WORKING PAPER 211

GREENHOUSE GASES EMISSIN AND POTENTIAL CARBON SEQUESTRATION: A CASE STUDY OF SEMI-ARID AREA IN SOUTH INDIA

K Lenin Babu

K V Raju

INSTITUTE FOR SOCIAL AND ECONOMIC CHANGE
2009

GREENHOUSE GASES EMISSION AND POTENTIAL CARBON SEQUESTRATION: A CASE STUDY OF SEMI-ARID AREA IN SOUTH INDIA

K Lenin Babu[2]
K V Raju[3]

Abstract

Global warming and climate change have made adoption measures essential, more so in semi arid regions. Kolar district is typical of semi arid regions with a low Development Index in Karnataka State. Greenhouse gases emissions from various sectors are in tune of 2717 kilotons, however, with a significant potential in the district for Carbon Emission Reduction (15,572 tCO2) and carbon Sequestration measures (3,508,010 tons CO2e) under Kyoto Protocol. If developed, revenues from these measures can enable to realize Millennium Development Goals in district faster.

Section A

This section gives a brief introduction to the climate change and international measures to control the same. Implications of climate change on various sectors along with different adaptive measures initiated at national level are also described. It also presents a brief Green House Gases (GHG) emission scenario in India.

1.0 Introduction to Climate Change

Energy from the sun heats the earth's surface, and drives the earth's climate. Earth, in turn, radiates energy back into space (albido). Some of the atmospheric gases (Carbon-di-Oxide, Methane, Nitrous Oxide, Ozone etc, also known as Green House Gases (GHGs), trap this outgoing energy,

---

[2] Research Officer, lenin@isec.ac.in

[3] Professor and Head of the Department, kvraju@isec.ac.in

like glass panels of a greenhouse. Without this natural "greenhouse effect," temperatures would be much lower than they are now, and life as known today would not be possible Table A 1. But, problems may arise when the atmospheric concentration of GHGs increases beyond limits resulting in warming of earth. For instance, since the beginning of the industrial revolution, atmospheric concentrations of carbon dioxide (CO_2) increased nearly 30 per cent, methane (CH_4) concentrations doubled, nitrous oxide (N_2O) concentrations rose by 15 per cent. Consequently enhanced heat-trapping capability of the earth's atmosphere resulted in a rise in global mean surface temperature by 0.5-1.0°F (Fig. 1). It has been estimated that average global surface temperature could rise 0.6 to 2.5°C in next fifty years, and 1.4 to 5.8°C in next century. Major activities that contribute to GHGs are depicted in Fig. 2.

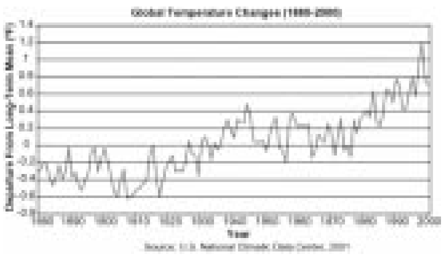

Fig. 1: Global Climate Change over the years.

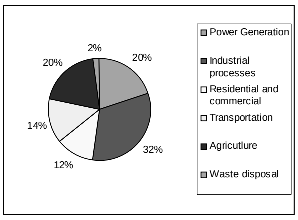

Fig. 2: GHGs contribution from various sectors

1.1 Implications of Global Warming

Human induced climate changes are sudden in nature in comparison to time taken by biological system to adjust and impacts of global warming would be all pervasive and could vary from increased growing period in higher altitudes to shifting of rainfall patterns. In simple words, all spheres of life would invariably bear the impact of global warming. Some of the impacts, sector wise are given in Table 1.

Table 1: Possible impacts of climate change

Sector	Impacts		Regions to likely to benefit	Regions likely to loose
	Direct	Indirect		
Agricultural yield alterations	Through temperature and rainfall changes	Changes in soil quality,pest incidence and diseases	Higher altitudes (longer growing seasons)	Middle and higher latitudes (due to higher pest incidence)
Weather	Extreme weather events, rainfall pattern changes	Evaporation rates, soil moisture contents		Changes in water demand in all regions
Sea level	Rise, coastal inundation	Salinity ingress, changes in rain fall pattern	-	Costal communities
Marine Life-Corals	Density decreases with temperature rise			Changes in fish school behaviour
Health	Heat and Cold related illness	Cardiovascular illnesses		Middle and higher latitudes through vector borne diseases
Vector diseases	Change in patterns of diseases	Rise in Malaria, filarial, kalaazar, Japanese encephalitis etc		Middle and higher latitudes
Health effects due to insecurity and food production	Mal-nutrition and hunger			Tropics

1.2 International Measures

Kyoto Protocol

Alarmed by research findings, World Meteorological Organization and the United Nations Environment Programme have established a special Intergovernmental Panel to look into the alleged changes of Climate. Findings of the Panel have spurred the creation of the United Nations Framework Convention on Climate Change (UNFCCC) and it was ready for signature at the 1992 United Nations Conference on Environment and Development ("Earth Summit" at Rio de Janeiro), albeit without any legal bindings on the parties of signatories. During the negotiations at the third Conference of the Parties (COP-3) in Kyoto, Japan, 1997, commitments of the UNFCCC were extended - targets for future emissions, reduce emissions of greenhouse gases (six gases - CO_2, CH_4, N_2O, HFCs, PFCs, and SF_6) by at least 5 per cent below 1990 levels in the commitment period 2008 to 2012. Under this protocol, the counting were divided into three groups, on account of their historical contributions. Developing countries placed in third group i.e. with no obligation for reduction of GHGs. Various measures under Kyoto Protocol can be divided into three instruments, viz. a) Joint Implementation (JI, Article 6 Kyoto Protocol), b) Projects in countries without emission targets (Clean Development Mechanism (CDM)[4], Article 12 Kyoto Protocol) and c) International Emission Trading (IET, Article 17 Kyoto Protocol). The first two measures facilitate project based co-operations between two countries, where GHG emission reductions take place in the country with lower marginal abatement costs, while third measure operates at international level for countries with additional carbons units who can trade the same.

The main derivatives of Kyoto mechanisms, on the hand is to reduce the costs of industrialized countries Kyoto Protocol targets and on other, to support and assist host countries (non-annex members) in sustainable development and realizing Millennium Development Goals (MDG)[5], [6]. In other words, revenues from CDM could be affectively used for faster realization of MDGs by the developing countries.

---

[4] With the help of CDM, countries which have set themselves an emission reduction target under the Kyoto Protocol (Annex I countries) can contribute to the financing of projects in developing countries (non-Annex I countries) which do not have a reduction target. Contributing to the sustainable development of the host country, the project should reduce the emission of greenhouse gases. The achieved emission reductions can be used by the Annex I country in order to meet its reduction target.

[5] www.undp.org

[6] Article No. of UNFCCC

India has acceded to the Kyoto Protocol in August 2002 and is fulfilling its obligations as per UNFCCC. It has a Designated National Authority for fast tracking various activities related to CDM. It is lagging on MDGs and therefore, this paper is an attempt to examine the potential linkages between CDM and MDGs.

2.0 National Scenario

India, second most populous country in the world, is vulnerable to climate change on several aspects. Directly, the impacts on coastal districts, which are very densely populated (above 500 persons/km^2). Coupled with low per capita incomes and low adaptive capacity, renders them vulnerable to the impacts of climate change. Indirectly, it is highly vulnerable as its economy is heavily reliant on climate sensitive sectors like agriculture (details of National communication to UNFCCC are given in Table A2 and composition sector wise in Tale A3).

2.1 Potential Changes

With 329 Mha of geographical area, India presents a veriety of agro-climatic situations with significant degree of dependence on the monsoon. Agriculture contributes only about 22 per cent to GDP, but employs 68 per cent of the country's workforce with heavy reliance on monsoon in all agro-climatic regions[7]. As per the regional model[8] (HadRM2, IS92a scenario), projections of climate variables for the year 2050s are summarized below;

- General increase in monsoon precipitation with decrease over land towards west and increase over Indian Ocean.
- A large spatial variation in relative increase in monsoon precipitation

[7] Western Himalayan, Eastern Himalayan, Lower Gangetic Plains, Middle Gangetic Plains, Upper Gangetic Plains, Trans-Gangetic Plains, Eastern Plateau and Hills, Central Plateau and Hills, Western Plateau and Hills, Southern Plateau and Hills, East Coast Plains and Hills, West Coast Plains and Ghat, Gujarat Plains and Hills, Western Dry, and the Islands region

[8] India's National Communication to UNFCCC

- An overall decrease in number of rainy days over a major part of country with increase in rainy day intensity by 1-4 mm/day
- An increase in temperature (maximum and minimum) of the order of 2 to 4°C over southern region which may exceed 4°C over the northern region

With these projections, the possible impacts of climate change are:

- Water stress and reduction in availability of fresh water due to potential decline in rainfall.
- Threats to agriculture and food security, as agriculture is monsoon dependent in many states.
- Adverse impact on natural ecosystems, such as wetlands, mangroves, coral reefs, grasslands and mountain ecosystems.
- Adverse impact of sea-level rise on coastal agriculture and settlements.
- Increased energy requirements and impact on climate-sensitive agriculture and infrastructure.
- Decreased farm-level net revenue between 9 to 25 per cent for a temperature rise of 2 to 3.5°C (National Communication 2004) thus affecting the food security and increase vulnerability of large sections of resource-poor population.
- In forest biome, About 70 per cent of forest biomes likely to find itself less optimally adapted to its existing location, making it more vulnerable and may have a 'domino' effect.

Greenhouses gas emissions at national level are expected to increase and projections for various sectors are given in Table 2.

Table 2: GHG emissions by sector and estimated projections in India (%)

GHG	Sector	1995	2005*	2015*	2025*	2035*
CO_2	Power	44	45	44	45	47
	Industry	35	34	31	29	28
	Transport	14	16	20	22	21
	Methane Livestock	39	39	39	38	37
	Paddy	23	21	19	17	15
	Biomass	16	15	14	13	12
	MSW*	8	11	14	17	21
N_2O	N-fertilizer	65	70	74	75	74
CO_2	Power	28	31	32	34	36
equivalents	Industry	22	23	23	22	21
	Agriculture	25	21	18	16	15
	Transport	9	11	15	17	16

*Estimated, * Municipal solid waste. *Source:* Shukla et al. 2003.

2.2 Potential for economic activities under aegis of Kyoto Protocol

While making steps to increase its adaptability and to reduce vulnerability, India, through Certified Emission Reduction (CER), is actively participating in Carbon Trading. An analysis of activities under taken in CDMs indicate that potential of CDM is highest in GHG emission reduction activities, but require high investment like technology up gradation and mostly privately owned with benefits to few, while sequestration activities are less capital intensive but small in nature and likely to benefit larger sections of the society. So far, India has registered over 600 projects with annual average reduction of 15,479,280 units (Fig. 3).

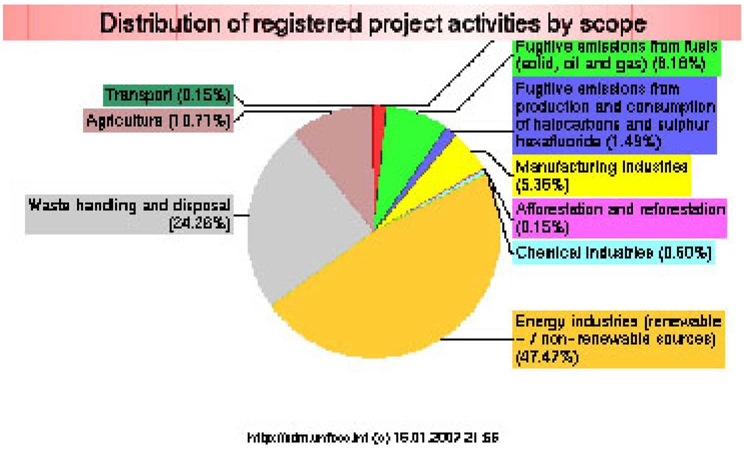

Fig 3: CDM projects registered with DNA, India

2.2.1 Small-scale CDM projects

Small-scale CDM project activities, beneficial to the sustainable development of local communities, are often burdened with high costs and low returns. UNFCCC, introduced fast-track modalities and procedures with some preferential treatment. A project activity can be qualified as small-scale CDM if it meets one of the three following conditions (UNFCCC 2001b, paragraph 6[c], 21):

- *Type I:* renewable energy activities with a maximum output capacity equivalent to up to 15 megawatts (or an appropriate equivalent)
- *Type II:* energy-efficiency improvement activities which reduce energy consumption on the supply and/or demand side upto the equivalent of 15 gigawatt-hours per year
- *Type III:* Activities reduce anthropogenic emissions by sources and emit less than 15 kilotonnes of CO_2 equivalent (CO_2e) annually.

Small-scale CDM project activities benefit from a number of privileges, which allows them to speed up their registration process. One special feature applicable only to small-scale CDM project activities is bundling and debundling.

2.3 Objectives of the study

Following are objectives of this study

- Estimate the level of contribution to Green House Gases emissions from one administrative unit – Kolar District
- Existing theoretical potential for carbon trading in the district and
- Potential for improving quality of life as envisaged under MDG through measures under Kyoto Protocol

Part B

This section presents a brief description of Kolar district along with its GHG emissions and existing Socio-economic profile.

3.0 Kolar District - Introduction

Kolar district with a geographical area of 8223 km^2 is located in the southern plains region of the Karnataka, lies between 77°21' to 78°35' east longitude and 12°46' to 13°58' north latitude, is divided into 11 taluks. Bordering the Eastern Ghats in north-east and the southern portions, it belongs to the Maidan (plain) group of districts in the state (fig 4). Local relief ranges from 1677 to 4749 feet and dotted with a number of hills and peaks of varying heights, particularly in north. The principal chain of mountains is the Nandidurga range. There are no perennial rivers in the district and the rivers Palar, North Pinakini and South Pinakini which take their birth in the district, flow in different directions, receive drainage of intermediate tracks of the district. The climate of district is sub-tropical monsoonic and comes under the influence of both South west and North-east monsoons with an average annual rainfall of about 730 mm, 69 per cent is through south-west monsoon. Natural vegetation is scanty and consists of dry deciduous or thorny scrub types of forests (occupies 10 per cent area of district), shrubs and grasses. Secondary data from the Forest Department shows that 7 taluks have less than 10 per cent, 2 taluks in the range of 10 to 20 per cent (Gudibanda and Srinivaspura) while remaining taluks (Bagepalli and Chikballapur) have forest cover greater than 20 per cent. One third of land is under agriculture and dry cultivation occupies a pre-eminent place. Out of 280 thousand hectares of land under cultivation, 35 per cent is under well and tank irrigation. Ragi is the most extensively grown crop and is also staple foodgrain. Soils are three types: red, clay loam and laterite. (Land use details are given in Table No A4).

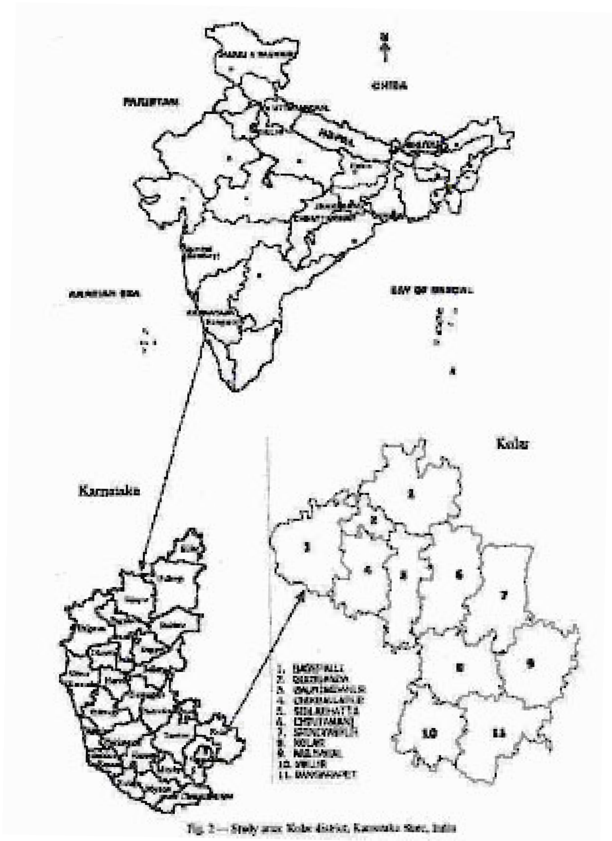

Fig. 4: Map showing Kolar district

Once booming economy due to gold extraction activities but with little industrial activity now, Kolar district is a pale shadow of its earlier self. The erratic and low rainfall in the region, have decreased farm productivity. Based on various sectoral development, High Power Committee on Regional Imbalances (HPCRR) has placed nine taluks of the district as drought prone (One taluq as 'most backward', three taluqs as 'more backward' and five taluqs as 'backward') and has declared the entire district as backward. Migration, both seasonal and long term is normal in the district as majority of agricultural land holdings are marginal and very little industrial activities in the district. In a nut shell, the district can be described as

- existence of large number of scattered habitations;
- dependence on agriculture and related activities;
- low share in state domestic product as compared to its population, or in other words, low per capita incomes;
- low levels of infrastructure like roads, electricity, housing, water supply, and
- low rank in terms of human development parameters.

3.1 Climate Change and its impact on Kolar District

Limiting factor to the overall development of Kolar district is availability of water for farm activities and industrial activities as well. Present source of water is monsoon precipitation and projections suggest that general monsoon pattern may not change but number of days may reduce significantly with potential impacts like;

- lower time available for percolation and resultant higher run off, so is the soil erosion.
- Increased consumption of fertilizers, particularly of nitrogen to restore soil fertility

- low groundwater recharge and a rise in energy required to extract groundwater
- increased cost of inputs and small land holding patterns resulting in farming as non-viable to majority of farmers
- stimulating the already existing migration practices from rural areas.
- high dropout rates from schools and mutrition etc.
- On domestic front, higher energy consumption
- Waste generation rates, though have not reached the stage of GHG contribution, it would soon become significant in urban sector.
- Similar rise in GHGs can be expected from transportation sector.

Net results in case of Business as Usual in coming decades will be higher migration and unsatisfactory socio-economic indicator status in the district.

3.1.1 Methodology

For inventorization of GHGs emission from the district, the methodology prescribed by the IPCC in 'Guidelines for Greenhouse Gases Inventory - 1994' was adopted for all sources and sinks, viz. Agriculture, Energy, Transport, Industry, Land Use and Forest (Table A 5). Summary of various activities contributing to GHG emissions are given in Table 3.

Table 3: Sectors influencing GHGs Emissions in Kolar District

Sector Wise	Sector	Sub Sector
Emissions	Agriculture	Flood irrigation of Rice
		Enteric Fermentation
		Manure management
	Industry	None
	Energy	Industrial
		Domestic
		Transport
Waste		Solid waste disposal
		Industrial waste treatment
Sink	Forests	
Green House Gas wise		
Carbon di oxide	Industry	
	Energy	
Methane	Agriculture	
	Livestock	
Nitrous Oxide	Livestock	
	Agriculture	

3.1.2 Limitation of the study

Major constraint was lack of proper database at district level. For instance, amount of fuel wood used in domestic/industrial sectors, quantity of biomass increment in forestry, consumption rates of fossil fuels, amount of fertilizers used for paddy etc were not available. Wherever the data is available, it has been used and if not, assumptions were made based on other reported studies.

3.2 Greenhouse Gas Emissions from different sectors

3.2.1 Agriculture: Agriculture and animal husbandry sector contributes to climate change through the following GHG emission sources.

Enteric Fermentation: Methane from enteric fermentation in herbivores is a by-product of digestive process by which carbohydrates are broken down by micro-organisms into simple molecules for absorption into blood stream. Both ruminant animals (e.g., cattle, sheep) and some non-ruminant animals (e.g., pigs, horses) produce methane, although ruminants are largest source. The amount of CH_4 that is released depends on type, age and weight of the animal, quantity and quality of feed consumed.

Primary contribution of CH_4 from enteric fermentation is from cattle and buffalos while contribution from other ruminants is low. Contribution from cattle is showing declining trend over the years and can be attributed to factors like increasing mechanization and difficulties of maintaining the livestock, while, population of smaller mammals like sheep and goats are increasing as encouraged by State through various programs to alleviate rural poverty (Fig 5), (Table A6).

Manure Management

Methane from management of animal manure occurs as a result of its decomposition under anaerobic conditions. Occur when large numbers of animals are managed in a confined area (e.g., commercial dairy, swine and poultry farms). Limited proportion of district's livestock is grown in such farms so is the emissions (Fig 6).

Rice Irrigation

Anaerobic decomposition of organic material in flooded rice fields produces methane. Upland rice fields are not flooded (approximately 10 per cent of the global rice production) do not produce methane. CH_4 flux is dependent upon several factors like climate, soil characteristics, agricultural practices, particularly water regime and vary both spatially and temporally. Methane emissions from rice fields over the years is depicted in Fig 7 and fluctuations in emission of methane from rice fields is directly proportional to the area sown and reasons cited were bad monsoon etc.

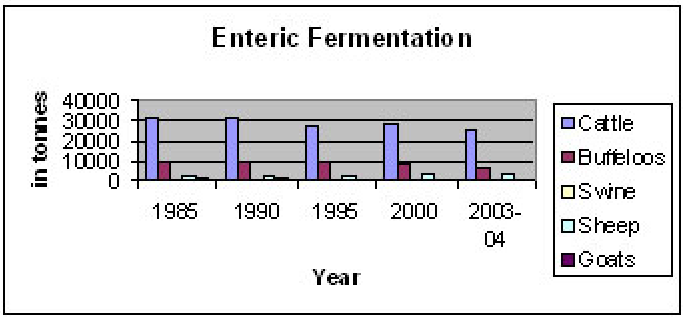

Fig 5: CH_4 from enteric fermentation

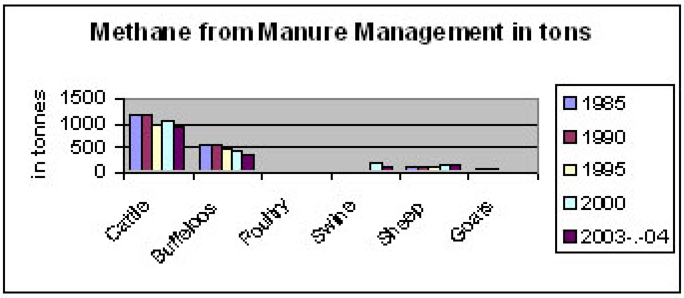

Fig 6: CH_4 from Manure Management

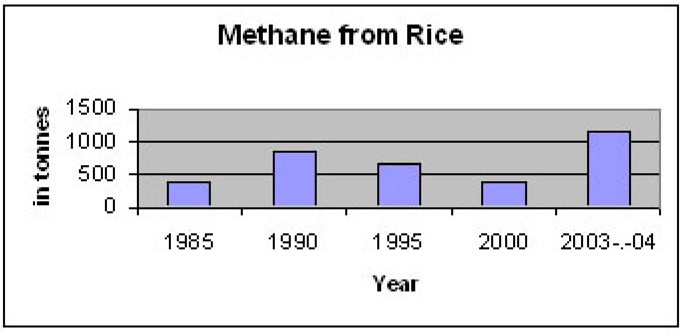

Fig 7: Methane emissions from rice fields

Nitrous Oxide from Agricultural sector

Nitrous oxide is greenhouse gas with approximately 310 times more powerful than CO_2 in trapping of heat in atmosphere over a 100 years times' horizon[9]. Major sources are manure management and agricultural practices.

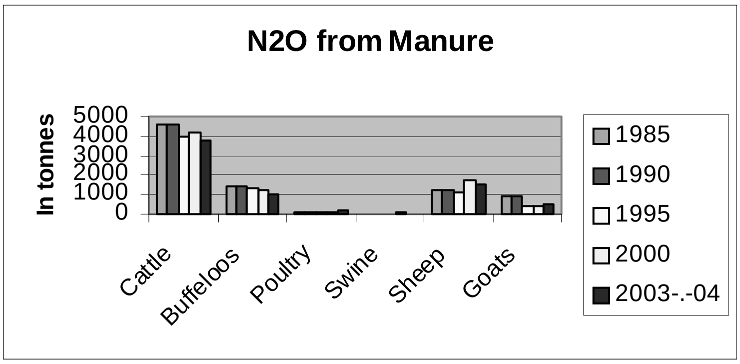

Fig 8: Nitrous Oxide emissions from manure in Kolar district

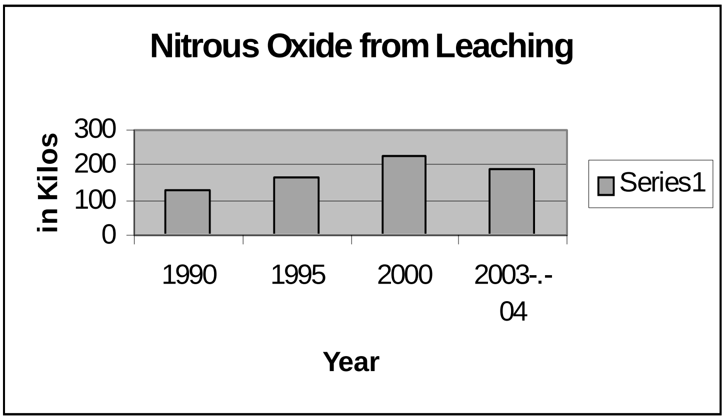

Fig 9: Nitrous Oxide from Atmospheric Deposition in Kolar district

[9] Assumptions: Except for the cattle, all other manure is pasture, while that of cattle is used either as fuel or manure

Summary of GHG emissions from agricultural sector for Kolar district for year 2003-04 is given in Table 4.

Table 4: Summary of GHGs from Agriculture in Kolar District (tons)

Activity	CH_4	N_2O
Enteric Fermentation	36663	-
Manure Management	1626	7007
Rice Cultivation	1170	-
Fertilizer Consumption		0.213
Total	39459	7007.2

3.2.2 Energy

Important sectors of energy consumption in Kolar district are[10] i) Domestic sector (lighting, cooking, heating and other uses); ii) Municipal sector (street lighting, public water works); iii) Transport sector; and iv) Agriculture sector. The consumption of energy in all sectors of district has recorded significant changes in the recent past. The source of energy in the domestic sector differs. For instance, urban homes largely depends on cooking gas and electricity while 85 to 90 per cent of the energy demand of a rural home is dependent on firewood or fuel wood. Generation of GHGs from electricity generation activities and availability status of various fuels area given in Table A 7.

Transportation

The second most important energy-consuming sector is transport. A reference can be made to large number of two-stroke powered two-wheelers used as personal vehicles. In terms of the share of commercial energy use, road transport is most important, accounting for 81 per cent of the total commercial energy use by this sector. Diesel is consumed in both private and public modes of transport (trucks, buses,

[10] http://wgbis.ces.iisc.ernet.in/energy/paper/DSS/rdep.htm#1 accessed on 05.12.2005

jeeps, car/taxis, etc.) as well as in agriculture (tractors, irrigation pumps, etc.). Details of registered motor vehicles and consumption of fossil fuels (Table A8) and carbon emissions (in tons) for the Kolar district is given in Fig. 10. (Table A 8)

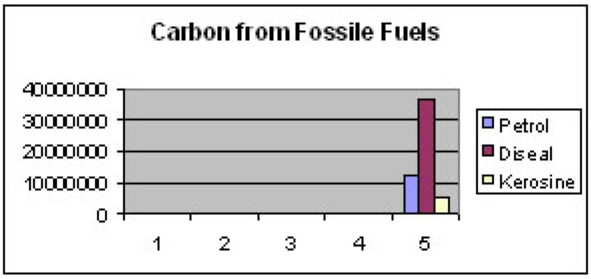

Fig. 10: Carbon emissions from fossil fuel consumption in Kolar district

Domestic sector

According to various studies[11],[12] the consumption of fuel in this district average [Ref 3a] is 2.85 tonnes of fuelwood per family per year and 31.2 litres kerosene per year. Consumption of electricity for water heating ranges from 0.2±0.08 to 0.16±0.08 kWh/capita/month. Electricity for lighting purpose ranges from 5.17±2.16 to 6.57±4.07 kWh/capita/month. Average per-capita consumption of kerosene for cooking, ranges from 0.44±0.16 to 1±0.76 l/capita/month and for lighting it ranges from 0.39±0.1 to 0.74±0.08. Average per-capita consumption of LPG for cooking ranges from 0.18±0.05 to 1.03±1.35 kg/capita/month. (2.6 tons carbon dioxide from one liter of kerosene) (Table A 9)

3.2.3 Industry

Greenhouse gas emissions are produced from a variety of industrial process activities like chemically or physically transforming materials. Non-

[11] Inventorying, Mapping and Monitoring of Bio-Resources Using GIS and Remote Sensing (Kolar District), By T.V. Ramachandra and G.R.Rao. http://wgbis.ces.iisc.ernet.in/energy/paper/Biores_using_RS_GIS/index.htm

[12] CDM-SSC-PDD prepaed by Women for Sustainable Development

combustion industrial processes resulting in N_2O emissions are recognized as important anthropogenic contributors to global N_2O emissions. It is estimated that this source category represents 10 to 50 per cent of anthropogenic N_2O emissions and 3 to 20 per cent of all global emissions of N_2O (IPCC, 1992). HFCs, PFCs and SF_6 are also emitted from industrial processes, such as production of aluminum, magnesium and halocarbons (e.g., HCFC-22). Major industries which generate GHGs through process activities are Cement production, Lime Production, Soda Ash, Asphalt roofing (NMVOC & CO), Glass, Pumice Stone manufacturing, Ammonia production, Nitric Acid, Adipic Acid, Carbide, Calcium Carbide, Aluminum, Paper and Pulp industries.

However, Karnataka State Pollution Control Board[13] records show that there are no industries under this category in the Kolar district. Primary reason for the less industrial development of this district is scarcity of water resources in district coupled with lack of raw materials sources. Kolar district is known for bricks and tile-manufacturing units. Particularly, the Malur taluk is famous for this industry.

Brick Kilns

Emergence of a large number of brick making units is due to abundant availability of Chinese clay in region, which has got powerful plasticity and can withstand any form of weather conditions. All kiln units use biomass as the source of energy, some use exclusively firewood while others use branches and leaves of eucalyptus (widely grown as farm forestry in the region) and coal. On an average, making one thousand bricks required 7,702 MJ energy and generats CO (8 kgs), TSP (4 kgs), NO_x (0.78 kgs), SO2 (0.55 kgs), CH_4 (0.23 kgs) and N_2O (0.03 kgs), apart ash (19 kgs). The CO_2 emission from this sector is as biomass used is GHG neutral. Assuming average daily production of bricks and tiles from Kolar district is 50 truck loads each carrying 4,000 bricks/tiles, annual production of N_2O and CH_4 would be 2.19 and 16.79 tons respectively.

[13] Personal Interaction with Regional Pollution Control Officer, Kolar, KSPCB

3.2.4 Waste Management

Anaerobic decomposition of organic matter by methanogenic bacteria in Solid Waste Disposal sites (SWDS) results in the release of CH_4 to the atmosphere. This source is estimated to account for about 5 to 20 per cent of global anthropogenic CH_4 emissions (IPCC, 1992). Waste disposal sites classified as managed or unmanaged. A managed solid waste disposal site must have controlled placement of waste and will include at least one of the following: cover material; mechanical compacting; or levelling of the waste. Disposal sites that do not fall into above category are defined as unmanaged sites. Unmanaged sites are further divided as deep (>5m depth) or shallow (<5m depth), to allow for their CH_4 generation potential. Nature of waste generated in study area is household, yard/garden, and commercial/market waste, but the disposal measures under practice are not expected to generate the GHGs.

3.3 Sinks

Trees and other green plants, using sunlight for energy, take carbon dioxide from atmosphere, releasing oxygen, thus reducing CO_2 buildup. Forests can be major allies in the battle against climate change and global warming. Forests accounting for about 9% of the total geographic area of district. The area under wastelands (or degraded lands) in the district is almost as much as the area under forests and is about 63,000 ha. The forest type of district according to Champion and Seth (1935) is southern tropical dry deciduous and thorn scrub. The dominant species include *Anogeissus latifolia*, *Terminalia tomentosa*, *Chloroxylon swietinia*, etc. The forest cover in the district along with their annual carbon removal details are given in Table 5. Forest department in association with other line departments and NGOs, also undertake plantation programs in degraded lands, Common property areas and other suitable areas along State and National highways. The possible carbon removal from such programmes is detailed below in table with an assumption of Annual carbon increment @14ton/ha and 600 trees per hectare.

Table 5 : Carbon Sequestration by forests and afforestration programs in Kolar district.

Year	Forest Area, Ha	in kHa	Kilotons/ year Uptake in kilotons	Total Carbon removal in kilotons	Annual CO2
1985-86	70324	70	914	457	1676
1990-91	70324	70	914	457	1676
1995-96	70324	70	914	457	1676
2000-01	70324	70	914	457	1676
2003-04	70324	70	914	457	1676
Carbon sequestration by afforestation programs					
Year	Afforestated Area	Plants in 000s		Total Carbon Uptake	Annual CO2 (Cumulative)
1990-91	4784	2870.4	40	20	73
1995-96	15755	9453	132	66	242
2000-01	25805	15483	216	108	397
2003-04	27256	16353.6	228	114	419

3.4 Summary of GHG emissions (in tons)

Emission and absorption rates from various sectors of the Kolar district are summarized in the Table 6. As one can guess, the rate of emissions are much higher than the carbon uptake and Energy consumption and agriculture are two major sectors contributing to the emissions.

Table 6: Summary of GHGs from various sectors (in tons)

Sector/GHG	Carbon	Methane	Nitrous Oxide	total total Carbon equivalents	Sequestration	Net difference
Agriculture	-	39459	7002	415596	-	
Industry	-	16.8	2.2	768	-	
Energy (wood+ electricity)	73624+ 2227500	-	-	2301124	—	
Waste Treatment	-	-	-	-	-	
Forest	-	-	-	-	(-) 209400	
CO_2 equivalent		-	-	2717488	(-) 209400	
Net COe release						2508088

4.0 Potential for Carbon Sequestration

From section 3.0 it is clear that GHG emissions are higher side, but there are ample opportunities to a) reduce emissions and b) carbon sequestration in Kolar district. Some of such sectors are described below.

Reduction of Emissions

By adopting various measures, GHG emissions could effectively be reduced in the energy sectors, viz., alternate sources and technology shift.

Alternate sources : Women and children spend as much as 20 hours per week per household collecting firewood for cooking. The main sources of fuel wood are nearby forest areas and other wild plants. 75.6% of biomass in Kolar District is non-renewable. Due to continual fuelwood extraction led to forest degradation in region (Dabrase and Ramchandra, 1999). The prevailing practice is to provide kerosene as cooking fuel to BPL families through PDS. Use of the fossil fuel in traditional stoves etc is not only energy inefficient but also has health repercussions. Several alternative energies are possible. Biogas is one and it could potentially meet about 35 per cent of domestic energy needs in rural areas of the Kolar District, and about 20 per cent of domestic energy needs in the district as a whole. However, so far only 1 per cent of domestic energy needs in the whole district are met by biogas (Dabrase and Ramchandra, 2000). The Central and State Government have supported only 500 biogas plants in Kolar District in 2005, whereas the demand may easily exceed 50,000 plants. If the fuelwood/ fossil fuels are replaced/ supplemented with the renewable biogas, such shift would result in

- Reduction in GHG (Greenhouse Gas) emissions by avoiding the uncontrolled burning of unsustainable fuelwood (non-renewable biomass) and use of kerosene.
- Improve women and children's overall health situation by reduced smoke in kitchen.
- Protect local environment by reducing the biotic pressure on vegetation.

Assuming a lower methane IPCC production value from dung, which best captures the situation in Kolar district, since the cows owned by the families are typically small, similar to non-dairy cows, feeding on crop-residues, potential of biogas is summarized in Table 7 and Cost Benefit Analysis in Table 8.

Table 7: Potential of Methane and CO2 reductions in Kolar district

CH4 energy from cow dung (IPCC conservative value MJ / cow / year)	1421.9
Energy derived from 4 cows (for $2m^3$ system kWh / year)	1579.8
Total number of cattles in district	590285
Potential for number of $2m^3$ biogas systems in district	147571.3
Potential clean energy generation	162MW/year
Saving of fuel wood @2.85tons/year	368928 tons
Replacing the use of kerosene @ 31.2liters/year	4604223 li
Resulting in reduction of CO_2 e in tons per year	525353
Potential annual earnings from carbon trading @10$/ton	5253536

Table 8: Cost Benefit Analysis (Deenbandhu model)

Plant Capacity	Cost per Plant
1 M^3	Rs 5500
2 M^3	Rs 9000
3 M^3	Rs 10 500
4 M^3	Rs 13 500
Central Subsidy	Rs 2700 (restricted to Rs 2100 for 1 m3 fixed dome type)
Potential for number of $2m^3$ biogas units	147571
Cost per unit without subsidy in Rs	9000
Cost per unit with subsidy in Rs	6300
Total investment required in Rs crores	92.9
Reduced emission of carbon in tons	525353
Potential returns in Rs crores/year	2.1
Total returns (@20 year life for plant) in crores	40

The benefits listed are direct returns from carbon trading only. If other tangible and non-tangible benefits like reduced a) pressure on forests, b) enhanced ecosystem services, c) better indoor air quality, d) reduced health related expenditure, e) reduced use of synthetic fertilizers considered etc, Cost Benefit Analysis would recommend adoption of this program.

5.1.2 Technology Shift

The conventional power supply grids are being spread out at a rapid pace in rural India. But in many areas in Kolar District, a majority of below poverty line families still rely on kerosene for lighting which is a highly inconvenient source of lighting as the quality of light is very poor and inefficient (only 2 to 4 lumens compared to a 60-watt bulb with 480 lumens and 5 x 2.5 WLED lights of between 375 and 625 lumens). Conventional lighting in the district is based on incandescent technology; because it is cheap and common lamps used for home lighting are of 60 W to 100 W incandescents. The theoretical maximum efficacy for white light is 199 lumens/ watt (lm/W), and these lamps generally have an efficacy of 8 lm/W with an efficiency of 4%. If these are replaced by existing incandescent lamps with medium efficacy LEDs with an average efficacy of 50 lm/W this would result in average increase in efficiency of 25%. By installing the 10000 SHSs and the 200000 LHSs, emission will be reduced to the extent of 15572 tCO_2 per annum, as 17695200 kWh every year which would have been generated by the Southern Region grid, will now not be consumed. Summary of baseline scenario with possible alternates and category of bundled categories are given in Table 9.

Table 9 : Potential for alternate energy sources

Baseline Scenario	**Possibilities**	**Category and Type**
Kerosene/Diesel/ mini-grid etc	Photovoltaic power DC Solar Home System (SHS) with and battery pack	Type I.A.
Erratic unreliable Southern region grid power with incandescent lamp	220 V AC grid connected Light Emitting Diode based Lighting System (LHS) with battery back up	Type II.C.
Southern region grid power with incandescent lamp	220 V AC grid connected Light Emitting Diode based Lighting System (LHS) without battery back up	Type II.C.
Cooking	Biogas, solar cooker, Solar heaters	
Water lifting	Wind power, electricity, solar power, bullock power	

Most of these activities can be undertaken in the Bundled Projects and an overview of various activities under purview of bundled projects with theoretical possibilities are given in Table 10.

Table 10: Potential under small scale projects in Kolar district

	Project Subtype	Possible small – scale options	Potential	Achieved
Type I: Renewable Energy product	1 A. Electricity generation by User (Off grid)	Solar home systems	All houses	Insignficant
		Wind power	Insignificant	-
		Hydropower	Insignificant	-
		Fossil fuel hybrid systems	Insignificant	-
		Biomass power		-
	1 B. Mechanical energy for user	Water mills	Insignificant	-
		Solar electric pumps	Iirrigation pumps below 10HP can be switched over	None
		Biomass based pumping projects	Insignficant	
		Wind electric pumps	Insignficant	
	1 C. Thermal energy for user	Solar water heating systems	@4.22 tons CO2 per year per system for all houses in the district	50,000
		Solar dryers		
		Solar cookers (community based)	Significant	Insignficant
		Biogas based plants for cooking	50,000 biogas plants @ CER 1 9000 per plant of 2 cu.m	500 bio gas plants
	1 D. Renewable electric generation for grid	Grind connected – cogeneration/ wind/biomass/ solar electricity generation	Insignficant	
Type II Energy Efficiency Improvement project	II B. Supply side energy efficiency improvement – Transmission and distribution	Improvement in fossil fuel based facility	All two stroke Two wheelers 90,000	30% only
		Energy efficiency in captive power plant	Insignificant	
	II C. Demand side energy efficiency program for specific technologies	Energy efficiency improvement in end use equipment	Significant	
	II E. energy efficiency and fuel switch measures for building	Fuel switch from oil gas	Insignificant	
		Energy efficiency improvements in hotels		
		Energy efficiency building design		

Contd......

	Project Subtype	Possible small – scale options	Potential	Achieved
Type III Other project activities	III A. Agriculture			
	III B. switching fossil fuel			
	III C Emission reduction by low GHG emission vehicles	Change from fossil fuels to battery fleet in industrial/ institutional premises	Insignificant	
	III D. Methane Recovery	Landfill gas recovery	Can be developed	
		Anaerobic wastewater treatment with methane recovery	Can be developed	
	III E. Methane Avoidance	Avoidance of methane from biomass or other organic residue	Can be developed	

Sequestration Potential

About 42 per cent of geographical area, about 350801 hectares of land is wasteland in Kolar district and it can be brought under plantations programs ranging from hardwood to softwood under poly and energy plantations with selection of speices to provide fodder, energy security in addition to provide the raw materials for the cottage industries and also the sequestration of carbon. Taking the average sequestration rate of carbon by mixed woods, the carbon thus capture would be 3508010 tons per year, @ Rs 40 (10US$), it could bring in about 14.03 crores over 15th years[14] (Table 11).

Table 11: Financial analysis of developing ecobelts

Details	Rs per sq mt	Land in sq mt	Rs in crores
Initial costs and maintenance for 47 years	Rs 28.50	350801000	999.8
Benefits like green manure, fruits, firewood etc	Rs 68.5 / sq mt	350801000	2402.9
Carbon Trading for 3508010 tons	Rs 40/ ton of carbon		14.03
Net gain			1417.2

[14] Eco Committee Report submitted to Government of Karnataka.

Institutional Arrangements

For carbon trading, detailed procedure was established and approved by member nations with inbuilt checks like Certified Emission Reductions to ensure the proposed intervention is meeting all the stipulated conditions. For carbon trading, particularly for small scale, it is optimal to adopt the 'bundling' and to bring all programs under 'single window' approach. A brief description is given Table 12.

Table 12: Institutional Arrangements

Sector	Proposed Intervention	What to monitor	How to monitor	To be monitored by		Indicators
				Present	Proposed	
Renewable energy	Biogas plant	Functionality	Methane formation levels	Not monitored		Reduced demand for kerosene and fuelwood
	Plantation	Survival rates of saplings		Not monitored	Forest Department	Annual biomass increment

5.0 Carbon Trading Revenues and Millennium Development Goals[15]

Families under Below Poverty Line (BPL) constitute about 40 per cent of the district. The district has reported 40 per cent of deliveries as unsafe against 35 per cent of state and is ranked 18th position in state, representing reach and spread of various health facilities and unsafe deliveries in district. It has about 0.11 per cent of children under severely malnourished and 55 per cent under moderately malnourished category and in 13th position in state. Children in age group of 6 to 14 years, out of school are about 10 per cent against the state average of 10 per cent. Male literacy in district is 73 per cent while that of females is only 52.8 percent with gender gap of 20 points against state average of 18 points only. The details pertaining to socio-economic development of Kolar district is summarized in tables below, such as literacy rates, small scale industries, per capita income, poverty rates in Table 13.

[15] High Power Committee Report on Regional Imbalances, GoK 2002.

Table No. 13: Indicators and State of MDGs in Kolar district

Goals and Targets (from the Millennium Declaration)	India's tenth Plan (2002–2007) and beyond targets	**Kolar Status**
Goal 1: Eradicate extreme poverty Land hunger		
Target 1: Halve, between 1990 and 2015, the proportion of people whose income is less than one dollar a day	Double the per capita income by 2012. Reduction of poverty ratio by 5 % by 2007 and by 15 % by 2012. Reduce the decadal population growth rate to 16.2% between 2001-2011 (from 21.3% during 1991-2001).	No of BPL families as on 1-4-2000 - 138445 Green Card - 202680 Yellow Card - 25797 Saffron Card - 51867
Target 2: Halve, between 1990 and 2015, the proportion of people who suffer from hunger		
Goal 2: Achieve universal primary education		
Target 3: Ensure that, by 2015, children everywhere, boys and girls alike, will be able to complete a full course of primary schooling	All children to complete five years of schooling by 2007. Increase in literacy rates to 75% by 2007 (from 65% in 2001).	Children of BPL sections are engaged in livelihood earning
Goal 3: Promote gender equality and empower women		
Target 4: Eliminate gender disparity in primary and secondary education, preferably by 2005, and in all levels of education no later than 2015	At least halve, between 2002 and 2007, gender gaps in literacy and wage rates	Literacy gap between genders is 18 points

Contd……

Goals and Targets (from the Millennium Declaration)	India's tenth Plan (2002–2007) and beyond targets	**Kolar Status**
Goal 4: Reduce child mortality		
Target 5: Reduce by two-thirds, between 1990 and 2015, the under-five mortality rate	Reduction of Infant Mortality Rate (IMR) to 45 per 1000 live births by 2007 and to 28 by 2012 (115 in 1980, 70 in 2000).	Unattended deliveries are 45
Goal 5: Improve maternal health		
Target 6: Reduce by three-quarters, between 1990 and 2015, the maternal mortality ratio	Reduction of MMR to 2 per 1000 live births by 2007 and to 1 by 2012 (from 3 in 2001).	
Goal 6: Combat HIV/AIDS, malaria and other diseases		
Target 7: Have halted by 2015 and begun to reverse the spread of HIV/AIDS	Have halted by 2007; 80 to 90% coverage of high risk groups, schools, colleges and rural areas for awareness generation by 2007. 25% reduction in morbidity and mortality due to malaria by 2007 and 50% by 2010.	
Target 8: Have halted by 2015 and begun to reverse the incidence of malaria and other major diseases		

Contd......

Goals and Targets (from the Millennium Declaration)	India's tenth Plan (2002–2007) and beyond targets	**Kolar Status**
Goal 7: Ensure environmental sustainability		
Target 9: Integrate the principles of sustainable development into country policies and programmes and reverse the loss of environmental resources	Increase in forest and tree cover to 25% by 2007 and 33% by 2012 (from 23% in 2001). Sustained access to potable drinking water to all villages by 2007. Electrify 62,000 villages by 2007 through conventional grid expansion, the remaining 18,000 by 2012 through decentralized non-conventional sources like solar, wind, small hydro and biomass. Cleaning of all major polluted rivers by 2007 and other notified stretches by 2012. Expeditious reformulation of the fiscal management system to make it more appropriate for the changed context.	Canopy cover is reducing every year. Though habitations are electrified, supply of electricity is very uncertain and kerosene remains primary soruce of lighting for majority of rural habitations
Target 10: Halve, by 2015, the proportion of people without sustainable access to safe drinking water and basic sanitation		25 per cent of population is yet to be covered with safe drinking water system

Note: Some of MGD goals only are examined here

As can be seen from Table 13, there is significant demand to improve the quality of life in Kolar district and revenues from Carbon trading may be used for fulfilling the MDGs.

6.0 Summary of Findings

1. Kolar district is a backward district with heavy dependence on erratic monsoon. GHG emissions from energy sector contribution is highest in the district followed by agriculture.

2. GHG emissions are 2,717,488 tons per year. Energy sector contributed highest in the GHG emission at 2,301,124 tons followed by farm sector with 415,596 tons. Contribution from industry is insignificant. Present rate of carbon sequestration is 2094 tons only. Net addition of GHGs from the district is about 2,715,394 tons per annum.

3. High rates of emission are primarily due to inefficient use of biomass for energy purposes. More than 85% of rural households are dependent on fuelwood/ firewood for energy requirement. This practice not only contributes to the GHGs but also health problems.

4. Potential for GHG emissions reduction in district is high in both the emission reduction and through sequestration measures.

5. Adopting a shift in biomass based energy systems from inefficient chulas to Deenabandhu model of bio gas plant, the district has potential of reducing 525353 CO_2e tons/ year and also the better indoor atmosphere. Similarly shift from incandescent lighting to florescant lighting in 200,000 houses would reduce GHG emissions of 15572 tCO_2 per year.

6. On sequestration measures, the district has potential of up taking 3508010 tons per year by undertaking plantations in wastelands of district. In addition to the carbon uptake, poly culture plantations have numerous intangible benefits like ecosystem services, employment, protection of local environment etc.

7. Major limitations are institutional and financial, but overcoming these shortcomings would ensure faster realization of MDGs in this backward district of state

ANNEXUES

Table A 1: Major Greenhouse gases and their characteristics

Time Zone	CO_2	CH_4	N_2O	CFC-11	HCFC-22	CF4
Pre-industrial concentration	~280 PPM(a)	~700 PPB(b)	~275 PPB	0	0	0
Concentration in 1992	358 PPM	1720 PPB	312 PPB**	268 PPT(c)**	110 PPT	72 PPT**
Recent rate of concentration change per year (during 1980s)	1.5 PPM/yr 0.4 %/yr	13 PPB/yr 0.6 %/yr	0.75 PPB/yr 0.25 %/yr	18-20 PPT/yr 0 %/yr	7-8 PPT/yr 5 %/yr	1.1-1.3 PPT/yr 2 %/yr
Atmospheric lifetime (in years)	50-200(d)	9-15(e)	120	50	12	50.000
Global Warming Potental	1	20	310			
Major sources						
Major contributing nations						
Major Sinks		Oxidation by	OH radicals	Photolysis		

Note : (a) Part per million by volume, (b) Part per billion by volume, (c) Part per trillion by volume(d) No single lifetime by CO2 can be defined because of the different rate of uptake by different sink processes.(e) This has been defined as an adjustment time that takes into account the indirect effect of methane on its own lifetime.** estimate from 1992-1993 data.[Source: IPCC 1996a]

Table A 2: Green house gases emission from India in 1994 (Gg)

Sector	Subsector	Emissions	Sequestration
All energy		679470	
	Energy and transformation industries	353518	
	Industry	1498806	
	Transport	79880	
	Commercial/institutional	20509	
	Residential	43794	
	All other sector	31963	
Industrial Process		99878	
	Cement production	30767	
	Lime Production	1901	
	Lime stone and dolomite use	5751	
	Soda ash use	273	
	Ammonia production	14395	
	Carbide production	302	
	Iron and Steel Production	44445	
	Ferro alloys production	1295	
	Aluminium production	749	
Land use, land use changes and forestry		37675	23533
	Changes in forest and other woody biomass stock		14252
	Forest and grassland conversion	17987	
	Uptake from abandonment of manage forest		9281
	Emission and removals from soils	19688	
Emission from bunker fuels		3373	
	Aviation	2880	
	Navigation	293	
Methane Emission			

Contd......

Sector	Subsector	Emissions	Sequestration
Total National Methane emission		18080	
All energy		2896	
	Transport	9	
	Fuel combustion	1636	
	Oil and Natural gas system	601	
	Coal mining	650	
Industrial Process		2	
	Production of Carbon block	2	
Agricutlure		14175	
	Enteric fermentation	8972	
	Manure management	946	
	Rice cultivation	4090	
	Agricutlural crop residue	167	
Land uses, Land use change and Forestry		6.5	
	Trace gases from biomass burning	6.5	
Waste		1003	
	Municipal solid waste disposal	582	
	Domestic waste water	359	
	Industrial waste water	62	

Source: National Communication to UNFCCC

Table A3: Composition of GHGs in various sectors in India

Green Houses Gases	Contribution (%)
Carbon dioxide	55
Methane	15
CFCs 11 & 12	17
Nitrous oxide	6
Others	7

Source: Central Pollution Control Board

Table A4: Land use details of Kolar district

Land use	Area (Hectares)	Area (%)
Forest	22986	2.77
Plantation	25439	3.07
Agriculture	386942	46.69
Wastelands	350801	42.32
Built-up	38221	4.61
Water bodies	4360	0.53

Table A5: Methodology for calculation of GHGs emissions/ Sinks

Sector: Agricutlure		
Methane		
Enteric Fermentation: Multiply number of livestock with the Methane Emission Factor to get Kg CH_4 Per Head Per Year	**Manure Management**: Multiply livestock with Emissions Factor to get Kg CH_4 per head per year.	**Rice Fields**: Multiply the Harvested Area by the Scaling Factor using the Correction Factor as suits the condition.
Nitrous Oxide		
From Manure management: Multiply number of animals with respective Nitrogen Excretion Factor to get total Nitrogen excreation (Nte) (kg/animal/yr). Multiply Nte with the respective Emission Factor depending on the type of Manure Management system to get the percentage of Manure. Multiply the percentage Manure with N_2O emission factor and with 44/12 to convert into annual NO_2 emissions.	**Emission from Soils**: Multiply the total amount of Synthetic Fertilizer N Applied to Soil with that of the fraction of synthetic fertilizer that volatilizes to get the total amount of synthetic fertilizer that volatilizes. Multiply this with Emission Factor (default values are 0.01 (0.002-0.02) kg N_2O–N per kg NH_3 –N and NO x –N emitted	**From Leaching**: Multiply the total amount of Synthetic Fertilizer with the Fraction of N that Leaches (default values are 0.3 kg N/kg nitrogen of fertilizer or manure) to get total leachable N. Multiply this with Emission Factor (kg N_2O–N per kg nitrogen leaching/runoff).
Sector: Transport		
Carbon from Transporation: Find out Net Calorific Value (NCV) in Terra Joules (TJ) using the default factors. Multiply NCV with Carbon Emission Factor Multiply Net Carbon with Fraction of Carbon oxidized to get actual Carbon emission. Multiply actual carbon emission with 44/12 to get CO_2 emissions		
Sector: Carbon sequestration		
Carbon Uptake: Calculate Annual Growth Rate (tons of dry matter per hectare/year) by multiplying with default values. Calculate Carbon Uptake Increment by multiplying with Carbon Fraction in dry biomass		

Table A6: Livestock details of Koalr district

Year	1985	1990	1995	2000	2003-04
Cattle	571577	572000	500000	526000	467316
Buffaloes	177604	178000	162000	147000	122969
Poultry	742888	743000	696000	1027392	1904022
Swine	-	-	-	29609	15375
Sheep	497946	498000	488000	718858	633201
Goats	385309	385000	188000	158646	203363

Table No A7: Carbon Emission Factor for southern Region 2002-03

Fuel	Generation GWh 2003-4	Emission tCO2	Per centage
Hydro	27531	0	0
Nuclear	0	0	0
Coal	79885	86238064	74.38
Diseal			
Diesal	2386	1523211	1.31
NG	12277	6033835	5.2
Lignite	18078	22155012	19
Total	140159	115950125	100
Average EF		827 tCO2/GWh	

Source: www.cea.nic.in

Table A 8: Availability of resources[16]

Resource Type	Availability	Potential to support energysystem in sustainable manner	% Contribution
Bioresource			
Forest	VP	VP	35
Other Plantation	G	G	40
Agriculture Residue	G	G	8
Animal waste	VG	VG	5
Oils			
Kerosene	P	P	2
Diesel	G	P	0.2
Petrol	G	P	0.1
Others			
Electricity	P	P	0.5
LPG	P	P	0.05
Solar	VG	VG	0(Negligible)
Wind	G	VG	0
Hydro	P	P	0

G: Good, VG: Very Good, P: Poor, VP: Very Poor

[16] T.B. Ramachandra, D. Pramod: Integrated Renewable Energy System – Perspectives and Issues. Integrated renewable energy: some issues in Kolar. Proc. Of International Seminar

Table A 9: Profile of motor vehicles and fossil fuel consumption in Kolar district

Type of vehicle	1985-86	1999-9	2000-01	2003-04
MC	24246	39894	69025	98272
Cars	1268	2456	4091	6050
Cabs	32	265	166	283
Autos	813	2032	3435	4414
KSRTC	768	783	NA	NA
Goods	1166	1955	3541	4821
Others	3078	5713	10695	15593
Total	31371	53098	91444	130120
Fossiel Fuel (KL)/ year	Petrol	Diesal	Kerosene	LPG (MT)
2003	15000	42000	5918	12000

Reference

Raghuraman, V. 2002. *Climate change and Indian industry – challenges, opportunities, and response*.

Shukla, P. R., D. Ghosh, and A. Garg. 2003. Climate change economics and policy: Indian rerspectives. Resource for the Future. In *Future energy trends and GHG emissions for India.*, Washington DC.

United Nations Development Programme (UNDP). 2001. *Human development report: 2001*. New York: Oxford University Press.

United Nations Framework Convention on Climate Change (UNFCCC). 1995. Documents of the Conference of the Parties COP 1 Berlin 1995 (COP1). http://unfccc.int/cop4/cop1.html.

———. 1997. *Kyoto Protocol to the United Nations Framework Convention on Climate Change*

Venkata Ramana, P., S. K. Sharma, and P. R. Shukla, eds. 2002. *Climate change and India: Issues, concerns and opportunities*. New Delhi: Tata McGraw Hill.

Winkler H., R. Spalding-Fecher, and L. Tyani. 2002. *Comparing developing countries under potential carbon allocation schemes*. Climate Policy 2(4):303-318.

Winrock international India (WII). 2004. *Report on access to energy prepared for the British High Commission*. New Delhi: WII.

Parikh, J K (1995): 'Joint Implementation and the North and South Cooperation for Climate Change', *International Environmental Affairs,* 7(1), pp 22-41.

FSI (1996) Volume Equations for Forests of India, Nepal and Bhutan, Forest Survey of India, Ministry of Environment and Forests, Government of India, 1996.

Hamburg, S.P. 2000. Simple rules for measuring changes in ecosystem carbon in forestry offset projects. Mitigation and Adaptation Strategies for Climate Change.

IPCC, 1996. Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories: Reference manual, section on Land Use Change and Forestry Sector, Cambridge University Press, Cambridge, UK.

IPCC, 2003. IPCC Good Practice Guidance for LULUCF Sector. Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, UK.

Ravindranath N.H., Sudha, P. and Sandhya Rao (2001). Forestry for Sustainable Biomass Production and Carbon Sequestration in India, *Mitigation and Adaptation Strategies for Global Change*, 6: 233-256.

Ravindranath, N. H. and Somashekar, B, S. (1995) Potential and Economics of Forestry Options for Carbon Sequestration in India, *Biomass and Bioenergy*, Vol. 8, pp. 323-36.

Karnataka Development Report, GoK, 2004

State of Environment, GoK, 2004.