GREENHOUSE GAS INVENTORY FOR SRI LANKA [1990]

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1. GHG Sources

Atmospheric gases which have low absorption cross sections in the UV and visible range of the solar spectrum and high cross sections in the infra-red region fall into the category of Greenhouse Gases (GHG). The gases that are considered in this paper are CO_2, CH_4, CO, N_2O, NO_x, and non-methane volatile organic compounds (NMVOC). Though CO is not strictly a GHG, it is included because of the possibility of it being converted to CO_2, in the atmosphere. These gases are emitted into the atmosphere both from natural and anthropogenic sources. However, in this paper only the anthropogenic sources are discussed.

The human activities that give rise to emission of GHG are shown Table 1.

TABLE 1

Activity	*GHG Emitted*
Forest Clearing	CO_2, CH_4, CO, N_2O, NO_x
Petroleum Combustion	CO_2, CH_4, CO, N_2O, NO_x, NMVOC
Biomass Combustion	CO_2, CH_4, CO, N_2O, NO_x, NMVOC
Livestock	CH_4
Paddy Cultivation	CH_4
Land Filling	CH_4
Cement & Lime Industry	CO_2
Fertilizer Application	N_2O

The calculation of the rates of emission of these gases from the above sources needs a variety of data ; the actual extent of the different activities and also the conversion factors. Data on the actual extent have to be obtained from local sources. CO_2 emission rate due to combustion can be computed once the carbon content of each type of material burnt is known. The rates of emission of other gases were obtained from the data and methodologies given in the OECD Report on 'Estimation of GHG Emissions and Sinks" prepared for the Intergovernmental Panel on Climatic Change (IPCC).

2. Forest Clearing

2.1 *Basic Data*

The emission of GHG due to forest clearing depends on the follow-up activity; whether the land cleared is used for agriculture, permanent cropland, shift cultivation of left unutilized. The OECD Report gives different formulae to obtain the emission rates for different activities. However, in this study no such differentation was made, mainly because of the lack of quantifiable information.

Even to compute the basic emission rates due to forest clearing and burning, a variety of data is required some of which are listed in Table 2. Ideally, all this should be obtained within the country after carrying out field experiments under local conditions. Since that would be a major exercise, the next best thing to do is to make use of data obtained elsewhere even though such data may have been obtained for different eco systems. The data used in this paper have been adopted from the values given in the OECD Report and are shown in Table 2.

TABLE 2

Information Required on Forest Clearing	*Unit*	*OECD Values*	*Adopted Values*
Extent of forest cleared /yr	ha	—	30,000
Extent of forest destroyed by fire/ye	ha	—	2,000
Above-ground C per unit area	t(C)/ha	27–97	60
Percentage of biomass burnt	%	45	75
Percentage of biomass allowed to decay	%	55	25
Percentage left as Charcoal	%	9	9
Period over which decaying takes place	years	10	10
Amount of C in soil	t(C)/ha	50–120	60
Fraction of C released	%	25–50	33
Period for releasing C from soil	years	25	25
Ratio of N/C released during burning	—	1/100	1/100
Extent of new forest planted	ha	—	6,250
Time taken for maturity	years	20	20

2.2 *Emission Factors*

The rate of CO_2 emission is obtained fromthe carbon released during burning and decaying of biomass less the carbon uptake by regrown vegetation which is taken as 5 t/ha/year. The other GHG released depends on the actual emission factors applicable to each gas which in turn depends on the soil conditions. The OECD Report gives a high and a low value for each of the GHG (except CO_2); CH_4, CO_2, N_2O and NO_x. In this report, only the mean value is taken for the computation, as shown in Table 3.

TABLE 3

GHG	*Emission Factor*		
	Unit	*OECD Value*	*Adopted Value*
CH_4 from burning	t(C)/ha	.007–0.013	0.010
CO from burning	t(C)/ha	.075–0.125	0.10
N_2O from burning	t(N)/ha	.005–0.009	0.007
N_2O from disturbed soil	t(N)/ha	.0021–0.0055	0.0038
NO_x from burning	t(N)/ha	.094–0.148	0.12

The emission factors for both CO and CH_4 were applied to the amount of carbon released during burning to obtain their emission rates into the atmosphere. In the case of N_2O and NO_x, first the amount of nitrogen relesed was determined assuming it to be 1/100th that of carbon released, and then given the respective emission factors applied to it.

Based on the above data, the amounts of GHG released into the atmosphere due to forest clearing and burning are given in Table 4.

TABLE 4

GHG	*Quantity emited per year*	
	Element Weight	*Compound Weight*
CO_2	1221.0Gg CO_2–C	4477.0Gg CO_2
CH_4	13.1Gg CO_4–C	17.5Gg CO_4
CO	131.0Gg CO–C	306.0Gg CO
N_2O	0.22Gg N_2O–N	0.35Gg N_2O
NO_x	1.73Gg NO_x–N	3.70Gg NO_x

3. Petroleum Combustion

Petroleum products meet 19% of the total energy requirements of thecountry, while contributing 62% of the commercial energy supply.The transport sector is totally dependent on petroleum products while in other sectors hydro-electricity and biomass combustion meet

TABLE 5

Source	*Consumption k(TOE)*	*Conversion Factor*	*Percentage*
Electricity, Hydro	755.1	0.24 TOE/MW	11.3
Petroleum	1248.8	0.98–1.09 TOE/t	18.7
Coal	0.9	0.70 TOE/t	—
Biomass	4684.3	0.45 TOE/t	70.0
TOTAL	6689.1	—	100.0

Source : Sri Lanka Energy Balance and Energy Data 1990, CEB.

the major share. The energy scenario in Sri Lanka for 1990 is shown in Table 5.

Since the consumption of petroleum products is well documented, their contribution to GHG emission could be determined with little uncertainty. In the calculation of CO_2 emission, the only uncertainty is in the conversion of commodity unit to heat unit which is expressed in terms of Tons-oil-Equivalent (TOE). The Ceylon Electricity Board which compiles the National Energy Balance Sheet annually uses the same set of conversion values each year. These values are shown in Table 6 and 13. However, these differ from the values given in the OECD Report by about 1–2% for gasolene from the diesel, and by 7% for LPG. Strictly speaking, a more accurate way is to measure the calorific value of the fuel for each batch and use a weighted value.

3.1 *Mobile Combusion*

The amounts of petroleum products consumed in the transport sector in 1990 are given in table 6. The aviation turbine fuel is not included in this study as it is used mostly for international flights.

TABLE 6

Fuel Type	*Annual Consumption kt*	*Conversion Factor TOE/t*	*Annual Consumption k(TOE)*
Gasolene	160.14	1.09	174.55
Diesel	471.88	1.05	495.47
Aviation gasolene	0.25	1.07	0.26
Aviation turbine	70.63	1.05	74.16

Source : Sri Lanka Energy Balance and Energy Data 1990, CEB.

The emission of GHG in the transport sector depends on several factors such as the size of the engine (reflected in the weight of the vehicle), fuel economy, presence of emission controllers etc. Though the gross consumption of different types of fuels is available, but not their distribution among different types of vehicles.

TABLE 7

Vehicle Type	*Population 1990*
Motor cars	173,519
Motor Cycles	391,732
Buses	39,074
Vans	19,622
Lorries	101,671
Land Vehicles	66,407
Others	855

Source : Report of the Department of Motor Traffic for 1990.

Since the total vehicle population is also known (Table 7) one has to estimate the amount of fuel consumed by each type of vehicles on the basis of vehicle population assuming that each vehicle runs more or less the same distance during the year.

In Sri Lanka, no emission control is in force. Hence out of the tables given in the OECD Report for emission rates, the tables given for uncontrolled emission were adopted. These emission values are given in Table 8.

TABLE 8

Vehicle Type	*Emission Factor g/MJ*					
	CO_2	*CH_4,*	*CO*	*N_2O*	*NO_x.*	*NMVOC*
Gasolene motor cycles (Fuel economy:12.8km/l)	69.3	0.13	9.2	0.0009	0.07	2.5
Gasolene motor cycles (Fuel economy:6km/l)	69.3	0.0314	7.33	0.0009	0.39	0.14
Diesel light vehicles (Fuel economy:4.3km/l)	73.3	0.00	0.19	0.0019	0.17	0.10
Diesel heavy vehicles (Fuel economy:2.2km/l)	73.3	0.01	0.51	0.0019	1.01	0.18
Farm Equipment	73.3	0.011	0.60	0.002	1.5	0.23
Boats	73.3	0.005	0.50	0.002	1.6	0.11
Locomotives	73.3	0.006	0.61	0.002	1.8	0.13
Aircraft (Gasolene)	69.3	0.06	24.00	0.0009	0.08	0.54
Construction Machinery	73.3	0.004	0.38	0.002	1.2	0.09

Source : OECD Report , Tables 2.20, 2.24, 2.25. 2.26 and 2.30.

The published statistics on vehicle population only identifies the vehicles by their category and not by their weight as given in Table 7. The classification here is different to OECD classification, particularly with respect to diesel vehicles. Generally there are light trucks and heavy trucks almost equally. Hence half the lorry population along with the vans could be classified as light diesel vehicles while balance half of lorry population along with the buses could be brought under heavy diesel vehicles. The fuel consumption in each category could then be worked out proportional to vehicle population for each category.

In the case of gasolene, it is consumed both by motor cars and motor cycles. Since the average fuel economy of a motor cycle is twice that of a motor car, the gasolene consumption between the two types could be divided in the ratio of motor car population to half the motor cycle population.

Using the emission factors given in Table 8 and the fuels consumed by different categories of vehicles the GHG emitted by vehicles are determined and the values shown in Table 9.

TABLE 9

Vehicle Type	Annual Emission Rate Gg					
	CO_2	CH_4,	CO_2,	N_2O	NO_x.	NMVOC
Motor cycles (gasoline)	268.6	0.50	35.7	0.003	0.27	9.69
Motor car (gasoline)	237.0	0.11	25.1	0.003	1.33	0.48
Light trucks (diesel)	566.8	0.0	1.47	0.015	1.31	0.77
Heavy trucks (diesel)	727.8	0.10	5.06	0.019	10.03	1.79
Farm vehicles (diesel)	61.2	0.009	0.50	0.002	1.25	0.19
Boats (diesel)	23.5	0.002	0.16	0.001	0.51	0.04
Locomotives (diesel)	69.9	0.006	0.58	0.002	1.72	0.12
Aircraft (piston) (avaition gasolene)	0.8	0.00	0.26	0.00	0.00	0.006
Construction Machinery (diesel)	67.7	0.004	0.35	0.002	1.11	0.08
TOTAL	2023.3	0.730	69.20	0.047	17.50	13.17

4.2 Stationary Combusion

The amounts of petroleum products consumed to genetate energy in stationary applications are given in Table 10.

TABLE 10

Fuel Type	Annual Consumption kt				
	Industry	House hold	Agriculture	Commercial	Power generators
Gasolene	3.27	—	17.96	—	—
Diesel	20.08	—	—	58	—
Fuel Oil	152.67	—	—	—	—
Kerosene	2.70	146.96	17.54	—	—
Residual	—	—	—	—	0.56
LPG	—	27.68	—	6.3	—

Source : Sri Lanka Energy Balance Data 1990, CEB.

No proper records are kept on the actual end-use of these fuels in each sector. However, it can be said in general that fuel oil used in industry is mostly for firing boilers while diesel in both industry and commercial sectors is for running stand-by electricity generators. The operation of thermal power plants connected to the national grid during 1990 has been very minimal, mainly because of good rainfall received in the hydrocatchment areas. In the domestic sector, kerosene is used for both lighting and cooking, mainly by low-income groups. LPG is mainly used for cooking, in urban areas. In the agriculture sector, gasolene and kerosene are used to operate small engines coupled to water pumps and other agricultural machinery.

The GHG emission from these sources could be estimated using emision factors given in the OECD Report for boiler operation and diesel engine operation. Since data for stationary diesel engines are not found in the OECD Report, values given for heavy-duty diesel vehicles were adopted. Emission values for LPG and kerosene, burning in houses are also not available. Hence for LPG, values given for LPG driven light vehicles were yused and for kerosene, values for CO_2 and CO emision were assumed. The emission factors used in the study are given in Table 11. Since kerosene is one of the major contributors, lack of sufficient data on the GHG emitted by its burning in lamps and cooking devices is a serious shortcoming.

TABLE 11

Application	Emission Factor g/MJ					
	CO_2	CH_4,	CO_2,	N_2O	NO_x.	NMVOC
Fuel oil industrial boiler	76.3	0.003	0.015	—	0.16	—
Diesel heavy duty engine	73.3	0.01	0.51	0.002	1.01	0.18
Gasolene light engine	69.3	0.13	9.2	0.0009	0.07	2.50
LPG cookers	63.1	0.03	1.45	—	0.38	0.64
Kerosene burning*	73.3	—	1.0	—	—	—

Source : OECD Report, Tables 2.20, 2.24, 2.25. 2.26 and 2.30.

*Estimate

Table 12 gives the values of the GHG emitted from combution of petroleum products in stationery energy generations, based on the emission factors given in Table 11.

TABLE 12

Vehicle Type	Annual Emission Rate Gg					
	CO_2	CH_4,	CO_2,	N_2O	NO_x.	NMVOC
Fuel-oil boilers	478.9	0.02	0.09	—	1.0	—
Diesel heavy duty engine	251.5	0.03	1.75	0.007	3.5	0.62
Gasoline light duty engine	66.9	0.13	8.9	0.001	0.07	2.42
LPG cookers	95.0	0.05	2.2	—	0.57	0.96
Kerosene burning	538.5	—	7.3	—	—	—
TOTAL	1430.8	0.23	20.2	.008	5.14	4.00

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To be continued