ENERGY CONSERVATION MEASURES

Edited by **J D PARKER** *Oklahoma State University, USA*

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PREFACE

The problem of energy use and availability is common, to a greater or lesser extent, throughout the world. An equitable distribution of natural resources for our generation and our children is a major concern of the scientific community and society as a whole. Constraints and limited options to improve energy utilization and conservation have a major impact on the social welfare of our societies.

How to improve and minimize the undesirable socio-economic impacts of these constraints were major points of discussion in this symposium. Focus was on energy policies, conservation programs, and research and development priorities. Emphasis was given to electric utility growth and load management, and conservation in the petroleum and building industries.

The Symposium brought together experts from many countries to present and discuss the most recent advances in research, development, demonstrations, design, equipment, field testing and applications. It was an international forum for the formal and informal exchange of new ideas and experiences, especially those of direct relevance to Kuwait and The Arab World.

As Symposium Consultant and Editor of the proceedings, I wish to give my special thanks to each member of the organizing committee for their encouragement and help. A very special thanks to His Excellency The Minister of Oil, Sheikh Ali AL-Khaleefah AL-Sabah for his patronage and for his meaningful opening remarks at the Symposium, and to Dr. Adnan Al-Aqeel, Director General of KFAS.

Jerald D. Parker
Oklahoma State University

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ON ENERGY SYSTEMS IN HISTORICAL PERSPECTIVE:
The Last Hundred Years and the Next Fifty

C. Marchetti

International Institute for Applied Systems Analysis
Laxenburg, Austria

ABSTRACT

Volterra-Latka equations are used to reduce primary energy statistics to simple forms, useful for understanding the past and predicting the energy trends of countries and the world.

KEYWORDS

Energy trends, historical perspectives of energy consumption, Volterra equations, logistic equation, energy forecasting, energy use predictions, energy developments, interacting populations, dynamics of energy systems.

The sudden increase by a factor of three of the posted price of oil in 1973 was followed by an extraordinary flow of talk, papers and adrenaline. I had the privilege of joining IIASA, a Russian-American rumination tank near Vienna, just around that time, and squatting on that libration point, watch the mess and try to make sense out of it. Augias stables were cleaned using only one conceptual broom, and to tell the story is the object of this lecture.

The first prejudice I used, very instinctive for a person educated as a physicist, is that the "system" is basically stable and unitarian against everyday evidence of change. Consequently, history is a valid collection of experimental data, and the best results may be achieved by analyzing long strings. Mental models are however necessary to privilege falling apples vs. leaves in the wind.

The second prejudice, of faint relativistic flavor, is that energy is not really more important than matter and does not deserve a privileged treatment. Perhaps a better way of categorizing is to consider primary energies just as technologies competing for a market, in the same way as wood, iron and aluminum compete for window frames.

Ecologists, geneticists and market analysts, had more or less independently found that when their subsystems compete, Volterra-Lotka equations provide solutions that tend to fit experimental data with great economy of adjustable parameters. Having already reduced my primary energies to mutations competing for the gene pool, I just joined the bandwagon. The move proved extremely fruitful, and everything fell into place with a blissful click.

Volterra equations can litter all sorts of solutions, but for very dynamic systems, where victors have no time to rot on their laurels, a non-periodic solution, the old logistic equation, handy and simple, works satisfactorily. In the 400 cases examined to date, I never felt the necessity to go to more complicated frames, with the quality of statistical data available. I will use these equations in a normalized form, where a reference task is defined, always equal to one, even if it is a function of time. It is an essential choice. Systems, social ones included, seem to "think" in relative terms. Anyway, secular behavior comes out very sharp if we operate in such a way.

By choosing only one thing, tabula rasa is made of all the rest, implicitly dubbed as non-relevant. What I am aiming at is a self-consistent phenomenological description and reduction of a vast set of experimental observations, expressed in the form of statistics. "Explanation", i.e., reduction to a pre-existing conceptual set, may come later if necessary. One of the pitfalls of current economic thinking as I grasp it from my friend economists, is that there is an explanation for everything, usually post hoc and untestable. Much like epitaphs. Which for a scientifically trained mind have a strong stink of cemetery.

The logistics I use will then have the form $F(t) = 1/\ 1+\exp\ (at+b)$ where F is the fraction of the task or the reference set hidden into the 1 inside the bracket. This is the usual S-curve of the demographers and has obviously to be chopped somewhere to get rid of eternity. I found it useful to cut it at F=1% and F=99%, with the argument that 1% is well into the background noise of the statistics.

Just to keep things visualized one can derive it from the differential $1/F\ dF/dt = K(1-F)$ saying that relative growth is proportional to the room left for growing, which is the market share not yet taken in an economic system, or food concentration in a bottle culture of microorganisms.

When two competitors are present, the old one coming down from a dominant position and the new one picking up steam, they sum to one, so $F_2=1-F_1$ and the equation is the same for both except for the sign of a. If more competitors are present at the same time, and new ones keep pouring in, a typical case in a dynamic market, then the situation gets slightly more complicated, and finally we end in n-1 logistic equations plus a residual. The precise description of the manipulation and the software package to process statistical data is reported in Nakicenovic's paper.

Furthermore, most of my graphs will actually use a transform of the logistic equation: $\log F/1-F = at+b$, which has the advantage of showing up as a straight line.

When I started trafficking with these ideas in 1974, the first set of data I analyzed referred to US primary energy inputs. Just because it was sitting on my desk. I remember it was a Friday afternoon, and I skipped dinner fascinated by the straight lines emerging from the points I was plotting, and more than that from the very mixed up bag of statistical data.

The first case I will analyze today is that of the world. Input data are shown in Fig. 1. They go back to 1860 and were carefully collected and sifted by R. Hildebrandt for a thesis he was preparing in 1975. The processed data are shown in Fig. 2 with the two parameter logistics fitted over them. The part of the figure without statistical data results from the above equations plus the hypothesis that nuclear, "born" in 1972 when it reached 1% of world primary energy inputs, is going to grow at the same rate as coal, oil, and gas before it, which may prove not so bad. And that some hypothetical solar or fusion source is going to pop up in the year 2000. A very round figure I chose not to discourage solar enthusiasts, which proved wrong when the analysis was brought one rung higher in abstraction, as we'll see later.

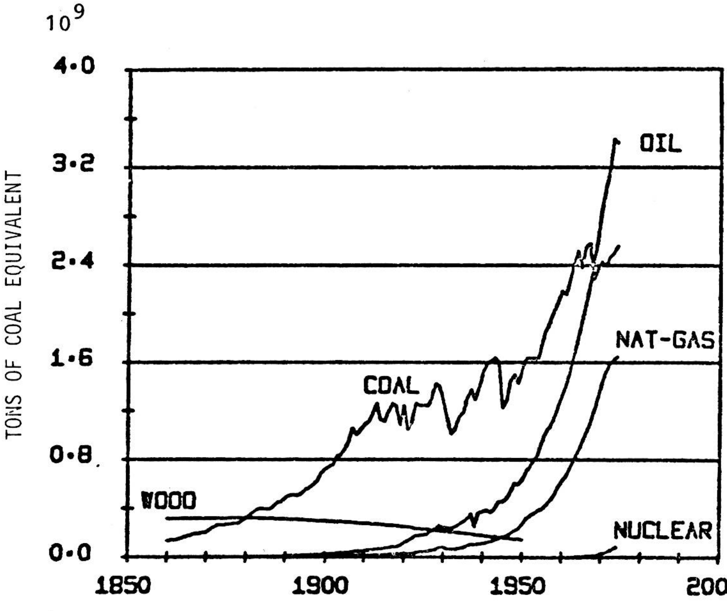

Fig. 1. World - primary energy consumption. The source for the historical data from 1860 to 1974 is Schilling and Hildebrandt (1977), except for wood, which come from Putnam. One ton of coal equivalent (TCE) is 7 10^9 cal. For nuclear we measure the heat from the core.

The perfect matching between data and equations clearly expresses my joy when I first heard the click. As I said before, this quality matching was achieved in practically all of the around 400 cases of energy system, subsystems and parasystems analyzed to date.

The first feature that struck me was the very slow rate of penetration of a new primary energy, against the current perception of energy specialists, not to talk of inventors. It took a solid 100 years for a new source to go

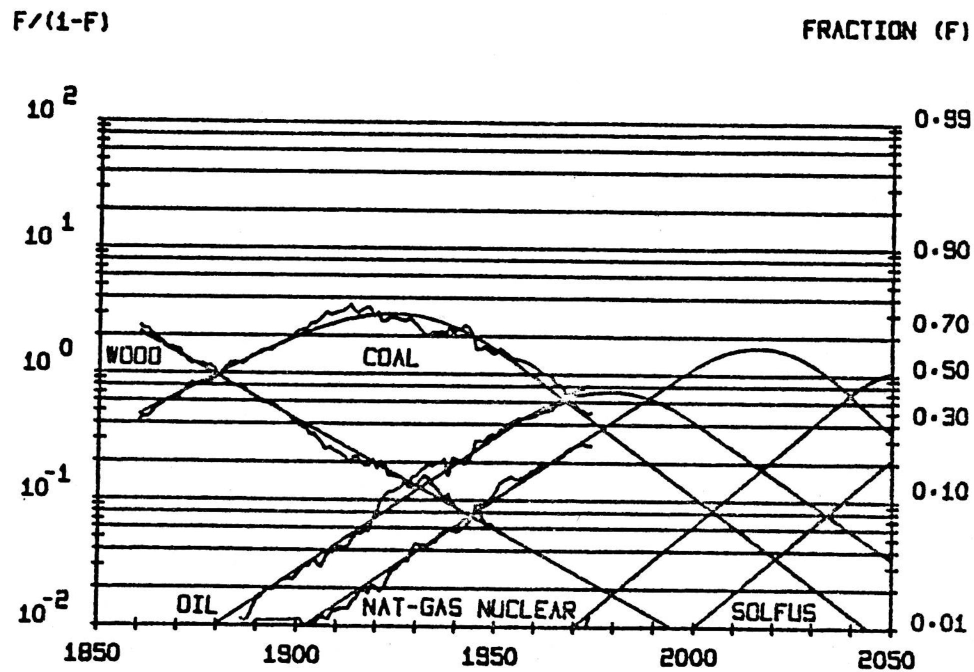

Fig. 2. World - primary energy substitution. The data of Fig. 1 are considered as fractions of their total sum (the market), and presented as ratios of each of them to the sum of the others. The time constants, or the time to go from 1% to 50% of the market, are consistently around 100 years.

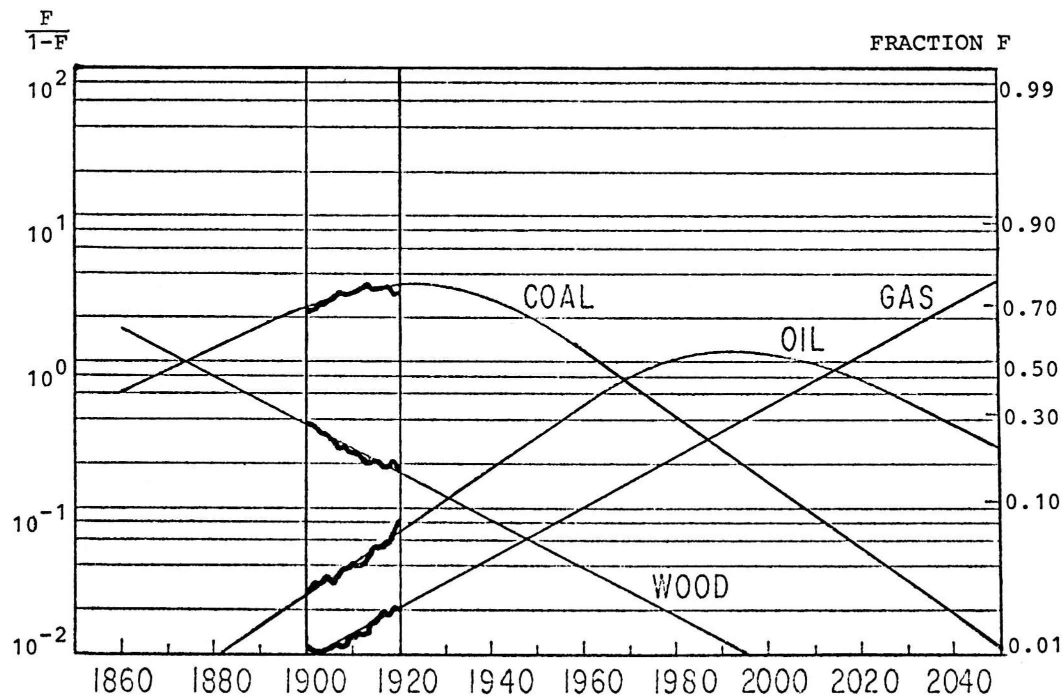

Fig. 3. World - primary energy substitution (short data). A set of logistic equations is fitted on the data base.

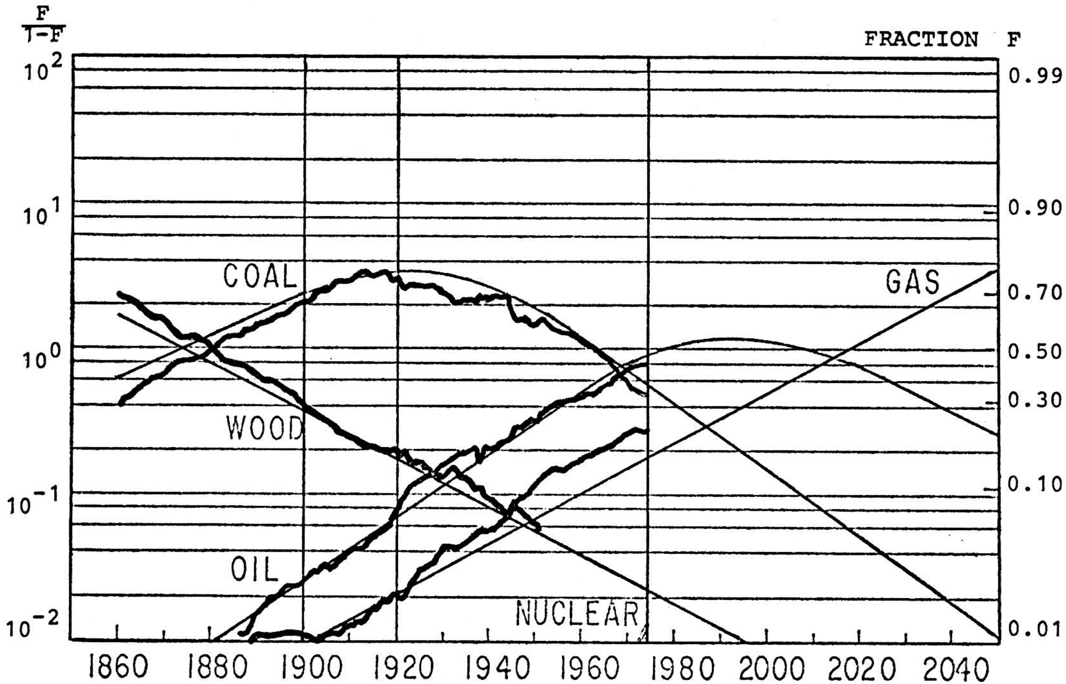

Fig. 4. World - primary energy substitution (short data). Actual statistical data are superposed to the logistic equations. Fifty years after 1920 the fitting is still good. Only natural gas deviates by about 7%.

from 1% of the market, already a well entrenched starting point, technologically and commercially, to a dominant 50%. And more striking still, the rate of penetration, i.e., the a in the equation, stays solid as rock all that long time. If one thinks of wars and pestilences, and all sorts of things that happen in the world in one hundred years, this is certainly amazing.

Especially because the constant is not kept at the Bureau International des Poids et Mesures in Paris, but preserved somehow in the collective memory of the human species.

Stability and slowness are a grave obstacle to instant solutions many quack doctors are proposing for real or presumptive energy problems, and somehow eroding our pride of computerized society. L'intendance ne suit pas.

On the other hand, they are a boon to forecasters. Predicting the structure of the energy market fifty years ahead becomes as easy as predicting a solar eclipse. The exercise is reported in Fig. 3 where bits of "trajectories" are reported for the period of time 1900-1920; where the equations are fitted and in Fig. 4 where the actual statistical data are superimposed. Coal, oil and wood match quite well back and forth in time. Gas forecast has an error, after 50 years, of about 7%. Mainly due to the fact that it was only 2% of the market in 1920, and at the beginning of the penetration the a's are still a little soft.

Not only quack doctors but very serious economists made long and sad faces when they saw this class of curves. What happens in fact is that a quintessentially economic structure like a market, can be precisely described and forecast, without ever using the concept of money, consumer behavior, price elasticity and all the paraphernalia economists use for their usually poor description of economic events. In a sense this purely phenomenological description of energy markets, and incidentally all sorts of markets, can be considered as a break in economics, and possibly a breakthrough. In my opinion money is just an external indicator of a deeper "physical" structure where the real causes and mechanisms are located. If I'm right, building an economic theory in the classical lines is a pointless exercise. It certainly failed up to now. I will show, later on, one case where prices can be deduced from this physical structure.

Another class of people who deeply dislike my considerations are the so-called decision makers. I have shown on various occasions that they are as real as the phoenix. My logical argument being that if their decisions can be predicted in timing, quality and quantity, they cease to be decisions. They are basically explicitations of a contextual necessity. Decision makers are at most optimizers, which is not a trivial quality, but qualitatively different from decision making. Energy market analysis can be used to show it, if not to proof it in general, and I also have other cases. On the other side I am still trying to find a really genuine decision taken at an aggregate level where statistical documentation allows proper historical embedding.

Apart from the question of decision making which is still unhardened, social systems certainly show an extraordinary resilience, doggedness and collective memory. All perturbations are elastically reabsorbed, even if they are so macroscopic like the October Revolution, or world wars and recessions.

In order to dispel the impression that this analysis is good only for extremely aggregated systems, I will take some items chosen more or less randomly from our 300 case energy portfolio.

In Fig. 5 the case of Germany is shown, disaggregated for coal, lignite, oil, gas, hydro, and nuclear. Germany appears the most dynamic state studied yet, with a time constant of about 20 years. In Fig. 6 Austria is reported, and in Fig. 7 the OCED countries. Figure 8 shows the U.S. and Fig. 9 the U.S. coal industry, analyzed by technology of extraction. For a broader set I refer to the Marchetti-Nakicenovic report, which is the compendium of a study sponsored by the Volkswagen Foundation in 1977-1978.

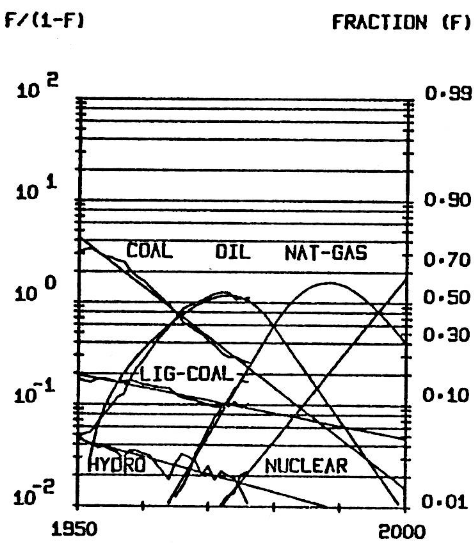

Fig. 5. OECD FRG - Primary energy substitution - statistical data for Germany are fitted up to year 1975 and forecast to year 2000. Hydropower comes in as its contribution is above our cut off line of F = 0.01. The slope of nuclear may not be fully consolidated yet. It will lead in any case to very high levels of nuclearization toward the end of the century. West Germany shows the exceptionally low time constant of about 20 years.

Let us now come back to Figs. 1 and 2, and see if more information can still be extracted from them. The structure of the market is reported there in relative terms. One of the arguments that have been drummed to death into our ears are that resources are scarce and doom is coming. In any case we have to pay more. If we can construct a reasonable projection for the total size of the market, then we can calculate projected demand per source, compare it with resources and reserves and have an objective idea about when death will come.

The total world energy consumption is reported in Fig. 10. Non-commercial