



## Pakistan: Preliminary National Greenhouse Gas Inventory

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**ABSTRACT:** This paper represents a summary of the Preliminary Inventory of Greenhouse gases of Pakistan during 1999-2000-study period. The gases covered in the inventory are the direct greenhouse gases (carbon dioxide, methane & nitrous oxide) and indirect greenhouse gases (carbon monoxide, oxides of nitrogen, non-methane volatile organic compounds, halocarbons and sulphur dioxide). GHGs producing sectors in the country are divided into five sectors i.e. Energy, Industrial processes, Agriculture, Land-use change and forestry and Waste (guided by Intergovernmental Panel on Climate Change). In each of above a series of emission sources were identified and emission from all these are reported. Two approaches were used (Reference approach and Source category approach) for GHGs estimation. Energy sector is at top, due to its highest share in the anthropogenic source of emission, with Carbon dioxide at biggest shared among the direct and indirect GHGs. A total 93257.39 Gig grams (Gg) of CO<sub>2</sub> emitted after consuming 1472953.89 Tera Joules (TJ) fossil fuels by the 137.5 million people. From the past few years, economic graph showed batter results, which stated that lot of resource mobilization has happened over the years, especially in energy sector to meet the country commercial/ domestic demands (Economic Survey of Pakistan, 1999-2000). Lot of interest shows from few years to explore the domestic resources and reduces the country import bill, particularly incase of Coal & Natural gas. Consumption of these hydrocarbons prescribed a scenario of acceding trend in the GHGs emission graph in near future. Inventory also addresses Mitigating options to cut down emissions pace of GHGs, which are not only feasible for country local environment, but based on domestic technology too @ JASEM

Atmospheric concentrations of greenhouse gas (GHGs) have been increasing as a result of wide range of human activities and have been particularly noticeable after 1950s. This increase is believed to alter the redistribution of energy in the atmosphere and consequently, affect climate by altering some related natural phenomenon, such as the mean global, temperature change in frequency and distribution of precipitation, circulation & weather patterns and hydrological cycle, among others (US EPA, 2001).

The anthropogenic emission of GHGs has been considered as a major concern within the scientific community in the last few years. Such a concern was the basis for the creation of the Intergovernmental Panel on Climate Change (IPCC) and for the process of international negotiation that led to the approval of the United Nation Framework on Climate Change (UNFCCC). The government of Pakistan also signed the convention that was ratified on 1995. This Study was under taken to compile the National Inventory, which could identified the potential sources of GHGs (both direct i.e. CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O and indirect GHGs i.e. CO, NO<sub>x</sub>, NMVOC, PFCs and SO<sub>2</sub>) emission with their estimates on one way, on the base of these Mitigation measures could be proposed on other hand. Inventory was supposed to cover 2000, but since in Pakistan most of the data are published by fiscal year, which in Pakistan runs from July to the next June, the inventory actually

covers the period from July 1999 to June 2000 (Pakistan Statistic Yearbook 2000).

A study of this kind is very important for developing countries like Pakistan, whose current National plans include programs of industrial development, increased public serves and expansion of petroleum industrial activities. All of these national developmental programs will likely to increase greenhouse gas emission, unless programs of conservation. Such as efficient use of energy and other mitigating measures are implemented simultaneously.

### METHODOLOGY

The estimation of emissions from all Sources was based on methodology provided by the IPCC Draft guidelines for National greenhouse gas Inventories (1995). Countries using the IPCC guidelines for inventory generally estimate emissions from the energy sector using two approaches, the Reference Approach and the Source category approach. The Reference approach reports, the inventory of CO<sub>2</sub> emissions by the type of fossil fuel used. Where as, the Source category approach calculates CO<sub>2</sub> emission along others GHGs at the levels of specific end-use activities, processes or technologies. It thus identifies the level of GHGs emissions in each productive sector, e.g. agriculture, transportation, industry, power ect. While the levels of detail of the approaches differ considerably, the source category

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approach being relatively more thorough, the essential methodology used for estimating emissions in both cases is almost the same.

The data required for this study was gathered from the relevant national publication, such as Economic Survey of Pakistan (1999-2000), Pakistan Statistics yearbook (2000), Pakistan Energy yearbook (1999) ect, in addition to sites visits along literature search. Some default values however were used in case where local data were unavailable (mostly regarding Waste Sector emission estimates). The complication of this inventory is also offered in accordance with the IPCC guidelines, following the instruction for reporting in the tables of guidelines.

## RESULTS AND DISCUSSION

In discussions, we have discuss the Sources category approach results, as it identifies the individual contribution of both direct GHGs (CO<sub>2</sub>, CH<sub>4</sub> & N<sub>2</sub>O) and indirect GHGs (NO<sub>x</sub>, CO, NMVOC, SO<sub>2</sub> & PFCs) emission. Where as emission estimates from Reference approach was presented in tabular form, concerned only about the CO<sub>2</sub> emissions from the fossil fuel consumption. Emission estimates were made from two practices, emission based on fossil fuel combustion and from non-combustion activities.

### *Direct Greenhouse Gases Emissions*

#### *Combustion Practices*

*Carbon Dioxide:* CO<sub>2</sub> emission results mainly from the combustion of carbon based fossil fuels. The magnitude of emissions depends on the quantities and carbon content of each fuel. In addition to above, the combustion technology used too influence the amount of emissions. Emissions from Energy sector included the following Sub-sectors. Energy industries (Power generation), Manufacturing industries, Transport (air, road & sea), Commercial, Domestic and Agriculture field practices and Fugitive emissions (during extraction, processing and transportation to final consumer) as well are discussed below.

The energy sector in Pakistan mainly concerns oil, coal and natural gas (Pakistan Petroleum Statistics Yearbook 1998-1999). In 1999-2000, the sector contributed a total of 86064.79 Gg of CO<sub>2</sub> as estimated through the Source category approach. Of these 52351.16 Gg came from oil based products consumption, while emission from Coal and Natural gas totaled 6872.25 Gg, 2684.40Gg respectively. Regarding the sector-wise, Power industry, Transportation and Manufacturing industries contributed 32,29 and 25 percent of CO<sub>2</sub> emissions. The remaining 14 percent share were

owned by the Commercial, Domestic and Agriculture practices.

Total 27252.37 Gg of CO<sub>2</sub> emitted from the power generating units in 1999-2000, which shows 27.36 percent increase in CO<sub>2</sub> over the past five years (1994-1999). Furnace oil showed highest CO<sub>2</sub> emission share, i.e. 61 percent with in Energy Sub-sector, natural gas and coal share 34.34 and 2.76 percent respectively, while diesel oil has only 1.44 percent and all others constitute less than 1 percent towards CO<sub>2</sub> emissions.

Manufacturing industries are the third biggest consumer of fuels within energy module. The major players are the Fertilizer, Iron & Steel and Cement plants towards the CO<sub>2</sub> emissions. Natural gas is the highest polluter mostly being used in the fertilizing units with 41.06 percent of total CO<sub>2</sub> along with Furnace oil emitting 27.37 percent with in the mentioned sector. Transport sector comprises of air, road and sea and they all accounted a totaled of 25082.81 Gg in the Net pool of Energy sector emissions, with 92.45 percent were alone contributed through the road transport. Diesel along with gasoline has 82.80 and 16.20 percent were contributed in the Net pool of road CO<sub>2</sub> Pollution of the transport sector. The commercial sector is not one of the major sources of CO<sub>2</sub> emissions. A total of 2270.83 Gg CO<sub>2</sub> was contributed in the Energy module. Natural gas with 51.69 percent and Kerosene oil with 27.28 percent are among the top and are mostly consume in small and medium industries for heating and energy generation purposes. In Residential sector, most of fuel consumed for cooking, heating and lighting purposes and they all accounted 8771.49 Gg of CO<sub>2</sub> emissions with in the Energy module. Totals 791.85 Gg were contributed from the agriculture practices regarding the energy consumption towards the CO<sub>2</sub> emissions as a Sub-sector of Energy module.

*Methane:* Methane is considered as the second most important gas accountable for global warming. Methane level are increasing, considerably, its concentration have more than double in the past 300 years and still continue to raise at the rate of 1 percent per year, even though global methane emission are much smaller than global CO<sub>2</sub> emission. Its overall contribution to global warming is larger, as it is 21 times more effective towards the trapping of heat in the atmosphere over 100 years time horizon when direct and indirect effects are accounted for (UNEP Climate Change Information sheet). The energy sector contributed 1744.77 Gg of Methane for 1999-2000, which represents 5.66 percent of national emission of methane. In these

only 400.82 Gg of CH<sub>4</sub> were contributed through the fugitive sources. The use of fossil fuel in transport is the most important source of Non-CO<sub>2</sub> originates by combustion, mainly those generated by incomplete combustion, such as methane. The stationary sectors are the highest emitter of CH<sub>4</sub> with 1322.60 Gg, representing 98.41 percent from residential sector, particularly due to the combustion of the biomass for domestic purposes, commercial on second with 16.84 Gg.

*Nitrous Oxide:* Nitrous oxide is an additional greenhouse gas. i.e. infrared absorbing trace gas that contributes to the GHGs effect. Nitrous oxide is approximately 310 times more powerful than CO<sub>2</sub>, towards the trapping of heat in the atmosphere over a 100 years times' horizon. In 1999-2000, total 437.91Gg emitted from all the defined sources (combustion +non-combustion) in the net GHGs pool. Energy sector is the least contributor to Nitrous oxide emission with 9.84 Gg, constituting only 2.24 percent of the National emissions, mobile sources owned 7.01 percent share, along some minor share comes from the commercial sources of emission. Where as 92.98 percent comes from others stationary sources of emission i.e. form residential sector with in energy module (due to highest biomass fuel consumption). Power, Manufacturing and Transport sector has not significant contribution towards the N<sub>2</sub>O emission with in the Energy sector.

#### Non-Combustion Practices

*Carbon Dioxide:* Non-combustion activities leading to CO<sub>2</sub> emissions including! Industrial processes, Land use & forestry change sub-sectors, land use & forestry change is only sector to be considered as removal of CO<sub>2</sub> (CO<sub>2</sub>skin). Industrial processes covered emissions regarding to the cement production, limestone & dolomite use, soda ash production & use, production of chemicals, pulp & paper industries and food & drink industries. From all above, a total of 15575.49 Gg CO<sub>2</sub> emitted, with 3370.29 Gg from cement units, 9440.02 Gg from ammonia fertilizer production and remaining all about 2765.18 Gg constituted from others defined sources. Biomass absorbs CO<sub>2</sub> from the atmosphere through photosynthesis and returns it to the atmosphere through respiration. CO<sub>2</sub> emissions from decay of organic matter in soil leading to the emissions into atmosphere. In the absence of anthropogenic share "net emission" from the mentioned sector expected to be negligible, however changes in land use practices alter the nature of direct GHGs emissions (IPCC Guidelines for National Inventories). Total carbon uptake was

estimated 11439.87-kilo tones, which resulted into 10450.35 Gg CO<sub>2</sub> removals (skin) from the change in forestry and other woody biomass (managed forests).

*Methane:* Agriculture along waste generation sector is the potential Source of CH<sub>4</sub> emission in-term of Non-combustion activities. A total 18053.07 Gg of CH<sub>4</sub> were estimated from the Domestic livestock enteric fermentation and manure management sub-sectors, which concludes 58.57 percent of National CH<sub>4</sub> emissions. Buffalo and goats are the major contributor accounting 73.23 and 13.11 percent of total domestic animal emissions of CH<sub>4</sub>. Pakistani economy is agriculture based, where agriculture is backbone of total GDP, which necessitates growing trends will be observed in the all-direct and indirect GHGs emissions from said sector.

Anaerobic decomposition of organic material in flooded rice field, produces methane, which escapes to the atmosphere primarily transported through the rice plants. The amount of emission is believed to be a function of rice species, number and duration of harvests, soil type and temperature, irrigation practices and fertilizer uses. Rice is one of country's major crop and most of its production in southeastern plains with almost of similar climate and cultivation practice. Rice fields generated about 211.64 Gg of CH<sub>4</sub> per year and represented less than 1 percent of the National Methane emissions. About 5 to 20 percent of annual global anthropogenic CH<sub>4</sub> produced by the product of the anaerobic decomposition of waste. In 1999-2000, a total 10808.61 Gg through wastewater in the Net pool of CH<sub>4</sub> emissions, representing 35.07 percent of total CH<sub>4</sub> emissions. Industrial wastewater has 88.06 percent share, with 10.59 percent from commercial & domestic and only 1.34 percent from solid waste disposal sites. No published data was available regarding the generation of wastewater, with rate of disposal from the industrial activities. Industrial production/outputs were used for the wastewater estimation. An industry like Food & beverages along Manufacturing has biggest shared towards the wastewater generation. Only fraction of wastewater has treated and remaining one thrown off in open water channels (Master Plan for Urban Wastewater 1999).

*Nitrous Oxide:* In 1999-2000, Nitrous oxide emission from the agriculture sector accounts 419.22 Gg from all defined practices, representing 95.74 percent of total National emissions of N<sub>2</sub>O. Direct N<sub>2</sub>O emission from cultivation of Histosols

contributed 188.89 Gg, where as indirect N<sub>2</sub>O emission from leaching accounted 217.12 Gg. Animal waste management system, field burning of agricultural residues, agricultural fields (excluding cultivation of histosols) and from soil (emission from

animal grazing) are accountable sources of the N<sub>2</sub>O in the agriculture sector. Waste sector also has small share in the N<sub>2</sub>O emission, a total 8.85 Gg were estimated from the wastewater as indirect N<sub>2</sub>O emission from human sewage.

Table: I Summary Report For National green house gases GHGs (Direct) inventory (Gg)

Total National Emission & Removal		CO <sub>2</sub> <sup>(1)</sup>	CO <sub>2</sub> <sup>(2)</sup>	CH <sub>4</sub>	N <sub>2</sub> O	CO <sub>2</sub> <sup>(1)</sup> Equivalent
		101640.29	10450.35	30818.85	437.91	965.004
Energy	Reference approach	93257.39	—	—	—	101.735
	Sectoral approach	86064.79	—	1744.77	9.84	137.186
	Fuel combustion	86064.79	—	1343.95	9.84	97.522
	Energy Industries	27252.37	—	0.18	0.03	29.943
	M. Industries <sup>3</sup>	21895.40	—	1.83	0.19	23.990
	Transport	25082.81	—	2.45	0.23	27.496
	Commercial/Institutional	2270.83	—	16.84	0.04	2.876
	Residential	8771.49	—	1322.60	9.15	42.961
	Agriculture /forestry/ fishing	791.90	—	0.05	0.01	0.867
	Fugitive emissions	—	—	400.82	—	9.182
	Industrial process	15575.49	—	0.25	—	16.996
	Agriculture	—	—	18265.22	419.22	560.211
	Land-use change & forestry <sup>(4)</sup>	—	10450.35	—	—	—
	Waste	—	—	10808.61	8.85	250.607
	International bunkers	419.86	—	—	—	0.458
	CO <sub>2</sub> from Biomass <sup>(5)</sup>	430602.64	—	—	—	469.748

#### Indirect Greenhouse Gases Emissions

**Nitrogen Oxide:** Nitrogen Oxide have often concern for environmentalist due to its role in forming ozone, as well as for their direct acidification effects in the atmosphere. NOx for the study period was estimated to 991.38 Gg emitted mainly from combustion, with 99.91 percent of total NOx emissions. The reminder 0.09 percent corresponding to fugitive, industrial and agricultural practices. Corresponding to other indirect GHGs, NOx is technology dependent gas. Their emission depends on the Nitrogen content of fossil fuel used during the process. Electricity generation and Industrial fuel combustion activities also provide combustion conditions conducive to NOx formation. Excess air and high temperature contributes high NOx emissions. They produced during incomplete combustion too.

**CO and Non -methyl volatile organic compounds (NMVOC), Halocarbous (PFCs):** During the combustion process some hydrocarbons remains unburned and emitting unburned gases are accounted as indirect GHGs emissions. Between these CO and NMVOC are mainly present in small quantities. The gases have key role as precursors of troposphere ozone. Addition to their contribution of ozone formation, they also modify the life time of others GHGs. CO emissions in Pakistan were estimated to be 41797.61Gg, various activities relating to Energy sector contribute with 99.86

percent, from industrial as well as from Agriculture accounted less than I percent. Where as a total of 1941.93 Gg NMVOC was estimated for the 1999-2000 from all the defined sources of emissions. Regarding to NMVOC emission, about 85.80 percent were contributed through the Residential sub-sector of the energy module, mainly due to highest biomass consumption and reminder 2.45 percent from all the Stationary sources of the energy module emissions. Only 639.63 Gg were contributed from Industrial activities (Non-combustion) in the total emissions of NMVOC. PFCs are considered as one of ozone depleting substance, its emission is directly related with consumption of ODS in the country. Consumption of ODS over the year decrease sharply and future trends also indicates a decreasing scenario (Ozone Cell, Minister of Environment, 1999). A total of 2.60 Gg PFCs was calculated for the study period (Halocarbons were used in the industrial processes and consumption is met through import only).

**Sulphur Dioxide:** SO<sub>2</sub> is not a "greenhouse gas" but its prances in the atmosphere may influences climatic pattern. SO<sub>2</sub> can react with variety of photochemical produced oxidants to form sulphate aerosols. The concentration of these increases due to extensive burning of fuels that contains sulphur. Although SO<sub>2</sub> is not a direct GHG, it is an aerosol precursor and as such, has a cooling effect on climate. More than 80 percent of emission arises

from fuel combustion practices. For the study period, total 859.15 Gg of SO<sub>2</sub> was estimated from all defined Energy/Non-energy based activities. From above these, 848.54 Gg were contributed from the

Energy sector, mostly owned by the fugitive emissions, where as only 10.61 Gg was shared from the industrial sector (Non-energy) to the totals of SO<sub>2</sub> emissions.

Table 2. Summary Report For National green house gases GHGs (Direct) inventory (Gg)

Total National Emission & Removal	NOx	CO	NMVOG	SO <sub>2</sub>	PFCs
	991.38	41787.61	1941.93	859.15	2.60
Energy					
Reference approach	—	—	—	—	—
Sectoral approach	990.96	41725.62	1302.29	848.54	2.60
Fuel combustion	990.57	41725.03	1293.69	839.69	—
Energy Industries	27.49	3.51	0.88	349.49	—
M. Industries <sup>(3)</sup>	68.82	18.18	2.95	233.55	2.60
Transport	257.39	709.21	136.80	63.98	—
Commercial/Institutional	7.09	279.21	33.50	1.52	—
Residential	616.82	40704.12	1117.40	189.66	—
Agriculture /forestry/ fishing	12.96	10.80	12.16	1.49	—
Fugitive emissions	0.39	0.59	8.61	8.85	—
Industrial process	0.01	49.72	639.63	10.61	—
Agriculture	0.42	—	8.85	—	—
Land-use change & forestry <sup>(4)</sup>	—	—	—	—	—
Waste	—	—	—	—	—
International bunkers <sup>(2)</sup>	—	—	—	—	—
CO <sub>2</sub> from Biomass <sup>(2)</sup>	—	—	—	—	—

Table 3. Direct Greenhouse Gases (Combustion Practices) Emissions (MMTCE)

Source	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	Total
Energy (power)	29.729	0.004	0.010	29.743
M. Industries <sup>3</sup>	23.885	0.041	0.064	23.991
Transport	27.363	0.056	0.077	27.496
Commercial	2.477	0.385	0.013	2.875
Domestic	9.568	30.299	3.094	42.962
Agriculture	0.863	0.001	0.003	0.867
Fugitive	0.000	9.182	0.000	9.182
Totals	93.888	39.971	3.263	137.119

<sup>(1)</sup> CO<sub>2</sub> equivalent are based on global warming potentials (GWPs), i.e. 1 for CO<sub>2</sub>, 21 for CH<sub>4</sub> and 310 for N<sub>2</sub>O, since GWPs have been developed for only these direct GHGs and emissions presented in Million Metric Tones of Carbon Equivalent (MMTCE).

<sup>(2)</sup> CO<sub>2</sub> emission from biomass burning & bunkers fuel are not included in the national totals.

<sup>(4), (5)</sup> For reporting purposes the sign for uptake are always (-) and for emissions is (+)

<sup>(3)</sup> Manufacturing/ Contraction Industries.

**Conclusions:** This preliminary National inventory provides a comprehensive picture of National GHGs emissions and constitutes a powerful tool to evaluate and plan the best mitigation strategies that the country could develop to reduced and control its emission levels. Nevertheless, some weakness and limitations still represent an important problem to be addressed in order to improve the reliability of the information used as well as the methodologies applied in some cases. Unavailability of updated data of country Statistics, lack of Institutional collaboration b/w the Research Academics and policy makers, lacks of political will to address the issues on top priority bases are some of potential concerns that were faced during the research phase.

Developing countries with 81 percent world's population are now low rate of per-capita emissions (e.g. for Pakistan is 0.678, i.e. tones of CO<sub>2</sub> emission per capita) are expected to increase considerably in future. A phenomenon that explained behind this growth is due to growth of oil based products consumption particularly along others fuels (Natural gas + Coal incase of Pakistan) to meet the energy challenges of the future economy. Thermal Power plants are the one of the biggest source of CO<sub>2</sub> emissions along others GHGs in Energy sector. The electricity generations by the thermal plants grow with 9.5 percent annual compound rate with 3.37 percent of fossil fuel consumption growth, these

along others suggest that CO<sub>2</sub> emissions in future grow to a larger extent from the mentioned sector.

The second highest contribution is from the Transport sector, the emissions trend indicates a future growth will happen under existing conditions, as vehicular production is growing which is function of country's economy. Although others sectors has little contribution towards the potential Sources of GHGs emissions, but still need to considered for mitigating options that cut down the pace of emissions.

The measures could be proposed to cut the pace of GHGs emissions from Energy based included the Promotion of innovative Technology development/technology sharing b/w develop & developing nations (e.g. R & D in efficient ness in Energy industry, development of material for light weight vehicles, energy efficient electric appliances), Promotion of nuclear power under assurances of safety targets, Assist fuel switching from coal to natural gas for old power plants, assist fuel switching for industrial boilers, develop safety standards on natural gas pipelines, subsidies to promote introduction of photovoltaic power, solar thermal, wind power, waste power biomass energy ect along greater sustainability in energy governess through maintaining/enhancing public benefits (Kevin A. Baumert, October 2002). CO<sub>2</sub>/GHGs emission form Non-energy sector could be cut down via reduction of waste incineration, reuse and recycling of waste (common practice in developing countries). Where as sink promotion activities included plantation, thinning along rehabilitation of forests, promotion of timber and wood biomass use, greening of urban area are some of potential concerns areas. To identify policy and measures that would make the developmental path more sustainable, primarily for the aim other than climate change, where greater social equity and domestic environmental protection while maintaining or may enhancing economic growth.

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