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THE BRAZILIAN ENERGY SCENARIO AND THE ENVIRONMENT: AN OVERVIEW

by

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I

If one adopts the most elementary definition of energy as the capacity for the production of work, the impact of energy on the environment along man's history is in fact overwhelming: Almost all environmental problems, apart from some major natural disasters are, one way or the other, connected with energy utilization.

The use of purely mechanical energy produced by the utilization of water, by the wind's mass forces and by animal and human muscles, involving elementary work of typically a millionth of an electronvolt, shaped, for centuries, a pattern of life which, was only profoundly disturbed after the industrial revolution. In fact the use of combustion, in steam engines, corresponding to about a few ev per molecule, had as a consequence a millionfold dramatic increase of man's capacity to interfere with the environment (1). While mass mechanical forces were of course incapable of inducing purely chemical alterations, and hence of directly generating unwanted and/or useless residues, combustion of wood and later of fossil fuels, and the use of electrodynamic forces in producing other much more intense and diverse energy forms, unavoidably generates novel chemical species-both reactive or inert-that alter, the very material balance of nature. Thus the steady 2,3% growth in energy use, along the last hundred and twenty years, with a doubling time of about three decades, which increased at a not much lower rate than that of the planet's population, would finally affect our globe in both predictable and unsuspected ways (Fig. 1 energy growth for the world and Fig. 2 for the USA) (2, 3).

Thus during this century energy consumption has multiplied by almost fourteen times to reach 11.4 TW year, in 1988. Fossil fuel accounted for 88% of the total while the world economy grew by a factor of 20 and the industrial sector by a factor of 50. All in all 80% of this tremendous increase took place over the last 40 years.

Out of this total of commercial energy consumption, traditional energy utilization amounted only to 1.4 TW year as burned wood and waste. While the developing countries have at their disposal 0.4 kW per capita of installed potential the industrialized countries enjoy 7.8 kW per capita of installed capacity. At the same time the GNP of the developing countries, with a population of 2.3 billions (out of 5.32) inhabitants reached only US$920 billions while the richest group of countries, with a population of 0.7 billion had attained a GNP of US$9,310 billion. These facts indicate that energy, economy and environment constitute a system with strongly interacting components that must be dealt with in an integrated approach (4).

As already noted, it is indeed remarkable that while in a century the world population increased by 3.57 and energy use by 13.7 and hence at growth rates that are not of altogether very different. This leads to a worldwide rise of the per capita energy consumption smaller than generally reported, and, consequently, if it were not for the enormous technological advances that promoted increased efficiency in energy production and utilization, our earth would truly be an inhospitable place to dwell in as seen in Figure 3 from Marchetti (5) and Figure 4, calculated by the author from data presented by C. Starr (6).

The effects of energy use may be global or local, they depend both on the intensity, on the quality and on the end use and efficiency of the energy consumption.

Local uses while mostly detrimental to the environment, may also of course contribute to global disturbances.

Combustion of organic matter of both fossil and nonfossil origins, utilized for different energy purposes, leads to the production of obnoxious gases and of solid residues-most notably of CO_2, CO, NO_x, SO_2, of ashes and tars-as in coal and oil-fired generating plants, and as gas emitted by internal combustion motored vehicles, all producing local, regional, and more and more global impacts. The relative contribution of these two sources to the CO_2 emission can be seen in Figure 5 where the biomass participation could be ascertained by C_{14} measurements in tree rings. This participation has been overcome by fossil fuels only after the 2nd world war (7).

As well known, in considering the effects of increasing world industrialization, S. Arrhenius (8), relying on the findings of Tyndall on the CO_2 infrared absorption, has anticipated in 1896 the warming up of the globe via the so called "greenhouse effect" (9). It can be seen that as compared to pre-industrial epoch the CO_2 concentration in air has increased from 280 ppm to about 330 ppm, causing public preoccupation with the intensification of the phenomenon and thus instigating respectable international scientific circles to predict catastrophic effects, that would result from a 2°-3° C increase, by the year 2025, if the present rate of anthropogenetic CO_2

generation was not curtailed by different internationally agreed upon measures (10). To this end a number of scenarios have been proposed as shown in Table 1. The increasing concentration of another greenhouse gas - CH_4 -, to be discussed later, is also shown in Figure 6 (11) and in Figure 7 (12).

Apart from global warming it should be stressed that probably as serious as the overall heating, are the ensuing inducement of differential thermal distributions which may entail dramatic climatic changes-to be followed by correspondingly large economic and social disturbances (13). Disregarding for the moment the possibility that the warming up of the globe might result from the increased impinging radiation characteristic of the last 100 years of intense solar activity (14) and that, the augmented atmospheric dust pollution from volcanic origin, may even counteract the greenhouse warming, with the consequent cooling the earth for considerable time, one should retain the effects of greenhouse gases as real and preoccupying.

In addition to CO_2, mention should also be made of the deleterious effects of NO_x and of SO_2 emissions, both in coal or oil burning energy producing plants, and by low quality fuel burning vehicles and stationary diesel engines, that, after chemical oxidation in air, are land deposited, severely affecting agriculture and forests in many countries. Apart from local incidence, these pollutants are relatively of lesser importance for Brazil, thanks to the major participation of hydroelectric power generation and the sizeable utilization of alcohol fuel to drive about 4 millions cars (Table 4) (15). A recent thorough survey on this effect in Europe reports the relative sensitivity of its ecosystems to acidic depositions (15).

Agriculture, animal husbandry, microbial anaerobic decomposition and/or the fermentation of biomass in paddy fields, in marshes and the digestion of ruminants, generate gases (in addition to CO_2 and CO, typical of the first process), such as CH_4 (methane) that directly (CH_4) or indirectly (CO, via interaction with $OH^{\bullet}$ radicals) contribute to deplete the atmospheric ozone layer, responsible for the absorption of the ultraviolet emissions from the Sun. These are proved to adversely affect live matter on the earth's surface. Although the contribution of these natural and anthropogenetic gases is sizable, as shown in the Table 2, the real culprits are the CFs (fluorocarbons) acting as powerful scavengers of Ozone forming radicals. Figure 8 illustrates the main contributors to global warming and ozone layer depletion (12).

To sum up the relative contribution of the greenhouse gases are as follows: CO_2 (46%), chlorofluorcarbons (24%), CH_4 (18%), ozone (7%), and NO_x (5%). While chlorofluorcarbons are of recent employment lending to atmospheric concentrations of about 1 ppb, its contribution to the greenhouse effect is 15,000 bigger than CO_2.

The measures proposed to face the warming up effect presently accepted as most probably originating from the greenhouse effect-induced mostly by anthropogenetic CO_2 - would entail, among other initiatives to promote:

1. Stringent conservation measures.
2. Voluntary and/or enforced reduction of emissions.
3. Increased utilization of natural gas.
4. Intensification of renewable biomass use.
5. Afforestation.

6. **Utilization of hydroelectricity.**

7. **Increased use, world wide, of nuclear energy.**

1. **The stringent conservation measures** via saving technologies both hard and soft, through the appropriate enforcement of policies for energy use and management. Energy conservation policies and management imply: i) intensified training of experts; ii) study and analysis of existing energy sources; iii) development and testing of improved and new technologies and systems; iv) implementation and application of improved new technologies; v) information and education of the public; vi) and, most important, the political willingness to promote administrative intervention in the form of legislation, rules and regulations. All technological and nontechnological, active and passive energy conservation activities can be assigned to one of three categories "energy saving", "rational use of energy" and "substitution of energy sources".

   All these measures demand close examination of the overall situations. A primary consideration would be the close scrutiny of the primary energy consumption pattern along time, in each country and/or region, such as the one shown for Brazil in figure 9.

2. **The voluntary and/or enforced reduction of emissions.** A taxation proportional to a country's emission has been proposed in many quarters. Admittedly enforced reductions of detrimental emissions would entail the creation of strong international agreed upon mechanisms of dubious efficacy, probably to be plagued by sundry political controversies.

3. **The increased utilization of natural gas,** directly or hydrogen enriched through, for instance, an approach first suggested by

Marchetti (3, 16). For the specific energy content of a fuel increases with its hydrogen content relative to carbon.

In any case the feasibility of this approach is contingent on heavy investments in capital, in technology, and-all important-in the solution of the pertinent nuclear reactor safety problems, indispensable to ensure public support (Table 3).

The global energy system is extremely inert, sluggish so that any measure to be taken to significantly alter the prevailing pattern shall demand much time and effort.

Bearing in mind the sequential energy substitution model shown in Figure 10, gas shall constitute the main primary energy source in the future. This increasing dominance of natural gas shall be in 20 years responsible for about 50% of the total CO_2 emission, as displayed in Figure 11 due to Marchetti.

4. **The intensification of renewable biomass use**-as in the Brazilian Alcohol Programme, which represents today 13,0% of our energy consumption..
5. **Afforestation.** The cultivation of 1 trillion trees, covering about 5 million square km is deemed to be necessary to significantly alleviate the warming up effect. The land surface to be covered reaches the area of the whole legal Amazon Region...

   Brazilian Floran Project, sponsored by the "Instituto de Estudos Avançados" (University of S. Paulo), is supposed to attain 20,000 sq km.
6. **The utilization of hydroelectricity** as a renewable energy source on which comments will follow further on. Its important

relative participation on the Brazilian matrix is shown in Table 4.

7. **Increased use, world wide, of nuclear energy.**

Regarding the last item one should keep in mind that the use of nuclear energy implies again an enormous technical revolution because another 40 to 50 million jump in energy intensity (200 million ev per fission), as compared to combustion energy, has to be dealt with (1).

In any case as one shall see, nuclear energy already represents about 18% of the world electricity generation and 5-6% of the total energy bill, its market penetration despite public resistance to its use, being according to Marchetti truly irreversible (3, 17) (Figure 12).

Regarding the measures so far adopted by the international community to deal with the ozone layer depletion problems are in a much more advanced stage than those to deal with the greenhouse effect, a protocol having been agreed upon at Toronto, which was ratified so far by a number countries.

II

After these introductory remarks consideration should now be given to some pertinent and more quantitative data.

The primary energy substitution world wide for about a dozen decades is shown in Figure 10, taken from a study conducted by Marchetti at the International Institute for Applied Systems Analysis (IIASA) (2, 3). It displays interesting features which hopefully will facilitate the examination of the problem at hand. Thus it is remarkable that:

1. Firstly, by 1860, biomass energy in the form of wood, represented almost 75% of the world primary energy, coal accounting for the balance. By 1950, that is to say in about 90 years, biomass participation amounted only for less than 5%.
2. On the other hand, coal utilization was maximum by 1928 (70%), reducing subsequently its participation to 25%, in 1985, which is the same level it displayed 120 years before, in 1865..
3. Oil started its penetration by the last decade of the XIX century, to peak 88 years later, in 1978, and, since then, with a steady tendency to reduce its participation.
4. Gas, introduced about 10 years later than oil, is still increasing (present share ~15-20%) and is anticipated to become the dominant primary energy source for the next 50 years.

These observations seem to constitute valuable indications:

a. Primary energies have been introduced into the market sequentially **with large time constants-taking about 50 years to have their market share reduced from 50% to 10%.**
b. The world energy system seems to obey a kind of internal, hard logics, irrespective of classical market monetary forces. Apparently two world wars and the 1930's major economic crisis seem to hardly have affected its inner workings, deviations from the predictive smooth lines amounting to less than 5%. Obviously the specific energy content of each fuel increases from wood to coal to oil to gas, that is with higher H/C

ratio. One may predict, as remarked above, a greater use of natural gas (> 60% by 2030), and surmise that pure hydrogen, or in mixture with natural gas, may emerge as a fuel, perhaps, according to Marchetti, via the thermolysis and/or the shift reaction of water and gas, in specially built high temperature nuclear reactors (16), according to a scheme shown in Figure 13.

Incidentally Marchetti rightly argues that should this technique come true, humanity would eventually mimic photosynthesis and thus disconnect itself from our Sun, a welcome solution to all. The remaining major culprits are the inevitable nuclear wastes, which according to Marchetti may not affect the irrevocable market penetration of nuclear energy illustrated in the Fig. 12.

A final reminder on Figure 10 is that it is no more than a mere snapshot depicting the energy situation prevailing in 1985: both population and energy consumption, since then, have been growing world-wide at approximately the same ~2,3% or, at a lower pace, due to recession to reach the presently observed 11.4 TW year referred to above in Table 1, taken from W. Häfele. It sums up not only the current world situation and also displays different scenarios that have been envisaged to somewhat freeze the CO_2 emission (18).

It is to be hoped that conservation measures and mainly technological advances may, as in the past, increase the efficiency of energy utilization, to permit the fulfillment of the more optimistic scenarios. In fact examination of scenarios cited in reference (2), in 1976, and shown in Figure 14 and 15 for two hypothesis of 4% and 15% of nuclear participation by the year 2000, would have considerable repercussions on the world energy balance, putting special pressure on gas resources as demonstrated in Table 3. By the way, nuclear and gas generated energies seem to constitute major interlinked contributions to the abetment of the greenhouse effect.

In fact as shown in Figure 16, taken from an analysis of different energy sources by Marchetti, already by the year 2010, 50% of all CO_2 emissions must originate from natural gas burning. Gas availability will depend both on increased reserve discoveries and, perhaps, critically, on the intensity of future nuclear energy use (Fig. 15).

The examination of the Brazilian primary energy consumption by source from 1941 to 1985 is presented in Table 4 and displayed in Figures 9 and 16. Figures 17-18 and Table 5, cover not only the 1973-1989 time span, but also prospects for year 2000 (World Energy Conference Ex. Committee Meeting).

Again, in close similarity to the world situation previously scrutinized:

1. the same behaviour pattern seems to operate in Brazil, though primary energy introduction occurs at a much faster rate, as shown in Figure 9, representing the evolution of total energy utilization in Brazil from 1970 on to 1985 (B.E.N., 1987). The observed rate of 4.3 to 7.1% per year varies at about twice the world consumption pace. Returning to the previous Figure 9 it can be anticipated that: i) as in the international scenario the relative participation of oil, in the national energy balance shall steadily decrease, perhaps to about 25% in ten years. This perspective is largely shared in a document prepared by the

National Committee for the World Energy Conference (19 and 20); ii) firewood and charcoal participations also decrease from 15% in 1988 to about 10% or little more 10 years period. It will probably take some 20-30 years for Brazil to reach the present world average biomass share, provided that the present 2.6% p.a. rate of reduction for firewood utilization is maintained, and that charcoal production be increasingly originated from cultivated forests via the use of the well known pyrolysis and/or of continuous carbonization-distillation techniques. This technology is presently under development by the ACESITA company. Its use would increase the yield of charcoal from 40% to more than 70%, apart from the recovery of other valuable gases and volatile products (21, 22, 23).

Extrapolation for charcoal and firewood's participation of 6-7% by 2006 would still represent a very important share of our energy balance since at that occasion, an equivalent consumption of 21×10^6 t.o.e., would still prevail, as compared to the 27×10^6 t.o.e. used in 1985.

iii) While coal as an energy source has had a modest increase from 0.9% to 1.4%, in 15 years (1970-1985), metallurgic coal's share has significantly grown from 2.6% to 3.9%, during the same period. The upward inflexion-shown for coal subsequent to the 1973 oil crisis, may well reflect the strong government incentives to replace oil particularly, in the cement making industry (Fig. 9). As expected the cessation of these incentives has reverted the situation to the long term relative reduction in coal utilization behaviour observed world-wide.

iv) Electricity participation will also continue to grow, certainly at a lower rate than in the past, when it reached rates as high as 12.3%/year in the 70's, to place the country as the 7th producer of electricity in the world (200 TWh in 1986)! If trust is to be placed in the Brazilian 2010 Plan, for the total consumption of electricity (364.4 TWh), the country shall be ahead of Italy and of England by the year 2000, provided a 6.3% p.a. rate of consumption is obtained in 1990-1995 and that a 4.5% p.a. rate of growth is attained, in the 1995-2000 period (19).

Actually the historical evolution of Brazilian installed electric potential and hydroelectricity production shown in Figures 19 and 20, covering the 1914 to 1985 (installed) and 1940 to 1980 periods (production), allows for an extrapolation to only 270 TWh, for the year 2000, a figure much more conservative than the 2.2 growth factor in 14 years assumed by the Eletrobrás planners, cited above (19).

In Figure 19 it is shown that only about one fourth of the existing potential of 230 GW has been installed.

Social and political controversies connected with the construction of dams, with the consequent flooding of land, particularly in the Amazon Region, are anticipated (~100,000 sq. km), if the major power plants under construction, those undergoing expansion, as well as those under the studies and design phases, depicted in Figure 21 are effectively installed in our country. This figure includes both the Angra I, II, and III nuclear plants (3,307 MW) as well as a number of coal-fired stations in the South (H = hydroelectric; N = nuclear; T = thermic).

The installation of these plants would lead to considerable firm power flow between regions in the country, as shown in

Figure 22, with consequent impacts of the extended projected and/or existing power transmission lines (19).

In any case hydroelectricity will certainly play a major role in the future Brazilian energy consumption and production. In fact increased electricity consumption is a worldwide tendency.

To sum up: the energy consumption pattern in Brazil displays in actual fact one of the largest renewable energy participation in any world's national systems. In fact as can be observed in Figure 23 and Table 6, hydro, sugar-cane (alcohol, sugar, and bagasse), and firewood consumptions increased by a factor of 3 in 15 years, from 39,143 x 10^3 t.o.e., in 1970, to 106,009 x 10^3 t.o.e., in 1985, representing respectively 58.7% and 61.3% of the total consumptions of 66,712 and 172,946 x 10^3 t.o.e., at these dates..

It should however be noted that a large share of the firewood consumed originated from natural forests and, therefore, can not be strictly considered as **truly renewable**. For a ~60% non-renewed contribution, a corresponding to 20,000 x 10^3 t.o.e. would lead to a CO_2 injection, in an amount reaching the same order of magnitude as that associated with the renewable energy produced by the sugar-cane cultivation (22,653 x 10^3 t.o.e.). These numbers do point out to the need for exercising a major effort in afforestation. The more so, since this destruction is basically effected in the "cerrado" (savanna), a region covering ~1.5 x 10^6 sq. km. of the country's area, which as a consequence remains the most adversely affected ecosystem in Brazil.

The CO_2 emission problem in Brazil is, of course, further aggravated by the ongoing destruction of the rain forest which now is at a slower pace, particularly in the Amazon Region. These activities together with the combustion, in 1988, of oil (44,263 t.o.e), coal (6,113 t.o.e.), gas (2,249 t.o.e.), charcoal (6,538 t.o.e.), and firewood (17,847 t.o.e.) - all X 10^3 the last two being partially renewed (42% for charcoal and 33% for firewood (24)) all contribute considerably to Brazil's share in CO_2 emission.

The Brazilian carbon emission situation prevailing in 1987 results from a total of 68.26 X 10^6 t.o.e., which includes in addition to oil, coal and natural gas the contribution of firewood and charcoal that in all would lead to minimum emission of 68 X 10^6 ton C/year which correspond to a little more than 1% of the total world CO_2 emission, thanks to the hydroelectricity, alcohol fuel, and other biomass contributions to the Brazilian energy matrix. These numbers - given remaining uncertainties on the pertinent data - are in reasonable agreement with recent results reported by Pinguelli and collaborators in 1990 (26).

Since then the situation has improved as seen in Table 5, for 1988 (19), and for 1990.

Anyway the above data does not include the contribution of the present forest burning in the Amazon which involves about 13,800 km^2/year, for 1990, and 11,130 km^2/year, for 1991 - (INPE), to the CO_2 emission. Uncertainties remain regarding the carbon emission contributions as a result of inhomogeneities in the biomass distribution in the Region. Estimates have however been made to indicate that about 4 to 5% of the total world emission results from forest burning in the region (25, 26, 28).

It is hoped that the present meeting will offer an opportunity to throw some light on the real quantities involved in the tropical forests destructions contribution, for certainly its reduction constitutes, in the coming years, together with energy conservation, increased hydroelectricity use, alcohol production, afforestation and intensified natural gas utilization, the main fields for action to abate global atmospheric pollution in Brazil. Admittedly recession as well as lack of a clear energy policy have not allowed for a more determined implementation of these measures.

These objectives shall however be attained only through the adoption of policies permitting the developing countries, like Brazil, access to credit, benign technologies and reduction of commercial barriers to their products. These measures finally would allow for a sane and greater energy utilization for, as we know progress is, as in the past, inescapably dependent on energy use.

Before closing these remarks an anticipation of the consequences that might result from the greenhouse effect is shown in Figures 24 and 25, where the impact of a heat wave which stroke Marseille in the Summer of 1983, has lead to an increase in the mortality rate by 28%. Surprisingly enough the mortality X inverse of the absolute temperature relationship obeys Arrhenius' Law for rate processes (27).

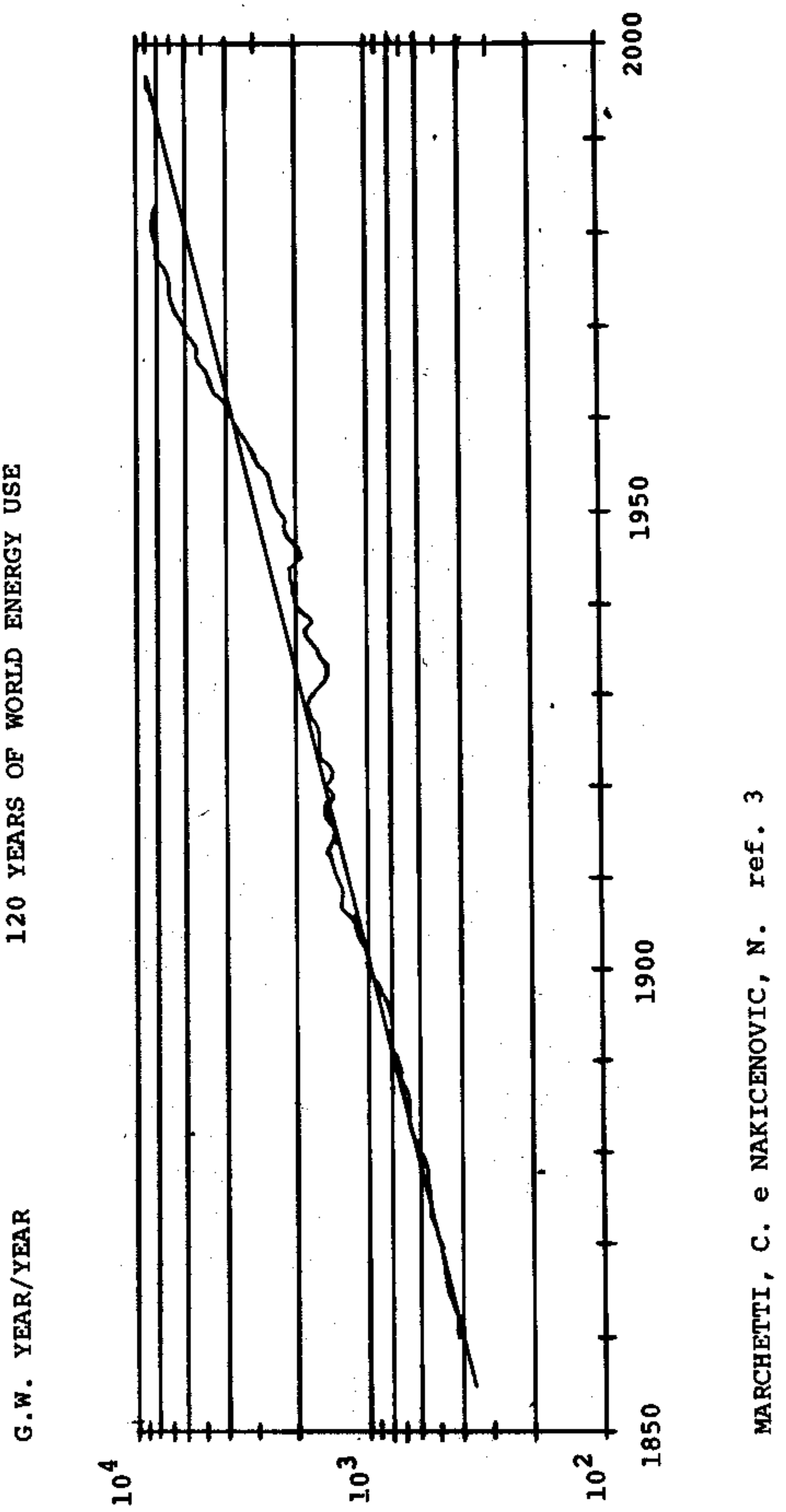

120 YEARS OF WORLD ENERGY USE
G.W. YEAR/YEAR
10^4
10^3
10^2
1850
1900
1950
2000
MARCHETTI, C. e NAKICENOVIC, N. ref. 3

FIGURE 1

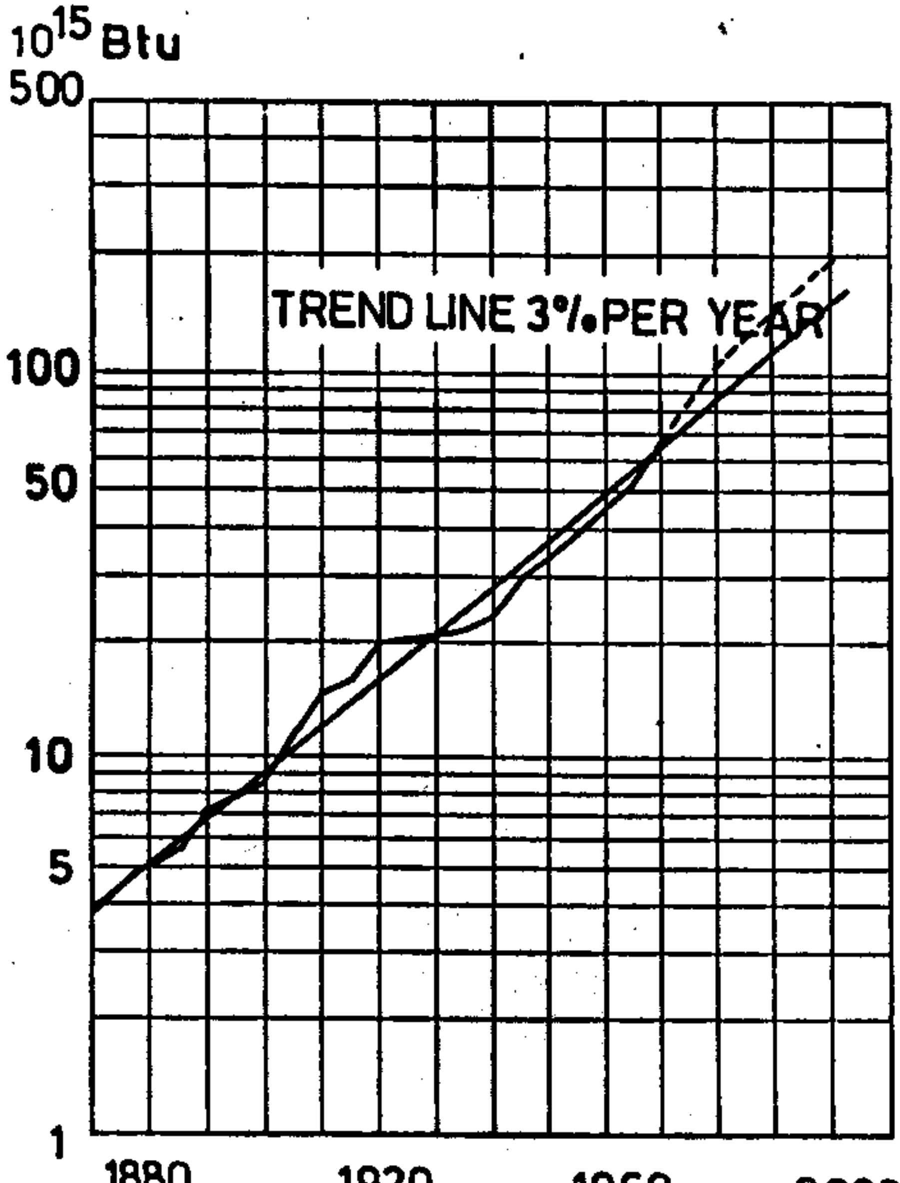
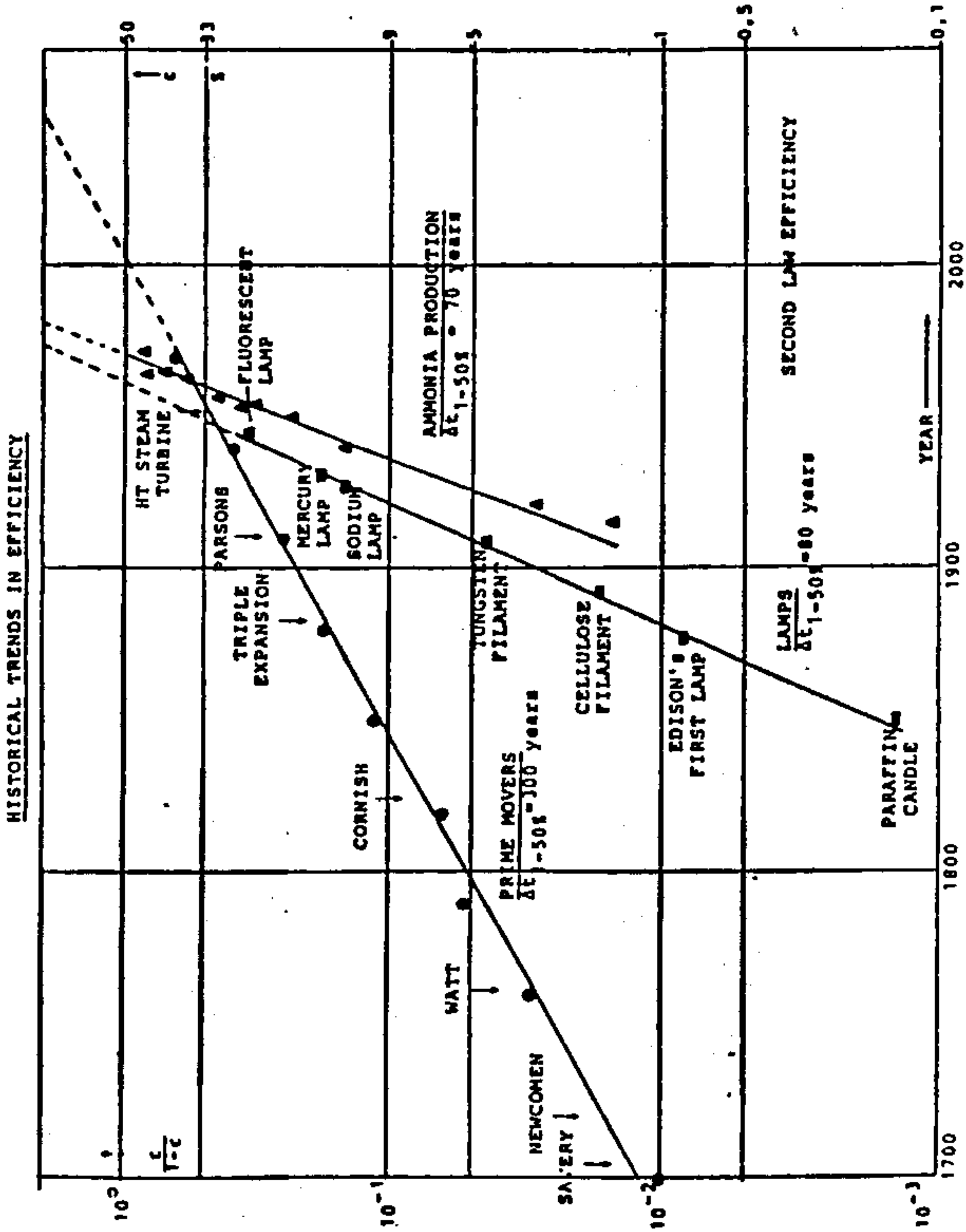


Figure 2: U.S. total energy consumption (ref. 2)



Historical evolution of efficiency ε for three technologies. Δt is the time for efficiency to go from 1% to 50%.

FIGURE 3 (ref. 5)

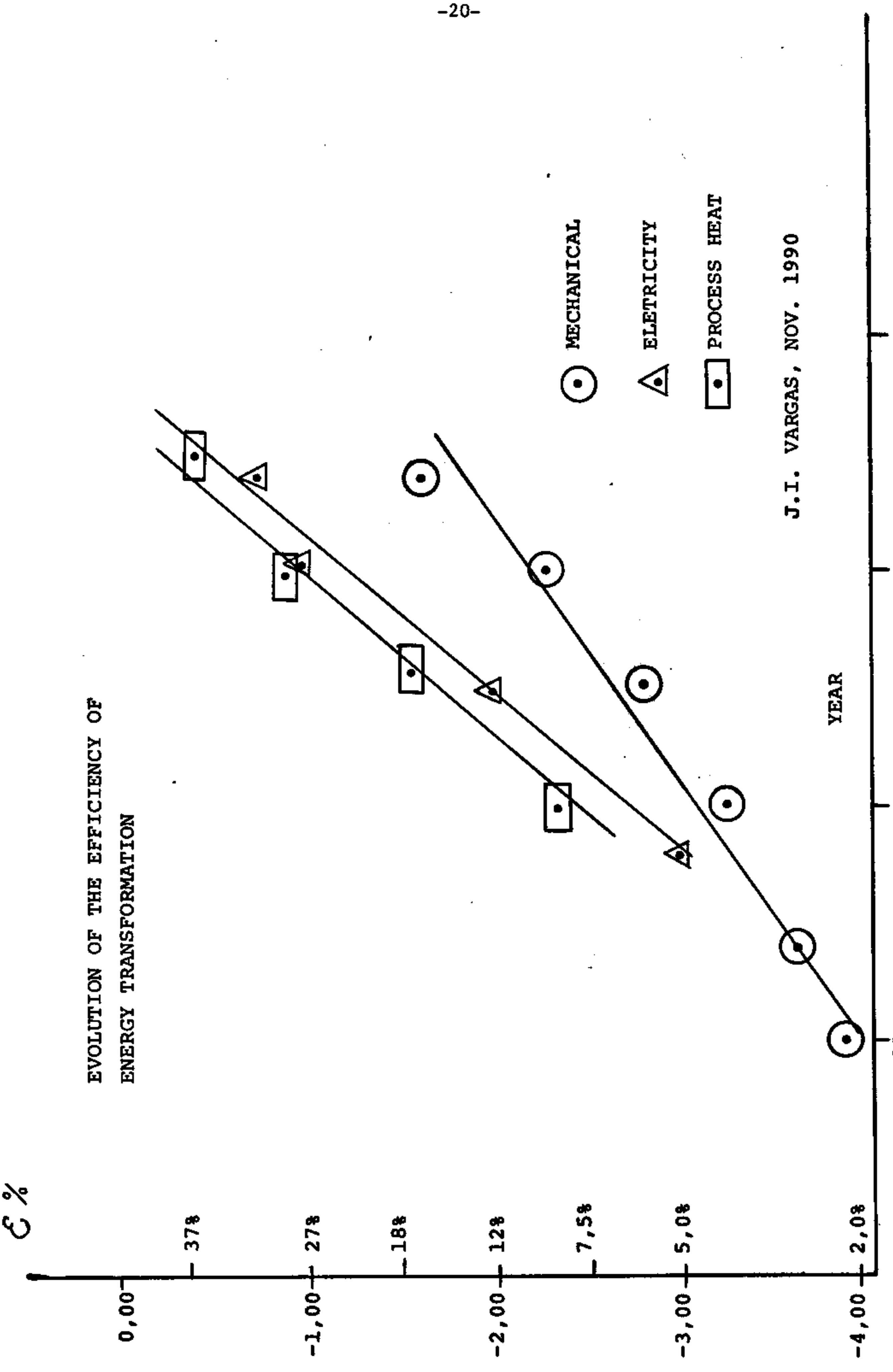


FIGURE 4. Calculated from ref. 6

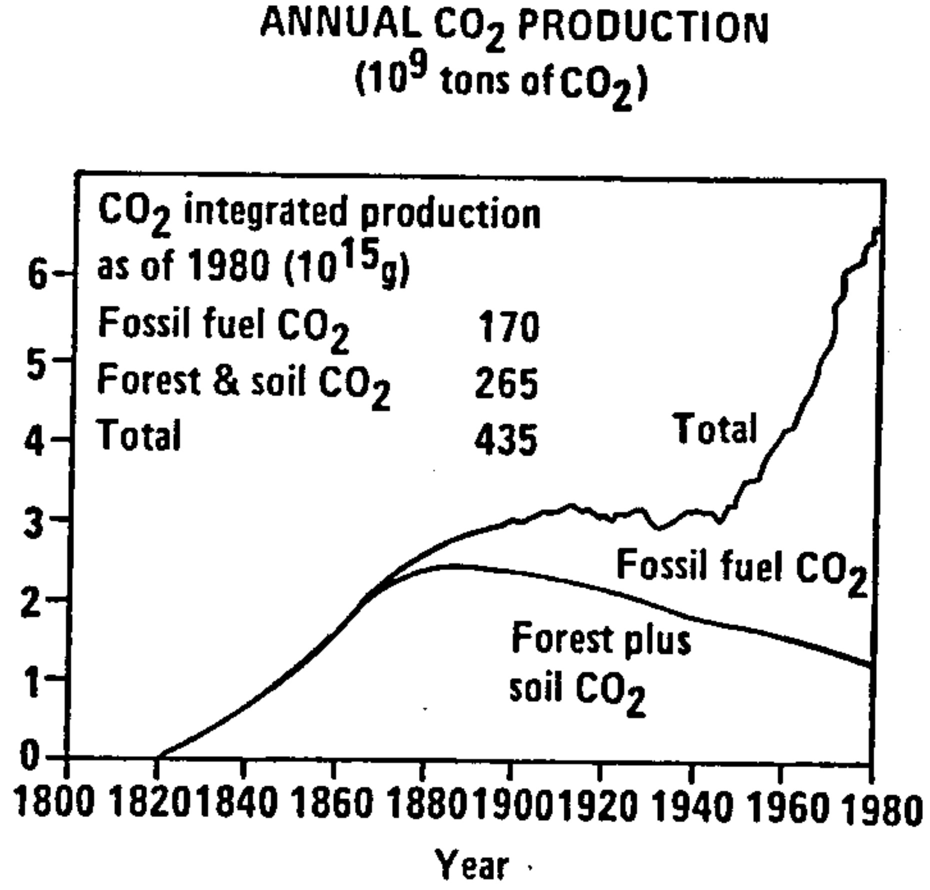


FIGURE 5 Knowledge of the fossil CO_2 emissions and analysis of tree rings for ^{14}C and ^{13}C permits a reasonable reconstruction of the amounts of CO_2 put into the atmosphere by changes in the level of carbon storage in standing forests and soil. From these calculations it appears as the integrated amount of CO_2 that burdens CO_2 levels in air, is due mostly to activities related to agriculture and forests. Only after World War II emissions from fossil fuels have become dominant. (ref. 12)

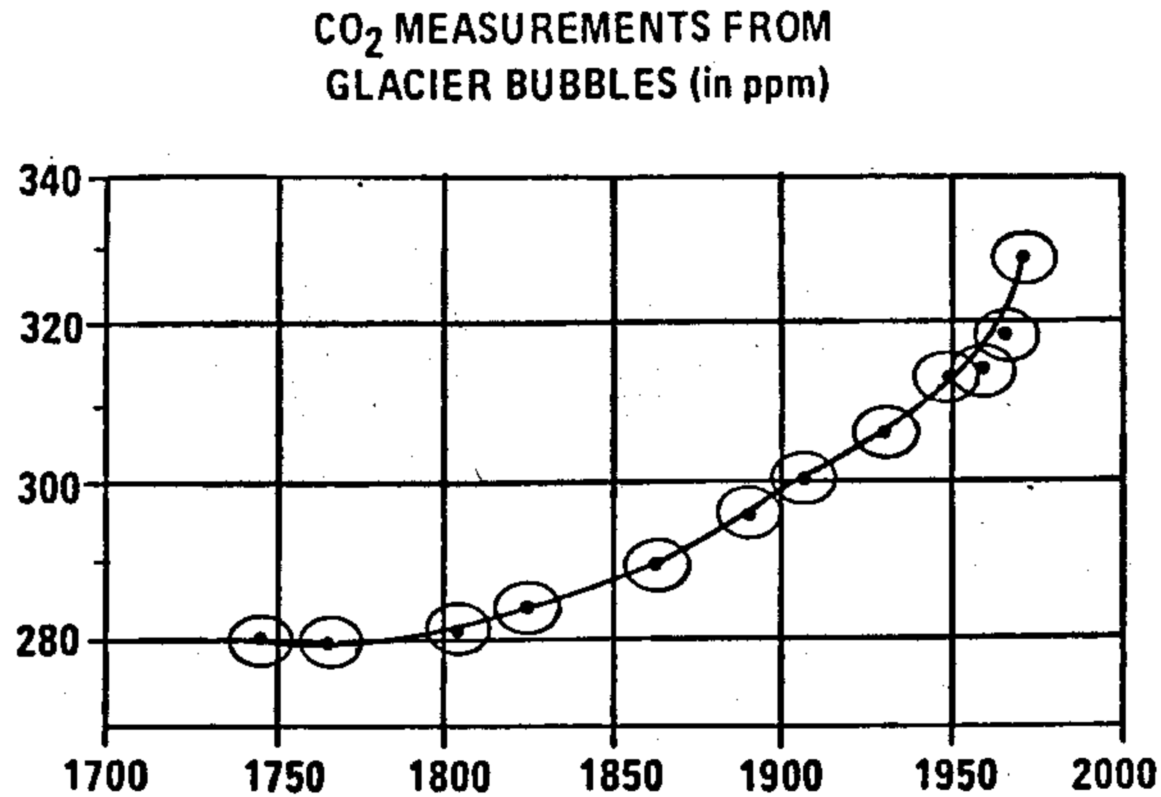


FIGURE 6 Historical series of the concentration of CO_2 in air can be produced *today* by looking at air bubbles trapped in glaciers. This methodology may permit to go back perhaps 100,000 years and compare CO_2 levels with prevalent climatic situations that can be evaluated by various types of analyses of sediments (and tree rings for the last 1500 years). This reconstruction may help calibrating the climatic models over which much of the CO_2 controversy is based. (ref. 12)

ENERGY POLICY AND ENVIRONMENTAL POLLUTION

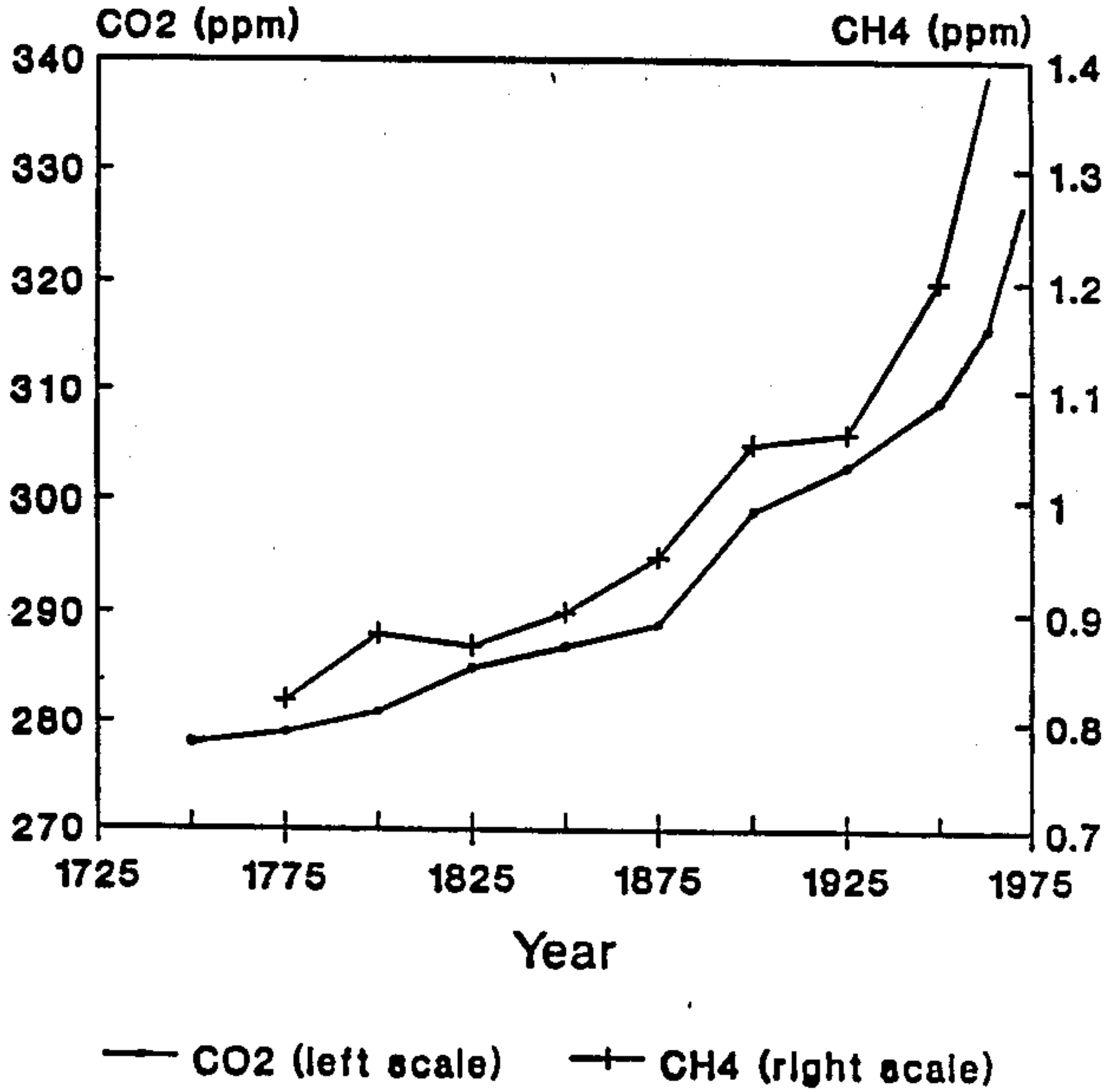


Figure 7 *Long-term atmospheric concentrations of* CO_2 *and* CH_4. (ref. 12)

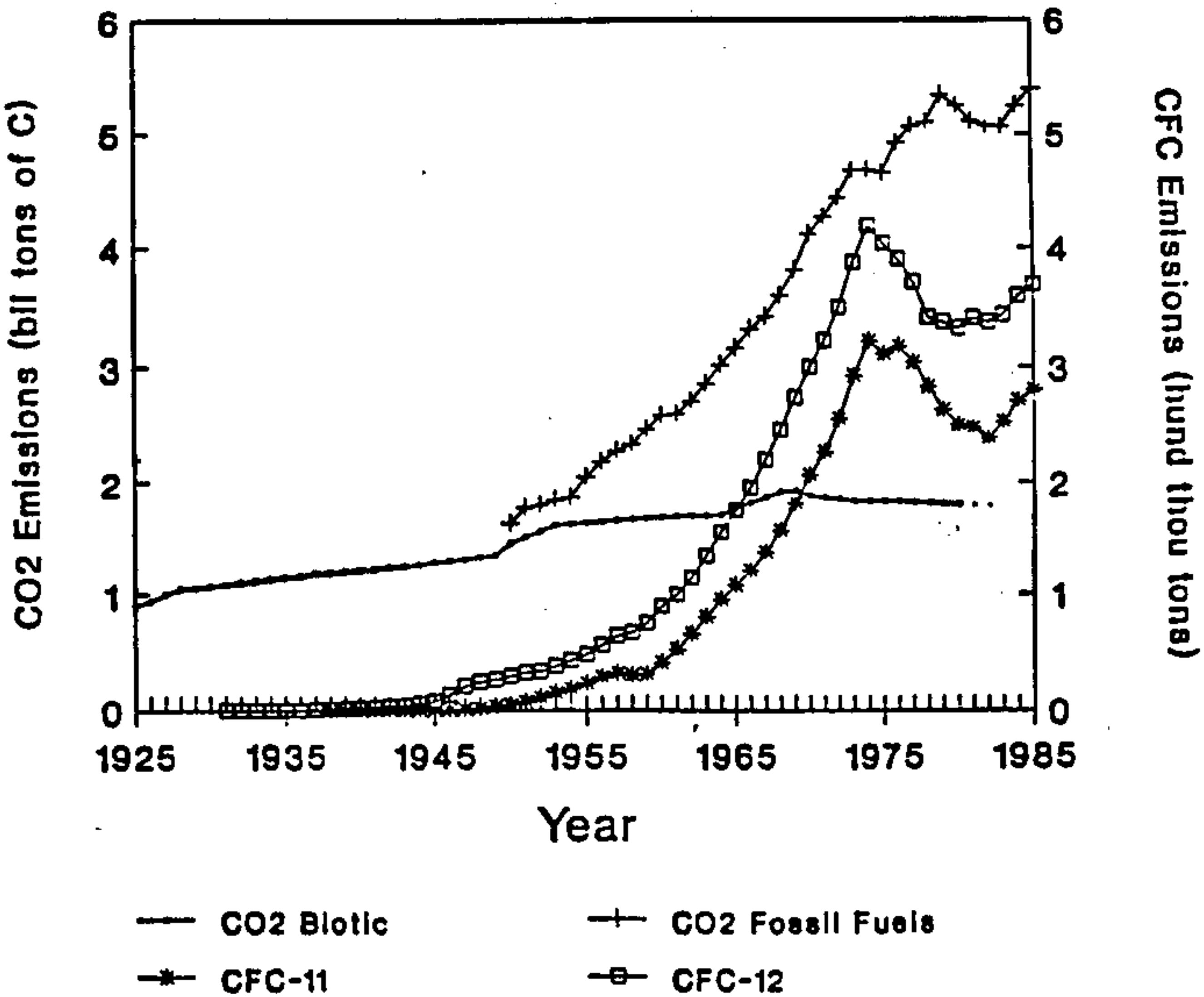


Figure 8 *Major contributions to global warming and ozone depletion*. (ref. 12)

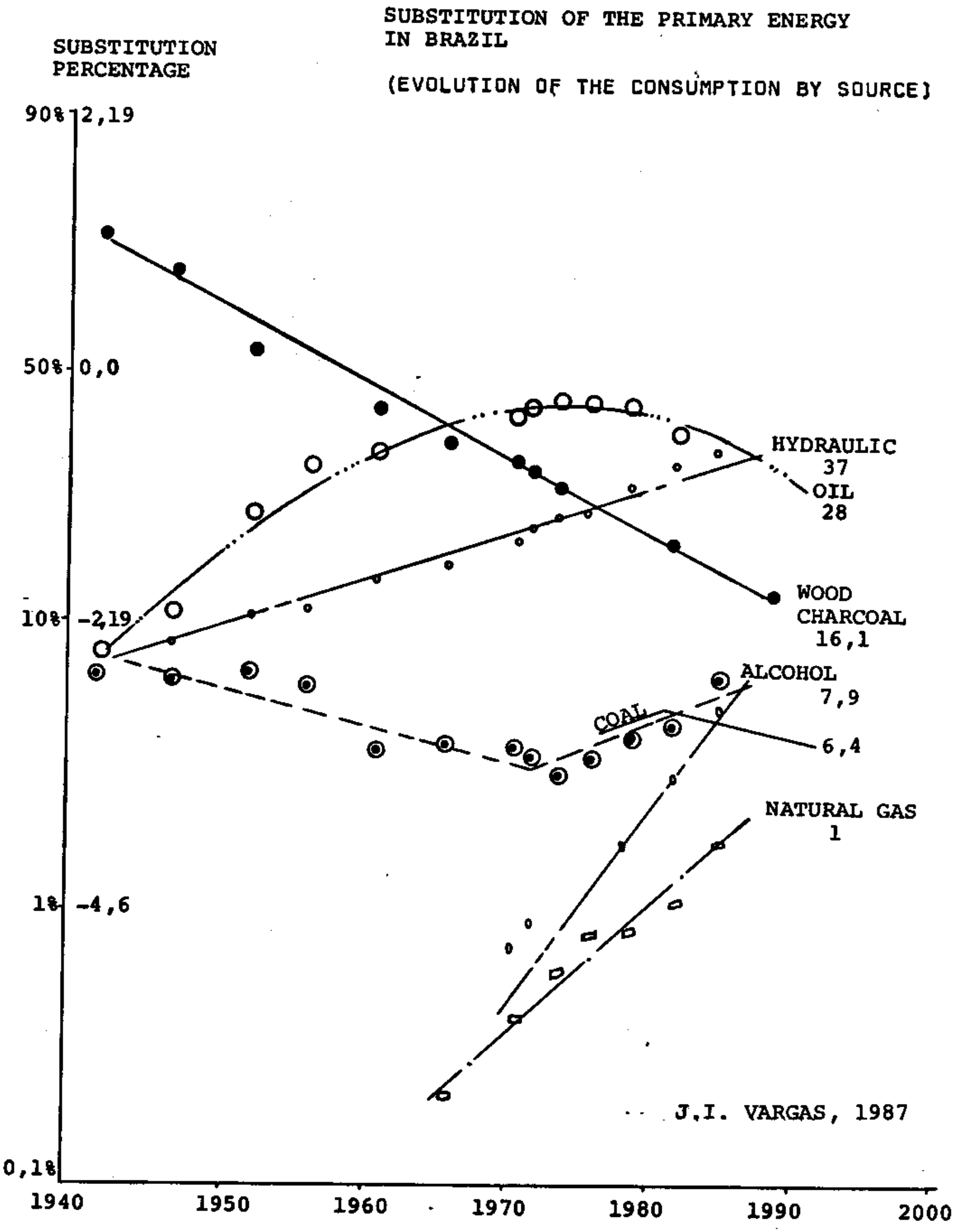

SUBSTITUTION OF THE PRIMARY ENERGY IN BRAZIL
(EVOLUTION OF THE CONSUMPTION BY SOURCE)
SUBSTITUTION PERCENTAGE
90% 2,19
50% 0,0
10% -2,19
1% -4,6
0,1%
HYDRAULIC 37
OIL 28
WOOD CHARCOAL 16,1
ALCOHOL 7,9
COAL
6,4
NATURAL GAS 1
J.I. VARGAS, 1987
1940
1950
1960
1970
1980
1990
2000

FIGURE 9

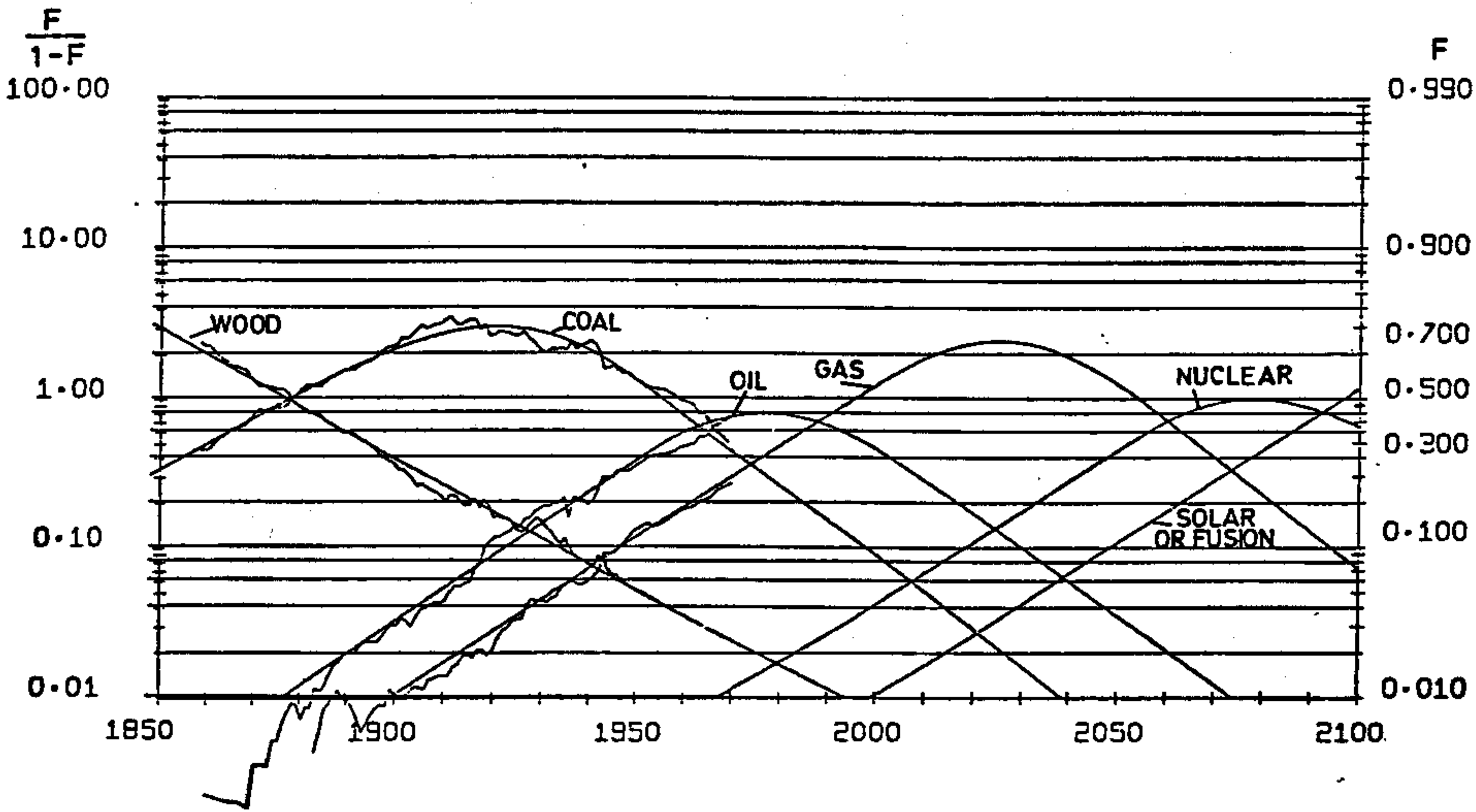


FIGURE 10 World with slow nuclear and hypothetical new source in year 2000 (From Nakicenovic). (ref. 3)

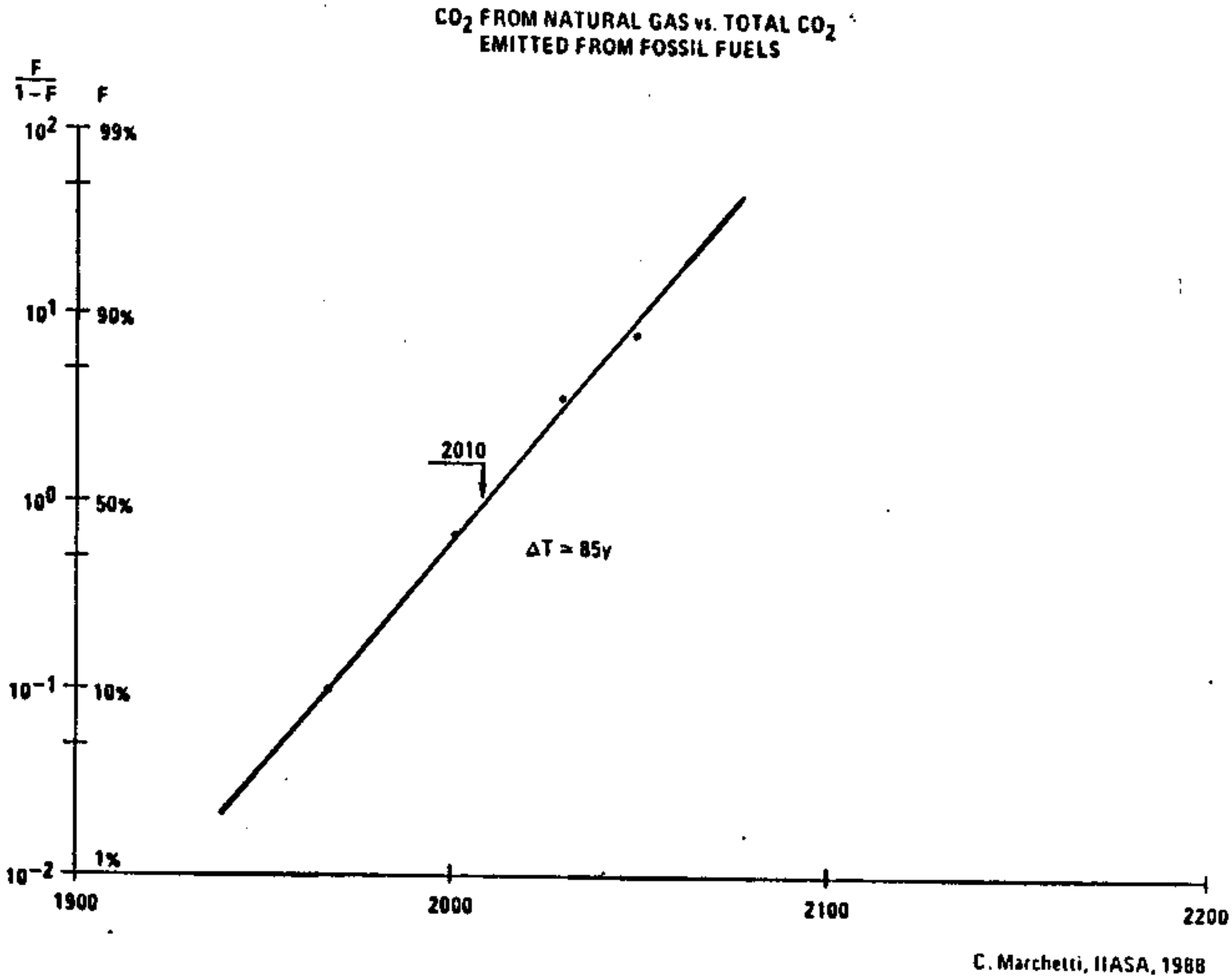


FIGURE 11 We can use again the concept of substitution to the "penetration" of CO_2 emitted by burning natural gas by respect to the total CO_2 emitted by burning fossil fuels. Because of the increasing dominance of this fuel, 50% of the CO_2 emitted will come from it already in 2010. This shows that processes for controlling CO_2 emissions to the atmosphere should concentrate on natural gas. (ref. 17)

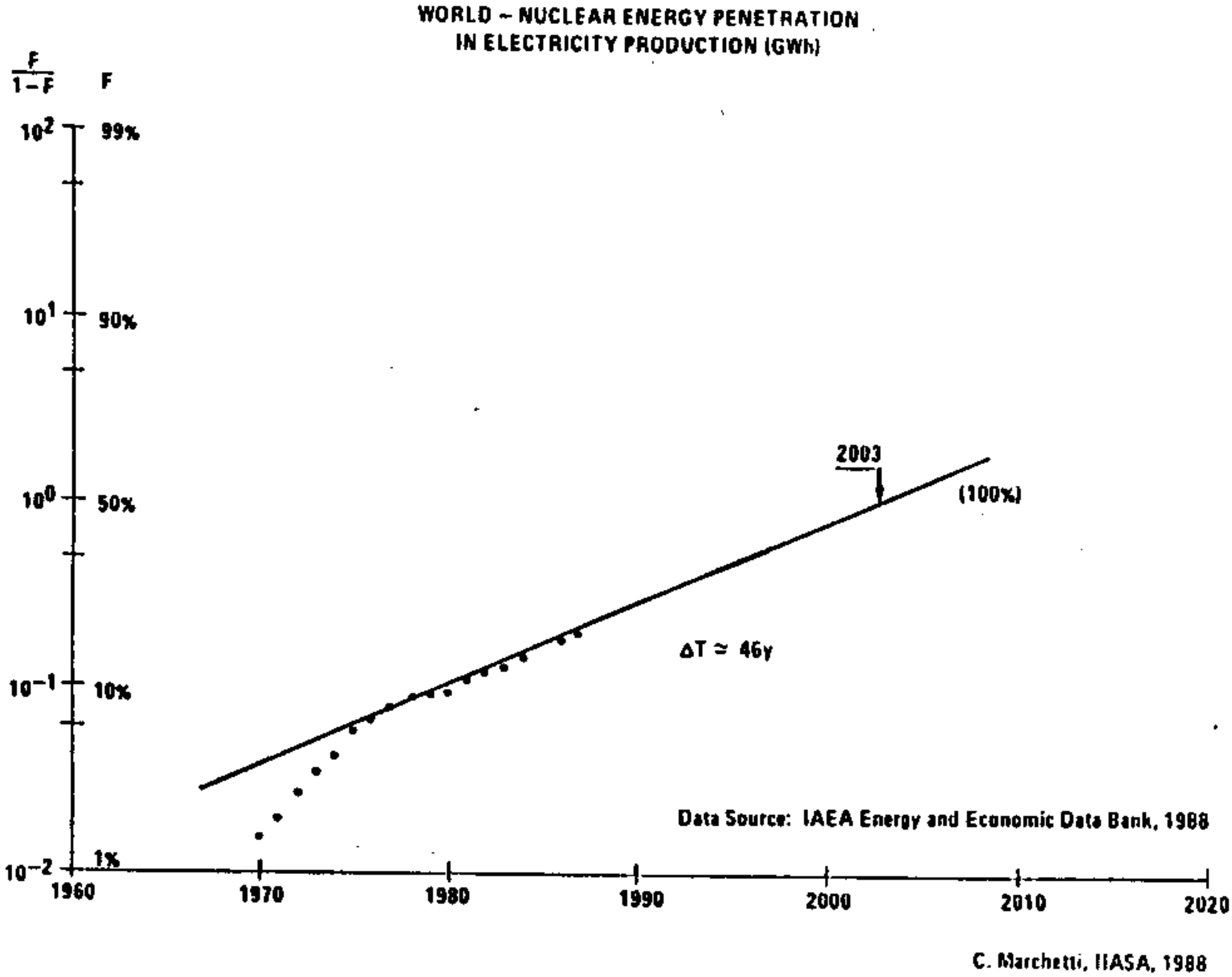


FIGURE 12 Nuclear energy penetration in the market of electricity production (GWh) is here reported. In spite of the very moody descriptions, the situation does not seem to be bleak. Penetration proceeds at a slow but consistent pace and has reached (1987) about 18% of all electricity produced (including hydro). The fitting is done assuming a 100% penetration as a maximum level. The low penetration level reached to date impedes the calculation of a more realistic saturation point (75%?). The analysis is at world level. The chart shows that by 2020 the "conquest" of the electrical system will be substantially concluded, and that, if penetration has to follow the lines of Figure 4, new very important uses have to be found in the meantime.
MARCHETTI, C. (ref. 17)

REFORMING PLANT

Gross Energy Balances

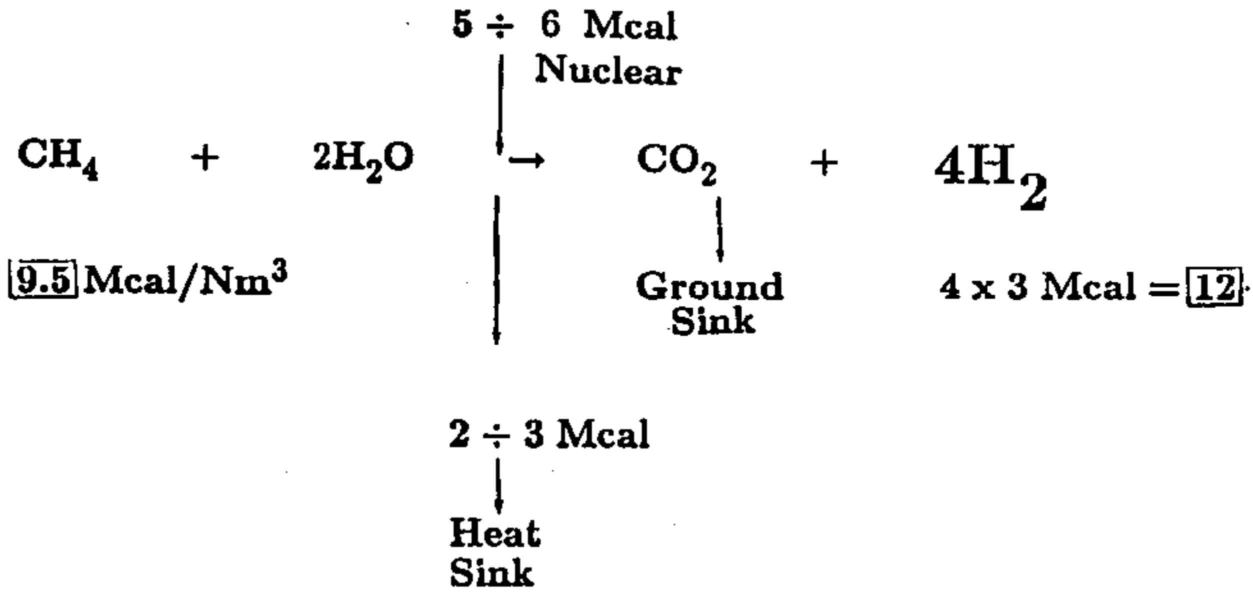


FIGURE 13 A skeleton description of the steam reforming process with the help of nuclear heat is here given to show the energy balances. Basically, reforming adds about 30% to methane's energy input. This extra energy obviously comes from the nuclear heat, with an efficiency of 50% or more. This process appears relatively simple and very suited to introduce large amounts of nuclear energy into the fuel system. (ref. 2)

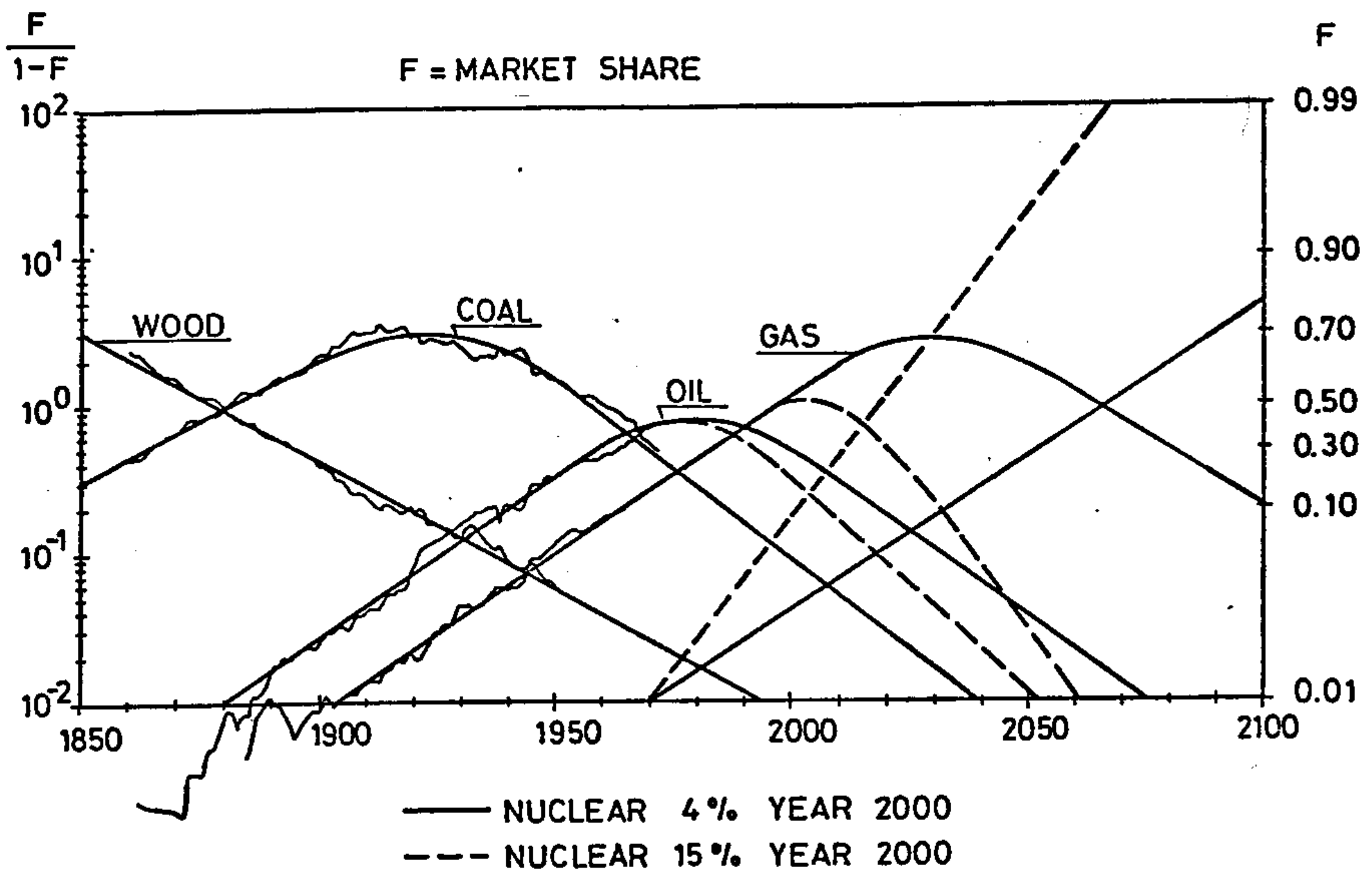


FIGURE 14 World with two hypotheses for nuclear penetration (From Nakicenovic). (ref. 2)

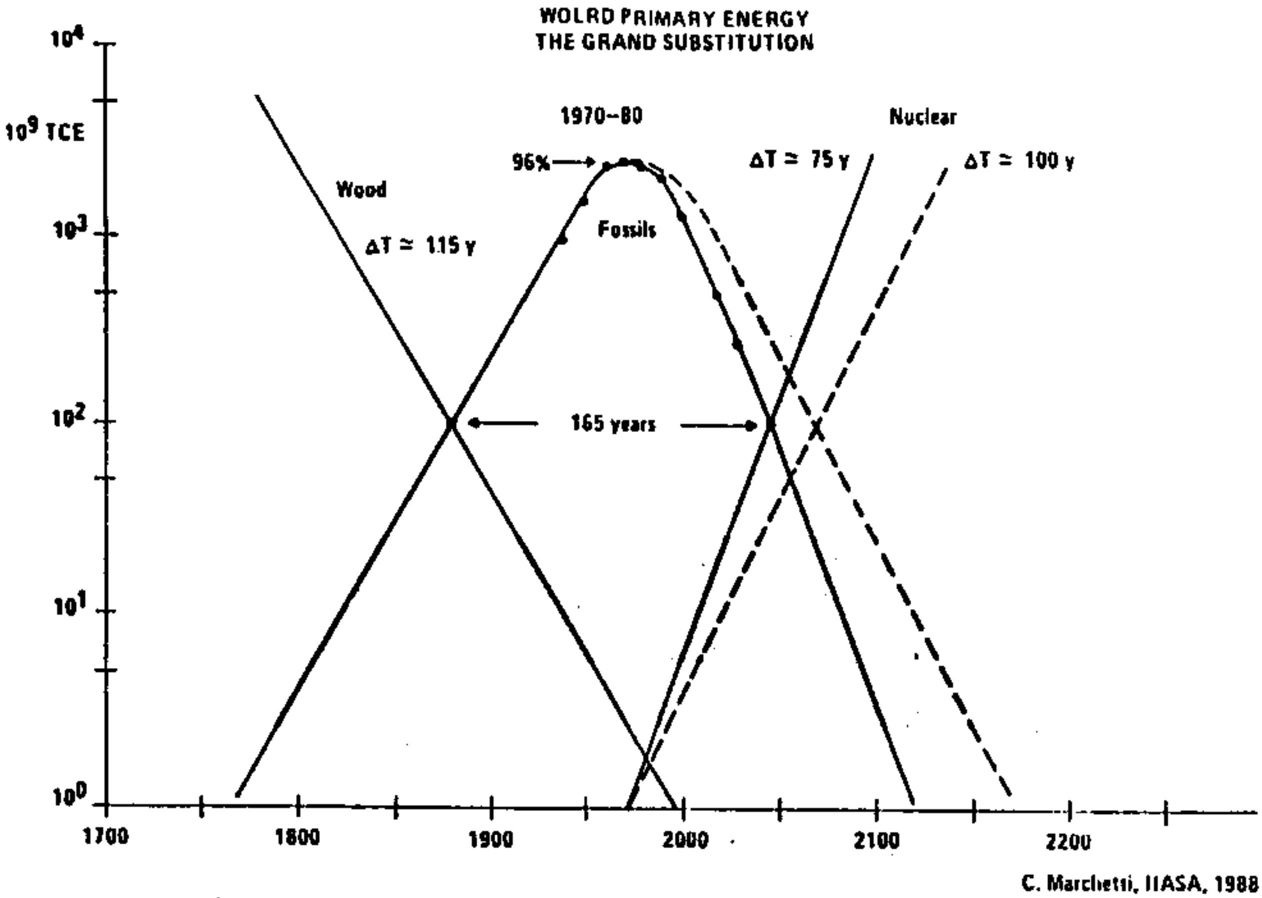


FIGURE 15 Fossil fuels can be lumped together by summing their energy contribution to the energy market. We obtain then a line for phasing out wood and other renewable energies. Fossils have a "product life cycle" of about 400 years, after which they will be substituted by nuclear energy in various forms. We gave two time constants for the penetration of nuclear energy to show their effect on the phase out of the fossil fuels. (ref. 2 and 17)

EVOLUTION OF THE FINAL CONSUMPTION BY SECTOR - %

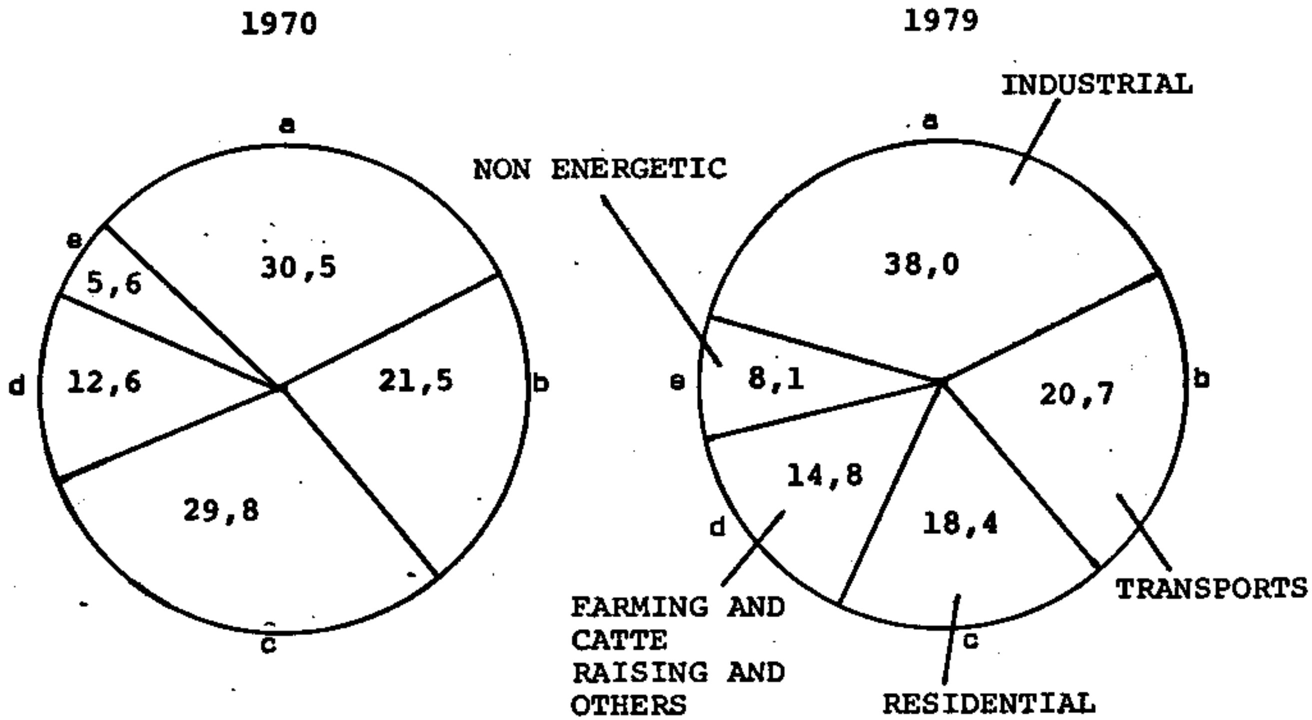


FIGURE 16. (ref. 19)

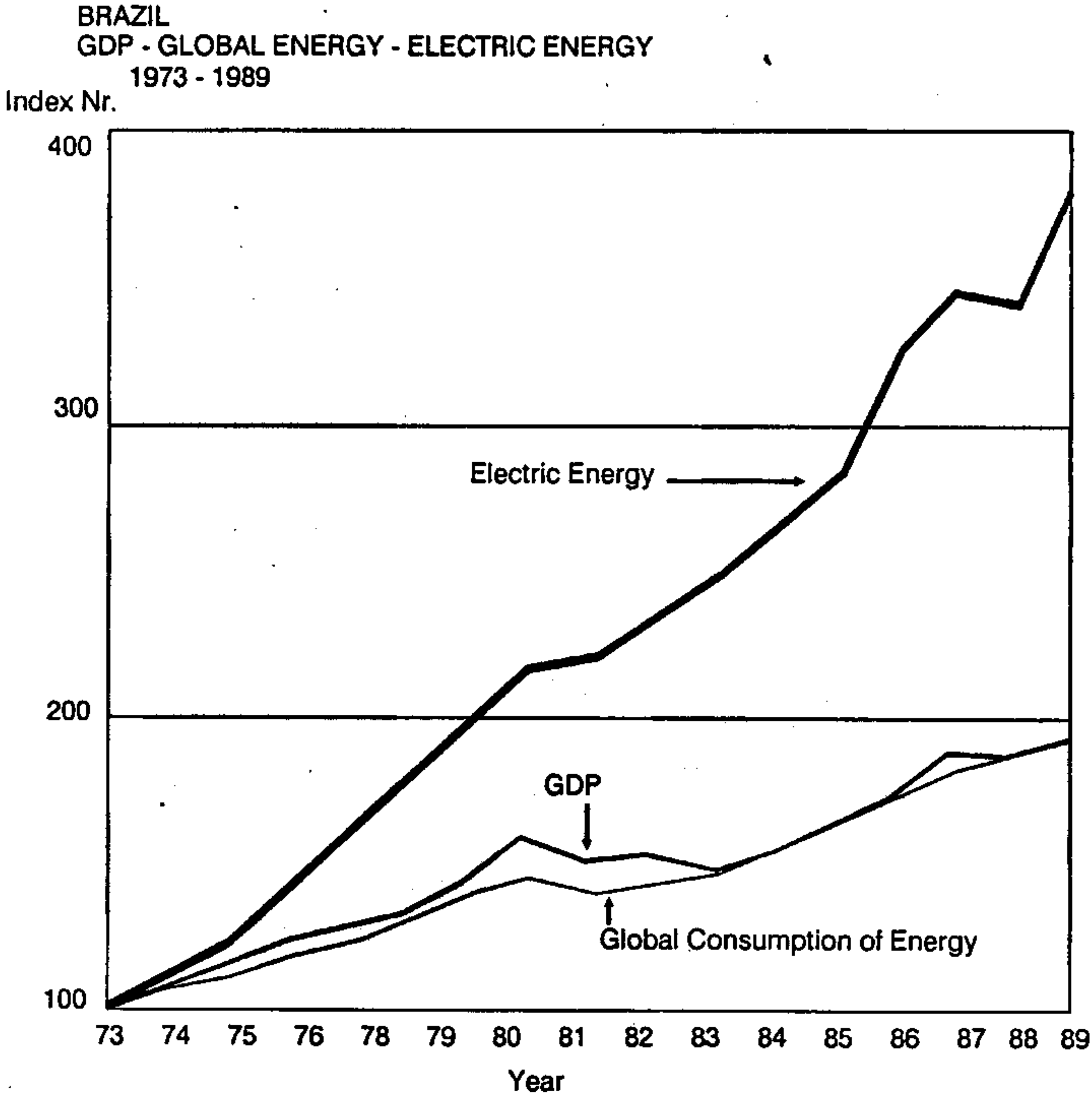


FIGURE 17. (ref. 19)

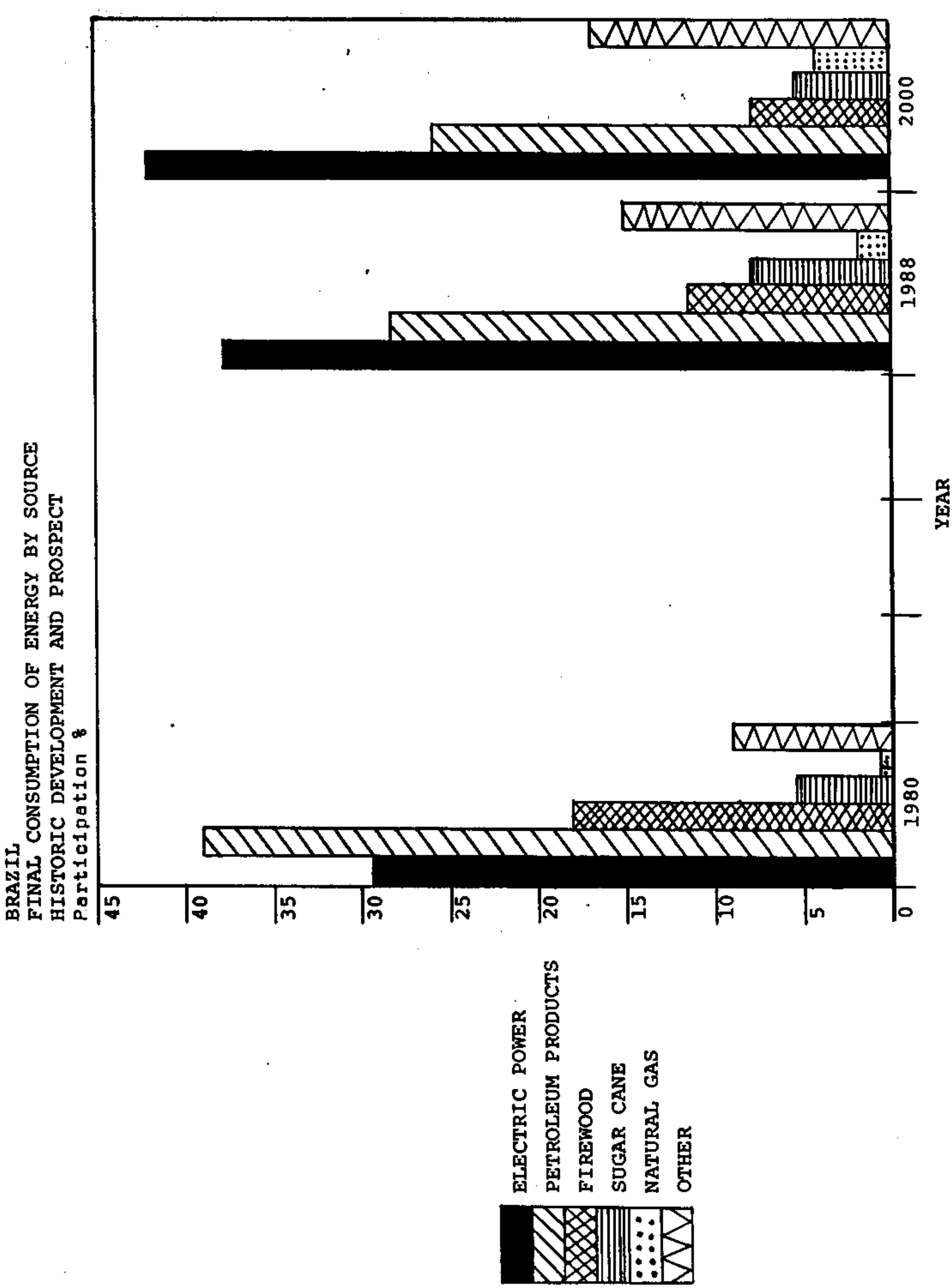
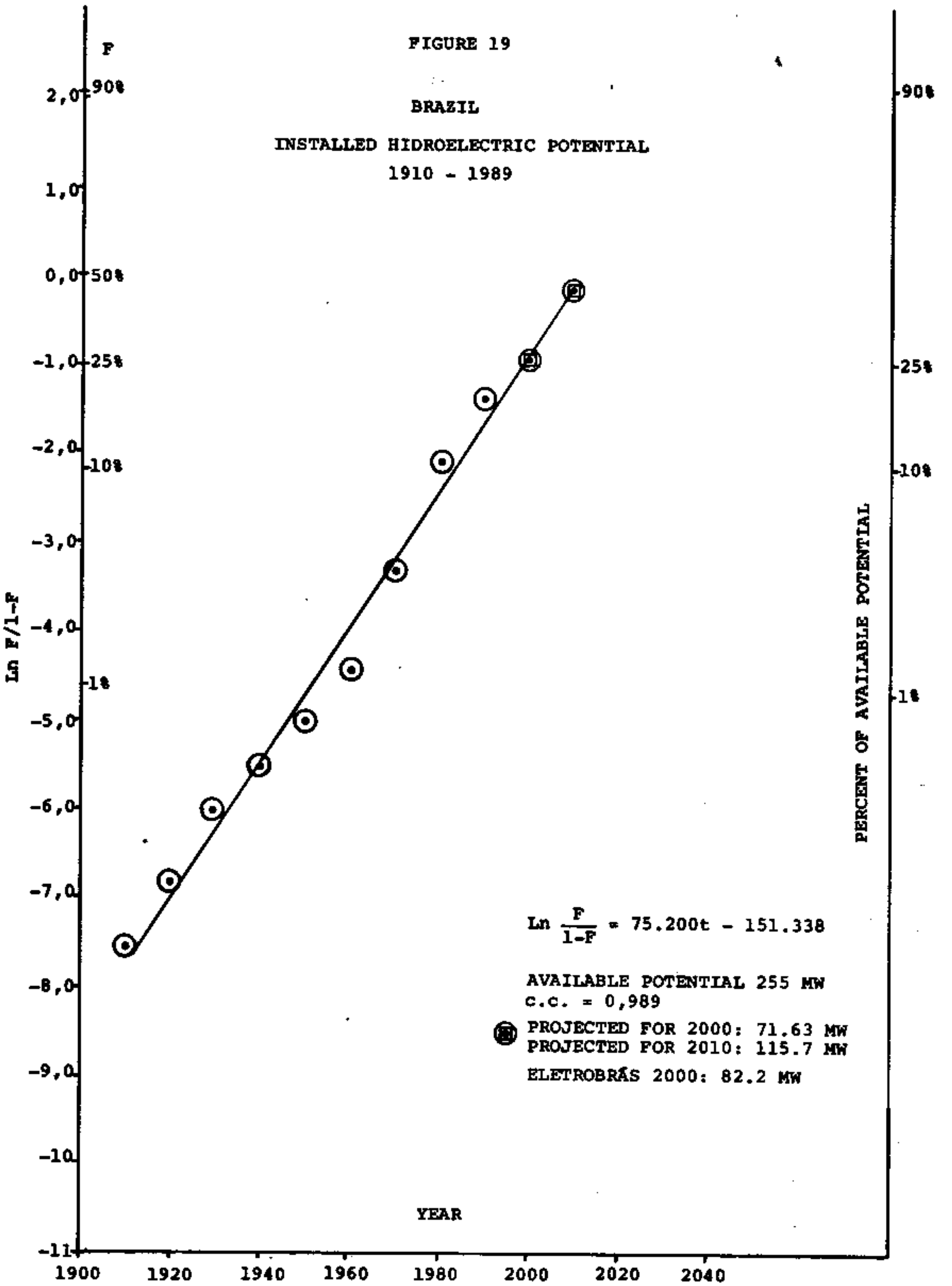

BRAZIL
FINAL CONSUMPTION OF ENERGY BY SOURCE
HISTORIC DEVELOPMENT AND PROSPECT
Participation %
45
40
35
30
25
20
15
10
5
0
1980
1988
2000
YEAR
ELECTRIC POWER
PETROLEUM PRODUCTS
FIREWOOD
SUGAR CANE
NATURAL GAS
OTHER

FIGURE 18


F
FIGURE 19
BRAZIL
INSTALLED HIDROELECTRIC POTENTIAL
1910 - 1989
2,0
1,0
0,0
-1,0
-2,0
-3,0
-4,0
-5,0
-6,0
-7,0
-8,0
-9,0
-10
-11
90%
50%
25%
10%
1%
Ln F/1-F
PERCENT OF AVAILABLE POTENTIAL
Ln F/(1-F) = 75.200t - 151.338
AVAILABLE POTENTIAL 255 MW
c.c. = 0,989
PROJECTED FOR 2000: 71.63 MW
PROJECTED FOR 2010: 115.7 MW
ELETROBRÁS 2000: 82.2 MW
YEAR
1900
1920
1940
1960
1980
2000
2020
2040

LOGISTIC ANALYSIS OF THE EVOLUTION OF THE HYDROELECTRIC ENERGY PRODUCTION IN BRAZIL

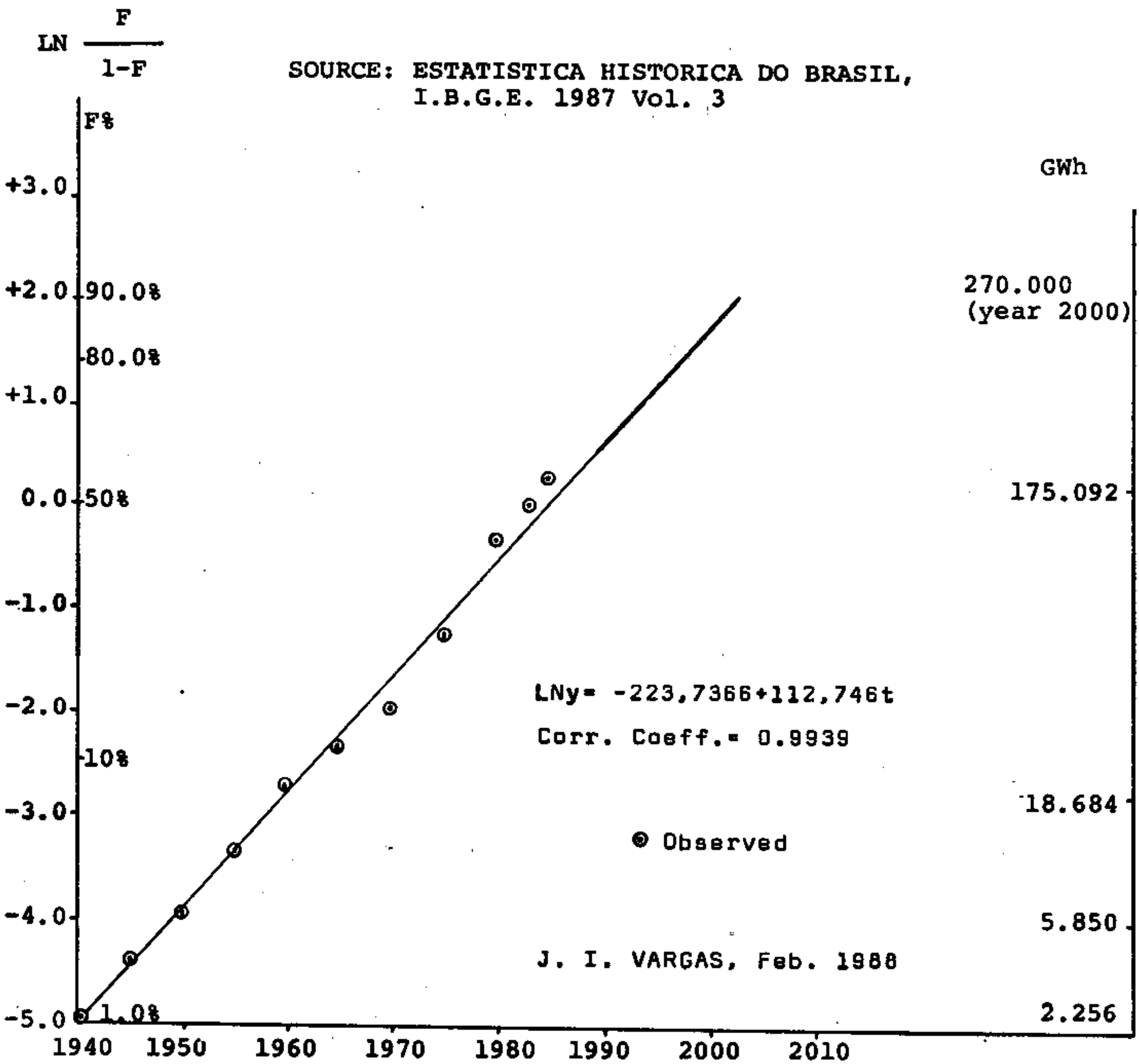
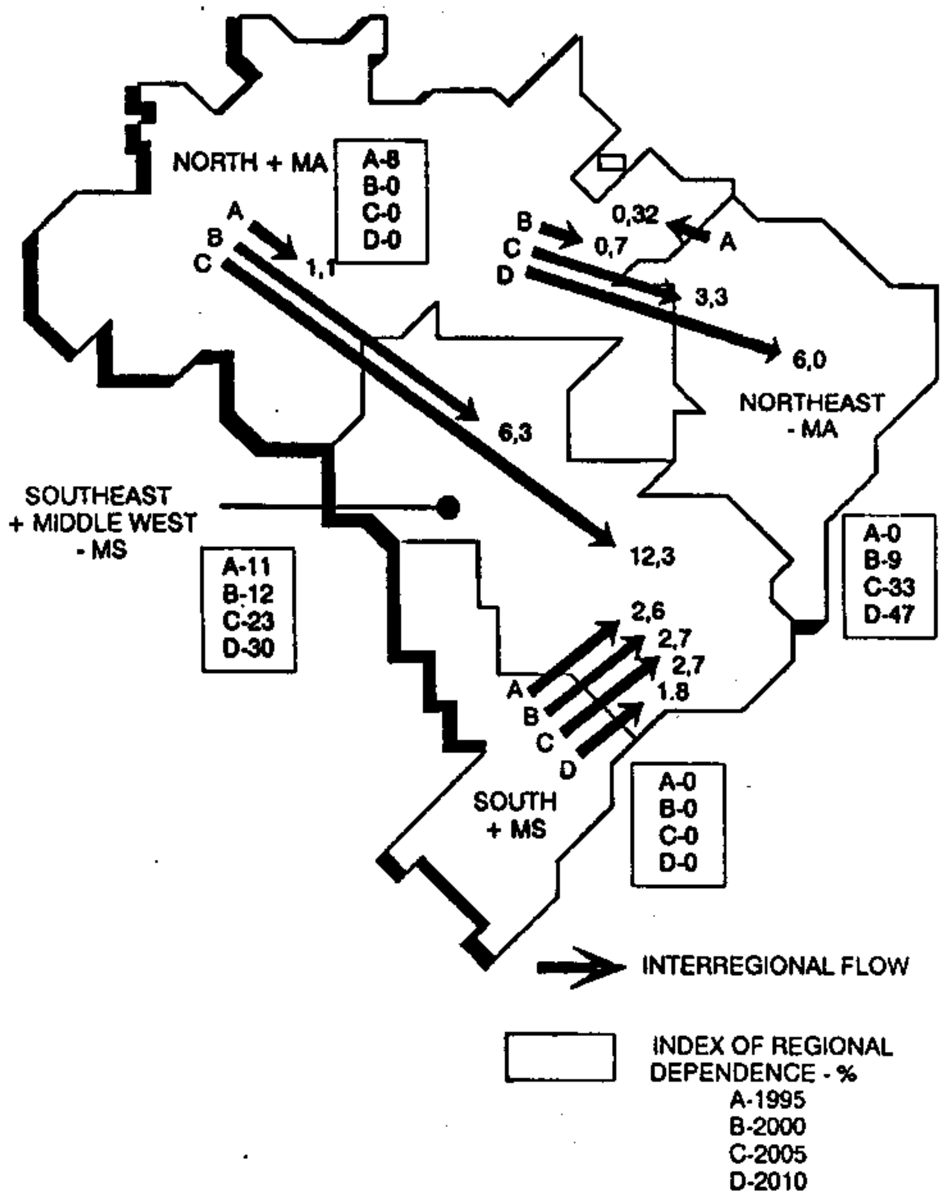


FIGURE 20

MAJOR POWER PLANTS
(Under construction, supplementary expansion, and in studies or design phase)

FIGURE 21. (ref. 19)

BRAZIL - POWER FLOW BETWEEN REGIONS-FIRM POWER - (GW. YEAR)



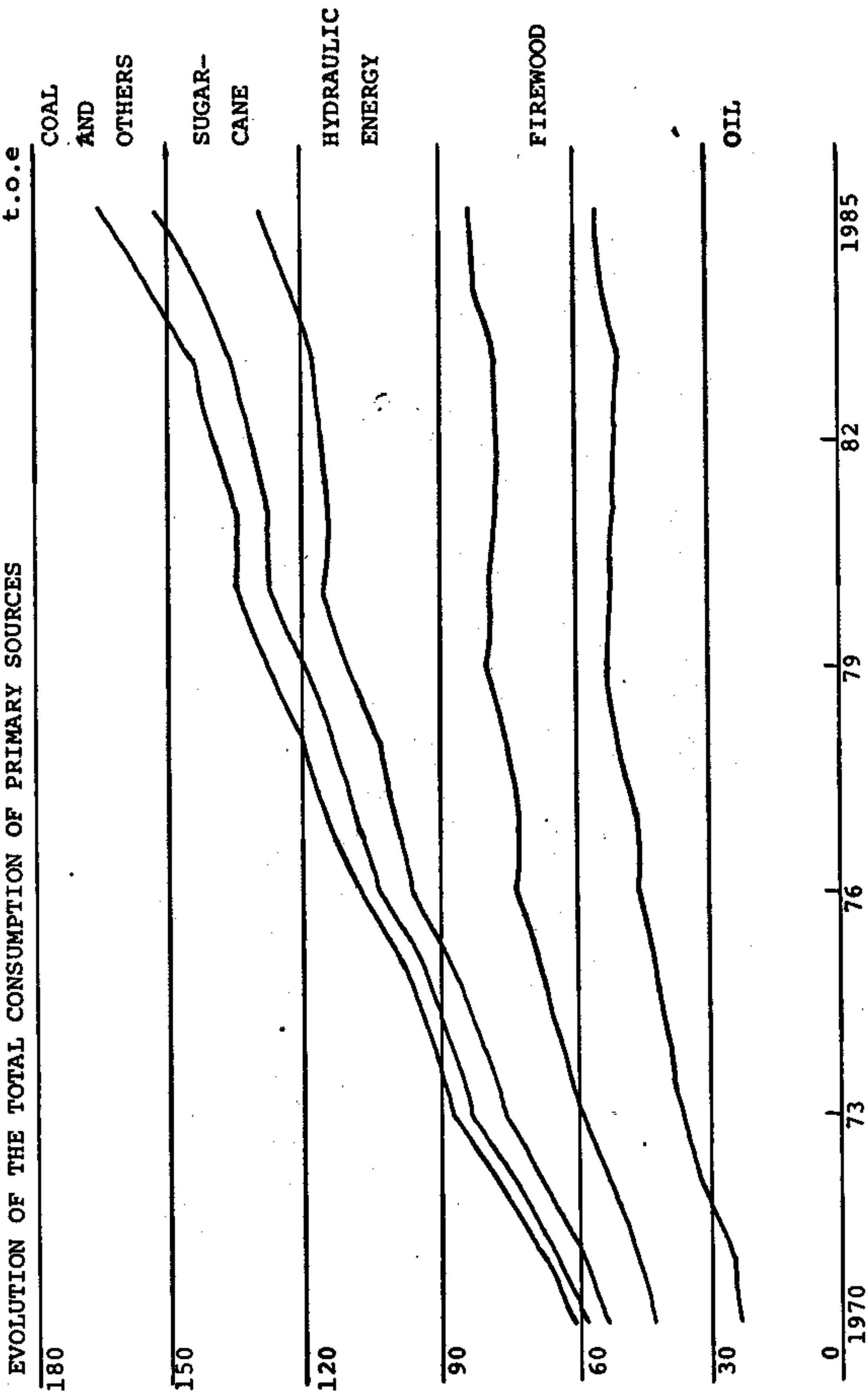
THE ENVIRONMENTAL IMPACT OF ELECTRIC POWER DEVELOPMENT PROJECTS

Brazilian legislation considers "environmental impacts" not only effects on physical and biological elements, but also social, economical and cultural effects. The first group, which might be classed as "ecological impacts", covers effects on climate, air, water, soil, flora and fauna. The second group deals with impacts on people and on social communities. Indigenous population groups, which require special treatment according to the Brazilian constitution, are included in this category.

FIGURE 22. (ref. 19)

FIGURE 23. (ref. 19)

EVOLUTION OF THE TOTAL CONSUMPTION OF PRIMARY SOURCES



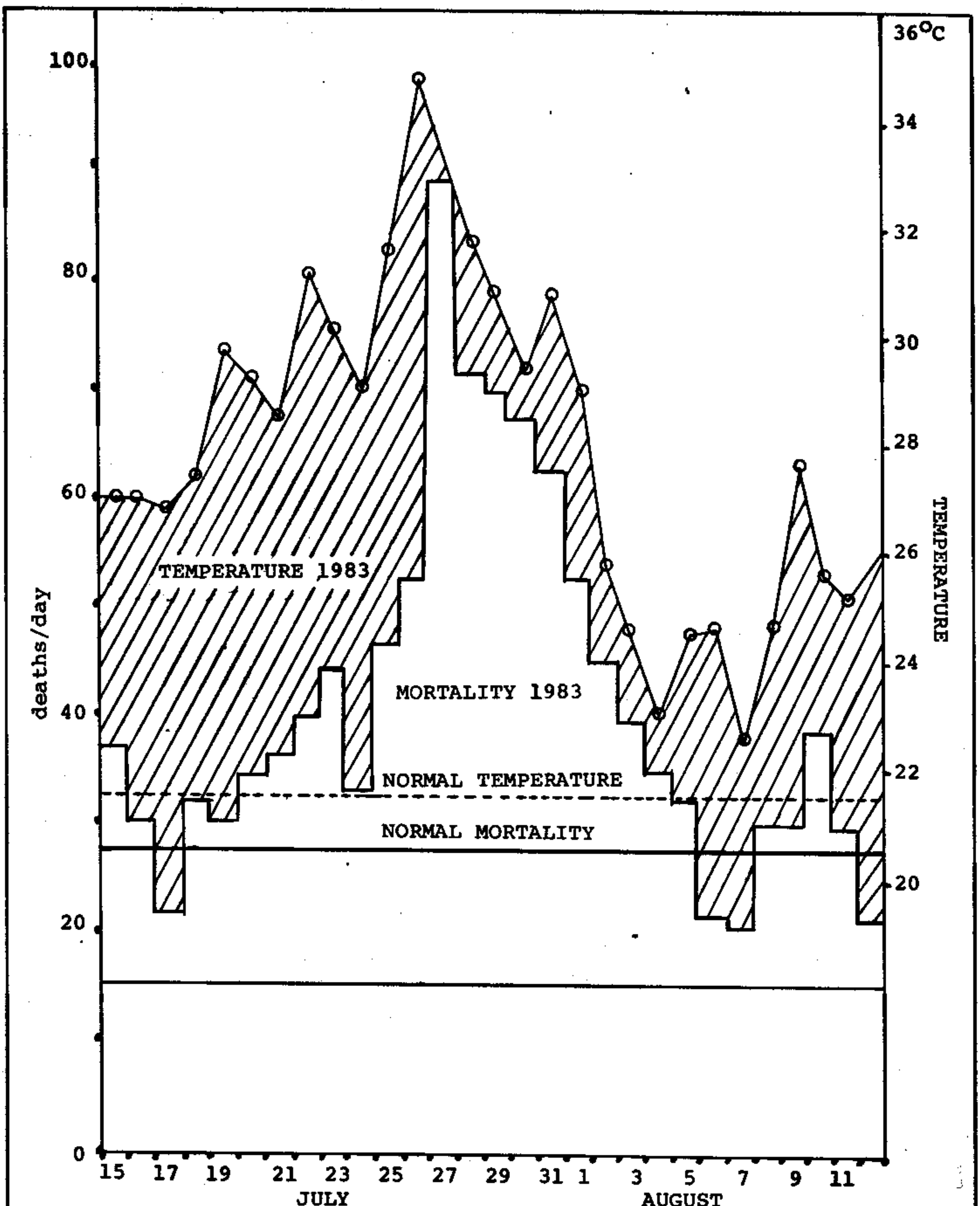

100
80
60
40
20
0
deaths/day
36°C
34
32
30
28
26
24
22
20
TEMPERATURE
TEMPERATURE 1983
MORTALITY 1983
NORMAL TEMPERATURE
NORMAL MORTALITY
15 17 19 21 23 25 27 29 31 1 3 5 7 9 11
JULY
AUGUST

FIGURE 24

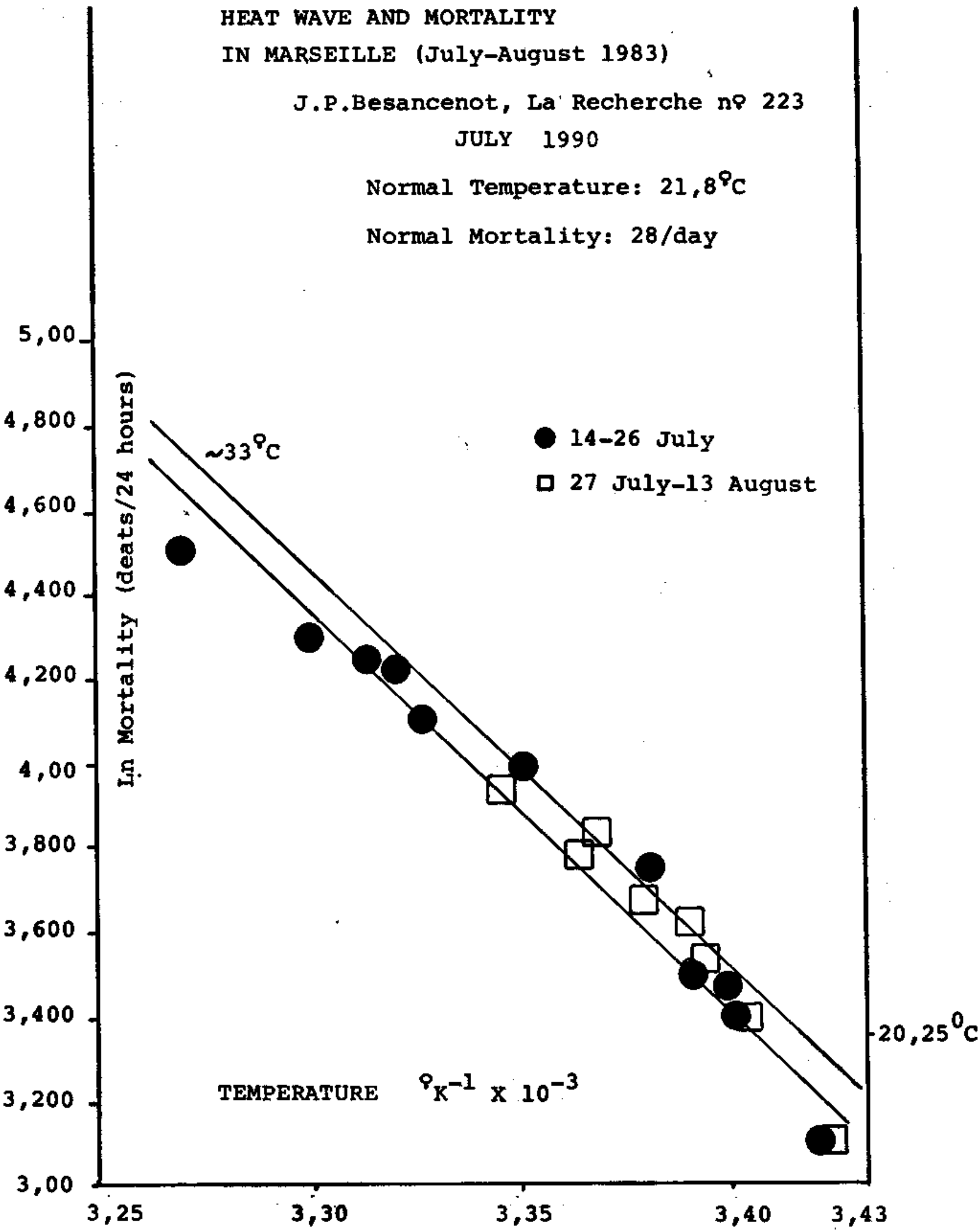

HEAT WAVE AND MORTALITY
IN MARSEILLE (July-August 1983)
J.P.Besancenot, La Recherche nº 223
JULY 1990
Normal Temperature: 21,8ºC
Normal Mortality: 28/day
5,00
4,800
4,600
4,400
4,200
4,00
3,800
3,600
3,400
3,200
3,00
Ln Mortality (deats/24 hours)
~33ºC
14-26 July
27 July-13 August
20,25ºC
TEMPERATURE ºK-1 x 10-3
3,25
3,30
3,35
3,40
3,43

FIGURE 25

TABLE 1

COMPARISON BETWEEM THE PRIMARY ENERGY GENERATION IN TWa p.a. AND THE CO_2 EMISSION (CO_2E) IN Gt. p.a., ACCORDING TO DIFFERENT SCENARIOS. (ref. 18)

	1987[a]		IIASA		1989-REDUCED SCENARIO 2030				COLOMBO 2030		GOLDEMBERG 2020	
							REDUCED NUCLEAR					
	E	CO_2E	PE	CO_2E	PE	CO_2E	PE	CO_2E	PE	CO_2E	PE	CO_2E
OIL	4.19	2.53	5.02	3.04	3.5	2.12	3.5	2.12	1.72	1.04	3.21	1.94
GAS_1^b	2.20	o.95	3.47	1.50	2.0	0.86	2.0	0.86	0.99	0.42	3.21	1.39
GAS_2^b	–	–	–	–	2.0	–	–	–	–	–	–	–
$COAL_1^b$	3.39	2.55	6.45	4.84	1.5	1.13	1.5	1.13	4.95	3.72	1.94	1.46
$NUCLEAR_1$	0.57	–	5.15	–	2.2	–	0.75	–	1.74	–	0.75	–
$NUCLEAR_2$	–	–	–	–	1.5	–	–	–		–	–	–
SOLAR					1.2	–	1.2	–			0.09	–
HYDRO[c]	0.73	–	} 2.28	–	0.8 } 3.3	–	0.8 } 3.3	–	6.60	–	0.46 } 2.13	–
BIO[b.d]					1.3	–	1.3	–		–	1.58	–
TOTAL	11.08	6.03	22.39	9.38	16.00	4.11	11.05	4.11	16.00	5.18	11.24	4.79

[a] BRITISH PETROLEUM STATISTICS, 1989

[b] DOES NOT INCLUDES METHANE LOSS TO THE ATMOSPHERE

[c] ELETRIC PRODUCTION

[d] ORGANIC RESIDUES

E= TOTAL ENERGY

PE= PROJECTED ENERGY

TABLE 2

PRODUCTION AND USE OF THE CHLOROFLUORCARBONS.

	PRODUCTION	USE
USA	31%	29%
WESTERN EUROPE, JAPAN, CANADA, AUSTRALIA, NEW ZEALAND, EASTERN EUROPE AND SOVIET UNION	59%	55%
DEVELOPING COUNTRIES	<3%	16%

(ref. 13)

TABLE 3

World energy balances in 10^9tce

(for growth rate of 2%)

(From Nakicenovic). (ref. 2)

PERIOD	WOOD	COAL	OIL	GAS	NUCLEAR	SOLFUS	CO_2 REJECTED
1850–1950	25	73	10	3	-	-	50 ppm
1950–2100	5	70	a) 120	200	2000	-	50 ppm
			b) 170	1000	1000	-	130 ppm
			c) 170	800	800	550	190 ppm
			d) 200	1600	-	550	350 ppm
RESERVES		1000	100	100			
RESOURCES	30R	10000	400	300			

a) NUCLEAR 15% YEAR 2000 NO SOLFUS

b) NUCLEAR 4% YEAR 2000 NO SOLFUS

c) NUCLEAR 4% YEAR 2000 SOLFUS 1% YEAR 2000

d) NO NUCLEAR SOLFUS 1% YEAR 2000

R RENEWABLE

TABLE 4

ENERGETIC PARTICIPATION IN THE CONSUMPTION

YEAR	COAL			NATURAL GAS			OIL PRODUCTS			FIREWOOD			SUGAR-CANE BAGASSE			CHARCOAL			HYDRAULIC ENERGY			FIREWOOD+ CHARCOAL			ALCOHOL+ BAGASSE		
	%	$\frac{F}{1-F}$	$\log\frac{F}{1-F}$	%	$\frac{F}{1-F}$	$\log\frac{F}{1-F}$	%	$\frac{F}{1-F}$	$\log\frac{F}{1-F}$	%	$\frac{F}{1-F}$	$\log\frac{F}{1-F}$	%	$\frac{F}{1-F}$	$\log\frac{F}{1-F}$	%	$\frac{F}{1-F}$	$\log\frac{F}{1-F}$	%	$\frac{F}{1-F}$	$\log\frac{F}{1-F}$	%	$\frac{F}{1-F}$	$\log\frac{F}{1-F}$	%	$\frac{F}{1-F}$	$\log\frac{F}{1-F}$
1941	6,7	0,072	-1,140	N			7,9	0,086	-1,067	71,0	2,448	-0,389	2,6	0,027	-1,514				6,8	0,073	-1,137	75,2	3,032	-0,482	2,6	0,027	-1,590
1946	7,7	0,083	-1,078	N			11,0	0,124	-0,908	65,9	1,993	0,286	3,3	0,034	-1,467				7,8	0,085	-1,013	69,5	2,279	-0,358	3,3	0,034	-1,467
1952	6,9	0,074	-1,13	N			23,9	0,314	0,503	48,8	0,953	0,021	4,2	0,044	-1,358				11,0	0,124	-0,908	53,2	1,137	-0,056	4,2	0,044	-1,358
1956	6,1	0,065	-1,187	N			30,6	0,441	-0,356	42,8	0,748	-0,126	4,5	0,047	-1,317				11,2	0,126	-0,899	46,8	0,880	-0,058	4,5	0,044	-1,327
1961	3,6	0,0373	-1,428	N			32,9	0,490	-0,318	40,3	0,675	-0,171	5,1	0,054	-1,270				14,2	0,166	-0,781	43,5	0,770	-0,114	5,1	0,054	-1,270
1966	3,9	0,041	-1,392	0,2	0,002	-2,698	33,9	0,513	-0,90	33,9	0,513	-0,296	4,8	0,050	-1,247				16,0	0,190	-0,710	36,4	0,572	-0,242	4,8	0,050	-1,297
1971	3,7	0,038	-1,415	0,4	0,004	-2,396	40,0	0,667	-0,176	28,9	0,406	-0,391	4,4	0,046	-1,337	0,7	0,007	-2,152	19,1	0,236	-0,627	31,6	0,462	-0,335	5,1	0,054	-1270
1972	3,3	0,034	-1,467	0,4	0,004	-2,396	41,2	0,701	-0,154	26,7	0,364	-0,439	4,5	0,047	-1,327	0,7	0,007	-2,152	20,4	0,256	-0,591	29,3	0,414	-0,383	5,2	0,055	-1,261
1974	3,0	0,031	-1,510	0,6	0,006	-2,219	44,1	0,789	-0,103	22,8	0,295	-0,530	4,0	0,042	-1,380	0,5	0,005	-2,299	21,9	0,280	-0,552	25,8	0,248	-0,459	4,5	0,047	-1,327
1976	3,4	0,0352	-1,454	0,6	0,008	-2,093	44,1	0,789	-0,103	21,1	0,267	-0,573	3,6	0,037	-1,428	0,4	0,004	-2,396	23,8	0,312	-0,505	24,0	0,316	-0,501	4,0	0,042	-1,386
1979	4,0	0,042	-1,380	0,8	0,008	-2,093	42,7	0,745	-0,128	16,5	0,369	-0,443	4,6	0,048	-1,789	1,6	0,016	-1,789	27,0	0,370	-0,432	29,2	0,412	-0,385	6,2	0,066	-1,180
1982	4,5	0,047	-1,327	1,0	0,010	-1,996	35,9	0,560	-0252	15,5	0,183	-0,737	5,9	0,063	-1,203	3,0	0,031	-1,510	31,1	0,451	-0,345	18,5	0,224	-0,644	8,9	0,098	-1,010
1985	6,4	0,068	1,165	1,8	0,018	-1,737	29,5	0,418	-0,378	12,1	0,136	-0,861	7,9	0,086	-1,667	5,1	0,054	-1,270	33,2	0,497	-0,304	16,1	0,192	-0,717	13,0	0,149	-0,826

TABLE 5

EVOLUTION OF THE TOTAL CONSUMPTION OF PRIMARY SOURCES (Ref. 19)

t.o.e
%

YEAR	OIL	NATURAL GAS	STEAM COAL	METALLURGICAL COAL	URANIUM	HIDRAULIC ENERGY	FIREWOOD	SUGAR-CANE	OTHER PRIMARY SOURCES	SUBTOTAL OF THE RENEWABLES	TOTAL
1970	25.062	169	600	1.738	-	11.542	22.150	5.351	100	39.143	66.712
	37,5	0,3	0,9	2,6	-	17,4	33,2	8,0	0,1	58,7	100,0
1971	26.426	524	606	1.772	-	12.527	22.674	5.751	104	41.056	70.114
	37,6	0,4	0,9	2,5	-	18,0	32,3	8,2	0,1	58,6	100,0
1972	31.710	311	638	1.751	-	14.698	23.444	6.448	114	44.704	79.114
	40,1	0,4	0,8	2,2	-	18,6	29,6	8,2	0,1	56,5	100,0
1973	37.866	259	613	1.818	-	16.788	23.899	7.051	121	47.859	88.415
	42,8	0,3	0,7	2,1	-	19,0	27,0	8,0	0,1	54.1	100,0
1974	39.796	520	629	1.784	-	19.047	25.343	7.043	127	51.560	94.289
	42,2	0,5	0,7	1,9	-	20,2	26,9	7,5	0,1	54,7	100,0
1975	43.994	571	652	2.197	-	20.963	26.793	6.351	134	54.241	101.655
	43,2	0,6	0,6	2,2	-	20,6	26,4	6,3	0,1	53,4	100,0
1976	46.794	627	597	2.813	-	24.045	27.234	7.232	161	58.672	109.503
	42,7	0,6	0,5	2,6	-	22,0	24,9	6,6	0,1	53,6	100,0
1977	47.901	1.085	727	3.338	-	27.109	26.735	9.447	166	63.457	116.508
	41,1	0,9	0,6	2,9	-	23,3	23,0	8,1	0,1	54,5	100,0
1978	53.405	925	1.151	3.369	-	29.797	26.522	10.125	184	66.628	125.478
	42,6	0,7	0,9	2,7	-	23,7	21,1	8,1	0,2	53,1	100,0
1979	55.576	983	1.099	3,859	-	33.382	27.266	11.265	236	72.149	133.666
	41,6	0,7	0,8	2,9	-	25,0	20,4	8,4	0,2	54,0	100,0
1980	54.318	1.133	1.206	4.044	-	37.641	28.509	12.378	335	78.863	139.564
	38,9	0,8	0,9	2,9	-	27,0	20,4	8,9	0,2	53,5	100,0
1981	52.592	1.069	1.794	3.617	-	37.922	27.915	13.523	470	79.830	138.902
	37,9	0,8	1,3	2,6	-	27,3	20,1	9,7	0,3	57,4	100,0
1982	52.032	1.463	2,196	3.769	1.154	40.928	28.541	15.205	508	85.182	145.795
	35,7	1,0	1,5	2,6	0,8	28,1	19,6	10,4	0,3	58,4	100,0
1983	51.103	2.008	2.164	4.476	-	43.928	29.341	18.843	508	92.620	152.371
	33,5	1,3	1,4	3,0	-	28,8	19,3	12,4	0,3	60,8	100,0
1984	54.361	2.480	2.196	6.008	-	48.312	31.765	20.323	630	101.030	166.075
	32,8	1,5	1,3	3,6	-	29,1	19,1	12,2	0,4	60,8	100,0
1985	54.580	3.078	2.475	6.804	-	51.694	31.002	22.653	660	106.009	172.946
	31,6	1,8	1,4	3,9	-	29,9	17,9	13,1	0,4	61,3	100,0

TABLE 6

BRAZIL
GLOBAL ENERGY CONSUMPTION, BY SOURCE, 1973 - 1988 (Ref. 19)

	1973		1980		1985		1988	
	10^3 tPE	%	10^3 tPE	%	10^3 tPE	%	10^3 tPE	%
Natural Gas	48	0	503	0	1700	1	2249	1
Ethyl Alcohol	160	0	1385	1	4122	3	5863	4
Coke	1257	1	3134	3	4840	3	6113	4
Charcoal	2173	3	4143	3	6013	4	6538	4
Sugar Cane Bagasse	4084	5	6666	5	11723	8	11784	7
Firewood	26672	32	21620	18	19408	14	17847	11
Petroleum Products	32574	39	46728	38	38873	28	44263	28
Electric Power	16448	20	35614	29	50058	36	58830	37
TOTAL	84167	100	121961	100	140717	100	158256	100

Rates of Growth (% p.a.)

	80/73	85/80	88/85	88/73
Natural Gas	39.9	27.6	9.8	27.2
Ethyl Alcohol	36.1	24.4	12.5	29.2
Coke	13.9	9.1	8.1	11.1
Charcoal	9.7	7.7	2.8	7.6
Sugar Cane Bagasse	7.3	12.0	0.2	7.3
Firewood	-3.0	-2.1	-2.8	-2.6
Petroleum Products	53	-3.6	4.4	2.1
Electric Power	11.7	7.0	5.5	8.9
TOTAL	5.4	2.9	4.0	4.3

Rem.: Final energy consumption

TABLE 7

CO_2 EMISSION RATES

		GtC/YEAR AS CO_2
1987/88	ENERGY RELATED	6
	NON ENERGY RELATED	1
2005,	THE TORONTO TARGET	4.8
2030,	THE JULICH CO_2 REDUCTION SCENARIO	4.0
SUSTAINABLE?, 2080?		2.5

(Ref. 18)

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(26) Estimativa da contribuição brasileira para o efeito estufa e comparações internacionais. COPPE - Coordenação de Programas de Pós-Graduação de Engenharia - Rio de Janeiro, fevereiro 1992.

(27) Besancenot, J.P. *La Recherche*, 223, Juillet, 1990.

(28) Fernside P. Efeito Estufa - Poluição atmosférica global. Rio Ciência 92, Rio, may 26^{th}, 1992, reffers to 4% as the Brazilian contribution to the total CO_2 emission.

Note. The ordinates in figures numbers 9, 10, 11, 12, 14, 15, 19, and 20 are expressed in terms of Ln F/1-F, the Fisher-Pry transform of the logistic equation, N(t) = N / 1-exp (-at+b), for N/N = F, the fraction of N, the potential occupancy of the quantity under consideration. t = time; a = rate constant; b = integration constant. (For details see for instance references 3 and 5.)