Handout for the keynote speech by

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TRENDS AND CYCLES OF CHANGE

at the World Symposium '99 on Computing in the Gas Industry,

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In Spite of Copernicus

In spite of Copernicus, man, in his heart, still thinks to be at the center of the universe. And engineers think the world is, or will be, inevitably under their control.

On top of that, free will is today unchallenged. Each of us holds his destiny in his hands and consequently he is responsible to God, society, and to himself for every single act.

I extract these theological statements from the way people talk and write. But because I am a systems analyst, educated as a physicist, I spent 25 years checking what people do versus what people say.

The check was done using models, descriptive and predictive, where only the facts (the actions) are introduced, and taking man or society as a black box from which I have to extract the transfer function.

The result of these analyses, made on a few thousand case histories, shows a very different picture. Man's actions, at personal and aggregated level, are largely under control of basic mechanisms and interactive constraints robbing free will of much of its punch and castigating pride with invisible steel hands.

The core of my keynote is to show some of these phenomena in clear, and to point to the great practical usefulness in the knowledge of the mechanisms and pre-knowledge of the facts.

One of the conclusions, already emerging from my analysis in the seventies, is that natural gas will be the dominant primary energy for the next 50 years, that its use will increase by an order of magnitude, and that *handling properly the logistics of this mass of material will be the key to the success.*

The Pulse of Innovation

We all accept, and even neglect, that the behavior of man is under the spell of celestial cycles. The day of the sun controls strictly our activity, biological and social. Watch the car flow at rush hours.

The month of the moon and its splice, the week, have a little longer breath, but man's activities are rigidly channeled. Watch the week end hustle and bustle.

Incidentally, the month measures how long the subject can stay faithful to the boss, without intervening dominance signals. No empire ever grew stably beyond 14 days travel from the capital and multinationals meet their bosses once a month, to appropriately refresh the pecking order.

The year of the sun is again compelling not only for agriculture, but again for putting windows at human activity as well.

I was just here, when in 1979 I was invited by the Italian Association of Marketing to give at the congress on innovation in Turin a keynote on innovation. I took the challenge, as systems analysts tramp on such things, and discovered with a little shock that innovations do not rain from heaven with meteorological whimsicality, but are organized with Prussian discipline into bunches.

Figure 1 shows three of these bunches, extracted from historical data collected and filtered by Gerhard Mensch, then at Berlin University. In this particular chart, straight lines represent S curves, i.e., logistic equations (Fisher-Pry transform).

The first observation is that these very simple equations perfectly fit an apparently random process like the introduction of basic innovations into the economic-industrial fabric.

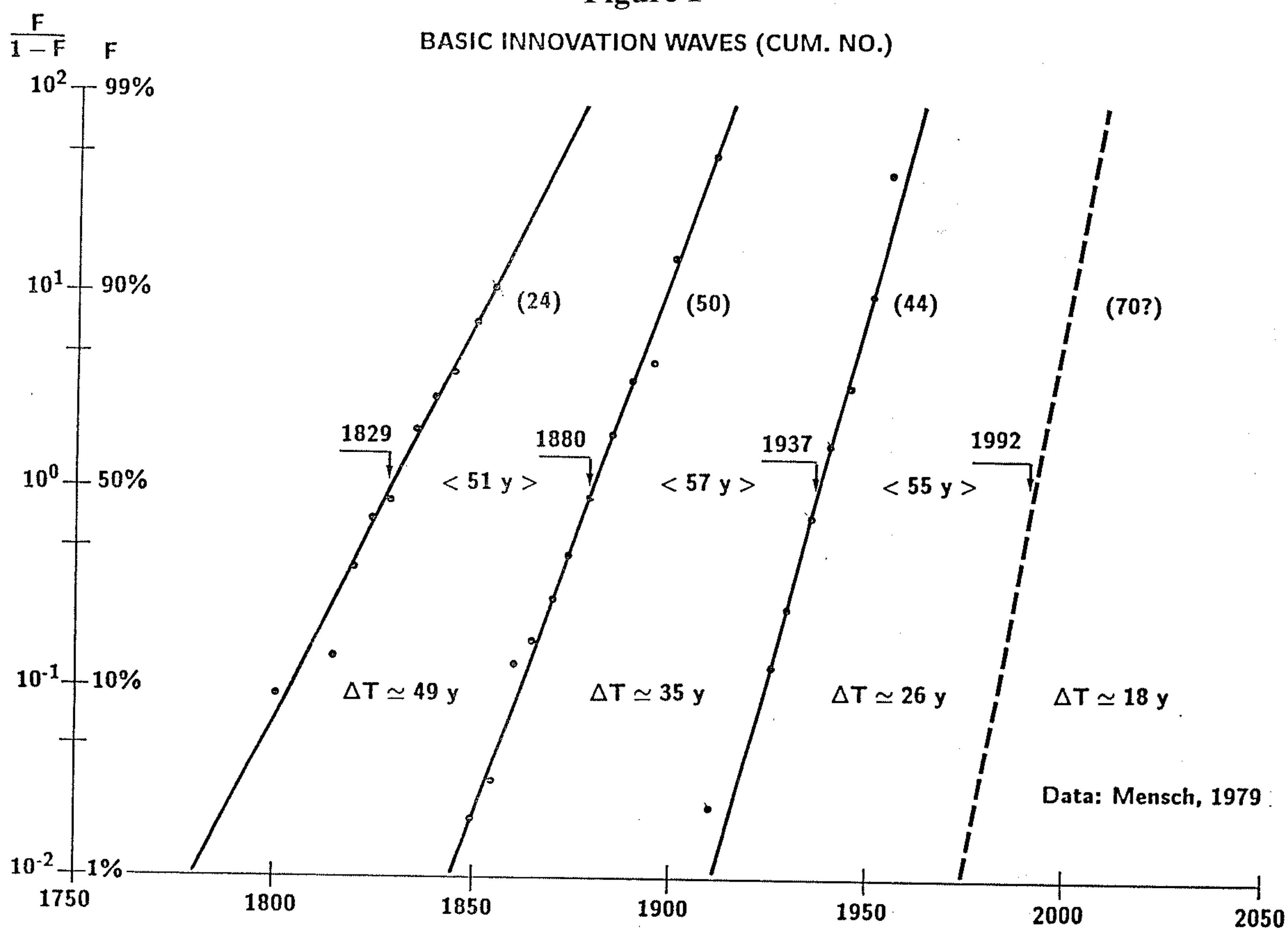
The dating was made precise by Mensch, by taking the year when the innovative object or process was first sold commercially.

The second observation was that the centerpoints of these pulses of innovation are spaced about 55 years. And that the internal regularities permit to forecast the fourth wave, very nicely deployed now.

These 55 years started a second search. If innovations, so basic to our Western economic system, are injected in pulses, what else may pulse with the same periodicity?

Figure 1

BASIC INNOVATION WAVES (CUM. NO.)



C. Marchetti, IIASA,

The Energy Signal

The answer is simple: everything. From car purchases to the kind of weapon used for homicides, everything resents the highs and lows of this long-term tides.

Because energy consumption is the metabolic indicator that epitomizes the infinite activities – big and small – of our society, also energy analysis could be used.

The test was performed by my Californian friend H. Stewart. He was trying to fit long-term consumption of energy in the United States, using exponential or logistic equations.

Over the long term the trend did fit, but deviations were large. So he plotted the deviations (Figure 2) which reveal to be actually a signal.

A fairly well shaped sinusoid, showing that energy (and electricity!) consumption can oscillate, regularly and with a period of about 55 years by as much as 20% from the trend.

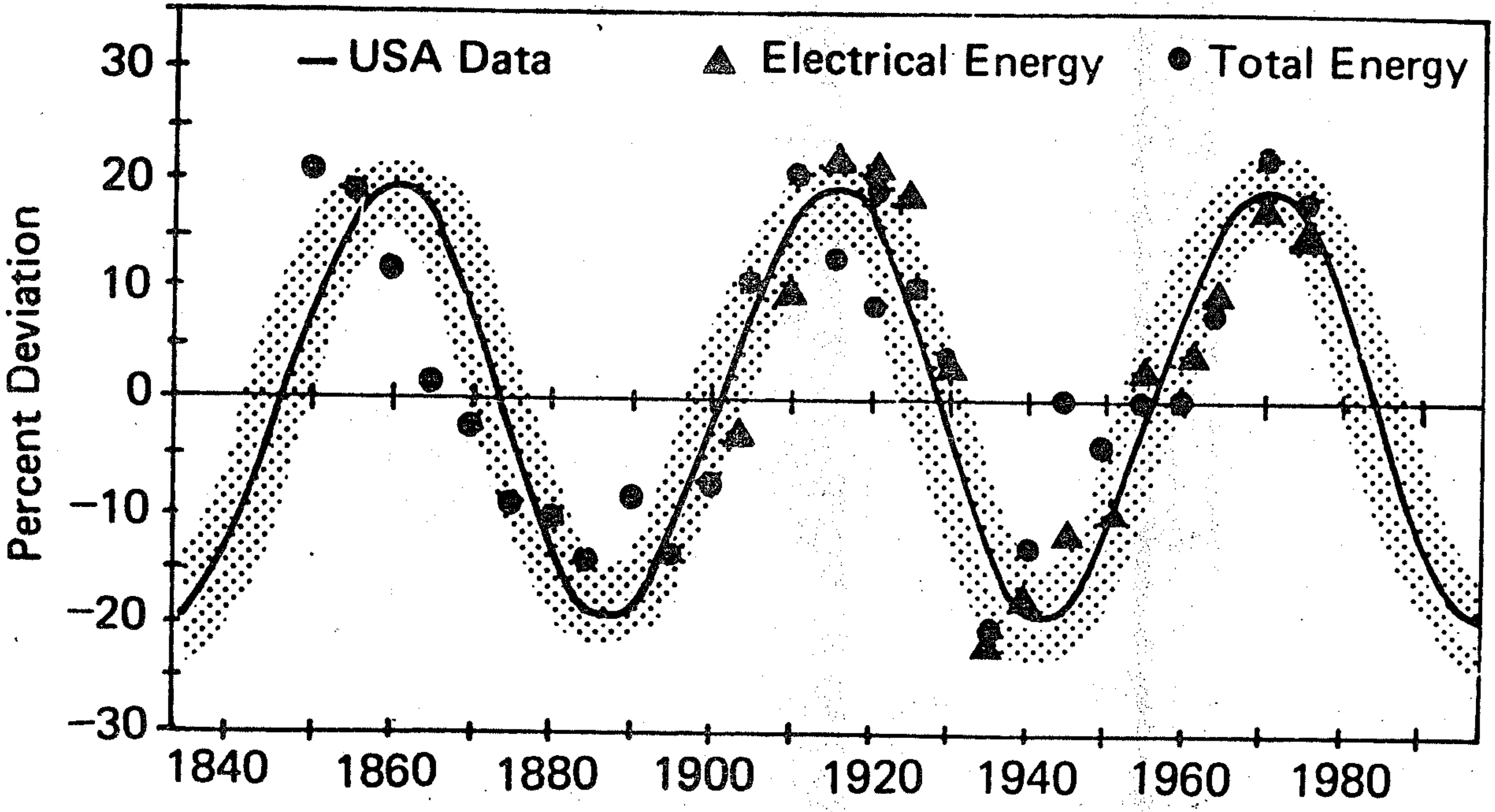
One can also measure the increase in energy consumption in terms of a sequence of logistic bursts of growth (Figure 3). This is a different formalization I will use for some specific purposes, but the oscillation is superior as a visual description.

The oscillation of Figure 2 has been extracted from US data. As my successive studies showed, it can also be used to clock the world, or at least industrialized countries. They are basically synchronous.

This can be simply shown by taking world events, like the opening of new Metros in world cities, or just the basic innovations you saw, again a world event.

The evolution of these processes can be fitted with a set of logistic and their centerpoint take a precise phase position on the sinusoid (Figure 4).

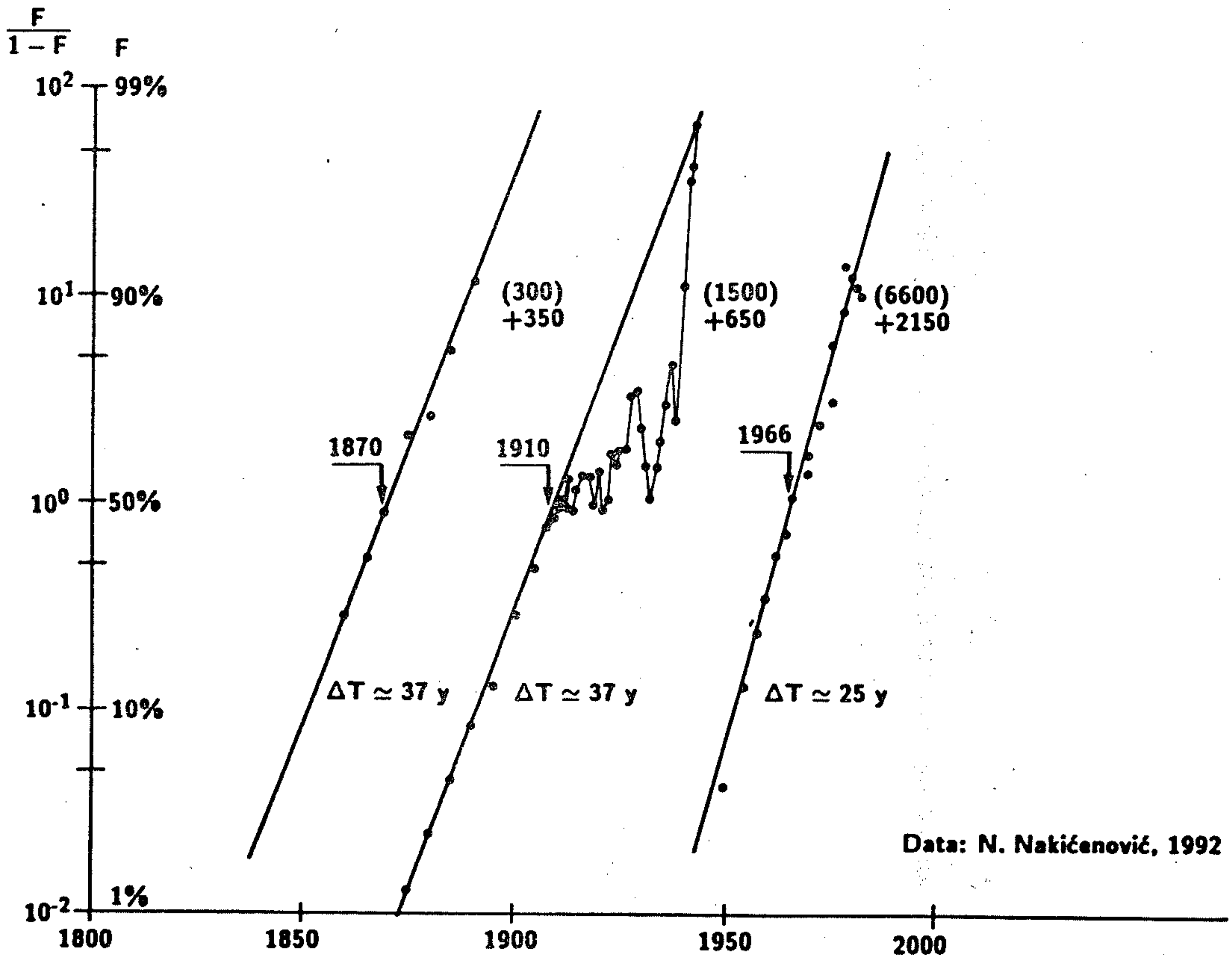
Figure 2



USA Data
Electrical Energy
Total Energy
Percent Deviation
30
20
10
0
−10
−20
−30
1840
1860
1880
1900
1920
1940
1960
1980

Figure 3

WORLD TOTAL ENERGY CONSUMPTION (GWyr/yr)



C. Marchetti, IIASA, 1992

Booms and Recessions

The existence of such cycles was discovered (with precursor) by Kondratiev in Russia, in the mid-1920s. With excellent intuition and meager data he constructed a theory that the economic system is going up and down by internal and uncontrollable mechanisms.

The West was on its way down then and Stalin chuckled at that. He did not, however, like the idea that through invisible mechanisms it would resurge after 1940. So he sent Kondratiev meditate in prison where he died.

His luck was not better in the West, where astute economists made a living advising politicians how to manage the economy by turning interest rates 0.1 points up or 0.1 points down. They did horrendously fail in the 1920s and 1930s, but they are still there playing the same tricks. For them, invisible uncontrollable mechanisms were blasphemy and Kondratiev was ostracized.

I helped rehabilitate him, showing 50 solid cases, worked with my powerful logistic model, that the cycle not only does exist, but penetrates the finest structures of the behavior of our society. The Russian Academy of Science recently gave me a "Kondratiev" silver medal for the rescue.

Looking at the sinusoid, we can say that in the up branch, when energy consumption grows faster than the secular trend, everything flourishes and in the down branch everything progressively wilts. Boom and recession.

Examples are infinite. GNP to take another synoptic indicator, grows in logistic pulses, one above the previous one (Figure 5), whose centers (where growth is maximum) coincide with the tops of the sinusoid.

To show the synchronization, the centerpoints of GNP for various states are reported in Figure 6. The centerpoint of the Kondratiev wave is in 1969. With a spread of a couple of years, which may also come from the imprecisions in fitting, and in the data they are all there.

I tried to go to the central mechanism of the cycle, but without success. I could easily discard all the mechanisms suggested by the economists, starting from Schumpeter. The basic mover seems to be psychological. A collective mood moving up and down with a periodicity of 55 years. I could detect such regularity over 500 years.

The recession can be seen as an aversion to buy. People have the money, have the needs they will explicitate a few years later when boom will restart, but they don't spend. They prefer to watch the numerals of their money inserted into various financial roulettes.

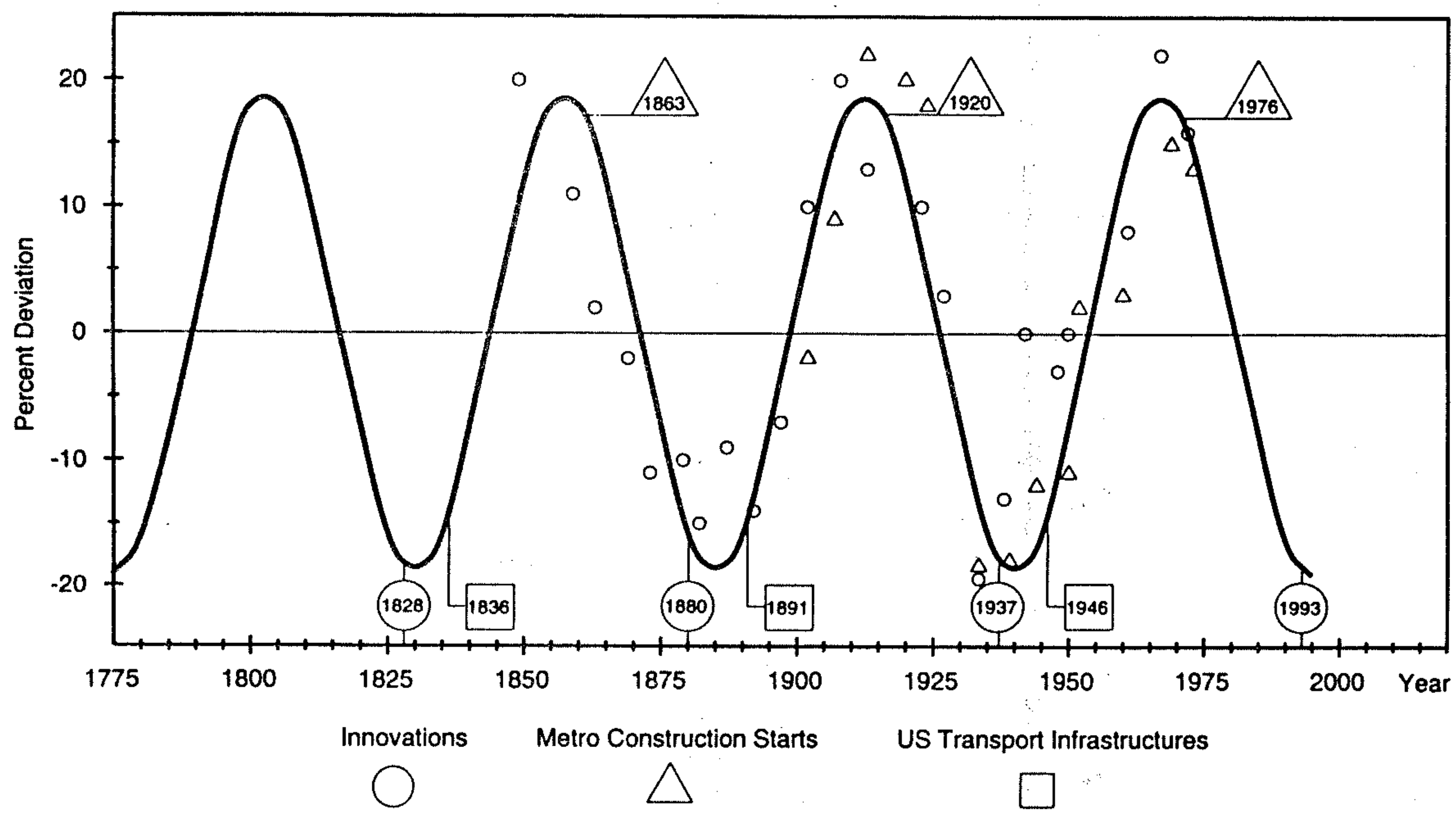
In this situation demand saturates, basically to substitution levels, so does production. E.g., that of cars was stuck to ±33 millions per year during the last 10 years.. Because productivity keeps increasing (say 3% per year) all core industries excrete personnel.

The new wave of innovations will reabsorb them in due time, but during the transition at the trough of the sinusoid, these industries are still small and can only reabsorb a fraction. The waves of unemployment, if explicit, can be perfectly synchronous in various economies (Figure 7). At present, unemployed are in many ways formally erased, e.g., through early pensions.

A danger related to industry is that engineers grown during the boom, and expecting it to last forever, once in decisional positions during the downswing, tend to overinvest. I have estimated this overinvestment at around 4 trillion dollars worldwide.

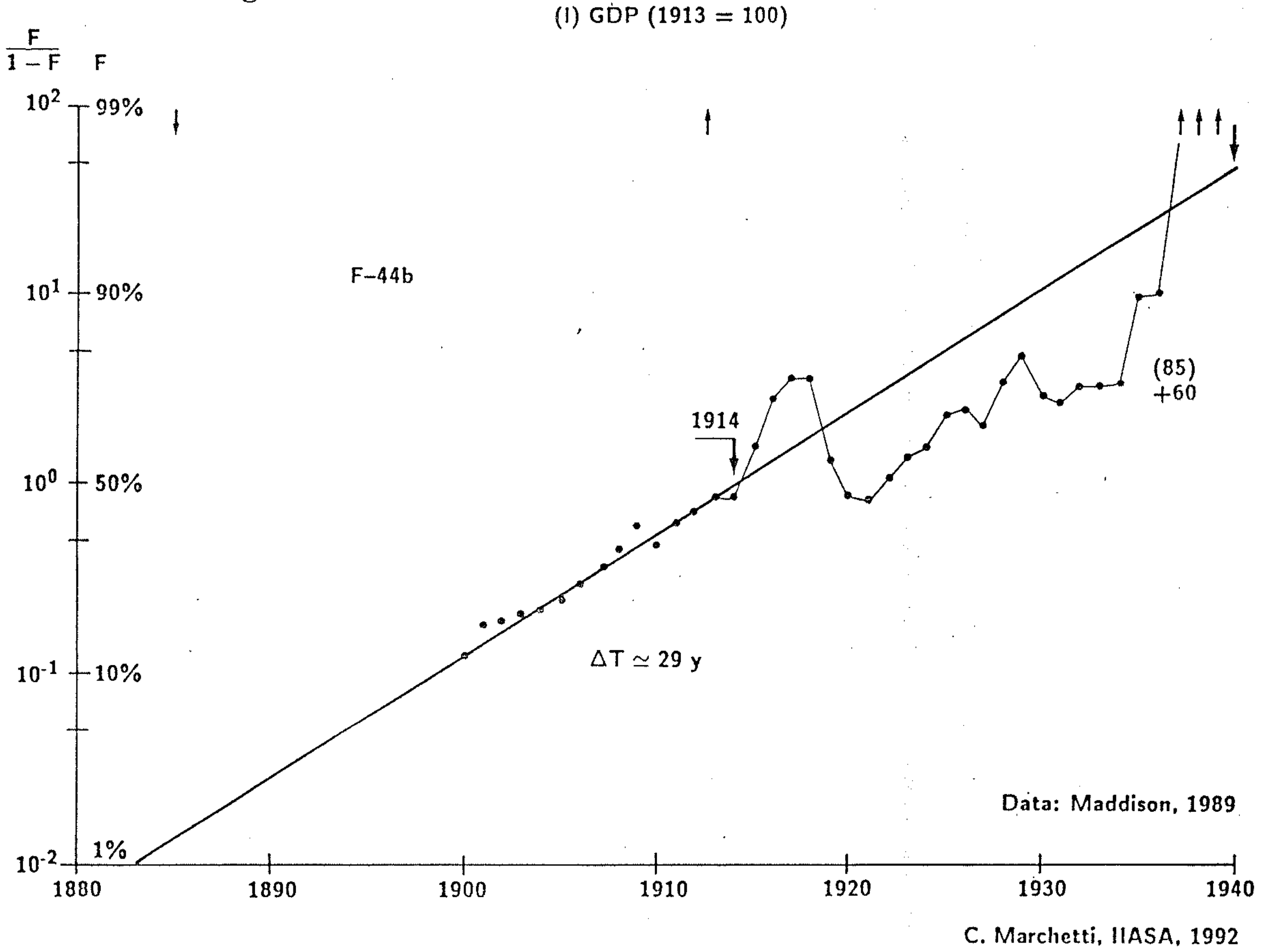
Figure 4

CENTER OF WAVES
LOCATED ON ENERGY INDICATOR



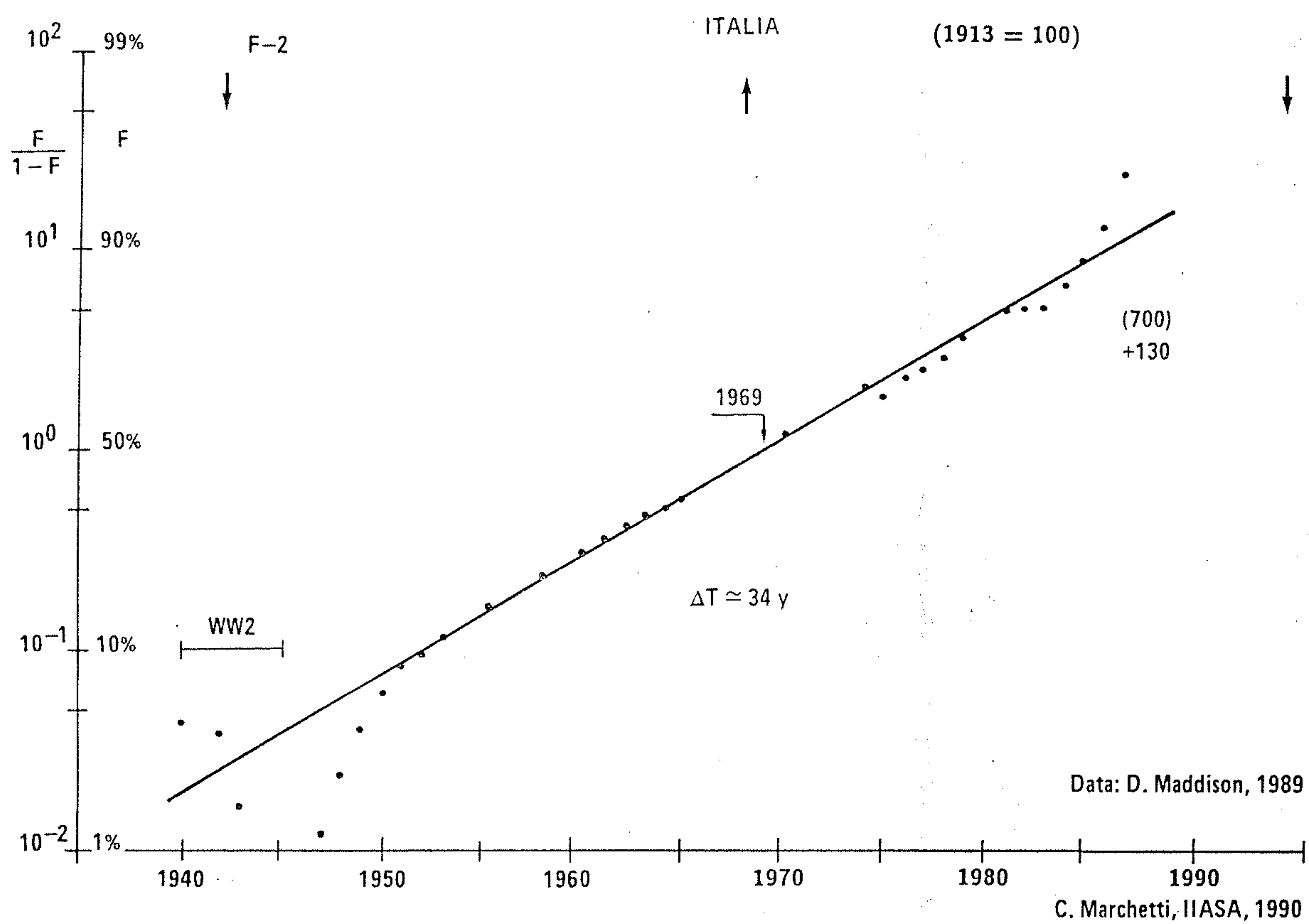
MARCINNO.DRW.

Figure 5A



(I) GDP (1913 = 100)
F/(1 − F)
F
10^2
10^1
10^0
10^-1
10^-2
99%
90%
50%
10%
1%
F–44b
1914
ΔT ≃ 29 y
(85)
+60
1880
1890
1900
1910
1920
1930
1940
Data: Maddison, 1989
C. Marchetti, IIASA, 1992

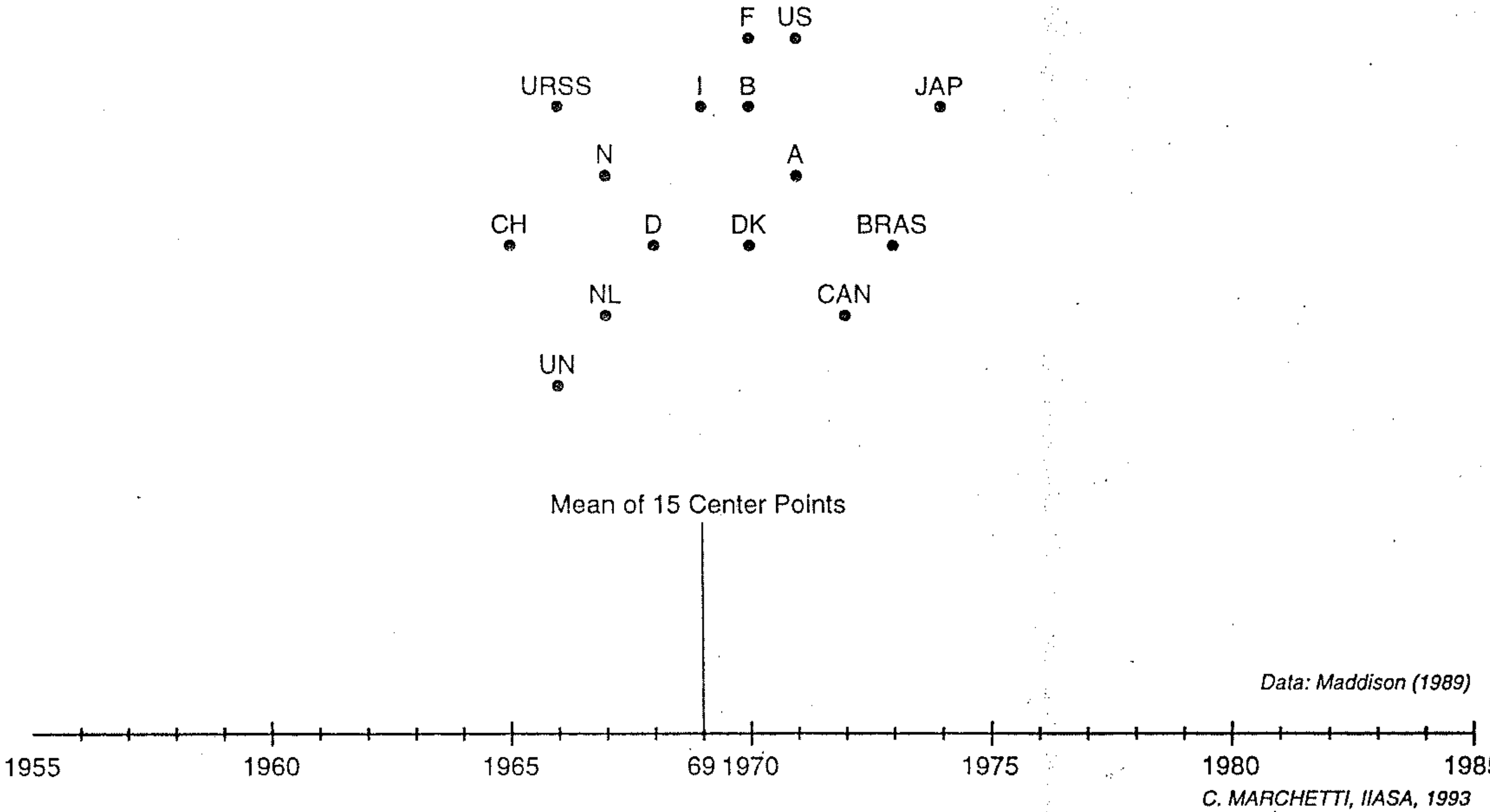
Figure 5B



ITALIA
(1913 = 100)
F–2
F
1 – F
10^2
10^1
10^0
10^−1
10^−2
99%
90%
50%
10%
1%
WW2
1969
ΔT ≃ 34 y
(700)
+130
1940
1950
1960
1970
1980
1990
Data: D. Maddison, 1989
C. Marchetti, IIASA, 1990

Figure 6

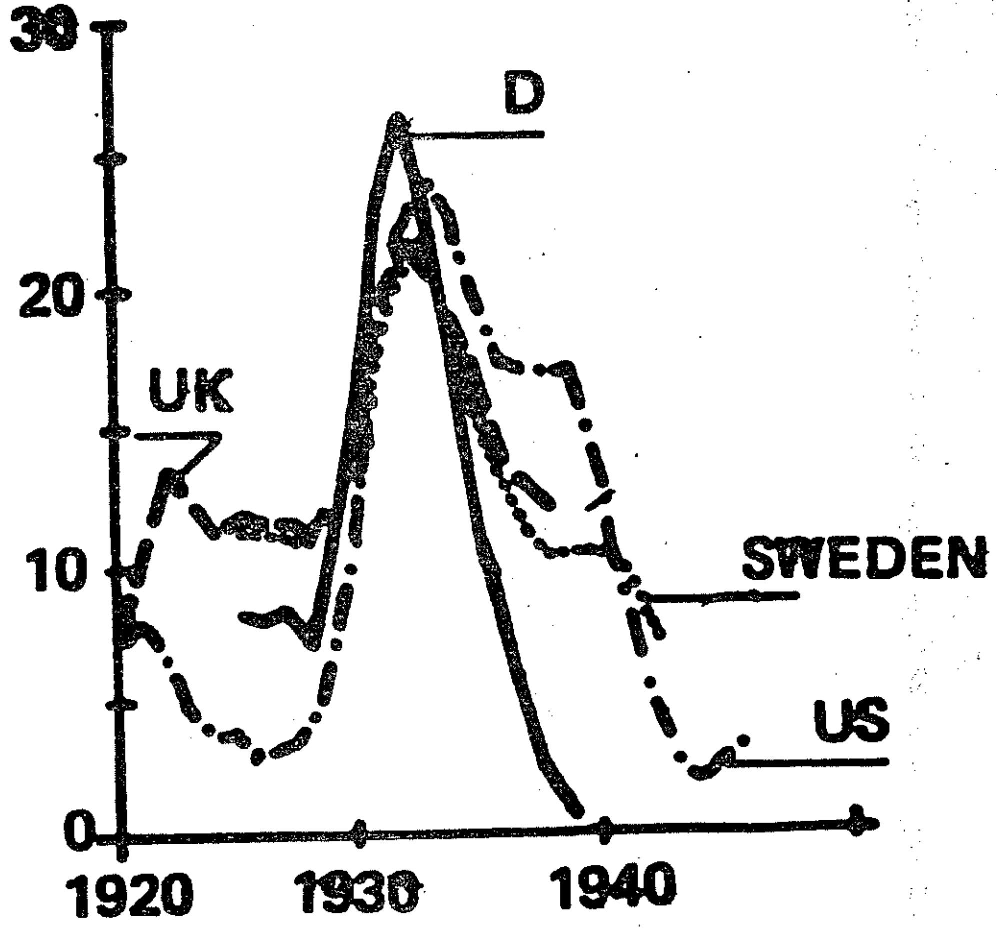
CENTER POINTS OF GDP GROWTH IN THE COUNTRIES INDICATED



CPOFGDP

Figure 7

SYNCHRONIZATION OF 1930–1940 UNEMPLOYMENT



The Energy Leaps

As said, the growth in total energy consumption can also be measured in terms of a sequence of logistics, each one starting from the platform of the saturation point of the previous one (Figure 3).

This representation is useful for our purposes because it shows a fairly constant growth ration per pulse with similar time distribution of the growth. This representation is obviously equivalent to the previous exponential plus sinusoid.

These energy leaps are strictly connected with the cycles. their centerpoints coincide more or less with the centers of the cycles. *Consequently we are now at the end of a leap waiting for the start of the next one.*

Because we are more interested in the amount of energy consumed commercially than in the total energy, the same exercise has been repeated with this constraint (Figure 8).

Energy consumption cannot growth to infinity but the fact that 70% of the human population is still in more or less poor stage, and moves to industrial plenty, makes a strong rate of growth inevitable, at least for the next 50 years which are the most interesting for us.

Many people ask where all that primary energy will come. History contains the answer, by switching from one primary energy to the next one, wood, coal, oil, gas, nuclear of various denominations (or solar if you believe in it).

When I came to IIASA in 1974, the problem of finding a model for the energy markets during the last two centuries or so was looming in the air. Simple and predictive recommended Prof. Häfele, a physicist, head of the Energy Project.

I took the challenge and through a series of improbable accidents I solved it. Using the pretty idea that primary energies are animal species competing for a habitat, the market, and using the mathematics ecologists had developed in the 1920s.

Figure 9 shows the result. Primary energies have product lifetimes of 200–300 years and substitute each other with the outmost regularity permitting solid forecasts up to 50 years or so as we checked using past data and "forecasting" forth and back.

This led me, in 1974, to a forecast quite important for this meeting, that *methane will be the dominant primary energy in the first half of the next century*, reaching perhaps 60% of the total energy market, a feat that only coal did, in the 1920s.

Figure 8

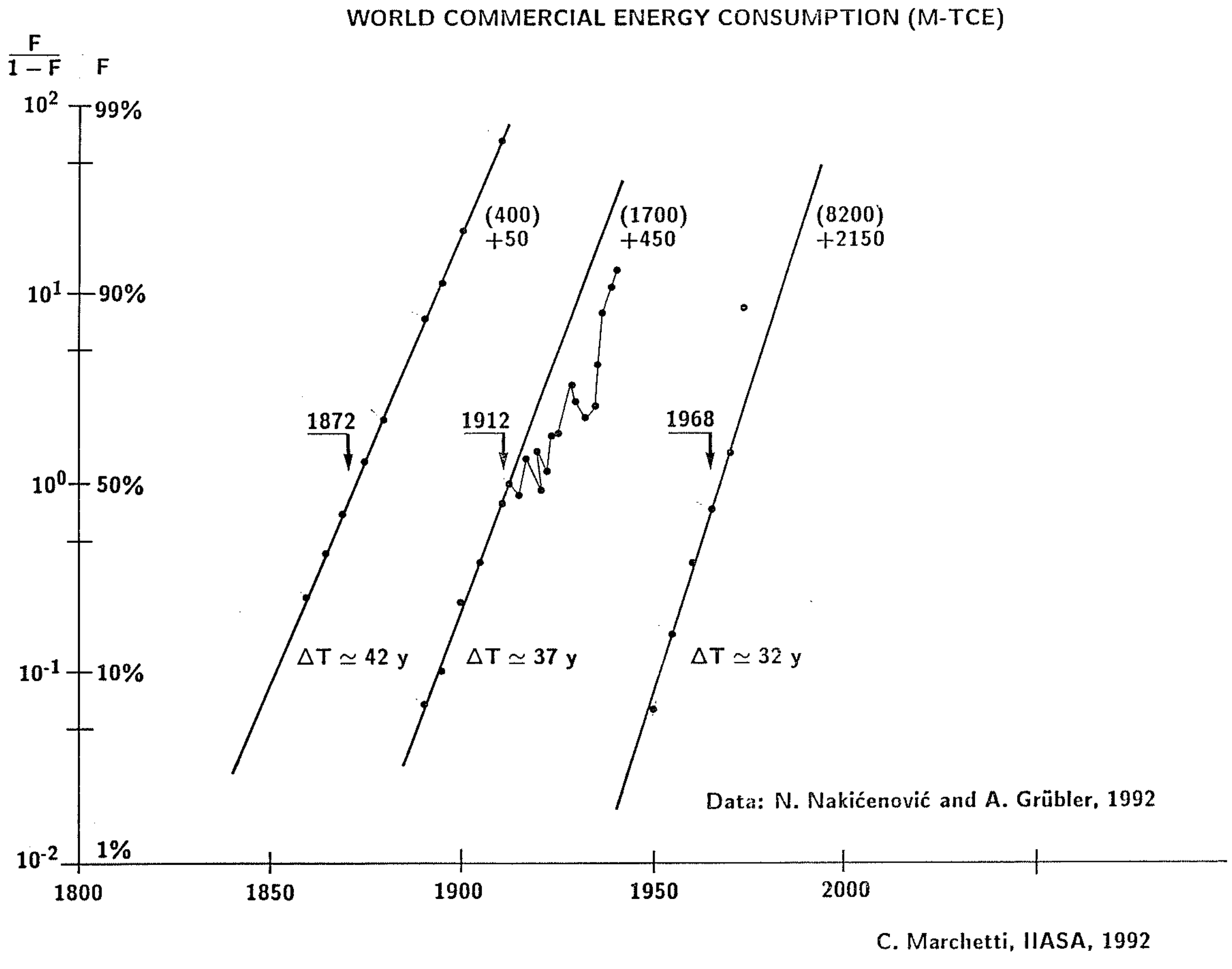
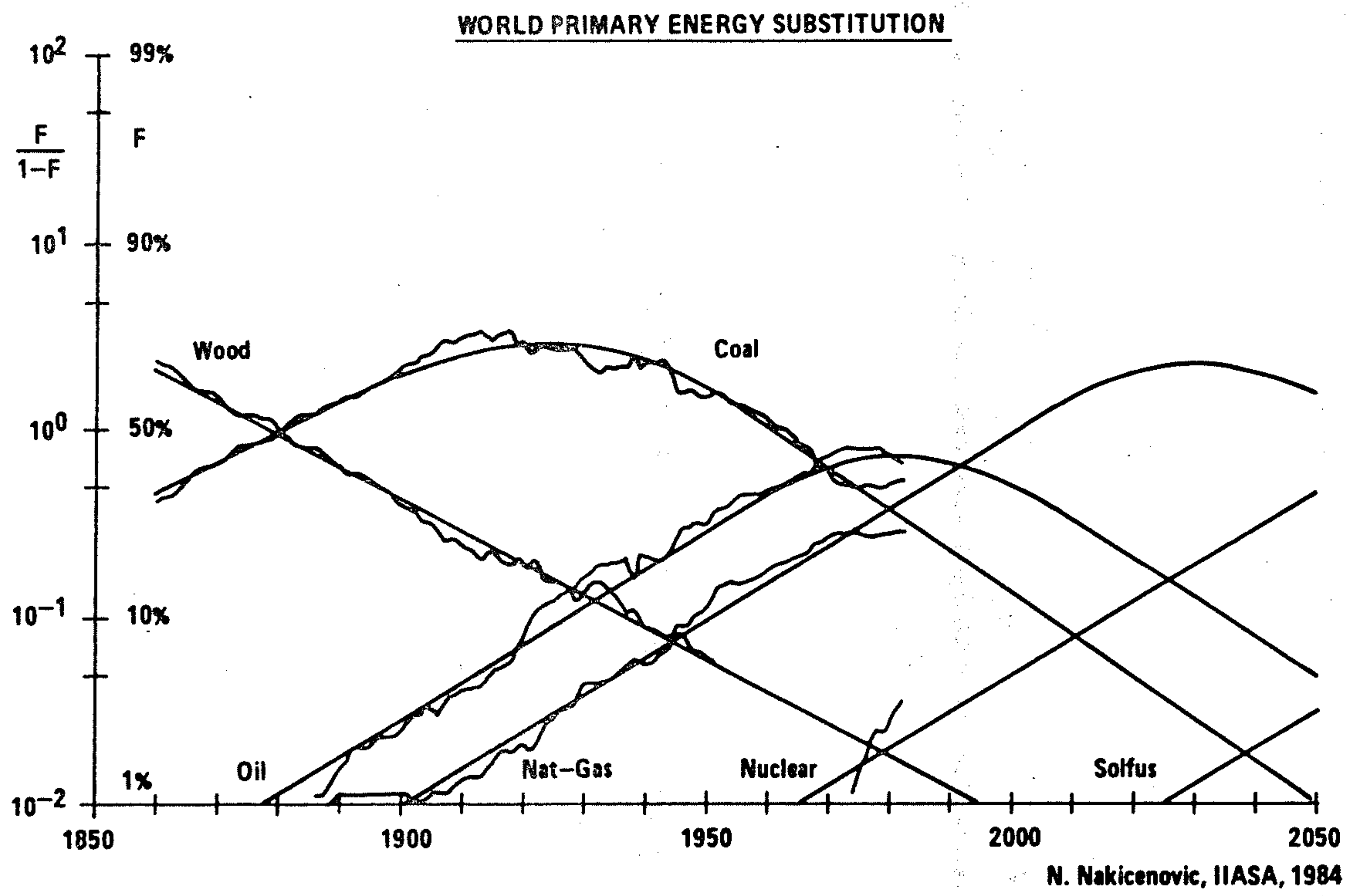
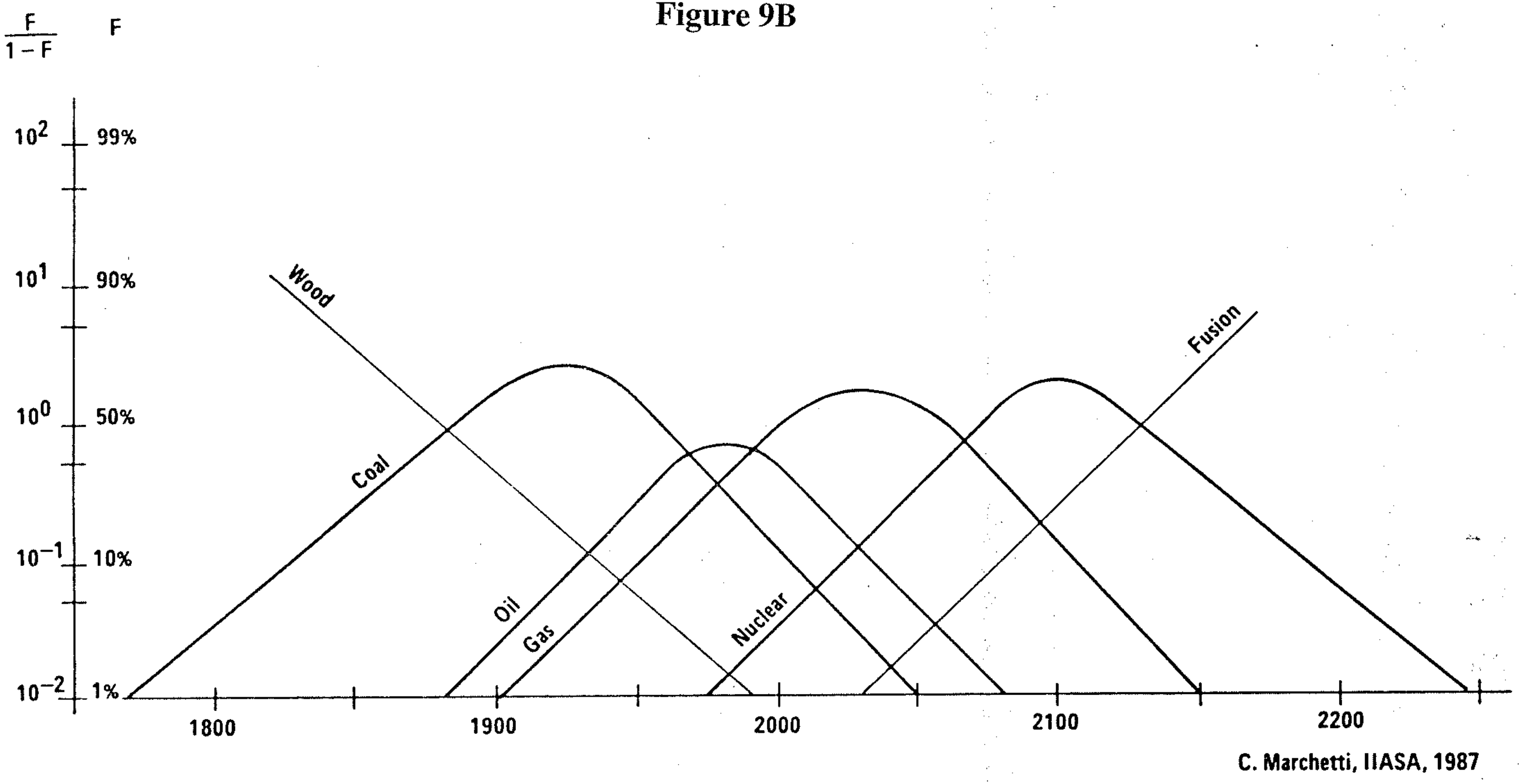

WORLD COMMERCIAL ENERGY CONSUMPTION (M-TCE)
F / 1 − F
F
10^2
99%
10^1
90%
10^0
50%
10^-1
10%
10^-2
1%
1800
1850
1900
1950
2000
(400)
+50
(1700)
+450
(8200)
+2150
1872
1912
1968
ΔT ≃ 42 y
ΔT ≃ 37 y
ΔT ≃ 32 y
Data: N. Nakićenović and A. Grübler, 1992
C. Marchetti, IIASA, 1992

Figure 9A



WORLD PRIMARY ENERGY SUBSTITUTION
10^2
99%
F/1−F
F
10^1
90%
10^0
50%
10^−1
10%
10^−2
1%
Wood
Coal
Oil
Nat−Gas
Nuclear
Solfus
1850
1900
1950
2000
2050
N. Nakicenovic, IIASA, 1984

Figure 9B



F/(1 − F)
F
10^2
99%
10^1
90%
10^0
50%
10^−1
10%
10^−2
1%
Wood
Coal
Oil
Gas
Nuclear
Fusion
1800
1900
2000
2100
2200
C. Marchetti, IIASA, 1987

And What After Methane?

Energy use on the scale prospected will produce nonnegligible impact in the earth ecosystem. Many things have been done in the last 20 years to reduce the emission of at least the most noxious products of combustion.

Cars have now catalytic converters and power plants dust filters and scrubbers. But nothing has really been done to eliminate CO_2 strongly suspected of altering the global climate.

In 1976, in my institute, we addressed the question and I concluded that the problem should be solved by the energy industry by distributing carbon-free energy, hydrogen and electricity, to the final consumer.

CO_2 can be separated by some refinery trick that produces hydrogen instead of gasoline or else, plus CO_2. This can be safely disposed in a number of ways I described in 1976 in the most quoted paper of mine: *Geoengineering and the CO_2 Problem.* The disposal can be in exhausted (or not) gas fields, oil fields (where it can help extract more oil), coal fields (where it can displace absorbed methane, producing then extra methane), methane hydrate fields (where it displaces methane producing CO_2 hydrates), and more plainly in aquifers and the ocean.

Now, 20 years later, and this is short time in terms of conceptual movements, these ideas are emerging as developments for actual applications. Norwegians study CO_2 injection in aquifers and Japanese in the deep ocean. And everybody is tinkering with fuel cell cars powered with hydrogen.

I started in 1969, at the top of the cycle, a crusade on the hydrogen economy using nuclear reactors to provide the primary energy to split water into hydrogen and oxygen.

I also suggested "Energy Islands" located in atolls (Figure 10), where huge reactors would be parked to produce hydrogen very economically, out of sight, out of mind, and extract the necessary uranium from sea water. This would provide plentiful fuel for at least 10,000 years. The oceans contain 4 billion tons of uranium in solution.

In just three decades, the Japanese I had indoctrinated in 1973 have solved all these problems: uranium extraction from sea water, high temperature reactors, and two processes to split water with nuclear heat.

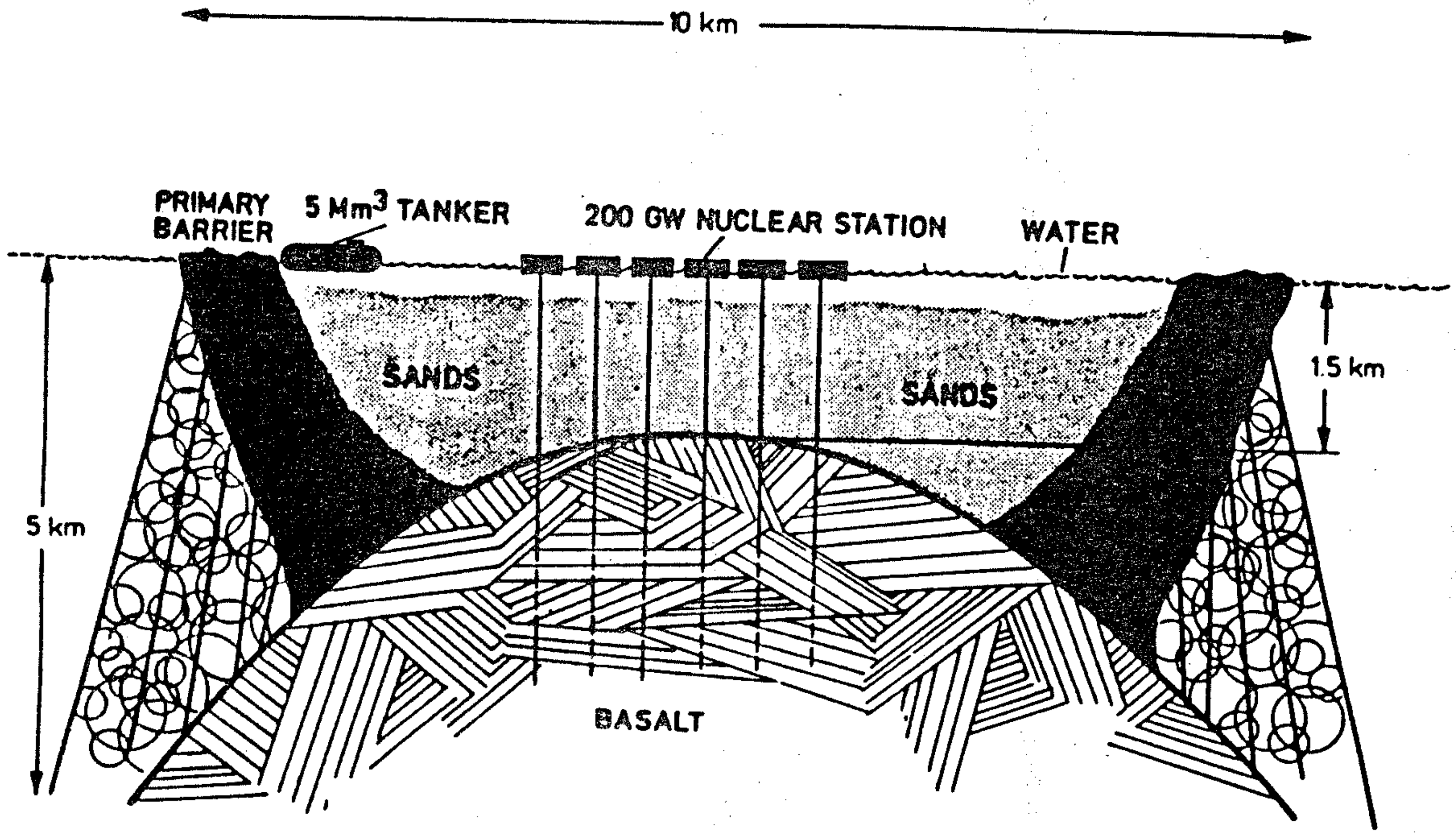
It is not improbable that the whole set will go through the teething troubles during the coming Kondratiev cycle, and be ready to take the relais of everything in 2050 when the next cycle will begin. So hydrogen from fossil fuel may have a long-term follow-up.

An interesting consequence for the participants of the conference is that *hydrogen can be compatible with the natural gas infrastructure*, and that will extend their prospects for another 10,000 years.

The strong message for engineers working on the optimization of this structure through the wizardry of electronics is that infrastructures built in the next 20 years may last for another 100 years and *it may be good to keep hydrogen as the next customer in mind.*

There is another moral I should evince. Copernicus could not touch the human heart. But beyond perception and suspicion, the great invisible machinery of the cycles drives the system with Copernican precision. This helped humanity to survive many rational follies.

Figure 10


10 km
PRIMARY BARRIER
5 Mm3 TANKER
200 GW NUCLEAR STATION
WATER
SANDS
SANDS
1.5 km
5 km
BASALT