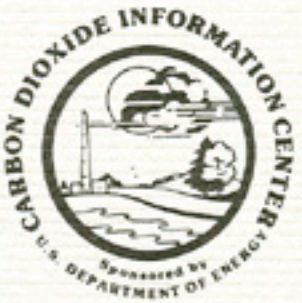
NDP-006



DOI: 10.3334/CDIAC/ffe.ndp006

CDIC NUMERIC DATA COLLECTION

Production of CO_2 from Fossil Fuel Burning by Fuel Type, 1860-1982

Information Resources Organization at Oak Ridge National Laboratory
MARTIN MARIETTA ENERGY SYSTEMS, INC.
operating the

Oak Ridge National Laboratory
Oak Ridge Gaseous Diffusion Plant
Oak Ridge Y-12 Plant
Paducah Gaseous Diffusion Plant

for the U.S. Department of Energy

P.O. Box X Oak Ridge, Tennessee 37831 Telephone (615)574-0390 or FTS 624-0390 Telex No. 8105721076 USDOE OKRE

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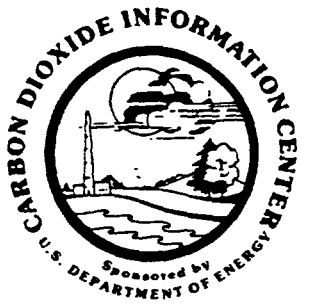
*Sponsored by the Carbon Dioxide Research Division (CDRD), Office of Basic Energy Sciences (BES), Office of Energy Research, U.S. Department of Energy.

NDP-006



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NDP-006

PRODUCTION OF CO_2 FROM FOSSIL FUEL BURNING

BY FUEL TYPE

1860 - 1982

Contributed by
R. M. Rotty and G. Marland
Institute for Energy Analysis
Oak Ridge Associated Universities
Oak Ridge, Tennessee

September 1984

Prepared by the
Carbon Dioxide Information Analysis Center
Environmental Sciences Division
Oak Ridge National Laboratory
Oak Ridge, Tennessee 378331-6050
Operated by
Martin Marietta Energy Systems, Inc.
for the
U.S. Department of Energy
under contract No. DE-AC05-84OR21400

TABLE OF CONTENTS

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Keeling, C. D. 1973. Industrial production of carbon dioxide from fossil fuels and limestone. Tellus 25(2):174-198.

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Rotty, R. M. 1977. Present and Future Production of CO_2 from Fossil Fuels - A Global Appraisal. ORAU/IEA(0)-77-15, Institute for Energy Analysis, Oak Ridge Associated Universities, Oak Ridge, Tennessee. (Also in Present and Future Production of CO_2 from Fossil Fuels - A Global Appraisal. 1979. pp. 36-43 IN W. P. Elliott and L. Machta, eds. Workshop on the Global Effects of Carbon Dioxide From Fossil Fuels. CONF-770385, National Technical Information Service, Springfield, Virginia.

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Rotty, R. M. 1983. Distribution of and changes in industrial carbon dioxide production. Journal of Geophysical Research 88(C2):1301-1308. (Also in ORAU/IEA-82-2(M), Institute for Energy Analysis, Oak Ridge Associated Universities, Oak Ridge, Tennessee. 1982).

LIST OF FIGURES

LIST OF TABLES

CDIAC NUMERIC DATA PACKAGE
ABSTRACT

1. NUMERIC DATA PACKAGE NAME

NDP-006: Production of CO_2 from Fossil Fuel Burning by Fuel Types, 1860 - 1982

2. CONTRIBUTORS

R. M. Rotty and G. Marland
Institute for Energy Analysis
Oak Ridge Associated Universities
Oak Ridge, Tennessee 37830

3. CITATION OF THE PACKAGE

The Carbon Dioxide Information Analysis Center (CDIAC) recommends the following citation for those citing or referencing this package:

Rotty, R. M., and G. Marland. 1984. Production of CO_2 from fossil fuel burning by fuel type, 1860 - 1982. NDP-006, Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, Oak Ridge, Tennessee.
doi: 10.3334/CDIAC/ffe.ndp006

4. BACKGROUND INFORMATION

The burning of fossil fuels is believed to be the major source responsible for the observed increase in the concentration of carbon dioxide (CO2) in the atmosphere since 1958. Keeling (1973) made calculations for CO_2 emissions from fossil fuels which were dependent upon the quantities of fuels used, the carbon fraction of each fuel, and the fraction of the fuel which is oxidized. Keeling used fuel production data estimated by the U.N. for a paper given at the "Peaceful Uses of Atomic Energy" conference held August 8-20, 1955 in Geneva to obtain CO_2 emissions for the period 1860-1953. Calculations for the period 1953-present have been continually updated by Rotty (1973, 1977, 1980, 1981, and 1982), Marland and Rotty (1983, 1984), and Rotty and Marland (1983), using fuel production data. Rotty (1983) presented the global latitudinal distribution of carbon dioxide production resulting from fossil fuel sources.

5. SOURCE AND SCOPE OF THE DATA

CO_2 emission calculations for the years 1860 - 1950 were obtained using fuel production data presented in the proceedings of the U.N. Conference on Peaceful Uses of Atomic Energy (1956). Calculations for the years 1951 - 1982 were obtained using fuel

production data from the U.N. Energy Statistics Yearbooks (1983, 1984). Fuel production rather than fuel consumption data are used, because fuel production data have appeared to be more reliable on a global basis than consumption data.

Marland and Rotty (1983) have found the annual rate of increase for the period 1950 - 1973 to be 4.46 $\pm$ 0.24 percent per year, and 1.86 $\pm$ 1.13 percent for 1973 - 1981. This reduction since 1973 is attributed to OPEC price escalations and subsequent reductions in production. Although post-1973 growth in fossil fuel emissions has been erratic and overall growth rates are subject to much uncertainty, it is clear that the growth rate following 1973 is about half the earlier rate (Marland and Rotty 1983). During 1979 - 1982 there is a negative trend in CO_2 emissions. Carbon dioxide emissions are expressed units of 10^6 tons C.

6. APPLICATIONS OF THE DATA

Fossil fuel consumption, along with deforestation are considered the major anthropogenic sources of increased atmospheric CO_2. Methods of determining the magnitude of CO_2 production as a result of fossil fuel burning is essential to the understanding of the possible causes and consequences of the observed increase in atmospheric CO_2 concentration. Improvement of these methods will enhance our ability to accurately project future CO_2 emission scenarios.

7. RESTRICTIONS/LIMITATIONS

Global fuel production numbers published by the United Nations are consistent with numbers published elsewhere and represent the best efforts of a staff dedicated to the sole task of bringing together all of the available information. However, all the data depend on the accurate reporting of individual nations and production companies. Fuel production data for any year are subject to revision as additional information becomes available. The estimated uncertainty in the CO_2 emissions for a given year is 6-10 percent (Marland and Rotty 1983).

8. KEYWORDS

FOSSIL FUEL EMISSIONS; CARBON DIOXIDE PRODUCTION; CARBON DIOXIDE CONCENTRATIONS; WORLD ENERGY SUPPLIES; ENERGY CONSUMPTION; ANTHROPOGENIC EFFECTS; ENERGY PRODUCTION MODELS

9. CONTENTS OF THE PACKAGE

The package contains the referenced documents (a), and three files of information written in EBCDIC on magnetic tape as card images: tape information, retrieval code, and the CO_2 production data set. Total records: 215.

a. Included in the package:

Keeling, C. D. 1973. Industrial production of carbon dioxide from fossil fuels and limestone. Tellus 25(2)1174-198.

Marland, G., and R. M. Rotty. 1984. Carbon dioxide emissions from fossil fuels: a procedure for estimation and results for 1950 - 1982. Tellus 36B(4):232-261.

Marland, G., and R. M. Rotty. 1983. Carbon dioxide emissions from fossil fuels: A procedure for estimation and results, 1950 - 1981. TR003 DOE/NBB-0036, U.S. Department of Energy. (Also ORAU/IEA-82-10(M), Institute for Energy Analysis, Oak Ridge Associated Universities, Oak Ridge, Tennessee. 1983.)

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Rotty, R. M. 1977. Global carbon dioxide production from fossil fuels and cement, A.D. 1950 - A.D. 2000. pp. 167-181. IN N. R. Anderson and A. Malahoff, eds., The Fate of Fossil Fuels CO_2 in the Oceans. Plenum Press, New York.

Rotty, R. M. 1977. Present and Future Production of CO_2 from Fossil Fuels - A Global Appraisal. ORAU/IEA(0)-77-15, Institute for Energy Analysis, Oak Ridge Associated Universities, Oak Ridge, Tennessee. (Also in Present and Future Production of CO_2 from Fossil Fuels - A Global Appraisal. 1979. pp. 36-43 IN W. P. Elliott and L. Machta, eds. Workshop on the Global Effects of Carbon Dioxide From Fossil Fuel. CONF-770385, National Technical Information Service, Springfield, Virginia.

Rotty, R. M. 1980. Past and future emission of CO_2. Experientia 36:781-783.

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Rotty, R. M. 1983. Distribution of and changes in industrial carbon dioxide production. Journal of Geophysical Research 88(C2):1301-1308. (Also in ORAU/IEA-82-2(M), Institute for Energy Analysis, Oak Ridge Associated Universities, Oak Ridge, Tennessee. 1982).

b. Background information:

Allen, E. L., C. Davison, R. Dougher, J. A. Edmonds, and J. M. Reilly. 1981. Global Energy Consumption and Production in 2000. ORAU/IEA-81-2(M), Institute for Energy Analysis, Oak Ridge Associated Universities, Oak Ridge, Tennessee.

Perry, A. M. 1982. Carbon dioxide production scenarios. IN W. C. Clark, ed., Carbon Dioxide Review: 1982. pp. 337-363. Oxford University Press, New York.

Perry, A. M., K. J. Araj, W. Faulkerson, D. J. Rose, M. M. Miller, and R. M. Rotty. 1982. Energy supply and demand implications of CO_2. Energy 7:991-1004.

Rotty, R. M., and G. Marland. 1980. Constraints on fossil fuel use. IN W. Bach, J. Pankrath, and J. Williams, eds., Interactions of Energy and Climate. pp. 191-212. D. Reidel Publishing Company, Dordrecht, Holland.

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United Nations. 1955. World energy requirements in 1975 and 2000. International Conference on Peaceful Uses of Atomic Energy, published by the Statistical Office, U.N. Department of Economic and Social Affairs, New York.

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Watts, J. A. 1982. Fossil fuel and cement production, 1860-1980. Section III.9, pp. 456-460 in J. A. Watts, The carbon dioxide question: data sampler. IN W. C. Clark, ed., Carbon Dioxide Review: 1982, Oxford University Press, New York.

10. HOW TO OBTAIN THE PACKAGE

The documentation of NDP-006 contains a printed listing of the data retrieved by the output routine for the use of requesters who may not need the automated data.

Requests for computerized data should be accompanied by a reel of tape and special instructions for transmitting the data.

Requests should be addressed to:

Carbon Dioxide Information Analysis Center
Environmental Sciences Division
Oak Ridge National Laboratory
Oak Ridge, Tennessee 37830-6050
Telephone: (615) 574-0390
FTS 624-0390

11. DATE OF ABSTRACT

September 1984

Each numeric data package (NDP) assembled by CDIAC goes through a process of assuring the quality of the data. This process includes review(s) by the contributors of the data to ensure that, in compiling the data, CDIAC does not misrepresent or inaccurately describe the data. NDPs are not distributed without the written consent of the contributors.

MAGNETIC TAPE CONTENTS

Code Package Name: NDP-006
Computer: IBM 3033
Packaged: September 15, 1984

File No. & Description	Mode	Logical Records	DCB Parameters		
1. General Information File	EBCDIC	54	FB	10800	80
2. FORTRAN IV Data Retrieval Program to Read and List File 3	EBCDIC	38	FB	10800	80
3. Data: CO_2 Production From Fossil Fuels and Cement, 1860 - 1982	EBCDIC	123	FB	10800	80
	Total Records	215			

MAGNETIC TAPE DESCRIPTIVE FILE

DATASET TITLE: Carbon Dioxide Production from Fossil Fuels and Cement, 1860-1981.

CONTRIBUTOR(S): R. M. Rotty
G. Marland
Institute for Energy Analysis
Oak Ridge Associated Universities
Oak Ridge, Tennessee 37831

SCOPE OF THE DATA: Global estimates of CO_2 production from fossil fuels and cement are given for the years 1860 - 1981. These estimates are based upon global fossil fuel production data published by the United Nations. CO_2 production is categorized by solid fuel, liquid fuel, gas fuel, gas flaring, and cement manufacturing. CO_2 production is expressed in units of 10^6 tons of carbon.

DATA FORMAT: The following eight variables are defined. IYR, SOLID, LIQUID, GAS, GASFL, CEMENT, TOTAL, and CUMUL. These values are read by the format statement: FORMAT (I4, 2X, 6F7.1, 1X, F10.1). The CO_2 production estimates are printed by the format guidelines; FORMAT (3X, I4, 1X, F7.1, 1X, F7.1, F7.1, 1X, F7.1, 1X, F7.1, 2X, F7.1, F10.1). Values for gas flaring and cement manufacture prior to 1950 were not available and are represented by NA (not available).

REFERENCES

Keeling, C. D. 1973. Industrial production of carbon dioxide from fossil fuels and limestone. Tellus 25(2)1174-198.

Marland, G., and R. M. Rotty. 1984. Carbon dioxide emissions from fossil fuels: a procedure for estimation and results for 1950 - 1982. Tellus 36B(4):232-261.

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Rotty, R. M. 1983. Distribution of and changes in industrial carbon dioxide production. Journal of Geophysical Research 88(C2):1301-1308.

FORTRAN IV DATA RETRIEVAL PROGRAM LISTING

```
C  FORMAT NUMBER FOR DATA INPUT
           NIN=12
C    FORMAT NUMBER FOR DATA OUTPUT
           NOUT=6
C FORMAT HEADINGS FOR OUTPUT LISTING
           WRITE(NOUT,100)
100        FORMAT(1H1,
     1            'Table 1. Production of CO2 from Fossil Fuels and Ce
     1ment, 1860-1981.'/
     2'                          (Units = 10**6 tons of carbon)'/)
1          CONTINUE
           WRITE(NOUT,101)
101        FORMAT(67(1H-)/10X,'SOLID',2X,'LIQUID',1X,'NATURAL',3X,
     1'GAS',4X,'CEMENT',8X,'CUMULATIVE'/3X,'YEAR',3X,'FUELS',3X,'FUELS',
     23X,'GAS',3X,'FLARING',2X,'MANUF.',2X,'TOTAL',3X,'TOTALS'/
     367(1H-)/)
C PRINT 40 VALUES PER PAGE. READ DATA FROM TAPE.
           DO 50 I=1,40
           READ(NIN,150,END=99)IYR,SOLID,LIQUID,NATURL,GASFL,CEMENT,
     1TOTAL,CUMUL
150        FORMAT(I4,2X,6F7.1,1X,F10.1)
          FLARE=GASFL
           CEMANU=CEMENT
         IF(YEAR .LT. 1950) FLARE='na'
          IF(YEAR .LT. 1950) CEMANU='na'
C WRITE DATA VALUES OUT.
           WRITE(NOUT,160) IYR,SOLID,LIQUID,NATURL,FLARE,CEMANU,
     1TOTAL,CUMUL
160        FORMAT(3X,I4,1X,F7.1,1X,F7.1,F7.1,4X,A4,4X,A4,2X,
     1  F7.1,F10.1)
50         CONTINUE
200        WRITE(NOUT,170)
170        FORMAT(1H1/)
           GO TO 1
99         CONTINUE
C WRITE OUT FOOTNOTE.
           WRITE(NOUT,105)
105        FORMAT(67(1H-)/3X,
     1'na=not available; applies to gas flaring and cement'/'manufactur
     1ing prior to 1950.')
           STOP
           END
```

Table 1. Production of CO_2 from Fossil Fuels and Cement, 1860-1981. (Units = 10**6 tons of carbon)

YEAR	SOLID FUELS	LIQUID FUELS	NATURAL GAS	GAS FLARING	CEMENT MANUF.	TOTAL	CUMULATIVE TOTALS
1860	93.2	0.1	0.0	na	na	93.3	93.3
1861	98.5	0.2	0.0	na	na	98.7	192.0
1862	98.1	0.3	0.0	na	na	98.4	290.4
1863	105.6	0.3	0.0	na	na	106.0	396.4
1864	114.9	0.2	0.0	na	na	115.1	511.5
1865	121.6	0.3	0.0	na	na	121.9	633.4
1866	128.3	0.4	0.0	na	na	128.7	762.1
1867	137.5	0.4	0.0	na	na	137.9	900.0
1868	136.3	0.4	0.0	na	na	136.7	1036.7
1869	141.3	0.5	0.0	na	na	141.8	1178.5
1870	144.4	0.6	0.0	na	na	145.0	1323.5
1871	161.3	0.6	0.0	na	na	161.9	1485.4
1872	175.2	0.7	0.0	na	na	175.9	1661.3
1873	187.3	1.2	0.0	na	na	188.4	1849.7
1874	182.6	1.2	0.0	na	na	183.8	2033.5
1875	188.1	1.1	0.0	na	na	189.2	2222.7
1876	190.4	1.2	0.0	na	na	191.6	2414.3
1877	194.3	1.7	0.0	na	na	196.0	2610.3
1878	194.6	1.9	0.0	na	na	196.5	2806.8
1879	205.1	2.5	0.0	na	na	207.6	3014.4
1880	223.9	3.2	0.0	na	na	227.1	3241.5
1881	240.8	3.4	0.2	na	na	244.4	3485.9
1882	258.4	3.8	0.3	na	na	262.5	3748.4
1883	276.4	3.2	0.4	na	na	280.0	4028.4
1884	277.7	3.8	0.6	na	na	282.1	4310.5
1885	271.8	3.8	0.8	na	na	276.4	4586.9
1886	272.7	5.0	1.0	na	na	278.7	4865.6
1887	291.4	5.0	1.3	na	na	297.7	5163.3
1888	315.0	5.5	1.5	na	na	321.9	5485.2
1889	320.3	6.5	1.7	na	na	328.5	5813.7
1890	339.7	8.1	2.0	na	na	349.7	6163.4
1891	353.7	9.6	2.0	na	na	365.4	6528.8
1892	357.2	9.4	2.1	na	na	368.7	6897.5
1893	349.8	9.7	2.2	na	na	361.6	7259.1
1894	365.4	9.4	2.3	na	na	377.1	7636.2
1895	385.3	10.9	2.4	na	na	398.6	8034.8
1896	396.9	12.1	2.7	na	na	411.6	8446.4
1897	415.7	12.8	3.0	na	na	431.5	8877.9
1898	438.2	13.2	3.2	na	na	454.6	9332.5
1899	479.9	13.8	3.5	na	na	497.3	9829.8

Table 1. (Continued)

YEAR	SOLID FUELS	LIQUID FUELS	NATURAL GAS	GAS FLARING	CEMENT MANUF.	TOTAL	CUMULATIVE TOTALS
1900	595.4	15.8	3.7	na	na	524.9	10354.7
1901	518.5	17.7	4.1	na	na	540.3	10895.0
1902	529.4	19.1	4.4	na	na	552.9	11447.9
1903	581.2	20.5	4.7	na	na	606.4	12054.3
1904	585.6	23.0	4.9	na	na	613.4	12667.7
1905	618.3	22.7	5.6	na	na	646.6	13314.3
1906	667.4	22.5	6.1	na	na	696.1	14010.4
1907	737.0	27.8	6.4	na	na	777.2	14781.6
1908	700.2	30.1	6.3	na	na	736.6	15518.2
1909	730.0	31.5	7.5	na	na	769.0	16287.2
1910	762.2	34.5	8.0	na	na	804.8	17092.0
1911	777.4	36.3	8.1	na	na	821.8	17913.8
1912	820.2	37.1	8.9	na	na	866.2	18780.0
1913	878.6	41.3	9.2	na	na	929.0	19709.0
1914	786.2	43.0	9.3	na	na	838.4	20547.4
1915	775.5	45.4	9.9	na	na	830.8	21378.2
1916	834.9	48.1	11.8	na	na	894.8	22273.0
1917	879.6	53.2	12.5	na	na	945.3	23218.3
1918	867.3	53.4	11.3	na	na	932.0	24150.3
1919	757.6	59.6	11.7	na	na	828.9	24979.2
1920	870.0	76.3	12.6	na	na	958.9	25938.1
1921	734.9	82.6	10.4	na	na	828.0	26766.1
1922	786.4	92.2	12.0	na	na	890.6	27656.7
1923	880.7	108.8	15.8	na	na	1005.3	28662.0
1924	871.9	108.7	17.9	na	na	998.5	29660.5
1925	873.1	114.4	18.9	na	na	1006.4	30666.9
1926	867.7	117.5	20.8	na	na	1006.0	31672.9
1927	939.9	134.7	22.8	na	na	1097.5	32770.4
1928	924.3	141.6	24.9	na	na	1090.0	33860.4
1929	982.7	158.9	30.3	na	na	1171.9	35032.3
1930	897.9	151.2	28.4	na	na	1077.5	36109.8
1931	794.9	145.7	27.6	na	na	968.2	37578.0
1932	709.1	139.0	25.7	na	na	873.8	37951.8
1933	741.3	151.6	25.9	na	na	918.8	38870.6
1934	807.0	160.1	29.4	na	na	996.5	39867.1
1935	827.3	174.3	30.1	na	na	1031.7	40898.8
1936	923.1	188.4	34.9	na	na	1146.4	42445.2
1937	972.1	215.3	38.8	na	na	1226.2	43271.4
1938	914.4	209.9	37.0	na	na	1161.4	44432.8
1939	973.5	219.6	39.8	na	na	1232.9	45665.7

Table 1. (Continued)

YEAR	SOLID FUELS	LIQUID FUELS	NATURAL GAS	GAS FLARING	CEMENT MANUF.	TOTAL	CUMULATIVE TOTALS
1940	1033.0	224.5	42.9	na	na	1300.4	46966.1
1941	1077.1	214.6	45.4	na	na	1337.1	48303.2
1942	1082.8	202.2	49.4	na	na	1334.9	11447.9
1943	1087.4	221.5	55.1	na	na	1364.0	51001.6
1944	1043.1	249.2	59.8	na	na	1352.2	52353.8
1945	875.2	263.0	65.5	na	na	1203.6	53557.4
1946	913.6	289.1	67.8	na	na	1270.5	54827.9
1947	1028.1	318.4	75.0	na	na	1421.5	56249.4
1948	1073.2	359.9	84.5	na	na	1517.5	57766.9
1949	1022.0	358.4	89.2	na	na	1469.6	59236.5
1950	1077	423	97	na	na	1638	60874.5
1951	1137	479	115	na	na	1776	62650.5
1952	1127	504	124	na	na	1803	64453.5
1953	1132	533	131	na	na	1847	66300.5
1954	1123	557	138	na	na	1872	68172.5
1955	1215	625	158	na	na	2050	70222.5
1956	1281	679	161	na	na	2185	72407.5
1957	1317	714	178	na	na	2278	74685.5
1958	1344	732	192	na	na	2339	77024.5
1959	1380	790	214	na	na	2460	79484.5
1960	1430	850	235	na	na	2597	82077.5
1961	1341	906	253	na	na	2587	84664.5
1962	1373	981	276	na	na	2723	87387.5
1963	1431	1054	300	na	na	2884	90271.5
1964	1481	1138	328	na	na	3055	93326.5
1965	1503	1220	351	na	na	3188	96514.5
1966	1524	1323	380	na	na	3350	99864.5
1967	1466	1421	409	na	na	3428	103292.5
1968	1497	1551	445	na	na	3636	106928.5
1969	1524	1669	487	na	na	3834	110762.5
1970	1577	1833	516	na	na	4092	114854.5
1971	1572	1944	553	na	na	4243	119097.5
1972	1584	2054	583	na	na	4406	123503.5
1973	1604	2238	608	na	na	4658	128161.5
1974	1613	2245	616	na	na	4677	132838.5
1975	1683	2131	621	na	na	4627	137465.5
1976	1727	2311	645	na	na	4895	142360.5
1977	1779	2391	668	na	na	5055	147415.5
1978	1795	2423	695	na	na	5136	152551.5
1979	1892	2527	730	na	na	5373	157924.5

Table 1. (Continued)

YEAR	SOLID FUELS	LIQUID FUELS	NATURAL GAS	GAS FLARING	CEMENT MANUF.	TOTAL	CUMULATIVE TOTALS
1980	1935	2412	718	na	na	5288	163212.5
1981	1947	2270	727	na	na	5159	168371.5
1982	1999	2162	727	na	na	5102	173473.5

na = not available; applies to gas flaring and cement manufacturing prior to 1950.

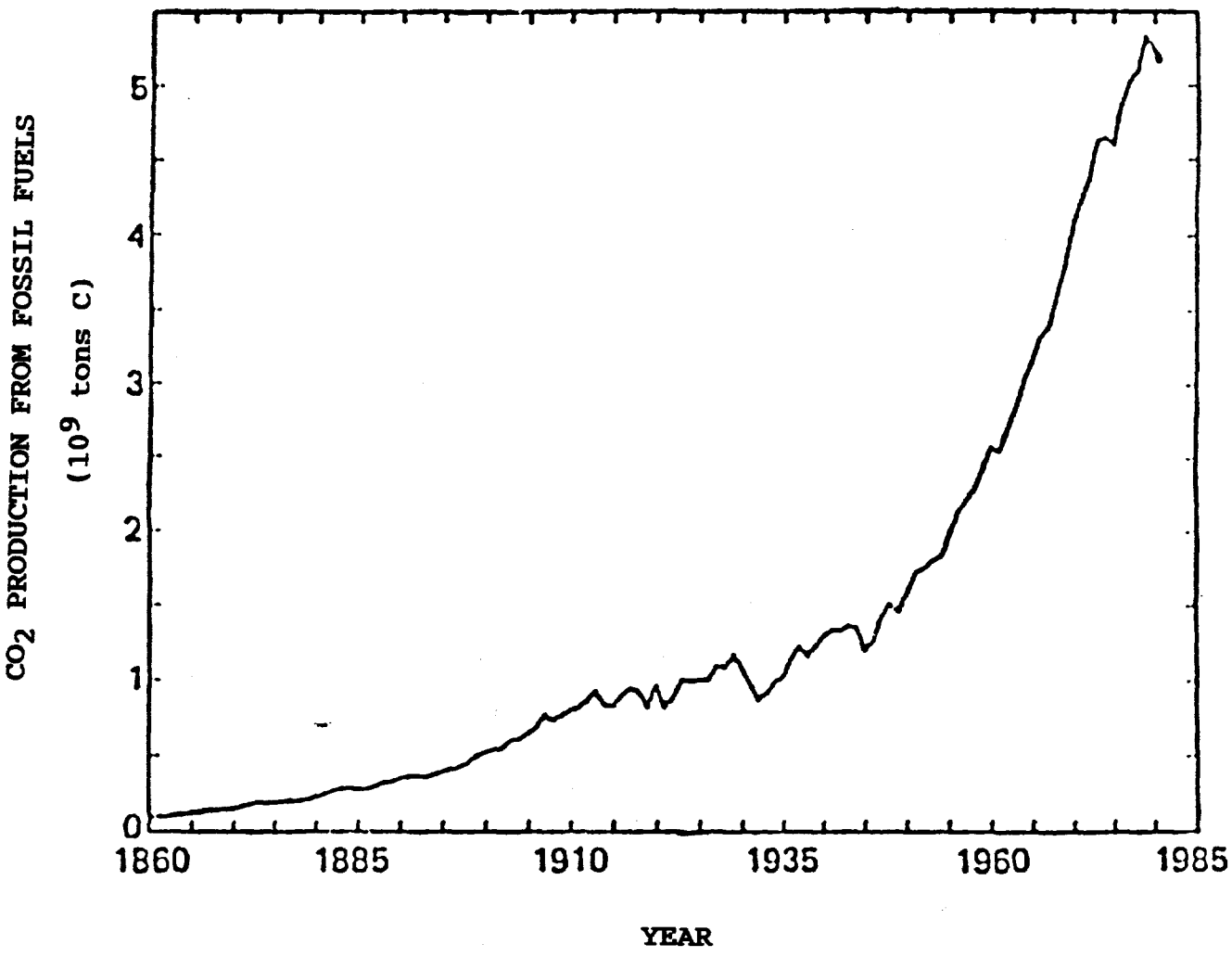

FIGURE 1. Production of CO_2 from fossil fuels and cement, 1860 - 1981. Annual estimates are derived from United Nations fossil fuel production data and are expressed in 10^9 tons of carbon.

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