Orissa	500	500	512	1,000			
Punjab	1,000		1,158		857		1,400
Rajasthan	873		747	1,121	668	1,260	
Sikkim							
Tamil Nadu		909	1,435	1,630			1,000
Tripura							
Uttar Pradesh	839	1,000	584	867	592	1,000	1,500
West Bengal	667		765		758		
Others		1,000	762	1,000	800	750	1,000
All India	813	564	840	1,078	667	1,126	550

Annexure 6.3: Yield (Kgs per hectare)....continued

	Cotton	Jute	Sugarcane	Potato	Onion	Tobacco	Coconut
Andhra Pradesh	246	1,180	72,263		16,500	1,000	7,800
Arunachal Pradesh							
Assam		1,656	43,000	8,375			
Bihar		1,497	45,818	8,588	7,000	500	
Goa							
Gujarat	356		69,647	20,667	31,000	1,636	
Haryana	300		53,929	18,000			
Himachal Pradesh				16,000			
Jammu & Kashmir							
Karnataka	324		91,387	12,667	6,000	857	5,148
Kerala							5,795
Madhya Pradesh	163		35,167	13,400	13,000		
Maharashtra	95	300	83,000		9,500	1,000	
Manipur							
Meghalaya							
Mizoram							
Nagaland							
Orissa		1,080	57,000	9,000	3,200	1,000	5,440
Punjab	219		56,385	17,000	8,000		
Rajasthan	231		58,000				
Sikkim							
Tamil Nadu	272		111,500			1,000	11,613
Tripura							
Uttar Pradesh			61,209	14,805	8,333	7,500	
West Bengal		2,116	61,000	20,517		1,000	15,300
Others	340		53,500	7,286	7,000		6,100
All India	213	1,795	69,584	14,554	9,235	1,391	6,888

Production of cotton : million bales of 170 kg each

Production of coconut : 100 million nuts

Production of jute : million bales of 180 kg each

Annexure 7.1: Income per hectare in various states (Rs per hectare)

	Rice	Wheat	Coarse Cereals	Jowar	Bajra	Maize	Pulses	Gram	Arhar
Andhra Pradesh	10,544	-	4,936	2,723	2,926	10,157	3,711	6,388	1,820
Arunachal Pradesh	-	-	-	-	-	-	-	-	-
Assam	5,887	-	-	-	-	-	-	-	-
Bihar	5,896	10,659	5,774	-	-	6,379	6,645	5,896	10,973
Goa	-	-	-	-	-	-	-	-	-
Gujarat	6,732	12,744	4,982	3,090	5,130	6,207	6,375	7,097	7,054
Haryana	12,152	19,533	4,148	-	4,346	-	8,285	7,334	9,405
Himachal Pradesh	-	7,846	7,202	-	-	7,524	-	-	-
Jammu & Kashmir	8,519	8,814	5,090	-	-	5,340	-	-	-
Karnataka	10,465	-	4,834	3,227	1,756	11,219	2,736	3,006	2,015
Kerala	7,156	-	-	-	-	-	-	-	-
Madhya Pradesh	3,606	8,666	3,041	3,135	3,762	4,986	6,077	7,958	5,964
Maharashtra	7,003	4,832	2,649	2,586	2,523	4,703	3,566	3,430	3,818
Manipur	-	-	-	-	-	-	-	-	-
Meghalaya	-	-	-	-	-	-	-	-	-
Mizoram	-	-	-	-	-	-	-	-	-
Nagaland	-	-	-	-	-	-	-	-	-
Orissa	5,975	-	2,772	-	-	4,514	3,251	4,258	4,703
Punjab	15,026	20,543	8,420	-	-	7,745	-	8,517	-
Rajasthan	-	13,324	2,606	1,814	2,009	4,781	5,634	7,438	-
Sikkim	-	-	-	-	-	-	-	-	-
Tamil Nadu	12,955	-	4,114	2,768	4,446	-	4,163	-	8,550
Tripura	-	-	-	-	-	-	-	-	-
Uttar Pradesh	9,325	13,318	5,515	3,366	5,387	5,836	7,765	7,146	9,405
West Bengal	9,732	11,667	8,061	-	-	12,227	6,413	5,678	-
Others	7,298	3,864	4,089	885	2,508	5,240	6,449	-	9,405
All India	8,220	13,161	3,768	2,734	2,979	6,469	5,380	6,924	5,301

Annexure 7.2: Income per hectare in various states (Rs per hectare)....continued

	Groundnut	Rapeseed & Mustard	Soyabean	Sunflower	Cotton	Jute	Sugarcane	Tobacco	Coconut
Andhra Pradesh	6,676	-	-	6,762	3,849	7,029	36,587	23,513	33,012
Arunachal Pradesh	-	-	-	-	-	-	-	-	-
Assam	-	5,262	-	-	-	9,864	21,771	-	-
Bihar	-	8,841	-	-	-	8,916	23,198	11,756	-
Goa	-	-	-	-	-	-	-	-	-
Gujarat	13,902	9,823	-	-	5,575	-	35,262	38,475	-
Haryana	-	6,490	-	17,417	4,705	-	27,304	-	-
Himachal Pradesh	-	-	-	-	-	-	-	-	-
Jammu & Kashmir	-	-	-	-	-	-	-	-	-
Karnataka	7,530	-	5,598	4,095	5,073	-	46,270	20,154	21,789
Kerala	-	-	-	-	-	-	-	-	24,526
Madhya Pradesh	10,651	5,575	9,009	-	2,562	-	17,805	-	-
Maharashtra	11,544	-	7,746	3,568	1,485	1,787	42,023	23,513	-
Manipur	-	-	-	-	-	-	-	-	-
Meghalaya	-	-	-	-	-	-	-	-	-
Mizoram	-	-	-	-	-	-	-	-	-
Nagaland	-	-	-	-	-	-	-	-	-
Orissa	10,241	-	-	-	-	6,433	28,859	23,513	23,023
Punjab	-	8,420	-	14,630	3,431	-	28,548	-	-
Rajasthan	11,482	6,559	9,875	-	3,622	-	29,366	-	-
Sikkim	-	-	-	-	-	-	-	-	-
Tamil Nadu	16,689	-	-	10,450	4,264	-	56,453	23,513	49,147
Tripura	-	-	-	-	-	-	-	-	-
Uttar Pradesh	8,876	5,812	7,838	15,675	-	-	30,990	176,344	-
West Bengal	-	7,442	-	-	-	12,602	30,884	23,513	64,753
Others	10,241	7,858	5,878	10,450	5,330	-	27,087	-	25,817
All India	11,043	6,553	8,824	5,744	3,335	10,693	35,231	32,713	29,154

Assuming 0.150 Kg copra per coconut

Annexure 8.1: Weighted average income per hectare - taking area under each crop as weight (Rs per hectare)

	Rice	Wheat	Coarse Cereals	Jowar	Bajra	Maize	Pulses	Gram	Arhar
Andhra Pradesh	3,152	-	594	177	22	347	466	65	48
Arunachal Pradesh									
Assam	4,919	-	-	-	-	-	-	-	-
Bihar	2,842	2,146	481	-	-	426	592	74	64
Goa									
Gujarat	429	837	863	82	537	236	546	81	268
Haryana	1,694	6,162	495	-	386	-	533	404	58
Himachal Pradesh	-	2,742	2,447	-	-	2,265	-	-	-
Jammu & Kashmir	2,004	1,926	1,454	-	-	1,391	-	-	-
Karnataka	1,074	-	1,362	456	39	467	336	76	63
Kerala	2,016	-	-	-	-	-	-	-	-
Madhya Pradesh	681	1,369	305	99	18	145	1,068	720	85
Maharashtra	372	130	730	511	151	41	419	89	139
Manipur									
Meghalaya	-	-	-	-	-				
Mizoram									
Nagaland									
Orissa	4,466	-	87	-	-	37	437	28	125
Punjab	4,839	9,575	250	-	-	186	-	12	-
Rajasthan	-	1,333	634	38	353	171	924	614	-
Sikkim									
Tamil Nadu	4,425	-	637	212	142	-	367	-	136
Tripura									
Uttar Pradesh	1,875	4,362	576	45	168	222	775	221	160
West Bengal	7,213	542	71	-	-	61	177	21	-
Others	2,712	467	284	45	23	443	682	-	170
All India	1,769	1,741	581	149	143	202	609	259	91

Annexure 8.2: Weighted average income per hectare ….. weight (Rs per hectare)…continued

	Groundnut	Rapeseed &	Soyabean	Sunflower	Cotton	Jute	Sugarcane	Tobacco	Coconut	Income per
Andhra Pradesh	1,032	-	-	196	296	54	594	402	282	7,727
Arunachal Pradesh										
Assam	-	494	-	-	-	331	219	-	-	5,963
Bihar	-	86	-	-	-	164	247	23	-	7,144
Goa										-
Gujarat	2,553	327	-	-	806	-	570	403	-	8,539
Haryana	-	557	-	80	461	-	585	-	-	11,415
Himachal Pradesh	-	-	-	-	-	-	-	-	-	7,454
Jammu & Kashmir	-	-	-	-	-	-	-	-	-	6,775
Karnataka	571	-	29	225	196	-	1,066	105	470	6,535
Kerala	-	-	-	-	-	-	-	-	17,617	19,633
Madhya Pradesh	93	144	1,348	-	47	-	37	-	-	6,160
Maharashtra	228	-	239	53	168	2	695	8	-	3,975
Manipur										-
Meghalaya									-	-
Mizoram										-
Nagaland										-
Orissa	153	-	-	-	-	43	96	39	191	5,704
Punjab	-	83	-	207	354	-	524	-	-	16,030
Rajasthan	141	803	184	-	87	-	22	-	-	5,304
Sikkim										-
Tamil Nadu	2,608	-	-	45	154	-	2,614	34	2,276	13,651
Tripura										-
Uttar Pradesh	47	248	14	11	-	-	2,158	125	-	11,008
West Bengal	-	309	-	-	-	1,029	116	30	163	9,733
Others	217	356	71	126	64	-	164	-	780	6,605
All India	398	229	254	49	147	59	693	75	274	7,721

Annexure 9: Emission coefficients

Fuel	Carbon emission factor (tc/TJ)	Net calorific value (TJ/1000t)	Fraction of carbon oxidised	CO_2 emission coefficient
Coal	25.8	18.5773	0.98	1.722
Coking coal	25.8	25.2589	0.98	2.342
HSD	20.2	42.9982	0.99	3.152
Motor spirit	18.9	45.9982	0.99	3.156
Kerosene	19.6	43.0478	0.99	3.063
LDO	20.2	42.9923	0.99	3.152
Fuel oil	21.1	40.1284	0.99	3.074
Naphtha	20	45.0100	0.99	3.268
Low sulphur heavy stock	20	40.1900	0.99	2.918
Natural gas (tonne/mcm)	17.2	0.03762	0.995	0.002

Annexure 10: Sources of electricity: Fuel mix by country

Country	Electricity prodn.	Source of electricity				
	Billion kWh	Hydro power	Coal	Oil	Gas	Nuclear power
		%	%	%	%	%
	1996	1996	1996	1996	1996	1995
Algeria	20.7	0.7	-	3.6	95.7	-
Argentina	69.8	32.9	2.2	5.4	48.3	10.7
Australia	177	8.7	78.9	1.6	9.0	-
Austria	53.5	64.0	11.5	3.7	17.5	-
Bangladesh	11.5	6.4	-	6.5	87.1	-
Belarus	23.7	0.1	-	29.1	70.8	-
Belgium	75.2	0.3	24.2	1.7	14.6	57.6
Bolivia	3.2	63.0	-	6.2	29.6	-
Brazil	289.8	91.7	1.6	3.1	0.2	0.8
Bulgaria	41.5	4.0	41.9	3.2	7.2	43.6
Canada	570.6	62.4	16.2	1.6	2.9	16.3
Chile	30.8	54.8	35.1	8.4	1.0	-
China	1080.0	17.4	75.0	6.0	0.2	1.3
Hong Kong, China	28.4	-	98.4	1.6	-	-
Colombia	44.6	79.1	6.9	0.5	12.8	-
Cuba	13.2	0.7	-	92.2	0.1	-
Czech Republic	63.8	3.1	73.3	1.1	1.2	20.1
Denmark	53.6	0.0	74.0	10.8	10.7	-
Egypt	57.6	18.8	-	37.1	44.1	-
Finland	69.4	17.1	31.8	1.9	12.3	28.1
France	508.1	12.8	6.1	1.5	0.8	78.2
Germany	550.6	4.0	55.0	1.4	8.7	29.1
Ghana	6.0	99.9	-	0.1	-	-

Country	Electricity prodn.	Source of electricity				
	Billion kWh	Hydro power	Coal	Oil	Gas	Nuclear power
		%	%	%	%	%
	1996	1996	1996	1996	1996	1995
Greece	42.3	10.3	69.3	20.2	0.2	-
Guatamela	4.3	74.3	-	20.6	-	-
Hungary	35.1	0.6	28.3	12.6	18.1	40.4
India	435.1	15.9	73.2	2.8	6.2	1.9
Indonesia	67.1	13.3	25.9	25.4	32.0	-
Iran	90.9	8.1	-	37.1	54.7	-
Iraq	29.0	2.0	-	98.0	-	-
Ireland	18.9	3.8	48.4	14.2	33.2	-
Israel	32.5	0.2	68.9	30.9	-	-
Italy	239.5	17.6	10.6	48.9	21.0	-
Jamaica	6.0	2.1	-	93.3	-	-
Japan	1003.2	8.0	18.2	21.0	20.2	30.1
Jordan	6.1	0.4	-	87.6	12.0	-
Kenya	4.0	81.6	-	8.8	-	-
Korea	35.0	64.3	35.7	-	-	-
Kuwait	25.5	-	-	21.7	78.3	-
Malaysia	51.4	10.1	6.4	12.3	71.2	-
Mauritius	-	-	-	-	-	-
Mexico	162.5	19.3	10.9	50.1	11.3	4.8
Morocco	12.4	15.7	44.9	39.4	-	-
Myanmar	4.3	38.3	0.1	15.9	45.7	-
Nepal	1.2	90.2	-	9.8	-	-
Netherlands	85.0	0.1	31.6	4.6	55.6	4.9
New Zealand	36.2	71.2	3.0	0.0	17.8	-
Niger	-	-	-	-	-	-

Country	Electricity prodn.	Source of electricity				
	Billion kWh	Hydro power	Coal	Oil	Gas	Nuclear power
		%	%	%	%	%
	1996	1996	1996	1996	1996	1995
Nigeria	15.0	36.7	-	26.1	37.2	-
Norway	104.5	99.2	0.2	-	0.3	-
Pakistan	57.0	40.7	0.8	30.8	26.8	0.8
Peru	17.3	77.1	-	20.9	1.3	-
Philippines	36.7	19.3	13.2	49.6	0.1	-
Poland	141.2	1.4	96.8	1.2	0.3	-
Portugal	34.4	42.9	36.6	17.5	-	-
Romania	61.4	25.7	33.9	10.9	27.2	2.3
Russia	846.3	18.2	18.5	9.4	40.4	12.9
Saudi Arabia	97.8	-	-	57.1	42.9	-
Singapore	24.1	-	-	78.7	18.6	-
South Africa	198.3	0.7	93.2	-	-	5.9
Spain	173.4	23.0	31.5	8.0	3.9	32.5
Sri Lanka	4.5	71.8	-	28.2	-	-
Sweden	139.6	36.9	3.0	5.2	0.3	52.5
Switzerland	55.6	51.0	0.0	0.5	1.2	45.2
Syrian Arab Republic	17.0	40.8	-	29.1	30.0	-
Thailand	87.5	8.4	20.0	29.3	42.0	-
Turkey	94.9	42.7	32.1	6.9	18.1	-
United Arab Emirates	19.7	-	-	17.1	82.9	-
United Kingdom	346.3	1.0	42.4	4.0	23.6	27.3
United States	3652.0	9.6	52.7	2.6	13.2	19.6
Vietnam	16.9	0.0	14.0	8.6	77.3	-

Source: Special Millennium Issue, PowerLine magazine, 2000.