Greenhouse Gas Emissions Inventory
&
Mitigation Study for Karnataka

An Interim Report Presented to

The Government of Karnataka

Prepared by

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Summary

The IPCC methodology was used to estimate the total emissions. The total annual GHG emissions in Karnataka will be roughly of the order of 80 million tons, with the power sector contributing around 36%, agriculture 20%, cement and iron and steel together accounting for 20%, transportation 10% and residential 7%. Other industries and waste account for the rest.

For any given vintage year, data for all sectors was unavailable; hence it was decided to use the most recent data available for each sector. Strictly speaking the emissions from all sectors should not be totalled; however it was done here to get an idea of scale. Whenever data was unavailable at the state level, national data was used as a proxy. Furthermore, it should be pointed out that the granularity of data available varied across sectors. To get a better estimate of emissions, more time and data are needed. In the second phase of this study, it is hoped to obtain a more precise estimate.

Introduction

Anthropogenic emissions of carbon dioxide (CO_2), weighted by global warming potentials, constitute by far the largest part of the emissions of greenhouse gases. Of these CO_2 emissions, those that are produced from fuel combustion make up the great majority. CO_2 emissions from burning biomass that a majority of rural households use for cooking is not considered, as biomass is considered to be carbon neutral.

In this section, we assess Karnataka's emissions of Greenhouse gasses (GHG) namely Carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) at the state level. The methodology here used was similar to the 'GHG Emissions 2007', report from Ministry of Environment and Forests (MoEF)[1], which in turn has followed IPCC 1996[2] methodology.

The simplest way to estimate CO_2 emission from fossil fuel combustion is assuming that the carbon in the fuel is released into the atmosphere in the short or the long run. Short-term emissions are defined within the *IPCC Guidelines* as those occurring within twenty years of the fuel use and are almost entirely reported in the fuel combustion module. Long-term CO_2 emissions result from the final oxidation of long-life materials manufactured from fuel carbon and are usually emissions from waste destruction[3]. This methodology is called the top-down approach. In the more detailed bottom-up approach, the computation of carbon released to the

[1] India: Greenhouse Gas Emissions 2007, MoEF, May 2010
[2] IPCC 1997

atmosphere is done at the plant level, where combustion takes place taking into account the type of fuel used. The CO_2 inventory in this report is calculated using top-down approach.

The sectors considered here are:

- Power
- Transportation
- Residential/Commercial Buildings
- Industry
- Agriculture
- Waste

Roughly, the annual total emissions from Karnataka are around 80.2[4] million tons of CO_2 equivalents (eq.). It is important to mention that relative to all the sectors considered for the total calculation, i.e. Waste, Electricity, Transport, Residential, Cement, Iron and Steel, Agriculture, and other industry, LULUCF (Land Use, Land Use Change and Forestry), constitutes a negligible amount of net emissions at the national level[5], and the same is assumed for the state. This was done due to data unavailability as well as time constraints. At this point, several assumptions had to be made to arrive at the state emissions number and it has to be validated in the next phase of the work.

It should be highlighted that information was not available uniformly across all sectors, particularly the granularity of available data differed amongst sectors. For some sectors or sub-sectors, due to lack of state level information, the national statistic had to be used as a proxy. Moreover, while power sector was well researched due to the high quality of available data, the analysis on other sectors lacked such rigor. As emissions due to electricity generation are taken into account in the power sector, it is not included in the other sectors.

As far as emissions due to industry is concerned, while emissions due to cement and iron and steel were easier to estimate (production data sufficed here), emissions due to others were difficult. In the transport sector, emissions due to each vehicular fleet are difficult to estimate due to lack of data on their numbers, efficiencies, operating conditions or mileage driven. Hence IPCC methodology was used to estimate the emissions due to this sector. There are several assumptions that had to be made as state level data was unavailable.

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[3] http://www.ipcc-nggip.iges.or.jp/public/gp/bgp/2_1_CO2_Stationary_Combustion.pdf
[4] Take a look at the notes under table 1.4
[5] Per 2004 NATCOM report, this is true for India, and the same is assumed for Karnataka

For example, the high speed diesel (HSD) is primarily used in transportation, diesel generators for backup power and irrigation pumps. While the total diesel and petrol sold in the state is known, the allocation between the sectors are not. Nationally, 55% of the HSD is consumed by the transportation section and this was used as a proxy for the state. As the number of diesel based irrigation pumps are negligible, the rest of the HSD sold (45%) was allocated to industry Allocation of other petroleum products such as kerosene and LPG were done using national proxies.

The emissions due to agriculture sector are primarily due to methane emissions from paddy cultivation and livestock management. In the Residential sector, they are due to the predominant use of biomass for cooking. Over 70%[6] of the rural households use traditional biomass for cooking. While biomass is considered carbon neutral, CH_4 and N_2O emissions are taken into account.

For the Waste sector, all necessary data was unavailable to compute the emissions from this sector. Attempts were made to use IPCC methodology and this is given in the sub-section. Households as well as commercial establishments such as hotels and hospitals use LPG and kerosene for cooking. The emissions number due to this sector reflects this.

Finally it has to be mentioned that while some data was for 2007-'08, others were for 2009-'10. Assuming there has not been any major shift in activity in these sectors, the number given is a fairly good estimate. The emissions from the three GHGs can be further broken down into the following:

- CO_2 emissions were 58.80 million tons (corresponding national number is 1221.70 million tons).
- CH_4 emissions were 0.90 million tons (corresponding national number is 20.60 million tons). This is equivalent to 18.7 million tons of CO_2 equivalent.
- N_2O emissions were 0.01 million tons (corresponding national number is 0.24 million tons). This is equivalent to 2.6 million tons of CO_2 equivalent[7].

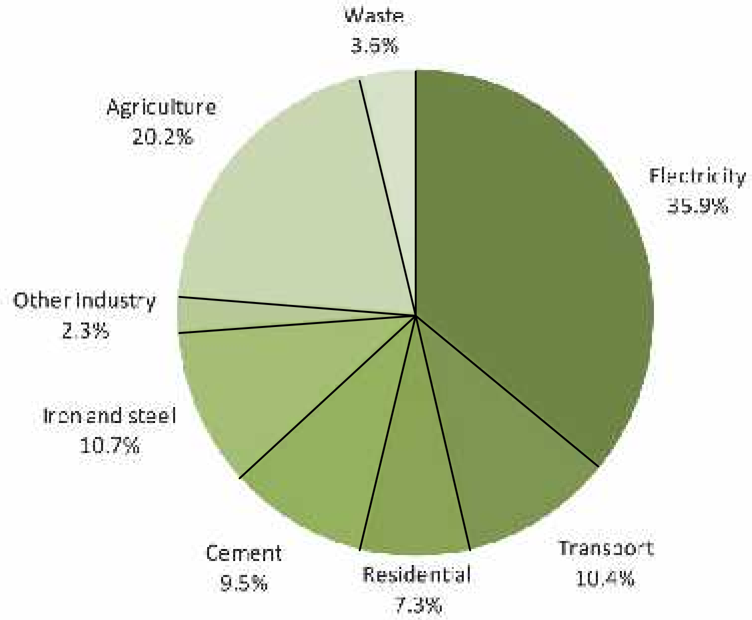
In each of the cases, Karnataka's emissions are around 4% of the national emissions.

The allocation of the emissions from each sector can be seen in the figure below. Details of the emissions and the methodology adopted are described after.

[6] TEDDY 2010, TERI Energy Data Directory

[7]

FIGURE 1.1 / KARNATAKA: GHG EMISSIONS BY SECTOR



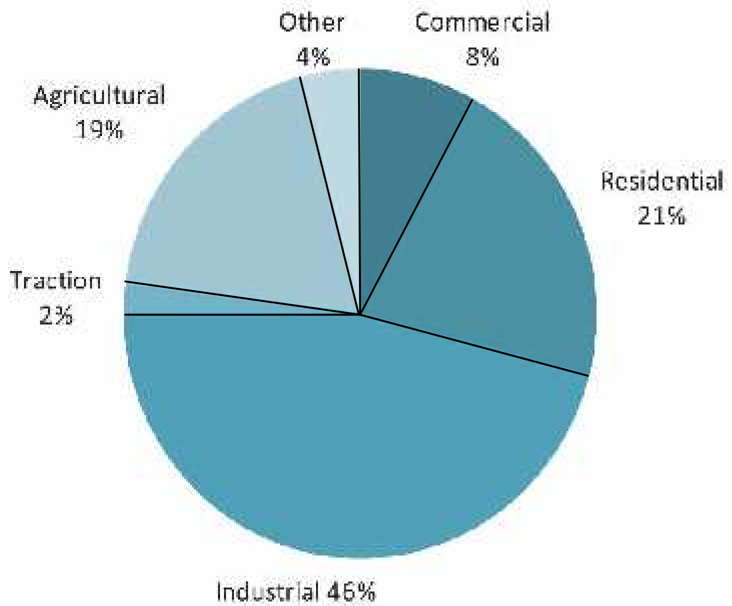
Note: Refer to Table 1.4 / Karnataka: Summary of GHG Inventory

Power sector

In the power sector, the net generation after factoring auxiliary consumption can be accurately calculated within a small margin of error. From the Central Electricity Authority's[8] CO_2 inventory of coal, gas, and diesel based plants, the specific CO_2 emissions due to net generation[9] from these sources was obtained. This was used to calculate the CO_2 emissions in this sector. The total CO_2 emissions from this sector were around 28.70 million tons for the year 2009-'10[10] corresponding to net generation of 44.30 billion kWh. Almost the entire emissions here can be attributed to coal based generation. Emissions due to methane and nitrous oxide are less than 0.5% (marginal) of the total emissions in terms of CO_2 equivalence; and therefore have not been taken into account. Figure 1.2 gives the all India sectoral breakup of the electricity usage.

[8] Central Electricity Authority, CO2 Baseline Database, Version 5, November 2009
The specific emissions assumed are: 1.1 kg/ net kWh for coal, 0.45 kg/net kWh for gas and 0.74 kg/net kWh for diesel based generation
[9] Auxiliary power consumption used to obtain net generation: coal 8%, gas and diesel 3.1%
[10] Installed capacity data from the Ministry of Power, Annual report 2010

FIGURE 1.2 / INDIA: ELECTRICITY CONSUMPTION BY SECTOR



Source: International Energy Association, 2008

Transport

Here, the emissions due to road, aviation and shipping are included. The total petroleum products sold by fuel type are known and from this the total emissions due to this sector is obtained by using the emission factors. While petrol sold in the state is exclusively used for transportation, aviation turbine fuel (ATF) is used only by airlines. However high speed diesel (HSD), is used for transportation, electricity generation by diesel generators and running irrigation pumps.

As there are very few diesel based irrigation pumps in the state, emissions from this source are assumed to be zero. Around 55% of the HSD sold in the country is used for transportation and the same percentage is assumed for the state as allocation in the state is unknown. The rest, 45% of the HSD sold is assumed to be used by industry, although we recognize that this may not be the true picture. For example, the amount of HSD used by diesel generators in commercial and residential buildings is ignored. Furthermore, the use of petroleum products by transportation might be different from the national statistic.

A total of 2.90 million tons of HSD was sold in the state11 and it was assumed that about 55%12 of this went towards transportation. Light diesel oil (LDO) and furnace oil (FO) are

[11] Consumption of major petroleum products in the state of Karnataka from India Stat

[12] This is the percentage of HSD that was used in the transportation sector for all India (data from Petroleum Planning and Analysis cell, MoPNG)

used for transportation and by industry. A total of 8.35 million tons of CO_2[13] were emitted by the sector as a whole in 2007-'08. Here again, CH_4 and N_2O are not taken into account.

Residential

This sector is a major consumer of electricity, accounting for over 29% of the total consumption in the country as can be seen in figure 1.2. However, as the emissions from power generation have been taken into account in the power sector, it will be not considered here to avoid double counting. However, the emissions due to cooking with liquid petroleum gas (LPG), kerosene and biomass are considered. Over 75% of the households in India use biomass. While biomass is considered carbon neutral, their CH_4 and N_2O emissions are taken into account. As per the national statistic, it is assumed that 27.70 kgs of biomass is used per person per month. The total population in the state using biomass is assumed to be 5.95 crores[14]. This implies roughly 20 million tons of biomass is used annually, resulting in CH_4 emissions of 0.09 million tons and N_2O emissions of 0.0012 million tons. The CO_2 emissions due to the use of LPG and kerosene are around 3.57 million tons. The total emissions due to the non-electric energy usage in this sector are 5.84 million tons of CO_2 equivalence.

Industry

The emissions due to the use of electricity consumption are not taken into account here as it has been accounted for in the power generation. The total emissions were then computed using the emission factors given in the IPCC guidelines. Here the production volumes of the resource were obtained from various sources[15]. The most energy intensive industries are considered.

Cement and Iron and steel are some of the most energy intensive industries of which Karnataka has a large manufacturing base. The total CO_2 emissions due to the same are high, at around 8 million tons each. The total CO_2 emissions from industry were around 18.20 million tons. It has to be emphasised, to avoid double counting, this emission does not include the emissions due to electricity consumption by industries, as this has been accounted for in the power sector (generation).

Five of the larger iron and steel plants, for which data was readily available, were examined in

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[13] The emission factors were obtained from, India: Greenhouse Gas Emissions 2007, MoEF, May 2010

[14] Population projections for India and states 2001-2026, Census of India 2001 http://nrhm-mis.nic.in/UI/Public%20Periodic/Population_Projection_Report_2006.pdf

[15] Directorates of Economics, Government of Karnataka, India Stat, Ministry of Petroleum and Natural Gas, Federation of Indian Mineral Industries (FIMI)

the state of Karnataka. In 2009-'10, these companies were responsible for producing 0.74 and 10.20 Million tons (Mt) of pig iron and steel respectively. The corresponding figures for 2008-09 were 0.69 and 6.64 Mt, respectively. The CO_2 emissions generated by these five companies were then calculated by multiplying the production capacity (in tons) with the specific emissions (in CO_2/t of production)[16]. The emission factors considered correspond to the different processes employed in these companies. In general, Basic Oxide Furnace (BOF), Electric Arc Furnace (EAF), Open Hearth Furnace (OHF) and Direct Reduced Iron (DRI) are the four different processes engaged by the different iron and steel producing companies to produce pig iron and steel.

The aforementioned methodology yielded 5.62 and 8.59 Mt of CO_2 in FY 2008-'09 and FY 2009-'10, respectively. The production capacity and the different processes employed were obtained from the annual reports of the respective companies[15].

In FY 2007-'08 and 2008-'09, Karnataka produced 10.50 and 12.10 Million tons (Mt) of cement. To calculate the CO_2 emission, IPCC's Tier 2 approach was employed. The CO_2 emissions generated were calculated by multiplying the production capacity (in tons) with the country's emission factor (in t CO_2/t of production). The emission factor is assumed to be 0.54 tons of CO_2 per ton of clinker produced[17], with the clinker to cement ratio of 0.85; the specific emission for cement production will then be 0.63 tons of CO_2 per ton of cement production. Hence the total CO_2 emissions for 2008-'09 work out to be 7.64 million tons from cement production in the state.

The state also produces silk yarn and has gold mines. The emissions due to these two industries are not taken into account due to lack of availability of data.

[16] JSW Steel Limited, 2010, Annual report 2009-10, p.25, Retrieved on March 3rd 2011 from http://www.jsw.in/investor_zone/pdf/Annual_Results/JSW%20Steel%20Full%202010.pdf Kalyani Steels 2010, Annual Report 2009-10, p.40, Retrieved on March 3rd, 2011 from http://www.kalyanisteels.com/annual_reports/Kalyani%20Steel%20AR%202010.pdf
KIOCL, 2010, Annual Report 2009-10, p.12, Retrieved on March 3rd, 2011 from http://www.kioclltd.com/annual_report.shtml

[17] India: Greenhouse Gas Emissions 2007, MoEF, May 2010 and www.cmaindia.org

Table 1.1 / Karnataka: Industrial CO_2 Emissions				
Industry		Production (Million Tons)	CO2 Emission Factor (Tons/Tons)	Total CO2 Emissions (Million Tons)
Aluminium		0.11	1.65	0.18
Iron & Steel	Pig Iron	0.74	1.46	1.08
	Steel	10.80	0.70	7.56
Paper		0.37	1.05	0.38
Sugar		3.40	0.24	0.82
Ammonia		0.24	0.82	0.20
Cement		12.10	0.63	7.64
Iron ore		36.39	0.01	0.29
TOTAL				18.16

Agriculture

Emissions due to this sector result from livestock management and paddy cultivation. Livestock enteric fermentation is a dominant source of CH_4 emission and accounts for over 60% of the total GHG emissions in terms of CO_2 eq. Table 1.2 summarizes emissions from this sector.

Table 1.2 / Karnataka: GHG Emissions from Agriculture			
	CH_4 Emissions (Million Tons)	N_2O Emissions (Million Tons)	CO_2 Equivalence (Million Tons)
Enteric Fermentation	0.50	-	10.54
Livestock Manure Management	0.04	0.0065	2.93
Rice cultivation	0.13	-	2.75
TOTAL	0.68	0.0065	16.23

Emissions from Livestock

The total livestock population in Karnataka in the year 2003 was 25.60 million as per the 17th livestock census[18]. This includes cattle, buffaloes, sheep, goat and pigs. Emissions here are due to two factors – enteric fermentation and manure management, and tier II approach of IPCC methodology was used in computing the actual emissions here.

It has to be noted that the Indian feeding standard of livestock is vastly different from the underlying assumption made in the calculation of the IPCC default emission factors. Hence, the

[18] 2003 all India 17th livestock census

emissions factor arrived at for India specific feeding standard was used in this analysis. The factors used here were developed by Central Leather Research Institute (CLRI)[19]. It should be noted here that this methodology might be different from what was adopted by MoEF. The MoEF report has used the NATCOM report[20].

The drawback in this analysis is that more recent data was unavailable. Livestock population for more recent years was not extrapolated due to lack of data and time constraint.

Rice Cultivation

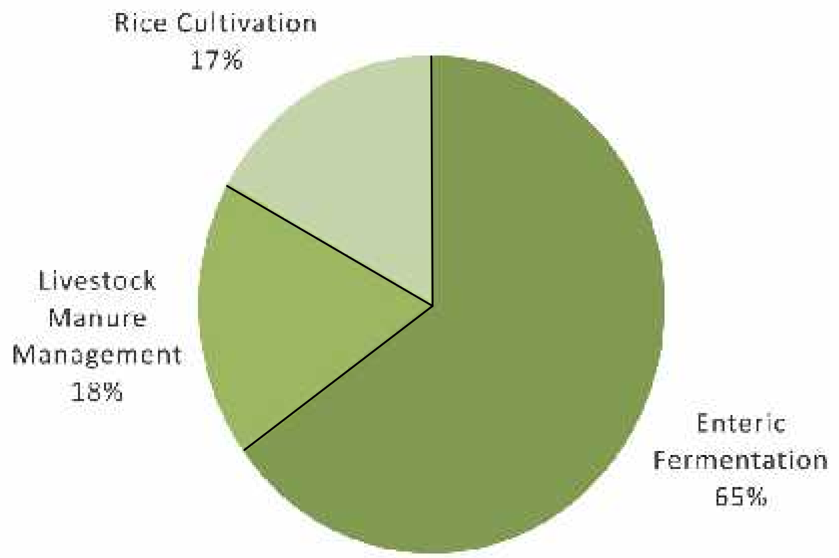
Approximately 1.4 million hectares of land was under rice cultivation in the year 2007. However, the breakup of the land under different water management practices (or irrigation) was not available. Hence, the national statistic was used as a proxy to arrive at a number for the state. Continuously flooded water management practice results in high methane emissions, while multiple aeration of paddy fields proves to be the most efficient. Rice cultivation in Karnataka resulted in a total emission of 0.13 million tons of CH_4 or 2.75 million tons of CO_2 equivalence. Here, emissions from agricultural soil and field burning of crop residue have not been done so far.

[19] Budgeting Anthropogenic GHG emission from Indian livestock using country-specific emission coefficients, Current Science, Mahadeswara Swamy and Sumana Bhattacharya, Vol 19. No.10, Nov 25, 2006
[20] NATCOM, 2004. India's Initial National Communication to the UNFCC. MoEF, GoI

TABLE 1.3 / KARNATAKA: SUMMARY OF CH_4 EMISSIONS FROM RICE CULTIVATION

ECOSYSTEM	WATER REGIME	RICE AREA 2007 ('000 HA)	METHANE EMISSION ('000 TONS)
IRRIGATED	Continuously Flooded	206	33
	Single Aeration	273	18
	Multiple Aeration	285	5
RAINFED	Drought Prone	115	8
	Flood Prone	309	59
DEEP WATER		42	8
UPLAND		168	0
TOTAL		1,396	131

FIGURE 1.3 / KARNATAKA: BREAK UP OF GHG EMISSIONS IN AGRICULTURE



Land Use Land Use Change and Forestry (LULUCF)

As per NATCOM 2004 report, the emission from LULUCF is considered to be negligible. Hence, it is assumed to be negligible for Karnataka as well and thus not included in the study.

Waste

The three main sources of GHG emissions are municipal solid waste, domestic, and industrial waste water. The CH_4 emissions are due to the decomposition of waste in anaerobic condition and N_2O emissions from domestic waste water are due to its protein content.

While calculating CH_4 emissions from municipal solid waste, only waste from urban areas is included, as the waste in the rural areas is scattered and does not contribute to the process of anaerobic fermentation. IPCC (1996) revised methodology is adopted to calculate CH_4 emission from municipal solid waste.

The urban population in Karnataka is considered to be 37% of the state population[21]. The total municipal waste generation rate from urban areas is estimated to be 0.55kg/capita/day on an average. 70% of this is estimated to reach the land fill site[22]. These assumptions are used in the calculation of CH_4 emission from total waste which is found to be 70 thousand tonnes.

The waste water produced in Karnataka is estimated to be 1,036 million litres per day[23]. By adopting IPCC 2006 guideline, it is calculated that 19 thousand tonnes of CH_4 is emitted. However, the N_2O emissions are negligible.

Since there is a dearth in data on industrial waste water, the emissions from this source was not obtained.

Finally the total emissions due to this sector could not be calculated due to the unavailability of emissions due to industrial waste water. More data is needed to arrive at a complete estimate. In absence of this, it was decided to come up with an approximate number for this for the preliminary report. As Karnataka's population is around 5% of the national population, it was decided that 5% of the national emissions, which works out to be 2.90 million tons of CO_2 equivalence (3.6% of the total emissions in Karnataka), be used as a placeholder for Karnataka. In the final report more data needs to be gathered to come up with a better estimate. For India as a whole, the emissions due to waste is 3% of the total emissions.

Conclusion

The estimates in this chapter were done based on secondary data. Except for the power and the industrial sectors, data was difficult to obtain and hence several assumptions had to be made.

[21] McKinsey Report and population projection- Census India

[22] National Environmental Engineering Research Institute, NEERI, 2005. Assessment of status of Municipal Solid Waste Management in metro cities, state capitals, class -I cities and class – II towns

[23] Housing condition in India NSS report July-December 2002, http://moef.nic.in/modules/others/?f=event

The table below gives a snapshot of the emissions due to each sector; the year for which data was available and hence emissions are for is given as well. As mentioned earlier, it was decided that data available for the most recent year be used for each sector.

For the next phase of the study, attempt should be made to obtain primary data. This can lead to more precise estimates of estimates.

TABLE 1.4 / KARNATAKA: SUMMARY OF GHG INVENTORY

	Particulars	Quantity/ Production/ Area	Production (units)	CO_2 emissions (million tons)	CH_4 emissions (million tons)	N_2O emissions (million tons)	CO_2 equivalence (million tons)
Energy	Electricity Generation (2009-2010)	11,495	*MW*	28.76	-	-	28.76
	Transport (2007-08)	-	-	8.35	-	-	8.35
	Residential (2007-08)	-	-	3.57	0.0900	0.0012	5.84
Industry	Cement Production (2008-09)	120.97	*Lakh tonnes*	7.64	-	-	7.64
	Iron & Steel Production (2009-10)	115.4	*Lakh tonnes*	8.64	-	-	8.64
	Ammonia Production (2008-09)	2.36	*Lakh tonnes*	0.19	-	-	0.19
	Aluminium Production (2008-09)	1.09	*Lakh tonnes*	0.180	-	-	0.18
	Iron Ore (2008-09)	423.14	*Lakh tonnes*	0.291	-	-	0.29
	Pulp and Paper (2008-09)	3.65	*Lakh tonnes*	0.38	-	-	0.38
	Sugar (2008-09)	33.97	*Lakh tonnes*	0.82	-	-	0.82
Agriculture	Enteric Fermentation (2003)	25.6 million	*Animals*	-	0.50	-	10.54
	Livestock Manure Management (2003)	25.6 million	*Animals*	-	0.04	0.00654	2.93
	Rice Cultivation(2007)	1.40	*Million hectare*	-	0.13	-	2.75
Waste (2007)		-	-	-	0.126	0.00079	2.89
Total							80.21

Note: It has to be pointed out again that the data for the same period was unavailable for all sectors. All attempts were made to get the most recent data for each of the sector. Hence it is likely that the total emissions will be higher than the 80 million tons given above. One could have fixed a particular year and projected the emissions of sectors where data was unavailable. However, this would introduce more errors as several assumptions had to be made in the projection. Going forward the government should make concerted efforts to collect annual data.

Section 2 **Mitigation Options**

Summary

Projecting future emissions from current levels is quite involved and is fraught with difficulty. To do this one needs a good estimate of future energy demand, future technology development and future fuel mix. Furthermore, future energy needs will depend on multiple macro-economic factors and hence hard to project. For most of the sectors, determining reasonable estimates requires more time and analysis. Though mitigation options are discussed for all sectors, except for the power sector, the extent of reduction in emissions due to mitigation options is not estimated.

In this section, mitigation options in the power sector are analyzed in great detail. For the sake of illustration, several possible scenarios of fuel mix are presented that could lead to reduced emissions from the business as usual case in 2020. The net generation of electricity at the bus bar in 2010 was 44 billion kWh resulting in CO_2 emission of 29 million tons in the state. However, in the business as usual case if the economy were to grow at 8% annually, the net generation required would have to increase to 112 billion kWh resulting in emissions of about 84 million tons. However, stringent implementation of energy efficiency measures and demand side management can reduce this demand considerably.

Introduction

Today the total annual emissions from Karnataka are in the range of 80 million tons of CO_2 eq[24]. Emissions from LULUCF constitute a negligible amount of net emissions[25] and hence were ignored. In order to project future emissions, one needs to project energy required, future technology developments, and the fuel mix. An estimate of elasticity of GDP of that sector is needed to project production or growth of any sector. However, estimating the elasticity to use in such a projection is difficult, as future elasticity trends would depend on several macro-economic factors such as relative fuel prices, technology advancement, development priorities of the state, structural shift in the state's economy, etc. In this section all projections have been undertaken limited up to the year 2020-'21 as it is difficult to project technology developments further into the future.

While the mitigation options in power sector are analysed in detail, the analysis for the other sectors are not as detailed. For example, in the transportation sector, significant shift to mass

[24] Section on GHG Inventory of Karnataka
[25] Per 2004 NATCOM report this is true for India, and we assume the same for Karnataka

transit could be a game changer in the reduction of emissions. However, it is hard to tell the extent to which the infrastructure will develop by 2020 to make a significant contribution towards the reduction in emissions.

Projecting forward to 2020-'21, assuming the gross state domestic product (GSDP) was to grow at 8% annually in line with that of the country; the total emissions could reach to over 244 million tons of CO_2 eq. in the business-as-usual case. However, this can be reduced by adopting GHG mitigation strategies. By increased use of energy efficient appliances, adopting energy efficient measures in manufacturing, and by introducing greater percentage of energy generated from renewable energy, the GHG emissions level can come down in the future.

India currently has policy, regulatory and legislative structure towards GHG mitigation in place. The integrated energy policy was adopted in 2006, followed by the National Action Plan for Climate Change (NAPCC), announced in 2008. Two of the core missions announced as part of the NAPCC, are the National Mission for Enhanced Energy Efficiency (NMEEE) and the National Solar Mission (NSM). These plans can help direct Karnataka to reduce the future energy demand and to improve the fuel mix. These policies in turn can help to reduce the GHG emissions substantially. Some of the key technology options that will help mitigate GHG emissions along with the current plans of the government of Karnataka are discussed below.

Power Sector

Hydro electricity in 2010 constituted about 27% of the total energy mix in the state, while coal accounted for 58%[26]. For comparison, hydro makes up 15% and coal accounts for 72% of the national generation. However, in determining the future energy mix for the state of Karnataka, one needs to consider resource limitations, cost of generation, and other social and political constraints. Going forward, the percentage of these renewable sources in the total energy mix is unlikely to increase given the severity of the constraints.

As of January 2010, the total installed capacity of utilities, including allocated shares in joint and central sectors, and captive generation was around 11,459 Mega Watts (MW)[27]. In the period 2009-'10, the net generation after considering auxiliary consumption was around 44 billion kWh and the associated CO_2 emissions were 28.70 million tons. As of January 2010, the peak power deficit was 22.80% and the energy deficit was 13%[28]. If the generation for this period were 50 billion kWh the state would have been able to meet its electricity demand. If this were projected using an elasticity of 0.95[29] (assuming a GSDP growth rate of 8% for Karnataka), the electricity

[26] Ministry of Power, Annual Report 2010
[27] Ministry of Power, Annual Report 2010
[28] Government of Karnataka, Department of Energy
[29] Integrated Energy Policy, 2006

demand required in 2020-'21 would be 112 billion kWh in the business as usual case. However, by adhering to strict energy efficient programmes and adopting DSM options, the demand could be reduced by 10-15% or to 95 to 100 billion kWh by 2020-'21.

Energy Efficiency and Demand Side Management

Promoting energy efficiency (EE) and demand side management (DSM) can help reign in the growth of demand of electricity. This would imply a reduced demand in the future and thus a reduced carbon footprint for the state. Several EE measures are cheaper to implement on a life cycle basis and should be considered as means of reducing the demand. The Bureau of Energy Efficiency (BEE) under the NMEEE has several programmes to encourage reduced consumption of energy in buildings, industry and irrigation.

Transmission loss in Karnataka is 4.20% in 2009-'10 which is on par with international Standards. In 2008-'09, the average distribution losses, including both technical and commercial losses, were 20%[30].The technical losses are marginal in cities, while being very high in the rural areas with 11 KV feeder lines running long distances. Re-engineering of these feeder lines and LT lines in the state would help reduce technical losses. The first step to achieve this would be to carry out the energy audit of the distribution system to segregate and pinpoint the commercial and technical losses. Having identified the causes, the DISCOM must analyze the same and further develop them in the form of several DPRs (detailed project reports). Finally, a list of projects showing gestation period, investment, and benefits must be listed so that the projects can be prioritized[31].

The increased use of energy efficient lighting such as compact fluorescent lamps (CFL) and Light Emitting Diodes (LED) has large potential in bringing down the total consumption of electricity due to lighting in buildings – residential and commercial. Under the 'Belaku scheme' in Karnataka (the national 'Bachat Lamp Yojana'), the power utility in exchange for incandescent bulbs will provide 4 CFLs at a subsidized rate of Rs. 15 each to every household. Similarly, the use of energy efficient five star labelled appliances such as air-conditioners and refrigerators have enormous potential to reduce energy consumption. Bangalore Electricity Supply Company's (BESCOM) success of shaving off morning peak load by incentivizing the use of solar water heaters should be replicated in other parts of the state. Public and commercial buildings should be mandated to install solar water heaters.

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[30] KPTCL

[31] Change Management in Power Distribution, Distribution Reform, Upgrades and Management (DRUM) Training Program, Report prepared by USAID for Ministry of Power

In the agricultural sector, most irrigation pumps in Karnataka are grid connected and hence diesel based pumps are rare. As grid power is heavily subsidized, the farmers do not have any incentive to switch to efficient pump sets (The majority of the pump sets in operation operate at an average efficiency of around 30%). Hence, most of the irrigation pumps are highly inefficient and are massive consumers of power. Better load management, and reducing water consumption along with replacement of the existing pumps with efficient pumps can result in very large savings in this sector. However, due to political repercussions this is difficult and requires strong political will.

Clean Coal Technologies

Coal will remain the mainstay for electricity generation for the immediate future. Moreover, at present, coal is one of the lowest cost options and will continue to be so for a large percentage of total generation by 2020 as well. To meet the projected demand of the state, the coal based generation might have to increase considerably in capacity by 2020. Today, all the coal-based plants in the state of Karnataka as well as in the country are based on sub-critical technology with an average specific CO_2 emission of about 1.10 kg per net kWh. However, the new 500 MW sub-critical plants will have a lower specific emission of 0.93 kg per net kWh[32].

To reduce the specific emissions from coal based generation, the combustion efficiency can be improved by the use of super-critical technology. The plants based on this technology operate at a temperature and pressure higher than the sub-critical ones leading to lower specific emission of 0.83 kg per net kWh. This technology is available and costs almost the same as sub-critical technology. NTPC has plans to set up five 800 MW of supercritical plants in Bijapur district[11]. However, it is not clear how much of this plan will be realized.

Natural Gas generation

Gas based power plants have low capital cost (around Rs 2.70 crores/ MW), even lower than coal based generation, and have a much lower specific emission of 0.42 kg per net kWh. Hence, they are an attractive option. However, the availability of gas is a concern. Gas Authority of India Limited (GAIL) is planning a 746 km of gas pipeline from Dabul in Maharashtra to Bangalore via Belgaum, Gadag, Davanagere and Tumkur in Karnataka. This will help setting up gas based power plants along the route of the pipeline. There are two combined cycle power plants planned in Bidadi and Tadadi of 1400 MW and 2100 MW[11] respectively.

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[32] Discussion with NTPC; *Future of Coal*, Massachusetts Institute of Technology, 2007.

Hydro Power

Karnataka is endowed with a large hydro potential of about 7,750 MW[33]. However, the installed capacity of large and small hydro together is only around 3,763 MW today. Full exploitation of hydel potential is difficult due to environmental concerns, people displacement problems and inter-state water disputes. At present, a 400 MW hydel scheme in Hassan district and a 345 MW seasonable scheme at Shivasamudram are awaiting environmental clearance from the Ministry of Environment and Forestry (MoEF). Hence, going forward, mini and pico hydel projects are more likely to come up than large projects. Though generation of hydro power is carbon free, the environmental impact of large hydro plants also has to be taken into consideration.

Biomass

Biomass cogeneration in sugar mills is a promising option in Karnataka, as about 165,000 tons of sugar cane is crushed daily in the state[34]. At present, 623 MW of biomass based power plants are in operation. A large percentage of this is perhaps based on sugar cane bagasse. In addition, the state has accorded permission to 54 new and old sugar factories to establish co-generation and up to 600 MW is expected to be exported to the grid from these after captive usage[35]. Biomass based power is considered carbon neutral and hence no CO_2 emissions is attributed due to this.

Solar and Wind

Karnataka Power Corporation Limited (KPCL) has set up three 3 MW solar photovoltaic plants. Plans are underway for more, making Karnataka an early mover into the utility scale solar PV based power generation. Most parts of Karnataka are reasonably endowed with global radiation suitable for large scale adoption of solar PV. The northern part is said to have sufficient direct normal irradiance (DNI) that is necessary for concentrated solar thermal power (CSP) generation. Given this and the impetus provided by the National Solar Mission, solar energy can play a large role in the power generation of the state. However, the current impediment of solar technology is its high cost. Again, careful planning, implementation and continuous servicing and maintenance of these plants will lead to successful generation of electricity from these technologies. The state could also consider incentivizing roof top PV systems to abate the usage of diesel in urban buildings.

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[33] Government of Karnataka, Planning Programme Monitoring and Statistics Department. http://www.planning.kar.nic.in/sites/planning.kar.nic.in/files/AnnualPlan2011-12/vol-I/10%20-%20Chapter10-F_199-218_.pdf

[34] Government of Karnataka, Planning Programme Monitoring and Statistics Department http://www.planning.kar.nic.in/sites/planning.kar.nic.in/files/AnnualPlan2011-12/vol-I/10%20-%20Chapter10- F_199-218_.pdf

[35] Centre for Wind Energy Technologies; http://www.cwet.tn.nic.in/html/departments_wra.html

About 15% of the total capacity and 6% of the total electricity generation in the state is from wind power. With an installed capacity of 1448 MW of wind, Karnataka has the fourth largest installed capacity in the country after Tamil Nadu, Maharashtra and Gujarat. The theoretical installable potential for Karnataka is very high around 8,600 MW[36]. However, it is unclear how much of this will be realizable.

Nuclear Power

The Nuclear power plant at Kaiga has 4 units of 220 MWs each (Pressurized Heavy Water Reactors technology). Three of these were recently commissioned. There is a proposal to expand the generating capacity by adding one more unit of 500 MW in the near future. Overall, nuclear power can contribute up to 1380 MW by 2020 if pursued diligently. Generation of electricity from nuclear power plants is almost carbon free and hence the emission from this is considered to be zero.

Conclusion

The table below gives the current and possible energy mix in 2020-'21, in the business as usual case. It has been assumed that almost all of the planned coal based power plants will be commissioned while some may not be fully realized. As per discussions above, Karnataka has been a forerunner in exploiting several of the low carbon renewable resources and it has a high percentage of renewable energy in its total mix. However, going forward, it is unlikely for the energy mix to have such a high percentage from carbon-free sources due to the constraints discussed above.

Perhaps if prices were to come close to grid parity, solar energy may play a bigger role. However, it is doubtful if it can contribute to more than 2-3% of the generation by 2020. Beyond 2020 one can perhaps believe that solar might be able to scale up and efficient coal technologies might be the order of the day. However, coal is likely to dominate the energy mix for the foreseeable future. The CO_2 emissions in 2020-'21 would be around 84 million tons in the business as usual case, extrapolating from the current level of 29 million tons. The adoption of DSM measures can reduce this by 10% to 65 million tons under moderate mitigation measures or by 15% to 60 million tons under aggressive mitigation measures.

However, even the moderate mitigation efforts require great deal of planning and meticulous implementation plans to achieve 10% reduction. It has to be pointed out again that renewable energy sources particularly hydro electric power is a significant percentage of generation in the state. Given this, it is going to be very difficult to decrease the carbon foot print due to electricity generation significantly in the next decade.

Table 2.1 below shows the current energy mix and generation today and under Business as Usual case (BAU). The subsequent table Table 2.1 A, in addition gives the possible supply mix under moderate and aggressive mitigation options. It has to be reminded again that these are only a possible scenario and by no means should be taken more than as an illustration.

TABLE 2.1 / KARNATAKA: POWER SECTOR – CURRENT AND PROJECTED

	2010		2020 Business as Usual Scenario	
	Total Installed Capacity (MW)	Net Generation (Billion kWh)	Total Installed Capacity (MW)	Net Generation (Billion kWh)
Coal Sub-Critical	3,903	23.59	12,600	81.24
Coal Supercritical	-	-	400	2.58
Gas	220	0.84	440	1.87
Diesel	333	1.28	460	1.06
Nuclear (PHWR)	195	0.62	880	5.55
Hydro + Small Hydro	3,763	11.44	4,200	12.77
Wind	1,448	2.49	2,000	3.43
Biomass + Cogeneration	623	2.03	800	2.61
Solar	10	0.02	100	0.16
Captive Generation	1,000	2.01	-	-
TOTAL (Utility + Non Utility)	11,495	44	21,880	112
CO_2 EMISSION (million tons)	-	29	-	84

Table 2.1A / KARNATAKA POWER SECTOR PROJECTIONS FOR 2020-'21

Projections for 2020-21	Total Installed Capacity (MW)		
	Business As Usual	Moderate Mitigation	Aggressive Mitigation
Coal Sub-critical	12,600	8,000	7,200
Coal supercritical	2,000	1,500	1,500
Gas	880	1,620	1,620
Diesel	460	500	500
Nuclear	880	1,380	880
Hydro + Small hydro	4,200	4,200	4,200
Wind	2,500	3,000	4,400
Biomass + Cogen	800	800	800

[36] Directorate of Economics and Statistics, Government of Karnataka

Solar	200	800	900
Total Installed Capacity (MW)	**24,520**	**21,800**	**22,000**
Net generation (Billion kWh)	112.18	100.77	95.02
Net CO_2 Emissions (Million tons)	83.99	64.7	59.9

Transportation

The transportation sector is a large emitter of CO_2 and its share of GHG emissions have been consistently increasing. India imports 80% of its petroleum requirements, and a significant percentage of this is used for transportation. In Karnataka, the emissions due to transportation were 8.35 million tons in the year 2007-'08. At a state GDP growth rate of 8%, assuming an elasticity of 1, the emissions due to this sector is likely to be 23 million tons.

To lower emissions in this sector, efficient modes and technologies must be used, while inefficient ones should be discouraged through policy or fiscal instruments. Some of the following measures will help the state reduce emissions along with improving the overall infrastructure of the state as well.

- Rail freight is considerably more energy and carbon efficient than road freight. The falling trend in the rail freight and the gain in share of the road freight should be reversed.
- Increase the share of public transportation in the cities – increased buses, metro.
- Bicycle lanes should be made available where possible in all the cities.
- Minimum efficiency standard for the country's vehicle fleet should be defined. Fuel efficiency should be improved by imposing periodically tightening fleet efficiency, with mechanisms to penalize non-conformance. The state government should work with the BEE to establish these standards.
- The hybrid electric vehicle combines the internal combustion engine (ICE) with an electric propulsion system. The electric vehicle's 'tank to wheel' efficiency is higher by a factor of three as compared to a conventional IC engine vehicle.
- The state government has set up a task force with the objective to prepare a road map for the GoK to make transition towards Electric/Hybrid public transportation. It is intended to develop a few prototypes to run within Bangalore and in a few select inter-city corridors in the state in the upcoming year. If the state were to transition into low-carbon public transportation system, it will be a great achievement and should be pursued.
- The national biofuel policy of 2008 mandated a biofuel mix of 20% in petroleum for transportation by 2017. However, due to concerns related to use of land this was abandoned. Recent reports suggest that the state government is considering this as an option. However, we caution large-scale thrust to biofuels because of the causes of food security and inflation.

Industries

Emissions related to the consumption of electricity in this sector are not considered towards emissions, as emissions due to the generation of electricity has been taken into account in the power sector. In this sector, industries that are highly energy intensive and hence big polluters have been taken into account. Several small ones have not been taken into account due to time and data constraints.

In the industrial sector, cement, iron & steel, aluminium, textile and paper are some of the most energy intensive manufacturing industries. While the large plants are generally very efficient, efficiency often reaching the global best standards, the small and medium scale plants are often not so. The government of India's Perform Achieve and Trade (PAT) scheme is a market based mechanism to optimize energy efficiency in industries. This mechanism allows plants to trade energy efficiency certificates in the market. However, energy savings from this implementation is hard to estimate even at the national level let alone at the state level, given that the future targets are not known yet. Moreover, it is unclear how many industries that will be mandated to subscribe to the PAT scheme. A very rough estimate would be 7-10% of energy savings in 2020 from the 2010 levels[37]at the national level. It is less certain what this would be at the state level.

Karnataka ranks seventh in the production of cement in the country with an annual production of 12.10 million tons[38] of cement which emits 7.60 million tons[39] of CO_2. The state is also the third largest steel producer in India with an annual production of 10.70 million tons[40]. In Karnataka these two industries account for over 20% of the overall emissions of the state and over 40% of the emissions from the industrial sector. Future consumption, of cement and iron & steel needed, to sustain economic growth of the economy can be projected using elasticity of these resources in GDP growth. These elasticities have been assumed to be a little over 1. The emissions in 2020-'21 are likely to increase to 51 million tons from 16 million tons for the year 2008-'09.

- Most industries consume thermal and electrical energy. It is the requirement of thermal energy that can be reduced by adopting energy efficient practices.
- In the case of cement sector, adding fly ash and slag to clinker would reduce the carbon footprint considerably.
- Use of natural gas based DRI steel making process where possible as this has approximately 40% less CO_2 emissions compared to a basic oxide (BOF) process.

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[37] CSTEP Estimate

[38] Directorate of Economics and Statistics, Govt. of Karnataka

[39] Cement Manufacturers Association and MoEF – Assumptions - 0.537 t CO2/t Clinker produced and production of clinker uses 85% of total energy used in cement manufacturer

[40] Karnataka advantage, steel sector; http://advantageKarnataka.com/pdf/steel.pdf

- The use of solar thermal technologies for process heat applications can reduce the fossil fuel usage in industrial applications.

Residential

Currently biomass is the mainstay as a cooking fuel in a large percentage of rural households. This results in deforestation and GHG emissions. Over 75% of the households in India use biomass. While biomass is considered carbon neutral, it's CH_4 and N_2O emissions are taken into account. Extending the supply of LPG to all households can have positive environmental impact and will help alleviate indoor air pollution related health problems.

Ease of Implementation of Mitigation Options

As per the analysis presented in table 2.2, the ease of implementation of the mitigation options varies across the range of technology options over the short- and longer term. The ease is evaluated across the parameter of overall cost of financing, regulatory support, agency issues, entrenched behaviour, supply constraints, and technological readiness. Technologies such as large-scale hydro would face challenges due to ecological and population rehabilitation concerns. Similarly, large-scale deployment of CSP would entail high-cost investment decisions. In addition, CSP plants typically need large tracks of land with water (5 acres/MW), posing a challenge.

TABLE 2.2 / EASE OF IMPLEMENTATION*

COST	Moderately Challenging	Challenging	Very Challenging
NEGATIVE	• Energy efficient appliances • Energy efficiency equipment • Solar water heaters in residential, public and private buildings • Mileage standard in automobiles	• Energy efficiency in iron & steel industry.	• Clinker substitute by fly ash and slag in cement • LED lighting • Efficient cook stoves • Efficient irrigation pumps in agriculture
MODEST	• Small hydro • Wind • Solar thermal applications for industrial heat, agricultural drying, and water heating • Supercritical technology • Nuclear	• Reduction in T&D losses • Building efficiency	• Efficiency from other sectors
HIGH	• Solar photovoltaic for electricity generation • Public bus-based transportation systems • Shift to freight by rail	• CSP • Shift to gas-based Direct Reduced Iron (DRI) in steel manufacturing	• Large hydro • Large scale deployment of CSP • Ultra supercritical coal technology

* Ease of Implementation based on financing issues, regulatory support, agency issues, entrenched behaviour, supply constraints & technological readiness.
Sources: McKinsey Report on Environment and Energy Sustainability and CSTEP's analysis.

Cost of Mitigation

The investments required for abatement and cost per ton of saved CO_2 should be ideally obtained by undertaking a life cycle analysis of each option. However, due to lack of data this has not been done here. The economics of abatement option in the power sector has been done to a reasonable accuracy. However, in this phase of the report we have not been able to look at the economics of mitigation of other sectors and options, in particular transportation and industry. It is because these entail more complex analysis and data availability curtailed the study from this analysis.

For some of the abatement options such as in the power sector, the approximate capital investment was known and this was used (cost of operations and maintenance was ignored) to compute the cost of abatement. This analysis is given in table 2.3. The abatement choices are compared with subcritical coal technology. The changeover to natural gas for generation of electricity has a negative cost for abatement since the capital cost here is lower than that of sub-critical technology. Here for the sake of analysis, it is assumed that all the planned supercritical and gas based plants are built.

In the case of compact fluorescent light (CFL) life cycle analysis, the switch to CFL from the incandescent lamp would result in the savings of Rs. 4,400 per ton of CO_2 avoided. In the state of Karnataka, assuming that on average each urban household is given 2 CFLs, the total investments today would be Rs 176 crores[40]. However, the total amount saved due to reduced electricity cost would be Rs 949 crores. However, a note of caution here is that the CFL lamps contain mercury and hence proper disposal should be designed for the same. Light Emitting Diodes (LED) have a negative abatement cost as well. However, this is not yet commercially viable.

It is recommended that the government take up several studies based on life cycle analysis to evaluate the potential of cost savings. Moreover, pilot projects to validate technology and verify economics should be planned.

Table 2.3 / Karnataka: Mitigation Options for Power Section						
Option	Total New Capacity Between 2010-2020 (MW)	Net Generation (Billion kWh)	Capital Cost Rs (Crores)/ MW	Total Investment (Crores)	CO_2 Savings vs. Sub-Critical (Kg/kWh)	Annual CO_2 Savings (Million Tons)
Sub critical	-	-	4.5	-	-	-
Super Critical*	4,000	25.79	4.7	18,800	0.10	2.58
Gas*	3,500	14.90	2.7	9,450	0.48	7.15
Nuclear	685	4.32	7.0	4,792	0.93	4.02
Wind	552	0.95	9.0	4,968	0.93	0.88
Solar	177	0.30	14	2,478	0.93	0.28

* Under the assumption that all the super-critical and gas-based plants under the current plans are built by 2020.

Conclusion

Adoption of energy efficient measures would result in reduced demand for energy and thus lower emissions. This is perhaps the lowest hanging fruit among mitigation options. Lower demand translates into reduction in the addition of generation capacity. Towards achieving this, the Bureau of Energy Efficiency, Ministry of Power of Government of India, is working towards setting targets for industries and household appliances. The state government should work closely with the national government to set up targets and ensure implementation of energy efficiency measures in industry and appliances.

Mitigation and abatement of GHG emissions in power sector can be achieved by adopting high efficiency low emissions coal technologies and by gradually shifting to generation from renewable sources. However, Karnataka already has a high percentage of generation from hydel power and has set up about 1500 MW of wind capacity. It has also set up three 3 MW of solar photovoltaic plants, one of the firsts in the country. The government of Karnataka is planning on expanding its wind and solar capacity.

As far as transportation is concerned, while considerable deployment of hybrid vehicles has the potential in reducing carbon foot print, it is the introduction of mass transit that can be a game changer. This necessarily entails vast improvement in the infrastructure.

Stringent implementation and adoption of mitigation measures can result in significant lowering of energy consumption and carbon emissions. Furthermore, this could lead to decoupling of economic growth and energy usage and hence emissions.

Assumptions in computing net generation

1. Plant load factors (PLF) for 2020: Coal 80%, gas and diesel 55%. Nuclear 80%, hydro 35%, wind 17%, solar 20%, biomass and others 40%, Non utility (40%)

2. Auxiliary power consumption: coal 8%, nuclear 10.50%, gas and diesel 3.10%, hydro

0.50%, wind 2%, solar photovoltaic 1 %, concentrated solar thermal power 7%, biomass and others 7%, non utility (3%)

3. Specific emission of the total current fleet of coal and lignite power plants is 1.10 kg of CO_2 per net kWh. Based on CEA data (Central Electricity Authority, CO_2 baseline database, version 5 and November 2009)

4. For the new 500 MW sub critical power plants, net heat rate is 2450 Kcal/kWh leading to a specific emission of 0.93 kg of CO_2 per net kWh (Discussion with NTPC and Future of Coal MIT report). For the super critical plants we have assumed a net heat rate of 2235 kCal per kWh leading to a specific emission of 0.83 kg of CO_2 per net kWh (Discussions with NTPC and Future of Coal, MIT report)

5. Non Utility CO_2 emissions are mainly based on diesel. Specific CO_2 emissions of 0.67 kg/kWh Net.