QUANTITATIVE EVALUATION OF THE POTENTIAL OF NON-CONVENTIONAL ENERGY SOURCES IN REDUCING CO_2 EMISSION IN INDIA

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NEW DELHI - 110067

SCHOOL OF ENVIRONMENTAL SCIENCES

CERTIFICATE

This dissertation entitled **"Quantitative Evaluation of the Potential of Non-Conventional Energy Sources in Reducing Co_2 Emission in India"** embodies the work carried out at the School of Environmental Sciences, Jawaharlal Nehru University, New Delhi. This work is original and has not been submitted in full or in part for any degree or diploma of any University.

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DEDICATED TO

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CHAPTER I

INTRODUCTION

CHAPTER - I

INTRODUCTION

With the development of Industrial activity, fossil fuels comprising solids, liquids and gases have become the most important source of energy throughout the world, although the distribution among these three major components would vary from country to country depending upon their availability and other economic consideration. The basic constituents of these fuels are. Carbon and Hydrogen, which on combustion give rise the necessary energy and yield carbon dioxide. Thus, Carbon dioxide is a biproduct of the combustin of fossil fuels and fossil fuel burning is the dominant source of global co_2 emissions.

The variations in Co_2 emission rates depend upon the relative content of carbon and Hydrogen. The concentration of Co_2 in the atmosphere has been growing at approximately 0.4 per cent year since 1950 with total carbon in the atmosphere reaching 720×10^{15} gm of Carbon in 1982. [J.A. Edmonds, H.C. Cheng 1989).

The realization that the emissions of greem house gases might change the climate of the earth goes back more than 150 years. Fourier was probably the first to discuss the Co_2/green house effect in 1827 by comparing it with the warming of air isolated under a glass plate (Bach 1982/84).

In 1941, Flohn noted that Man Made Co_2 production perturbs the carbon cycle leading to a continual Co_2 increase in the atmosphere. In 1957, Revelle and Suess concluded that human activity were initiating a global geophysical experiment that would lead to detectable climatic changes in few decades. In 1969 and 1970, a group of scientists undertook the first major studies on the climatic effects of human activity. The results suggested "study of critical environmental problems (SCEP, 1970) and a study of Man's impact on environment.

Because Co_2 is a green house gas which allows incoming solar radiation to penetrate but acts as an insulator for outgoing long wave radiation to space. The increasing concentration of Co_2, which today come mainly from fossil fuel use, but which in the past came mainly from deforestatin, have become a source of grave concern. A major global warming could have serious impacts on climate, including rainfall and Ocean levels.

Now scientists are certain that the increasing use of coal, petroleum and natural gas is responsible for the continuing Co_2 build up and they are fairly sure that this build up will cause a global warming trend.

A report has suggested this scenario if fossil fuel use is not eventually controlled : "The earth average temp increases several degree celsius much larger increases occur in the polar regions, Precipitation pattern shift dramatically from the average of the previous several hundred years, marginal agricultural areas in many arid an semi arid regions of the world become unproductive, with particularly serious impacts on many less developed nations -agricultural disruption causes wide spread flood shortages and hunger - Near the end of the 21st century, the West Antarctica ice sheet finally disintegrates, causing the sea level to rise and coastal regions to flood." (Bill Kovrik, 1989).

Concern over the possibility of climatic change due to fossil fuel burning and increased concentration of Co_2 have lead to questions about feasibility and cost of reducing the rate of Co_2 emissions through out the world.

In general non-fossil fuels donot release carbon-di-oxide to the atmosphere. For example energy sources such as hydroelectric power, nuclear power, tidal, wind, OTEC (Ocean thermal Electric Conversion), solar energy and other sources of energy such as geothermal energy do not release any Co_2 to the atmosphere.

Biomass energy is a special case. Biomass contains carbon, and therefore when it is oxidized, releases a significant amount of Co_2 to the atmosphere. The carbon that is released, however, was originally taken out of the atmosphere and stored in the plant during its period of growth. Thus, biomass derived fuels neither contribute to nor diminish atmospheric Co_2.

Many studies over the past several years have indicated the need to reduce the risks of global warming by mitigating the impact of human activities on the atmosphere [who 1988 EPC 1989]. The first step in a process of environmental protection is generally to set goals. For example, the statement of the toronto climate conference, (1988) the changing atmosphere implications for global secuirty, called on the governments to "Reduce Co_2 emissions by approximately 20 % of 1988 levels by the year 2005 as an initial global goal". The Bella gio report suggested setting a goal of limiting global mean temperature rise to 0.1^{o}C per decade.

Co_2 emission --> Atmospheric concentration --> climatic change --> social/economic and environmental impacts.

Several reports have discussed that how one should approach to reduce the emissions of Co_2 through advanced technology. Some have suggested for Co_2 emissions savins via energy conservation, the substitution of natural gas for coal. [J.A. Edmonds and H.C. Cheng 1989]. On the other hand some have suggested improvement in the efficiency of the engines. [Kolb, Gick Choff 1989). The other options are non-conventional energy sources. They are non polluting and provide clean energy and could be supplemented along with the non-conventional sources of energy.

To calculate the Co_2 emissions from India, we have discussed the procedure for estimation of Co_2 from fossil fuels i.e. coal, oil and natural gas. [Rotty, Marland 1984]. Probably keeling was the first who calculated the industrial production of Co_2 from limestone and fossil fuels. R.M. Rotty [1979] extended the work of keeling and made first approximation for global Co_2 production from fossil fuels.

In the light of the above, the work presented in this dissertation aims at :

- to determine annual emissions of Co_2 from India by using actual fossil fuel consumption data from 1970-71 to 1989-90.
- assessment of the potential of non-conventional energy sources in reducing emissions of Co_2 from India by the year 2005-2006 from 1988-89 levels.

The scope of this study covers effective utilization of non-conventional energy sources such as wind, sun, geothermal, Ocean and mini-microhydro and development of alcohol technology to provide alternate fuels for transportation sector. While calculating the reduction potential of Co_2 through technologies for the utilization of non-conventional energies certain assumptions are considered.

In Chapter II - method for the estimation of Co_2 is described. This enables us to calculate Co_2 emissions of Co_2. The Chapter III presents the values of annual Co_2

emission, which are calculated by the method described in Chapter II, the Chapter IV suggests the technologies for the effective utilization of non-conventional energy sources and assess the potential of Co_2 reduction from 1988-89 levels by the year 2005-2006. In Chapter V some options are elaborated for Co_2 reduction in transportation sector. Finally, results and conclusions are discussed in Chapter VI.

CHAPTER II

PROCEDURE FOR ESTIMATION OF CO_2 FROM FOSSIL FUELS

CHAPTER - II

PROCEDURE FOR ESTIMATION OF Co_2 FROM FOSSIL FUELS

2.1 Introduction

The annual Co_2 emissions for each type of fuel are calculated by multiplying three terms. these terms are the amount of fuel produced, the fraction of the fuel that becomes oxidized and the factor for the carbon content of the fuel.

For carbon dioxide estimation fossil fuels can be divided in to three groups of gases, liquids and solids. For each fuel group, we start with annual fuel consumption data P. When P is Multiplied by the fraction of each years fuel oxidized (FO) and by average carbon contant (C), It gives Co_2 emissions [R.M.Rotty. Marland 1984].

$$Co_2 = (P_i)\ (Fo_i)\ (C_i) \quad \text{-- (1)}$$

Where subscript indicates particular fuel and Co_2 is expressed in millons tons of Carbon.

The factor Fraction oxidized in equation (1) requires examining. Fuel used for combustion and the effectiveness of the combustion process are the main concern. For liquid fuel and natural gas, the hydrogen carbon ratio largely determines the heating value and for solid fuels Most of the combustion energy is from oxidation of carbon.

Thus for each type of fuel heating value is closely related to the carbon content and the energy equivalent concept used in the tabulation of consumption data makes it possible to deduce fuel composition accurately. the equation of conbustion for fossil fuel is expressed as.

$$C_xH_y + (x + \frac{y}{4})\ O_2 \longrightarrow x\ Co_2 + \tfrac{1}{2}\ y\ H_2O + \ H \quad \text{-- (2)}$$

Where H is the heat content of reaction and C_xH_y denotes any fossil fuel for combustion of Hydrocarbons the heat of the reaction is negative in the thermodynamic sense.

2.2 Calculations of Co_2 Emissions.

2.2.1 Co_2 Emissions From Natural Gas Production

In calculating Co_2 emissions from natural gas, we must account for all the gas that is withdrawn from wells and becomes oxidized Gas reinjected into the earth to repressure oil wells should not be counted and we will account separately for gas vented and flared.

In Indian fuel data natural gas is listed in cubic meters,but in our calculation natural gas data will be changed to reflect the energy content of the gas and are summed up in tera Joules (see Chapter 3), Because the carbon content is closely correlated with the heating value of the gas, we believe that this will improve the estimates of Co_2

emissions from natural gas. The resulting equation for the estimation of Co_2 is given below

$$Co_{2g} = (P_g)\ (F_{og})\ (C_g) \qquad ..(3)$$

Where Co_{2g} is Co_2 emissions from Natural Gas in Million Tons of Carbon. In both the fuel and non fuel cases, the hydrocarbons not burned are oxidized in the environment with varying times. In aggregate this non combustion slow oxidation could be approximated by an exponential law. In such situation over long time scale, the amount oxidized each year will equal the amount produced as long as the amount produced each year is not growing much fast.

A large fraction of natural gas goes to ammonia productin during which the carbon in the gas is mostly oxidized, the remainder to use in which the carbon will be oxidized at varying rates over a period of time. The total quantity for non fuel use is incresing with time and in accordance with the principal that slowly oxidizing material decays exponentially with time. This confirms that small amount of unoxidized gas accumulates every year. Because of incomplete combustion, a small amount of the carbon in the gas used as a fuel will not be oxidized and will remain as soot, either around the burner, in the stack or in the environment.

Although the amount of unoxidized carbon is not determined exactly, but it is very small in modern combustion systems.

For natural gas, the fraction of annual production which remains unoxidized each year is thus taken to be 0.02 [G.Marland, 1983]. Thus the fraction of gas oxidized is taken as. $Fo_g = 0.98$.

Since Carbon content is correlated with heating value, so it will be better to change amount of fuel in appropriate units (tera joules). The resulting equations will be straight-forward.

It is established that the carbon content per unit of energy is closely related by a linear equation with heating value.

$$C_g = \quad = 13.708 + 0.0828 \times 10^{-3} \ (H_H - 37.234)$$

Where C_g is amount of carbon in tC/TJ and H_H is the higher heating value of the gas. Value of DH for Indian natural gas is 36.533 KJ/m3. as reported by Ministry of Petroleum [Indian Petroleum and Natural Gas Statistics 1989-90 appendix X].

2.2.2 Co_2 Emissions From Petroleum Products :

Since Most of the liquids are used as fuels and hence oxidized with in a short time of production. However, the use of consumptin data for liquid fuels in computing Co_2 requires a correction for the liquids that are not oxidized in this use. These liquids comprise a mixture of compounds, some of which are used directly us fuel or cheical feed stocks and some of which are combined with crude petroleum. On the average natural gas liquids have a lower carbon content than crude petroleum.

For the purpose of calculating Co_2 emissions. The assumption is that crude petroleum contains 85% carbon and that NGL's contain between 80% to 84 %. The error in considering all crude oil is very small. Because the share of NGL'S is about 3%. The carbonfraction for mixture should be about (0.97) (0.85) + (0.03) (0.82) = 0.8491 which is very close to 0.85. Thus Carbon fraction for the crude petroleum is taken 0.85.

The emissions of Co_2 from crude oil and natural gas liquids depend upon the fraction of consumption which is oxidized on a short time scale as opposed to which ends up in fibers, lubricants, paving materials and is oxidized over a longer intervals . Some portion of liquids produced end up in petro chemical applications where they are not soon oxidized and another equivalent fraction passes through burners and is deposited in the environment without being oxidized. Thus the factor developed for oxidation of liquid fuel produced is FoL = 0.918 . [USEPA. 1977].

The analysis of crude petroleum for Co_2 emission could be complex. It is because crude oil is a complex collection of 600 hydro carbons identified to date (Hunt, 1979). The Americal Petroleum Institute's detailed analysis shows some 295 hydro carbons which made up 60% of the total crude. AP1 suggests a composition of about 85.25% of carbon. Brame and King and Hunt (1979) gave a rage of 79.55 - 87.1% carbon for crudes.

Finally it is concluded that C_L = 85% carbon could adequately describe the mean composition of crude oil.

For calculation of Co_2 emissions from liquid petroleum fuels the following equation may be used.

$$Co_{21} = (P_1)\ (Fo_1)\ (C_1)$$

where

Co_{21}	=	Co_2 emission in 10^6 Tons C
P_1	=	annual production in 10^6 Tons
Fo_1	=	Effective fraction oxidized in the year of production = 0.918
C_1	=	Carbon Content in tons C perton crude oil = 0.85

2.2.3 **Co_2 Emissions from Indian Coal :**

Coal is an immensely variable commodity both its heating value and Carbon content vary over wide ranges. It is clear that the tons of coal is not a fully adequate value for establishing how much carbon is likely to be released during burning. The UN statistical office has tried to achievd in reporting tons of coals equivalent. The UN basis for coal equivalency comprises 29.31×10^9 J/t(7000 cal/g).

To analyze Indian data for Coal consumption, Most of the question about coal quality arise. The data of coal consumption as reported in the annual report of Ministry of Coal and Mines are classified as coking and noncoking coal. But classified data about the quality of coal in the figures of coking and noncoking coal is not available while calculating Co_2 emissions from India by Coal almost reliable value of heat content is used. Various Indian agencies like, Ministry of Coal and Mines identifies the approx. average heating values of hard coal 20.90×10^9 J/tonne. [TEDDY,1989].

The correlation between heating value and carbon content suggest that we can establish estimate for carbon using the knowledge that India has published the mean heating value for coal in their annual report. (Annual report, Ministry of Coal and Mines 1990-91).

To estimate Co_2 from Coal, conversion heating value 20900 mJ/Tonne is used. For Carbon content, Co_2 emissions factor is used which express the value of Co_2 emissions 91.67 tonn. Co_2/TJ.

2.2.4 Co_2 Emissions From Natural Gas Flaring

The lack of market and infrastructure facility for using natural gas as a fuel leads to massive flaring at oil fields. Data for gas flaring prior to 1970 it not available.

The Co_2 emissions rate from natural gas flaring is accomplished with the following factors.

$$Co_{2F} = (P_F)\ (Fo_F)\ (C_F)$$

where

Co_2 = Co_2 emissions in 10^6 Tons C

P_F = annual gas flaring in billion m^3

Fo_F = Effective fraction oxidized in the year of Flaring 1.00

C_F = Carbon Content in tons per Thousand m^3 = .5 25

It is absolutely clear that the errors of only a few percent of total Co_2 emissions are possible as a result of accounting inadequacies with in the fraction remaining unoxidized. The factors unoxidized results from both the non-fuel use and combustion inefficiencies. But it has very small error, in Co_2 emissions.

CHAPTER III

COMPUTATION OF ANNUAL CO_2 EMISSIONS FROM FOSSILE FUEL CONSUMPTION

CHAPTER - III

COMPUTATION OF ANNUAL Co_2 EMISSIONS FROM FOSSIL FUEL CONSUMPTION

3.1 CALORIFIC VALUES AND EMISSION FACTORS

Before making efforts to calculate emissions of Co_2, it is very necessary to various discuss factors for different type of fuels. These factors are dependent, upto some minor extent, on the actually applied energy carriers and constitute therefore averages from various energy sources. These factors typically migh vary in between +10%. It is important to note that these factors do not include the emissions which already occured during the production and distribution of the fuel, but only the emissions of Co_2 occured during consumption of fuels.

The specific emission factors of Co_2 for different kind of fuels are listed as follows :

The specific emission factors of Co_2 for different kind of fuels are listed as follows:

Table 3.1 : Specific CO_2 emission factors

S. No.		The specific CO_2 emission rates for different fuel in Tons of CO_2/Tera Joules
1.	Hard Coal	91.67
2.	Fuel oil/Diesel	77.78
3.	Fuel Oil H	83.33
4.	Lignite	111.11
5.	Gasoline	72.22
6.	Methanol	69.44
7.	Natural Gas	52.78
8.	Fire Wood	94.4
9.	Bio gas	105.56
10.	Ethanol	72.22

Source : 1. Edmonds and Reilly (1985), p.266.

2. Kolb, G. Eickhoff, 1989.

Other factors are also important which express the heat content of various kind of fuel. The calorific value for different commercial and traditional fuels are presented below :

Table 3.2 : Energy Content of various fuels

S. No.	Name of the fuel	Caloritic Value
1.	Hard Coal	20.9 MJ/kg
2.	Fuel Oil H	40.76 MJ/kg
3.	Diesel Oil	42.64 MJ/kg
4.	Gasoline	43.89 MJ/kg
5.	Natural Gas	36.53 MJ/m^3
6.	Fire Wood	13.27 MJ/Kg.

Source 1. Department of Petroleum, Indian Petroleum and Natural Gas Statistics 1986-87. 2. The World Bank, Guidelines for the presentation of Energy data in Bank Reports. Energy Department paper No. 7, October 1982;

3.2 FOSSIL FUEL CONSUMPTION AND Co_2 RELEASE

The computation of Co_2 emissions from fossil fuel consumption is accomplished by multiplying the factors developed in Chapter 2. Recalling the equation (1) of chapter 2 which describe the factors to calculate Co_2 emissions is

$$Co_{2i} = (P_i)\ (FO_i)\ (C_i)$$

Where Co_{2i} is Co_2 emissions in million Tons of Carbon.

P_i = annual consumption of fuel in appropriate units

Fo_i = average effective Fraction oxidized in year of consumption

C_i = Carbon Content of the fuels.

The computation of CO_2 emission from Oil, natural gas and gas flared could be done easily using above equation. But, the calculation of CO_2 emissions is some what different in case of Coal. The emission of CO_2 could be obtained by multiplying specific emission factor of coal to the calori value content of Coal. The fuel consumption data of India for 20 years is presented in table 3.3. In the presented data of Fossil fuels, consumption of Coal and Natural gas are also presented in Tera Jonles. Finally, emissions of CO_2 in Million Tons from various fossil fuels are displayed in Table 3.4. Some assumptions and approximations are made in these computations, but we have tried to draw these approximations in such a way that the results cannot lead to large errors. We have made no attempt to examine CO_2 emissions prior to 1970 because of non-availability of consistent data.

Table 3.3 : Consumption of Fossil Fuels in India (1970-71 - 1989-90

Year	Natural Gas Production in MIllion cubic meters	Natural Gas Production in Thousands Tera Joules	Consumption of Petroleum products in Million Tons	Gas Flared Mill cubic Meters	Gross Consumption of coking and Non-coking coal in Million Tons	Total Coal consumption in Thousands Tera Joules
1970-71	647	23.64	17.91	762	52.71	1101.64
1971-72	718	26.23	20.07	768	57.7	1205.93
1972-73	771	28.17	21.72	653	63.94	1336.35
1973-74	762	27.84	22.35	836	61.94	1294.55
1974-75	951	34.74	22.12	951	77.91	1628.32
1975-76	1124	41.06	22.45	1082	80.12	1674.51
1976-77	1381	50.45	24.10	857	80.54	1683.29
1977-78	1464	53.48	25.54	1191	87.32	1824.99
1978-79	1711	62.50	28.24	953	81.07	1694.36
1979-80	1676	61.22	29.88	964	85.57	1788.41
1980-81	1522	55.60	30.90	769	87.48	1828.33
1981-82	2222	81.17	32.52	1519	96.85	2024.17
1982-83	2957	108.02	34.66	1888	100.39	2098.15
1983-84	3399	124.17	35.84	2517	107.21	2240.69
1984-85	4141	151.27	38.80	3052	94.76	1980.48
1985-86	4950	180.82	40.87	3118	123.26	2576.13
1986-87	7072	258.34	43.66	2718	129.81	2713.03
1987-88	7968	291.07	46.42	3445	138.43	2893.19
1988-89	9250	337.90	50.09	3883	146.72	3066.45
1989-90	11172	408.11	54.09	5721	154.51	3229.26

Table 3.4: Co_2 Emissions From India From Fossil Fuel Consumption, 1970-71 to 1989-90

Year	Co_2 From Natural Gas production in Mill Tons	Co_2 From Consumption of petroleum Fuel in Mill Tons	Co_2 From Gas Flared in mill Tons	Co_2 emissions from Coking and non coking Coal in 10^6 Tons	Total Co_2 emissions from fassil fuels Mill Tons
1970-71	1.16	51.26	1.47	101.02	154.91
1971-72	1.29	57.42	1.47	110.58	170.76
1972-73	1.39	62.15	1.25	122.54	187.33
1973-74	1.37	63.95	1.61	118.71	185.64
1974-75	1.71	63.29	1.83	149.32	216.15
1975-76	2.02	64.24	2.09	153.55	221.9
1976-77	2.45	68.97	1.65	154.36	227.43
1977-78	2.63	73.08	2.31	167.35	245.37
1978-79	3.08	80.81	1.83	155.37	241.09
1979-80	3.01	85.51	1.87	163.99	254.38
1980-81	2.74	88.40	1.47	167.66	260.27
1981-82	3.99	93.06	2.93	185.62	285.60
1982-83	5.32	99.18	3.63	192.40	300.53
1983-84	6.11	102.56	4.84	205.47	318.98
1984-85	7.44	111.03	5.87	181.61	305.95
1985-86	8.90	116.93	6.01	236.23	368.07
1986-87	12.72	124.92	5.24	248.79	391.67
1987-88	14.33	132.81	6.64	265.31	419.09
1988-89	16.64	143.33	7.48	281.19	448.64
1989-90	20.09	154.77	11.0	296.12	481.98

3.3 Co_2 Emissions from other Industrial Activity

Manufacturing of cement seems only other significant industrial activity which contribute to co_2 emissions. In this process of cement manufacturing, Calcium Carbonate ($CaCo_3$) is broken down into Carbon dioxide and the Cao which ultimately combines with silicates to form tricalcium and dicalcium silicates.

One mole of Co_2 comes out for each mole of Cao produced from $CaCo_3$. Thus, in the production of one ton of Cement $12.01/56.08 \times (0.638) = 0.502$ tons of Co_2 are released to the atmosphere. The annual emissions of Co_2 from cement manufacture is obtained by Multiplying the mass of total producion of cement in the country by 0.502.

3.4 Trends of Co_2 Emissions

Co_2 emissions presented in the table 3.4 are displayed in Figs. 1 to 4. These graphs show the pattern of cosumption of different fuels. These graphs are best fitted with exponential curves.

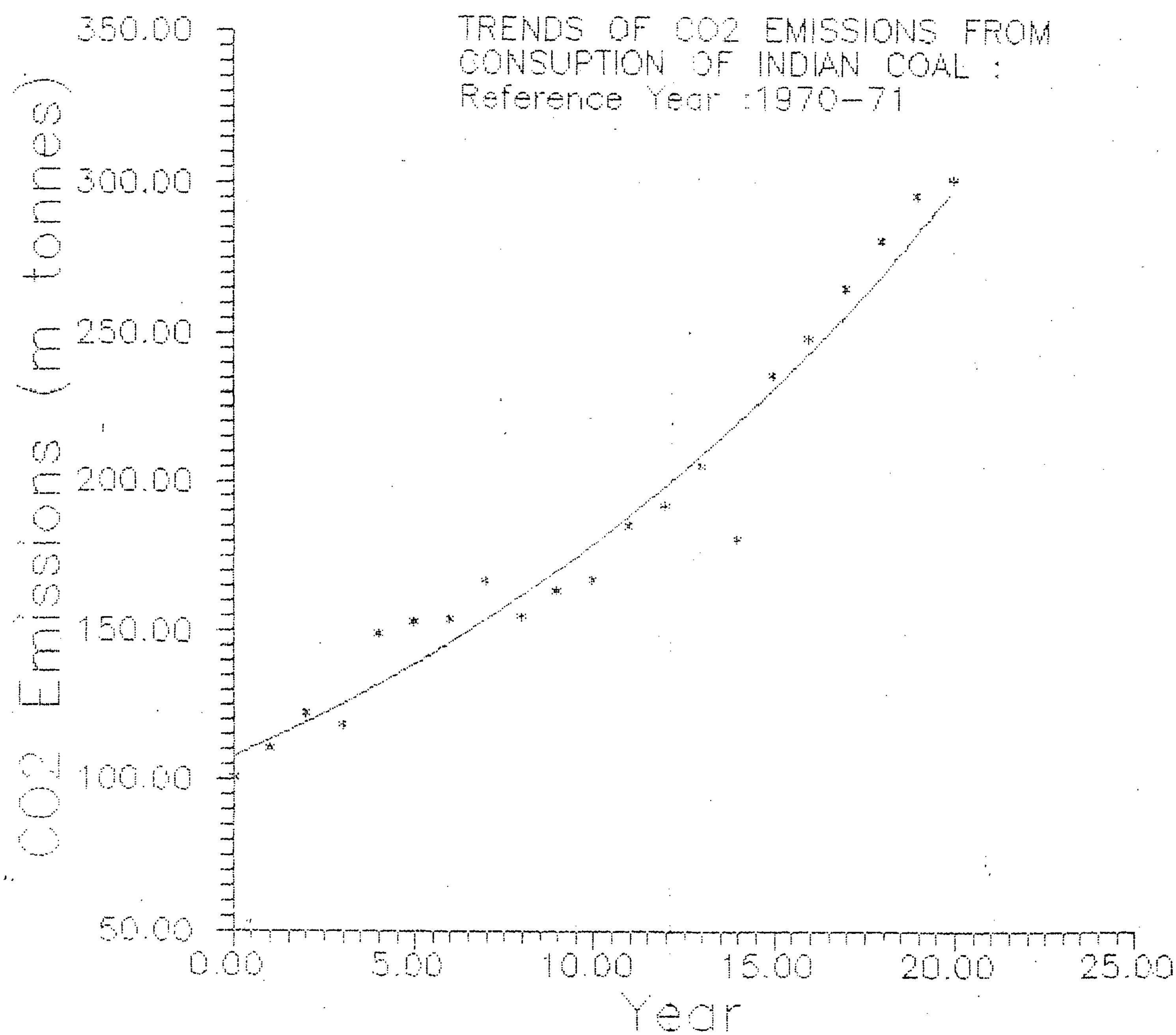

TRENDS OF CO2 EMISSIONS FROM
CONSUPTION OF INDIAN COAL :
Reference Year :1970-71
CO2 Emissions (m tonnes)
350.00
300.00
250.00
200.00
150.00
100.00
50.00
0.00
5.00
10.00
15.00
20.00
25.00
Year

Fig.1

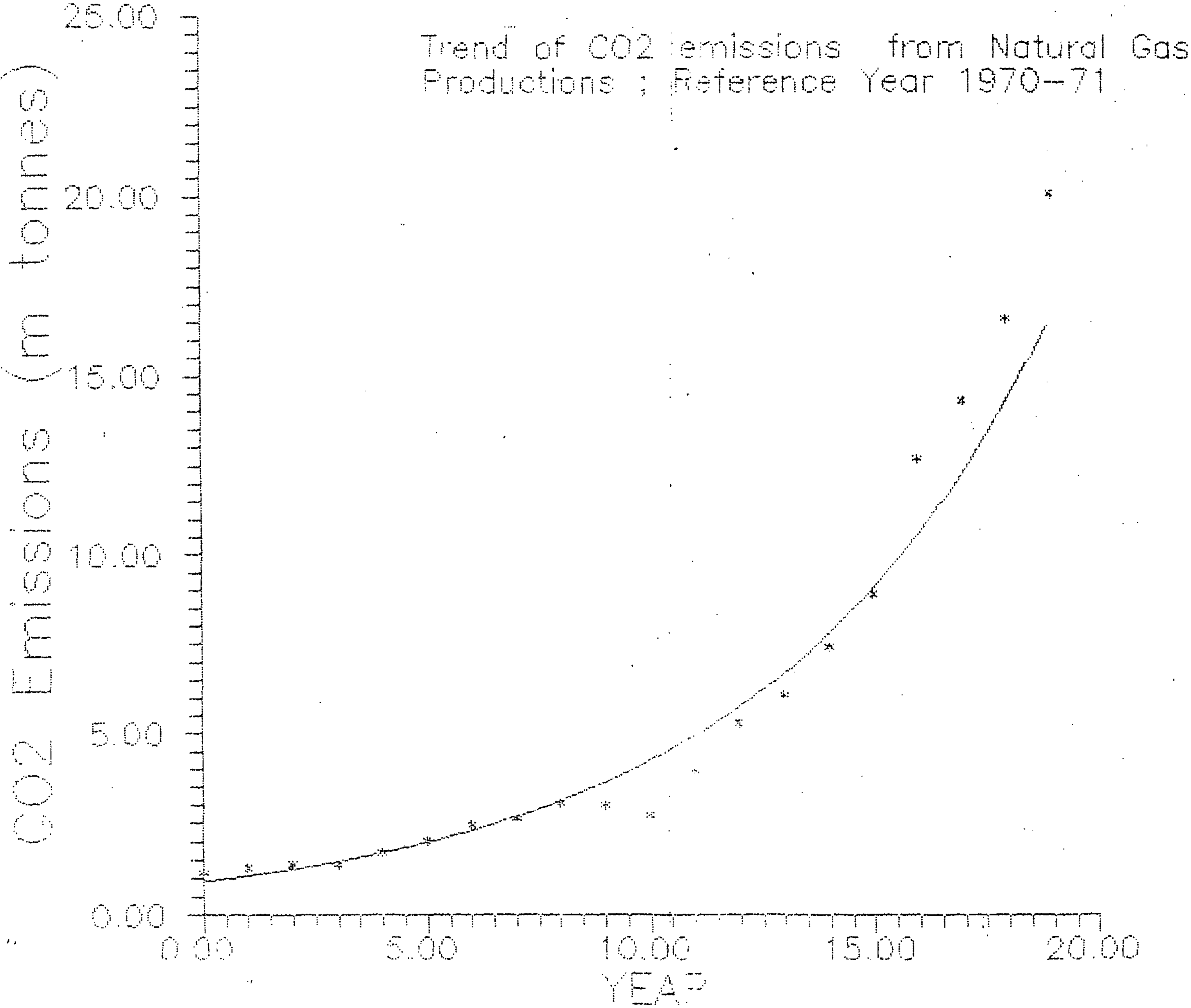

Trend of CO2 emissions from Natural Gas Productions ; Reference Year 1970-71
CO2 Emissions (m tonnes)
25.00
20.00
15.00
10.00
5.00
0.00
0.00
5.00
10.00
15.00
20.00
YEAR

Fig.2

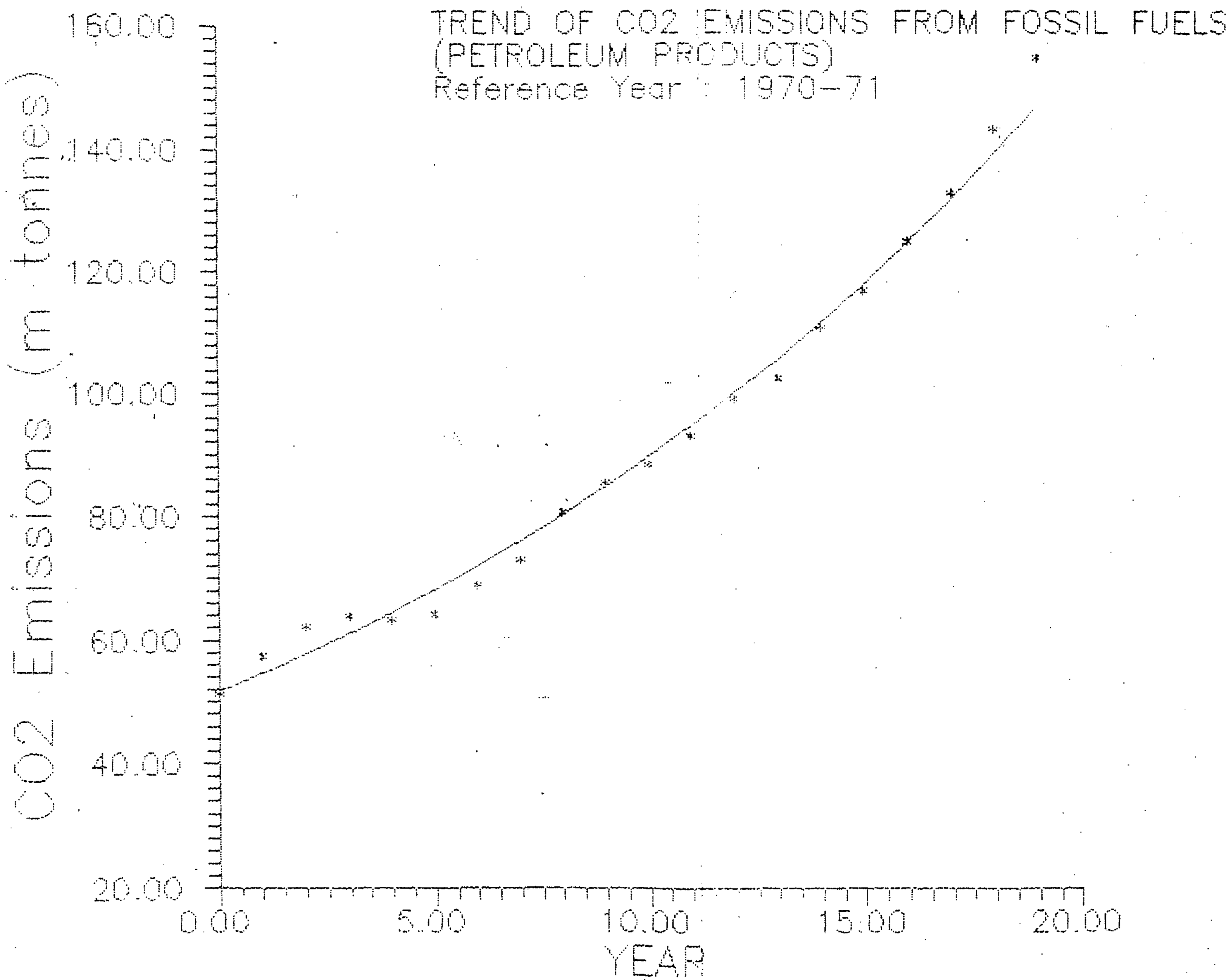
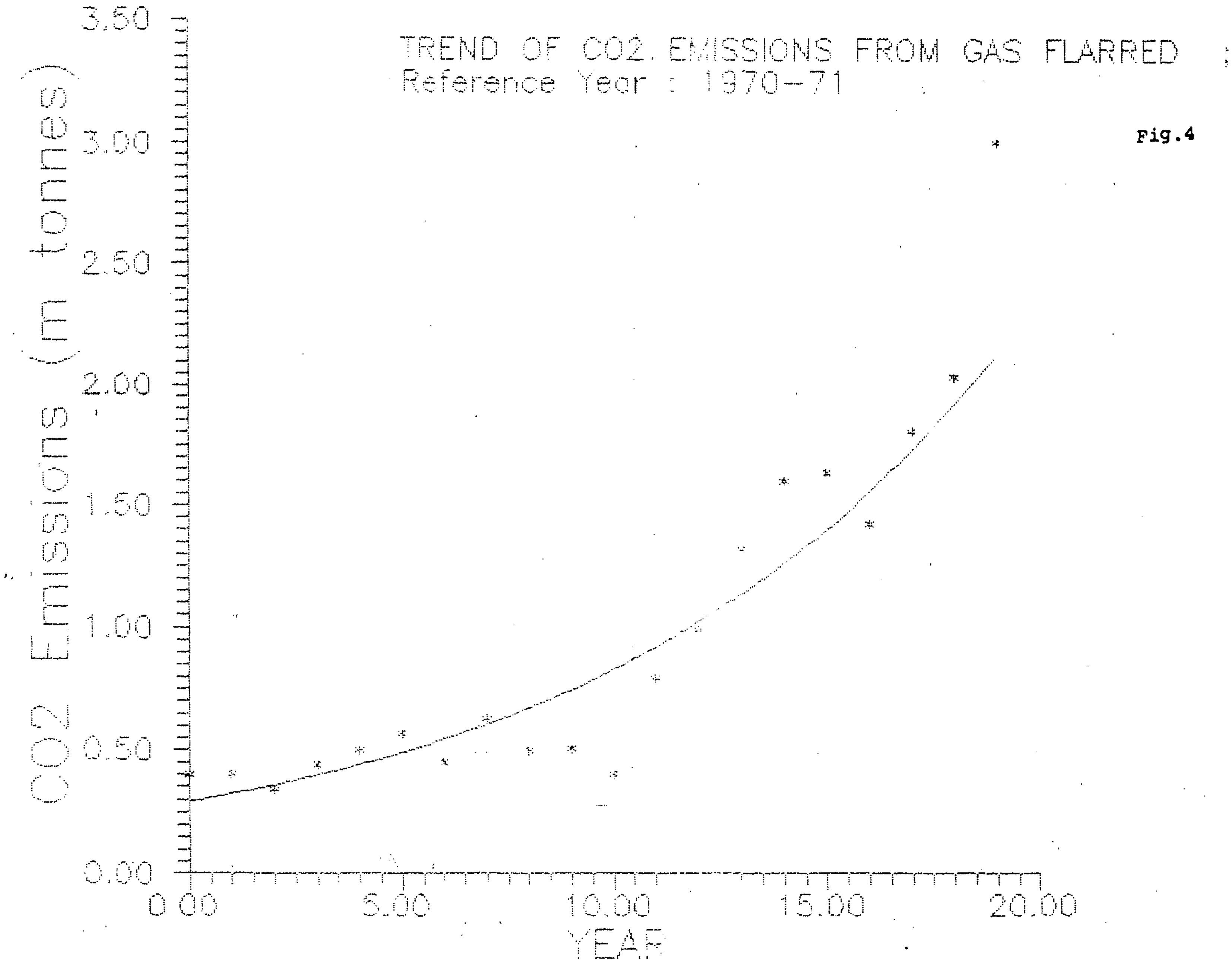

TREND OF CO2 EMISSIONS FROM FOSSIL FUELS
(PETROLEUM PRODUCTS)
Reference Year : 1970-71
CO2 Emissions (m tonnes)
160.00
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
5.00
10.00
15.00
20.00
YEAR

Fig.3


TREND OF CO2 EMISSIONS FROM GAS FLARRED ;
Reference Year : 1970-71
Fig.4
CO2 Emissions (m tonnes)
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
0.00
5.00
10.00
15.00
20.00
YEAR

CHAPTER IV

ASSESSMENT OF THE CO_2 REDUCTION POTENTIAL THROUGH NON-CONVENTIONAL ENERGY TECHNOLOGIES

CHAPTER IV

ASSESSMENT OF THE CO_2 REDUCTION POTENTIAL THROUGH NON -CONVENTIONAL ENERGY TECHNOLOGIES

4.1 Introduction

Energy is vital input for economic and social development of any nation. With the pace of industrial and agricultural development in the country the demand for energy is rising at higher rates. India like other countries largely depends for its energy needs on fossil fuels and the use of conventional energy sources is expected to continue to meet the increasing demand. However, the utilization of the non-conventional sources of energy could augment this increasing demand along with the development of conventional sources of energy. Since the non conventional sources of energy provide clean energy and do not contribute to the emissions of CO_2, their development and utilization would help in green house gas reduction strategies.

The use of non conventional energy sources is not a measure in the strict sense of efficient energy utilization, but a measure for replacing fossil energy sources. At present with the technologies available for utilizing non conventional sources of energy one hopes to contribute appreciably to the reduction of CO_2 emissions. The most promising utilization technologies according to the present level of knowledge are considered and described below.

4.2 Indian Potential of Non-conventional Energy Sources

Energy from Ocean, Wind, Sun, Biomass, Water and Geothermal is renewable and widely available. Electric power generation from renewable sources of energy is non polluting and has very little environmental impacts. These sources of energy do not produce CO_2 and hence could lead the way to check the global warming. Potential of various types of renewable sources of energy in India is given below.

Table 4.1

Renewable Potential in India

Sources	Approx. potential
Solar Energy	5×10^{15} KWh/year
Mini micro Hydro	5,000 MW
Wind Energy	20,000 MW
Biomass	17,000 MW
Geothermal Energy	15,200 MW (IEA, 1987)

(Source : Ministry of Power & non-conventional Energy, Annual Report 1990-91)

4.3 Solar Energy

Use of solar technologies for energy production would result in no emissons of CO_2 making it viable strategy for both global warming and air pollution mitigation. Photovoltaic and solar thermal technologies have been demonstrated to be effective durable and environmentally sound. Demonstration scal plants have been built around the world and commercialization of the technology has begun. Solar electric technologies are cost effective for remote sites off the electric power grid. Some solar thermal technologies are also cost effective for applications in residential and commercial buildings.

Solar energy is produced intermittently, with a peak in the middle of the day. For this reason, solar electricity especially from photovoltaics, is most effective for peaking power.

1. Photovoltaic Technology

Photovoltaic cells convert sunlight directly to electricity in a single step. The cell consists of thin conducting material which is doped with measured inpurities. Presently, the semi conductor is almost invariably silicon (Si), though other materials show promise and are discussed here.

Three types of Si are used in cell manufacturing crystalline (C_z-Si), poly crystalline (poly Si) and Amorphous (a-Si). C_zSi is produced by slowly growing a single crystal of Si into an ingot. The ingot is sawn into wafer and wafer are doped. The process of a-Si differs substantially. A transparent conducting material followed by layers of doped and undoped Si are deposited in very thin layers. on a glass and layer etching provides for the correct electrical connection to form a module. A new process now produces tandem cells i.e. two cells stacked one on top of the other. The advantage of this arrangement is that the second cell can be made to absorb a different frequency of light than the first modules of 7%. efficiency have been produced in this fashion. (Townsend 1989). The properties of each material are listed in table below.

Table 4.2

Properties of Si Photoraltaic Materials

Material	Efficiency (Lab)	Efficiency (Field)	Cost	Durability
C_z-Si	22%	14%	Hish	Excellent
Poly-Si	16%	11%	Moderate	Excellent
a-Si	12%	6%	Low	Fair

Source: Fischer (1986)

The efficiencies shown are for flat plate modules using a single junction cell under sun illumination. Much higher efficiencies are possible for tandem junction cells of other materials to intensify the solar radiation. One difference in the three Si Materials is durability C_z-Si modulus have been thoroughly field tested and shows failure rates less than 1 in 7500 per year (Risser 1987). Models of a-Si have been introduced during the past few years and field test results are to be reported. Because of their higher efficiency C_z-Si Modules have the advantage of requiring less land area for generating facility of a given output. This may be an important advantage for large generating facility. However, a-Si modules are much more suitable for mass production than either C_zSi or poly-Si and thus promise have significantly lower cost per watt of output power [ogden and Williams 1989].

Another semi conductor material which always appeared very promising is gallium arsenide (GaAs). GaAs has a band gap energy which best matches for solar spectrum and thus has highest theoretical efficiency of all materials.

The development of PV systems and the study of the their field performance has become an important activity in India. The government of India has funded protects for design and testing of small lighting systems. In the United States PV systems include off grid domestic power, water pumping and marine navigation.

Solar consumer products include familiar solar calculators, garden lights and Charging systems for boats. An interesting new consumer product is the solar commuter car. These cars have been introduced recently in Switzerland. These cars allow their owners to derive when pollution restrictions prevent them from deriving their gasoline cars.

2. Solar Thermal Technologies

Solar thermal technologies capture solar energy as heat to produce steam. This steam can then be used to generate electricity via a steam turbine generator system. In solar thermal technologies three basic systems are mentioned here. parabolic troughs employ single axis tracking of the sun achive temperatures of upto 400°C, and have achieved overall thermal efficiency of upto 65 to 75% [IEA 1987]. Parabolic dishes use two axis tracking system and produce temperatures of up to 1700°C. Electricity conversion efficiencies of upto 31.6% have been achieved [EPA 1989]. Central recievers consist of a tower surrounded by nearly flat tracking mirrors, have working fluid temperatures approaching 1500°C, and have achieved an overall efficiency of 13% [IEA, 1987].

The advantages of this technology include an efficiency about twice that of the best PV installation and a lower cost, at present. Disadvantages include a significantly more complex facility with higher operation and maintenance costs and less potential for significant cost reductions in future. Nevertheless, at present this technology is by far the most cost effective method of generating. Solar electricity and is growing at the fastest rate.

3. **SOLAR HEATING AND COLLING SYSTEMS:**

This describes various solar thermal systems for low temperature applications (C < 100^0) for domestic, commercial and industrial purposes. These systems are generally categorized as active or passive. In an active system a heat transfer fluid is moved by force using a pump. A passive system uses connective forces produced by thermal gradients to move the heat transfer fluid.

Using solar energy for space cooling is a particularly attractive application because the need for cooling is greatest when the sun is shining strongly. Since space cooling heeds are currently met with electricity, which uses foosilfuels with only about 36% efficiency, the potential amount of foosilfuel displacement by solar cooling is relatively large. These are two systems developed for active solar cooling.

Solar desiccant systems use a drying agent to absorb water vapor in circulated air to reduce humidity levels. The air is then cooled in an evaporation cycle to the desired temp [1EA 1987]. These systems work well in dry climate.

Another technology useful for cooling is absorption refrigeration. These systems use thermal energy to separate a binary mixture of refrigerant and absorbant fluid. The refrigerant is condensed, throttled and evaporated to yield a cooling effect. This technology works most efficiently at temp well above 100^{O}, which requires the use of parabolic collectors and cloudless days to provide the requisite direct solar radiation. However, for residential applications flat plate collectors have been developed [IEA, 1987].

The technical feasibility of active solar cooling for small to medium buildings has been demonstrated, but the technology is not yet cost effective.

SOLAR PONDS:-

A solar pond captures and stores solar radiation by using the sun's energy to heat a mass of water or other fluid. This fluid mass both collects and stores the energy, setting solar ponds apart from other solar energy technologies. The feasibility of solar pond technology has been proven for many applications. Electricity from solar ponds costs from two to four times as much as electricity from fossil force.

Like other solar technologies, solar ponds do not produce Co_2 or air pollutants.

Various types of solar pond technologies have been developed, of these, salinity Gradient Solar Pond technology is by far the most prevalent and advanced.

The SGSP Technology grew from the study of naturally occurring hilio thermal lakes, highly saline bodies of water, which have temperature gradients that are the inverse of those of normal, fresh water lakes. Solar ponds are being engineered for electrical generation. Hot brine (65-85^{0}C) from the storage zone enters the boiler of an organic Rankine Cycle (ORC) heat engine, vaporizing the organic working fluid which then drives a turbine, SGSP conversion efficiency for electricity has yet to surpass 5% and is usually between 2 to 3%. Most of the large scale ponds designed for electrical purposes have been built in desert areas with high insolation and good salt availability.

4. CONTRIBUTION OF SOLAR TECHNOLOGIES TO REDUCING CO_2

Based on the above study it is evident that solar technologies are much mature now. It appears that in some areas solar energy could serve as a substitution of thermal electricity. If India adopts the policy to substitute its 10% of gross electricity generation by solar energy by the year 2005-2006 and 20% by the year 2010-2011. In 1988-89, the gross generation of electricity was 221.12 billion kwh; this corresponds 22.11 billion kwh. for solar energy. This can avoid about 20.34 mill. tons of Co_2 by the year 2005 and 40.60 milltons /yearby 2010-2011 from 1988-89 levels. These figures have been arrived at under the assumption that solar energy replaces the electricity from coal fired source stations running at the efficiency of 36% for medium load operation.

4.4 WIND ENERGY

Assessing the magniture of the wind energy is complicated by the fact that it is highly site specific. Since the power of the wind varies as a function of the third power of the wind speed a difference in average wind speeds of 25% will mean a nearly two fold difference in energy available at the site. Wind Speeds are also greately influenced by surface turbulence, which is in turn highly dependent on the local terrain.

In order to set an accurate picture of Wind resource a detailed Wind atlas should be compiled. India has installed some monitoring stations to view accurate picture of Wind Speed.

As Wind technology has matured, there has been some convergence on the turbine designs of choice, out of many originally proposed. The experience gained in the past decade has some light on the question of optimum turbine size. Gipe [1990] reports that very large turbine sizes have not provided the expected economics of scale because wind speed do not increase dramatically with hight as was once assumed. Most of the turbine's have rotor diameter 15-19 meters. Turbine in the 20-30m in range are begining to reach the productivity levels of the smaller models [Gipe

1990] and may prove promising in the future.

CURRENT AND FUTURE WIND POWER UTILIZATION:

In reducing Co_2, there is good potential for expansion of wind energy generation in the near future. In India, the programme for establishing wind forms was initiated in 1985. The technical feasibility of using wind as a major source of energy has now been well established, and wind energy today ranks as one of the most promising source of renewable eneergy for generating elecltricity. A total wind power capacity of about 50 MW has been taken up so far in India. The complete projects include wind farm demonstration projects of aggregate capacity 32.2 MW comprising 247 wind electric generators.

Several nations have adopted ambitious goals for wind energy. Wind forms are being installed in Denmark, the Netherlands, U.K., Spain and Itly [IEA 1987 - Gipe 1990]. Denmark's target is for wind to provide 10% of the nation's electricity by 1995. Denmark also hopes to displace 8% of all fuel consumption with renewable sources with greater emphasis on wind [IEA 1987].

To assess the exact potential of Wind energy generation an extensive wind survey programme comprising wind mapping and wind monitoring is necessary. Wind resource study in complex terrain undertaken so far in six states, have confirmed possibilities of strong winds on low hills and in Mountain regions. Large potential areas have been identified particularly in Andhra Prades, Karnataka, Gujarat and Kerala. The data from the wind survey could be utilized in preparing detailed project reports for wind energy for specific sites, as well as area based master plans for identification of the potential for power generation. A master plan for the southern districts of Andhra Pradesh viz. Cuddapah, Chitoor, Nellore and Anantpur has shown large potential. A total exploitable potential of about 830 MW has been suggested for this region [non-conventional Energy sources report 1991-92].

Based on the above, it seems that a target for wind of producing an amount of energy equal to 8% of electricity generation would be an ambitious but feasible goal for India by the year of 2005-2006 and 15% by the year 2010-2011. Gross geneeration of electricity in the year of 1988-89 was about 221.12 TWH. Eight per cent of this amounts to 17.69 TWH/generation of electricity in the same year through wind energy. This corresponds to reducing Indian emissions of Co_2 by 16.27 X 10^9 Kg of CO_2 by the year 2005-2006 and 30.51 x 10^9 kg. CO_2 by the year 2010-2011 from 1988-89 levels, if used to displace hard coal.

ENVIRONMENTAL CONSIDERATIONS

We notice that, wind is clean source of energy, however it is not completely without environmental impact.

The most often cited environmental concern include land use, noise and impacts on wild life, especially birds.

Complaints have been made about the noise generated by Wind Plants. Some newer Danish Wind turbine designs reduce this problem significantly. There have also been problems with birds being killed in collisions with turbines.

In the past few years wind energy technology has matured and wind now provides small but significant amounts of electricity in california and Denmark, where wind development is most advanced. The cost of genneration from excellent sites is now competitive with that from fossil fired power plants. Several European nations have adopted ambitious targets for expansion of wind generating capacity. A goal of 8% electricity generation from Wind by the year 2005-2006 seems feasible for India.

4.5 MICRO-MINI HYDRO POWER PLANTS;

The Micro-mini hydro programme is to h;arness electricity from low head of water resources. Existing hydro electricity facilities provide some of the cheapest electricity available and electricity costs from micro-mini hydro power utilization is also generally competitive. Huge hydro electric projects are very capital incentive and have severe environmental impacts. The advantages of this programme include indegenous technology, short gestation and low transmission losses due to local generation and consumption of electricity and no severe environmental impacts.

India has an estimated aggregate potential of 5000 MW for this programme [Ministry of non-conventional energy sources 1991-92]. Projects up to the capacity of 3 MW power generation comes in this programme. At present 12 projects are underr execution out of which Bilkot, Khet and Naini in the remote areas of U.P. hill have been completed.

Hydro electric capacity has grown at an average rate of about 2% world wide from 1984 to 1987. With a growth rate of less than 1% in regions which have exploited most of their hydro power capacity. Since the growth in hydro power has been slowing down rather increasing in recent years due to environmental, socio economic factors. It appears reasonable that only mini-micro hydro development could be accelerated to exploit more power. It can make a substantial contribution to reducing emissions of Co_2.

After studying various aspects and taking the Indian potential in consideration, it appears that a target for mini-micro hydro for producing an amount of energy equal to 5% of gross electricity generation could be an appropriate goal by the year 2005-2006. This energy will correspond to a Co_2 emissions saving of 10.17 million tons under the assumption that the efficiency of the thermal power plants is 36% for medium load operation.

4.6 **OCEAN AND GEO THERMAL ENERGY**

OCEAN ENERGY. There are several forms of ocean energy which could potentially be harnessed for electricity generation. These include tidal energy, wave energy and ocean thermal energy conversion. The research and development for exploiting each of these forms of energy is not well advanced, consisting primarily of feasibility studies conceptual designs, and a few smallscale pilot projects. Since the size of the resource is potentially very large especially for ocean thermal Electricity Conversion (OTEC) a discussion of the current studies and future potential of this technology attacts importance.

The concept behind OTEC is to exploit the large temp gradient which exists in much of world's oceans. The temp gradient around Andman and Nicobar island's is good enough to exploit huge amount of energy. The minimum temp difference requied between the surface of the ocean and depth of 1000 M is 20^0C for OTEC [IEA 1987]. It has been estimated that from this temperature difference, a minimum of 0.2 MW / Km^2 electricity could be extracted [A very et Al 1984).

The U.S. and Japan studied and designed prototype plants. The two basic designs proposed are closed cycle and open cycle systems. The closed cycle would employ a working fluid such as NH_3, propane or other hydrocarbons. Warm ocean water is used to boil the working fluid which then runs a turbine. In an open cycle system, the ocean water would itself be used as the working fluid. In this process warm water is boiled at reduce pressure to run the turbine. Since the monthly average temp difference between the surface and depth of 1000 m in the south east of Indian Ocean is more than 20^0C (IEA 1987), the potential for ocean thermal conversion in Andman and Nicobar islands appears very high.

Early development of OTEC may occur in islands, where cost of generation is very high, since the ocean reaches the depths of 1000 m or more relatively close to shore. Based on the above it is concluded that OTEC for these Indian islands seems feasible in near future.

GEOTHERMAL ENERGY TECHNOLOGIES

Unlike the Wind or Solar energy, geothermal energy is available consistently during day and night. It is the heat contained within the earth's crust. Only a very small fraction of this energy is found at accessible depth. Even so the amount of energy which could be extracted from this source is potentially very large.

The temperature at the earth's crust increases with depth from the surface. The global average geothermal temperature gradient is 30^0/km; but this varies from region to region.

Geothermal energy is most economic to exploit in regions where the geothermal gradient is higher than average.

There are four types of geothermal resources. One can think of geothermal resources as a pyramid with hydro thermal resources at the top, Hot Dry Rock in the Middle and Magma at the bottom. The fourth type of geothermal resource is the geopressurized reserve.

The oldest type of geothermal plant is a dry steam plant. In this type of plant steam from hydrothermal resource is used directly to run a turbine. The technology to convert geothermal dry steam is a mature technology with typical plant capacity of around 35 MW (IEA 1987).

Two methods are used to convert hot water resources to electricity. A flash steam plant heats the hot water to evaporation and then uses it to run a steam turbine. This technolgy was first commercialized in the 1970's and is now mature technology with typical plant capacity around 10 MW. Another binary cycle plant uses hot water (< 150^0C) to heat a separate working fluid with low boiling point. The working fluid may be freon, NH_3, alcohol; the choice depends on the temperature of the geothermal reserve. Such plants can use much lower temperature reserves than dry steam plant.

All existing geothermal electric plants convert energy from hydrothermal resources. In 1988, 236 geothermal electric power plants totalled 5280 MW in capacity worldwide. [Independent power 1988]. This represents 0.2% of global electic generating capacity.

India has the total geothermal electric power capacity potential around 15200 mega watts [USDOE 1985]. Geothermal sites are widely spread in India, in the form of 340 hot springs. Many of them do have temp around the boiling point at their places of occurence. At present, Govt. of India has shown interest for the effective utilization of geothermal energy. A 5 KW pilot plant based on closed loop rankine cycle using F-113 as working fluid is installed at Manikaran which gives net power production of 5.2 kw_e.

A considerable amount of geothermal power electicity potential is available at puga valley, Ladakh (Jammu and Kashmir) located at a distance of 180 Km from Leh in the form of hot springs and pools. It has temperature roughly about 81^0C or more. (Depart of non-convention Energy report 1990).

If we see the developments in the geothermal electricity of the world as a whole, the electricity generated by geothermal plants is only 0.13% of the total potential of the world (USDOE 1985). Geothermal production has grown 14.5% per year from 1970 to 1980 and 17.5% per yar from 1980 to 85 in the world as a whole (WRI/IIED). If growth rate of 15% per year is assumed from 1988 to 2010. The geothermal electricity would provide 3% of the world's electric capacity (WRI/IIED-1989).

India has good potential for the development of its geothermal resources for the purpose of power generation particularly in the puga valley, Leh and Ladhakh region of himalaya.

Since India has total geothermal electric power potential of 133.15 TWH/Year, which is quite large, but huge exploitation is not possible in the near future due to the lack of advanced technology. Still if we assume 3% replacement of gross energy generation by geothermal power, which seems feasible by the year 2005-2006 and if year 1988-89 is taken as a reference year the 3% of gross electricity comes to be around 6.63 x 10^9 kwh/year. This corresponds to the Co_2 emission savings of 6.10 mill tons of Co_2 by the year 2005-2006. For attainment of good capacity in the field of electricity generation from geothermal resources, the development of hot dry rock resouurces will be required.

4.7 CO_2 EMISSIONS REDUCTION AND SELECTED TECHNOLOGIES

To determine the specific savings of Co_2 with respect to the energy, the non-conventional sources of energy are compared with Fossil fuel powered technologies.

TABLE 4.3

Emissions of CO_2 by using different technologies (in Tons/Tera Joules)

Non-Conventional Energy Sources		Conventional Energy Sources		savings of CO_2 emissions at energy output
Technology	CO_2 Emissions Tons/TJ*	Technology	CO_2 Emissions Ton/TJ*	
Photovoltaies	0.0	Hard Coal Thermal power plant	255.56	255.56
Solar heating and cooling system	0.0	Hard coal Thermal power plant	255.56	255.56
Solar Ponds	0.0	Hard Coal Thermal Power plant	255.56	255.56
Solar Heater	0.0	Hard coal Thermal Power plant	255.56	255.56
Wind Energy Converter	0.0	Hard Coal Thermal Power Plant	255.56	255.56
Mini-micro hydro plant	0.0	Thermal Power Plant	255.56	255.56
Electric heat pump	72.22	Oil Fired boiler	94.44	22.22
Gas heat pump	33.33	Gas fired boilder	66.67	33.34
Biogas fired heater	141.66**	oil fired boiler	94.44	94.44
Wood fired Chulha	133.33**	Oil fired boiler	94.44	94.44
Geothermal Energy	0.0	Oil fired boiler.	94.44	94.44

* CO_2 emissions at energy output

** It is considered biomass releases no net CO_2 to the atmosphere.

Source H.J. Wagner, G. Kolb. 1989.

The results are shown in table 4.3. In the comparison of two technologies it is assumed that the hard coal power plants run with an average efficiency of 36%. It should be noted that fuel coal power plants contribute, most of the fossil electricity and most of the heat for domestic and industrial use is provided by oil fired and gas fired cooking stoves/boilers with an average efficiency of 70-80% in our country. Since electricity generating technologies, i.e. solar heater, solar heating and cooling systems, photovoltaics, Wind energy converter produce no Co_2 emissions, the emissions of Co_2 by conventional plants can be fully saved.

The combustion of biomass is a rather special case. Biomass, if used sustainably, has the potential to be a renewable source whose use would result in no net emissions of Co_2. Thus if one asumes that the Co_2 emitted by combustion of biomass is completely assimilated or used up for the further production of biomass and if biomass substitutes for oil and gas fired cooking stoves/boilers, there could be a net saving in Co_2 emissions of 94.44 tons per tera joules (Table 4.3).

4.8 TOTAL CO_2 REDUCTION POTENTIAL OF NON-CONVENTIONAL ENERGY SOURCES:

It is very difficult to evalute exact potential of non-conventional sources of energy which could be used along with conventional energy sources in future, though the fair estimates for selected sources have been discussed above. The contribution of major hydro electric power plants in India, during the year 1988-89, was about 57.79 TWH/year. The further development of major hydro projects may not take place in future. However, there is a fair scope for the exploitation of other non-conventional energy sources (including mini-mico hydro plants) which could reduce the emissions of Co_2 significantly. tableE

The gross generation of electricity in the country during the year 1988-89 was about 221.12 x 10^9 KWH. Based on the use of solar thermal technologies photovoltaics, solar ponds and other factors, it is assumed that this source of energy could contribute at least 10% of gross generation of electricity by the year 2005-2006. Since solar thermal energy systems are mature and viable and many passive solar and hot water systems are economically competitive with conventnal technologies, hence a 10% contribution by this source of energy looks feasible. This translates to a 20.34 Million Tons to CO_2 emissions reduction, if substituted for fossil energy from 1988-89 levels by the year 2005-2006. Such high level of solar penetration will only be achievable with strong policy actions to energy adoption of these technologies.

The cost of generation of electricity from Wind is now competitive with fossil plants in some selected sites. Several European nations have adopted ambitious targets to generate electricity through Wind energy converters. Denmark provides more than 10% of its electricity from Wind. Going through the studies it is assumed that if India fixes its target to generate 8% of its electricity from wind by the year 2005-2006 it could reduce Co_2 emissions by 16.27 mill tons of Co_2 emissions from 1988-89 level by the year 2005-2006.

The studies suggest that the geothermal resource investment is some what risky. The main reason is that the upfront cost of developing a geothermal source can be quite large, due to the high cost of exploratory drilling. If India adopts the policy of 3% generation of electricity from geothermal from the level of 1988-89, by the year 2005-2006 it could reduce emissions of Co_2 upto 6.10 mill tons from the 1988-89 levels. Development of micro-mini hydroplants could substitute 10.17 mill tons of Co_2 emissions by the year 2005-2006 from reference level.

Because of the lack of information and underdeveloped technology of OTEC, the future estimates of ocean energy are not possible at this stage. But, it could be a promising resource in the future.

The Co_2 reduction potential of above mentioned non-conventional energy sources amounts to 52.88 million tons of Co_2/year according to the assumptions considered for India. This equals to 11.786% related to 1988-89's total Co_2 emissions from fossil fuel resources.

Assessment of the potential of non-conventional energy sources reflects that their efficient utilization could avoid the annual Co_2 emissions in India by an amount of 53 million tons of Co_2 (Biomass, Biogas resources are hot included). But Co_2 emission reduction is not the only criterion for non-conventional energy technologies, continuous supply and economic consideration have to be given attention.

CHAPTER V

OPTIONS FOR CO_2 REDUCTION IN TRANSPORTATION SECTOR

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5.1 INTRODUCTION

Transportation is a highly consuming sector of fossil fuel energy. In our study we have considered only transportation on road and railway. The end energy consumption in thousands of tera joules from transportation sector during the year 1988-89 is as follows.

TABLE 5.1

End Energy consumption from transportation

Sector (1988-89)

S.No. Mode of Transport	Gasoline '000' Tera Joules	Diesel in '000'Tera Joules	Coal in '000'Tera Joules	Total
1. Road	133.95	649.39		
2. Railways		62.16	132.72	985.38
3. Waterways		7.163		

The total calculated emissions of Co_2 from transportation sector in India in the year of 1988-89 are as follows :

Table 5.2 : Emissions of Co_2 in Million Tons

S.No.	Mode of Transport	Co_2 from Gasoline million tons	Co_2 from Diesel million tons	CO_2 from Coal million tons	Total Co_2 million Tons
1.	Road	9.67	54.11		
2.	Railways		5.18	12.17	81.13

Table 2 reflects, that in 1988-89, transportation on road and railways in India contributed almost 18.08% of the total CO_2 emissions from fossilfuels. Our study give emphasis on the improvements in efficciency of cars, whith Auto and diesel engines and replacement of all steam engines of railways by diesel engines. It is belived that for comercially applied diesel engines improvements in efficiency are feasible up to very minor extent. Hence efficiency improvements of private cars and replacement of steam enginess by diesel engines in the railways are considered.

A significant reduction could be achieved by optimizing the transmission and final drive, by the increased use of fuel injection and by smaller cooling systems leading to a faster heating of the engine. Also by Reducing the weight of the vehicles, the drag force and rolling resistance.

Diesel engines with advance technology consume up to 25% less fuel than Otto engines on the other hand CO_2 emissions are also decreased by the same magnitude.

Advanced modern Diesel engines at the full load. Shows efficiency roughly around 35% while autto engines shows that of 29-30% [Kolb, G.Eickhoff, 1989]

There are some appropriate technologies by which self-igniting engines can be made even more fuel efficient. For example germany has developed a new environment friendly Diesel car. In this Diesel Car exhaust gas turbo charger is aimed at better and efficient fuel consumption.

In order to reduce CO_2-emissions in passenger cars some measures like electronic fuel injection control for the ottop engine Diesel fuel injection into open combustion chambers in motor car design are suggested to provide a new trend of efficient fuel consumption.

5.2 ALCOHOL AND VEGETABLE OIL TECHNOLOGY

Two types of Alcohol are commonly used as fuel, either by themselves, or blended with gasoline, methahol known as wood alcohol and is deadly poisonous as a drink.

Ethanol is grains alcohol, the basis of alcoholic drinks.

- Upto 25% alcohol can be used in unmodified gasoline engines, but to burn purn alcohol modern auto mobile engines must normally be modified to run efficintly. A blend of 10% ethnol and 90% gasoline is turmed as Gasoled.

More complex forms of alcohol - propanol, butanol, pentanol etc are used in small amounts to keep blends mixed, or to improve the performance of straight ethanol and methanol fuels. they could also be blanded with diesel fulels. But, alcohol blends creates some problems. these are.

If a blend of anhydrous alcohol and gasolinc is exposed to more thans 0.25% water, phase separation would occur. the gasoline and alcohol could separate into different layers in the fuel tank, causing serious driving problems such as surging and loss of powers.

* Vapour lock could occur when the alchohol began evaporating. Bubbles of alcohol could accumulate in fuel lines, block fuel pumps, and prevent car from starting.

* The lower heat content of alcohol fuels would mean that mileage would suffer. But non of the problem looks serious.

5.2.1 ALCOHOL CARS :-

It has been found that blends containing as much as 20 % ethanol has no illeffects on automobiles. For example, in Brazil ethanol cars are different in several respects from conventional gasoline autos. But in terms of power and performance they are equal to gasoline fueled cars.

(i) there carburettors have slightly wider inlet nozzl,es to allow more fuel to enter the cylinder.

(ii) They have auxilary fuel tanks containing gasoline; to allow strating under cold weather conditions.

(iii) They have increased compression ratios to obtain better mileage,

The volks wagen 1300 cc engine for use with alchol is built with a compression ratio of 10.1:1 compared to gasoline models 7.5 :1. As well as producing new cars that could run on hydrated ethnol, Brazil has started to convert existing automobilies.

In India for this, engines have to be partially rebuilt, with higher compression ratios. Carburettors nozzles and gaspets would require to replace and fuel tanks must be coated with an alcohol resistant materials.

Mileage per BTU is higher with alcohol, but mileage kms/litre is lower. For example a Brazilian Magzine Vega showed that

* The Fiate runs 10.9km/litre with alcohol compared to 12.4 km/litre with gasoline models
* Ford's luxury Landau runs only 5.0 km/litre with eathanol, compared to 5.79 km/litre with gasoline.

* The Volks Wagen 1300 runs 10.3 kms/litre with alcohol as compared to 12.8 km/litre with a standard gasoline engine.

At present alcohol cars would use an auxiliary gasoline tank to start the engine in cold weather. This is inconvenient for motorists, and the engineers believe that it could be solved either by preheating or by electronic fuel injection or combination of the both.

Since alcohol does not form carbon deposits, it could be possible to engineer piston rings and valves much more tightly than with gasoline engines. In this way, greater efficiency could be achieved. Greater efficiency means the presence of more environment friendly car on the road.

5.2.2 **VEG OILS, ALCOHOL AND DIESEL FUELS :-**

Since diesel engines have no spark plug so they ignite fuel with high compression ratio 17:1. But ethanol and methnol are not very explosive. to solve this problem dual full tanks are suggested.

It we prefer a fuel that could substitutes for diesel entirely, without blends or additives. This ideal fuel may be vegetable oils. Oils from peanuts, sunflower seeds, rapeseeds, soyabeans, and palmtrees when mixed with little ethanol or ester bonds to split the giant molecules, will operate an unmodified diesel engine. recent researches have shown that vegetable oil needs very little processing to be used as a fuel. As compared to alcohol technology which involves complicated fermentation on the other hand veg oils are easy to produce.

5.2.3 THE USE OF ALCOHOL AND ITS IMPACT ON ENVIRONMENT

Two lpowerful environmental arguments are mentioned for alcohol fuels.

Firstly, unlike fossilfuels, plant alcohols donot contribute to the global build up of CO_2 in the atmosphere second important point is that alcoh ol causes less damage to the air quality than Coal, oil and nature gases.

Fig. 5.3 Emissions of (HC, Co and Nox) in Grams per mile

S.N	Gases	Gase line	20% Ethanol with gosoline	Pure Ethanol
	HC	3.32	2.44	2.50
	CO	49.37	20.62	17.00
	Nox	1.86	2.86	1.66

Source :- Ford USA FORD BRAZIL.

Thus we abserve that the alcohol present an alternate to the continued use of fossil fuels.

Plant alcohol fuels are based on biomass, which fixes carbon from the atmosphere during its life cycle, and releases it when it is fermented, the same amount of Carbon that goes in to a plant as it grows is returned to the atmosphere when it is burned and thus biomass alcohol neither contributes nor diminish atmospheric Co_2

5.3 ESTIMATION OF THE REDUCTION POOTENTIAL OF CO_2

Estimation of reduction potential of Co_2 takes into account the fuel consumption for transportation on roads, private vehicles including agriculture sector and railways. Considering the same mileage as in 1988-89 (133.95 Gasolinc + 649. 39 Diesel for roads in cluding agriculture + 62. 16. Dieesl for rails and 132.72 Coal for rails), all are measured in tera jonles. It could be noticed that the blends containing up to 30 % Ethanol had no ill effects on auto mobiles, but some modification in engines would be required. It could reduce emissions of Co_2 from 81.13 million tons to 60.44 mill tons, equivalent to a reduction by 20.69 mill tons of 1988-89 level. complete replacement of all coal engine in Railways by Diesel business could reduce Co_2 emissions by 1.80 mill tons of Co_2.

Since Diesel cars consume 25% less fuel than otto cars, thus it might lead to reduced emissions of Co_2 by 2.42 mill tons. though vegetable oil could help in reducing Co_2 emissions. of Co_2 up to Substantial extent but assessment cannot be made here as economic considerations are beyond the scope of this work.

CHAPTER VI

RESULTS AND DISCUSSIONS

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Three major results can be drawn from forging examination of the trends of the CO_2 emissions; technologies for the utilization of non conventional energy sources and alternate fuel for transportation sector and their implications for Indian CO_2 emissions reduction by the year 2005 - 2006.

Tends of CO_2 emissions reflect that the emissions of CO_2 are likely to increase significantly from present levels in the absence of the strict implementation of energy conservation and non -conventional energy sources technologies.

The assessment of CO_2 reduction potential through non conventional energy technologies indicates that Indian CO_2 emissions reductions are potentially achievable in the period 2005 - 2006 by the amount of 52.88 million tons of CO_2 from 1988-89 level.

Reductions of CO_2 emissions upto 20% may be technically feasible in the year 2005 - 2006, but it would require additional options such as strict penetration of the conservation of energy, replacement of coal fired engines by diesel engines, and introduction of alternate fuels.

We bring together the estimates of CO_2 reduction potential through non conventional energy technologies and novel liquid fuel from biomass to examine some initial issues:

Is it possible for India to reduce CO_2 emissions by 20% from 1988-89 levels by the year 2005-2006 and 40% by the year 2020 - 2021.

We have calculated that in the year 1988-89 total CO_2 emissions were approximately 448.64 million tons of CO_2 (Table 3.4). We recall that the gross CO_2 reduction potential by the efficient utilization of Non-conventional energy sources comes around approximately 53.0 million tons of CO_2/year. According to the assumptions made for India, these emissions correspond about 11.8% related to 1988-89's total CO_2 emissions from fossil fuel resources. To make it easy to understand, we fix some CO_2 reduction targets from 1988-89 levels as follows

CO_2 Reduction target	Total emission of CO_2 million tons/year
0%	448.64
10%	403.78
20%	358.91
40%	269.18

Most of the energy studies discussed such as alcohol, vegetable oil technology and non conventional sources of energy indicate that reducing Indian CO_2 emissions by 20% from 1988-89 level could be feasible.

A full exploitations of the optimistic substitutions potential of the renewable sources of energy amounts to be 57.49 TWH/year. Which could reduce emissions of CO_2 by 52.88 Million Tons./year. But it should be noted that from the present expectations the potential contribution of non conventional energy sources might be realized not before the year 2005-2006.

The alternate fuels for transportation sector provide a great deal to reduce emissions of CO_2. It is almost roughly assumed that the blends containing upto 30% ethanol had no ill effects on automobiles; but some modifications in engines might require for fair responses.

Emissions of CO from private transportation sector were about 81.3 mill tons in 1988-89. Intended improvement of efficiencies upto the year 2005-2006 would reduce CO_2 emissions at max. by 2.42 million tons of CO_2. Alcohol fuel technology could reduce approximately 20.69 mill tons of CO_2 by the year 2005-2006 from 1988-89 level. It should be noted that effects of speed limitation and model split have not been considered because being a nontechnical measure.

Options suggest that the complete replacement of all coal engines in railways by fuel efficient diesel engines could reduce CO_2 emissions by 1.80 million tons of CO_2. The another factor we include is replacement of otto engine cars by diesel cars. Since advance diesel cars consume 25% less fuel in the comparison of otto cars it might lead to reducing CO_2 by the amount of 2.42 mill tons of CO_2.

The market penetration issue is quite difficult to analyze here. This issue is critical to determine the cost of achieving CO_2 emissions reduction goals. The process of market penetration of technologies for non- conventional energy sources and for alcohol fuels could not be assessed exactly by at this stage and are not included here.

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