

The Energy Juggernaut

by C.R. (Buzz) Nixon and J. Rennie Whitehead

Over the last few years, each of the Authors has written several articles¹ related to global energy for the CACOR Proceedings. They are listed at the end of this paper. In particular, Dr. Whitehead gave a luncheon talk on energy 12 years ago, which was later turned into an article in *The Ottawa Citizen* and a paper in the CACOR Proceedings entitled "Global Energy: the Inevitable Transition". In it he introduced a diagram that recalled Hubbert's work² in the 1940s, in order to illustrate the transitory nature of the Fossil Fuel Age and the implications on our energy and environmental policies of the supply/consumption spike. It is strongly recommended that readers refer back to these papers. Since they were first written, the worldwide consumption of energy has continued to grow at an astonishing and frightening rate. The following is in the nature of an update of these earlier articles and a reinforcement of the warnings they contained. It is a consolidation of the material the Authors presented at the CACOR 1999 Annual General Meeting. The new figures are based on data in the latest (1999) reports³ of the International Energy Agency (IEA) and the International Institute of Applied Systems Analysis (IIASA).

Introduction

Figure 1 shows the actual and projected growth of total global energy consumption based on data and projections by leading international authorities.

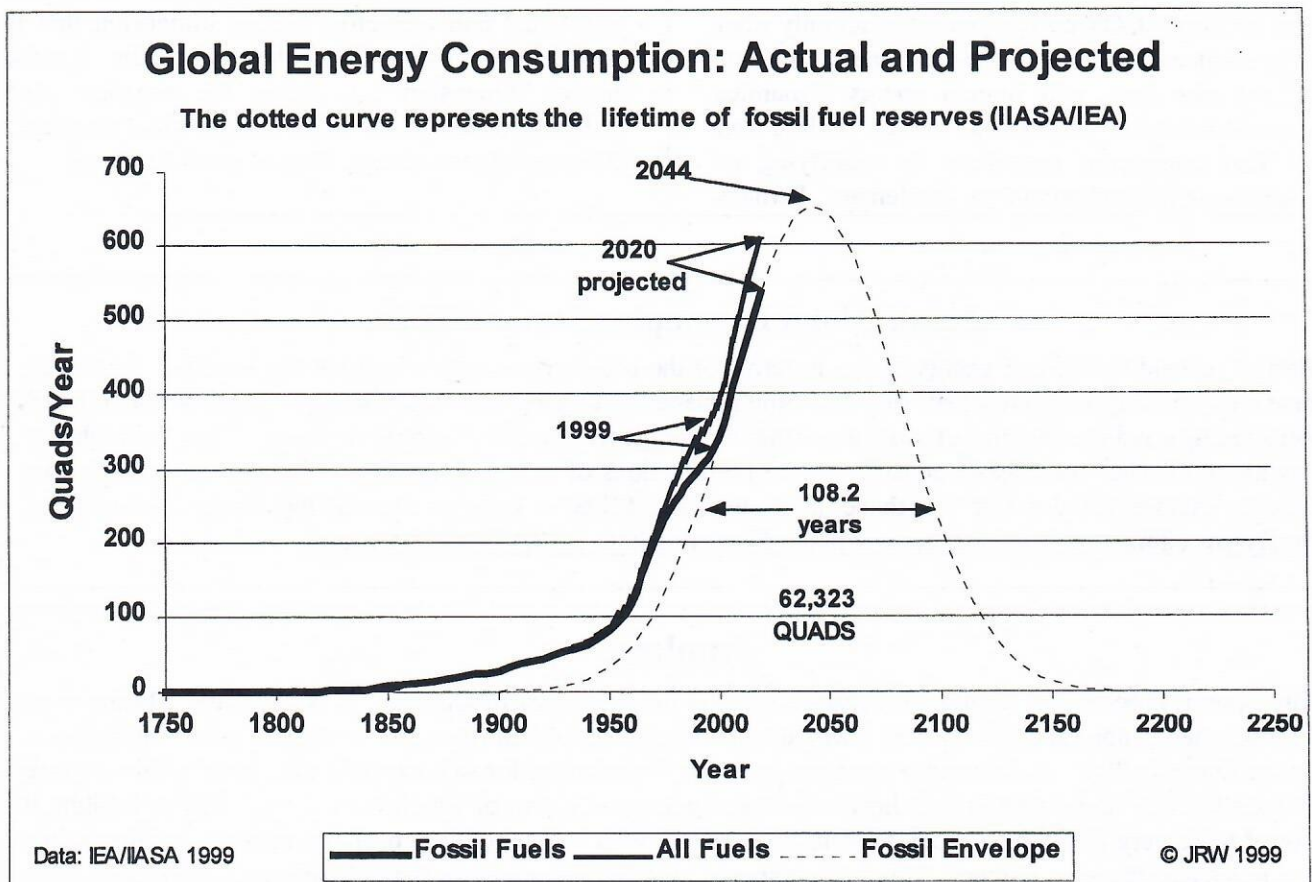


Figure 1: Global Energy Consumption and the Fossil Fuel Spike

The thinner solid line shows the growth of consumption of energy from all sources. The thicker

line is the actual and projected consumption of all fossil fuels. The dotted curve (idealized as a Gaussian distribution) is calculated to contain the

energy from all the fossil fuels past, present and future based on the IEA and IIASA figures for total reserves and resources of oil, gas and coal that they are confident can be retrieved with present technology and economic conditions. Given this total, the height (and therefore the width) of the dotted curve, and its position on the time axis, have been adjusted for best fit.

The scale is in Quadrillion Btu. (Quad). You will see below what one Quad means in terms of various sources of energy. On the scale of Figure 1, one Quad is not very significant, yet it is obviously an enormous amount of energy to manipulate.

One Quad is approximately the amount of energy obtained from each of the following:

- **36 million tonnes of coal (400,000 rail cars)**
- **24 million tonnes of oil (167million barrels)**
- **28 billion cubic metres of natural gas**
- **33 standard (1 gigawatt) electric power stations in one year. (Coincidentally, the generating capacity of Ontario)**
- **>600 sq. km. aggregate surface area of 10% efficient photoelectric solar collectors at sea level in clear conditions in one year.**
- **44,000 750 kW strategically placed windmills operating at peak level for one year.**

[No allowance is made for transmission or conversion efficiency beyond the point of generation, or for cloudy (solar) or calm (wind) conditions.

A reduction of fossil fuels by 1 Quad (e.g. replacing 33 coal-fired power stations by 33 nuclear stations for one year) is too small a change to make a noticeable difference in the above diagram. Note that consumption is rising at the rate of 12 Quads/year.]

Figure 1 is worthy of very careful study. It illustrates two main points:

- The fossil fuel age is transitory. It will reach its

peak towards the middle of the coming century.

- The quantity of fossil fuels now used every year and the rate of growth are huge. It will therefore be very difficult to replace them by substituting alternative sources of energy as quickly as supplies of fossil fuels dwindle.

This is a dramatic, if somewhat idealized way of presenting the global energy dilemma. The issues it raises are elaborated below. Please keep in mind throughout that most of the problems arise because we are dealing with unprecedentedly huge quantities of energy. *There is consequently no precedent for the current energy dilemma.*

Review of the Issues

Let us review the historic and foreseeable dynamics of the global energy situation.

The review will focus on these five points:

- The importance of energy in our lives, and therefore the importance of focusing attention on the dynamics of energy supply.
- The magnitude, the rate of increase and the forecast levels of global energy consumption.
- The inevitable and monumental change in the sources of primary energy.
- The powerful momentum to continue the current pattern of energy supply until the sources run out.
- The widespread political and public inertia, which ensures that actions to counter this momentum are too little and much too late.

The Importance of Energy:

Energy has become as important, and as essential an ingredient in our lives as the air we breath, the water we drink, the food we eat and the shelter we need. In every aspect of living in a modern, urbanized, industrialized society, the influence of energy is pervasive.

The Merits of Energy Use:

The growth of civilization, of knowledge, of science, of medicine, of industry, of transportation and of communication, of labor saving devices and machinery, in fact the progress in all fields of human endeavor, directly or indirectly have been accomplished by virtue of man's ability to produce, transport, use and control energy. The quality of life is a direct reflection of the use of energy.

The agricultural revolution was essentially an energy revolution, which, through the domestication of plants and animals, enabled humans to obtain more energy than they could by hunting and gathering.

Similarly, the industrial revolution was also essentially an energy revolution where humans became able to take advantage of more energy through the burning of coal so as to power steam engines.

The Demerits of Energy Use:

Simultaneous with all of the progress attributable to energy have been the unintended and undesired side

effects that can equally be attributed to our use of energy and detract from the quality of life, such as:

- the consumption of renewable resources faster than they can be reproduced,
- the extinction of species vital to the sustainability of the ecosphere, and,
- the production of wastes faster than they can be either recycled or absorbed by the ecosphere.

The very sustainability of our planet's ecosphere is in jeopardy due to the way we have produced, stored, controlled and used energy.

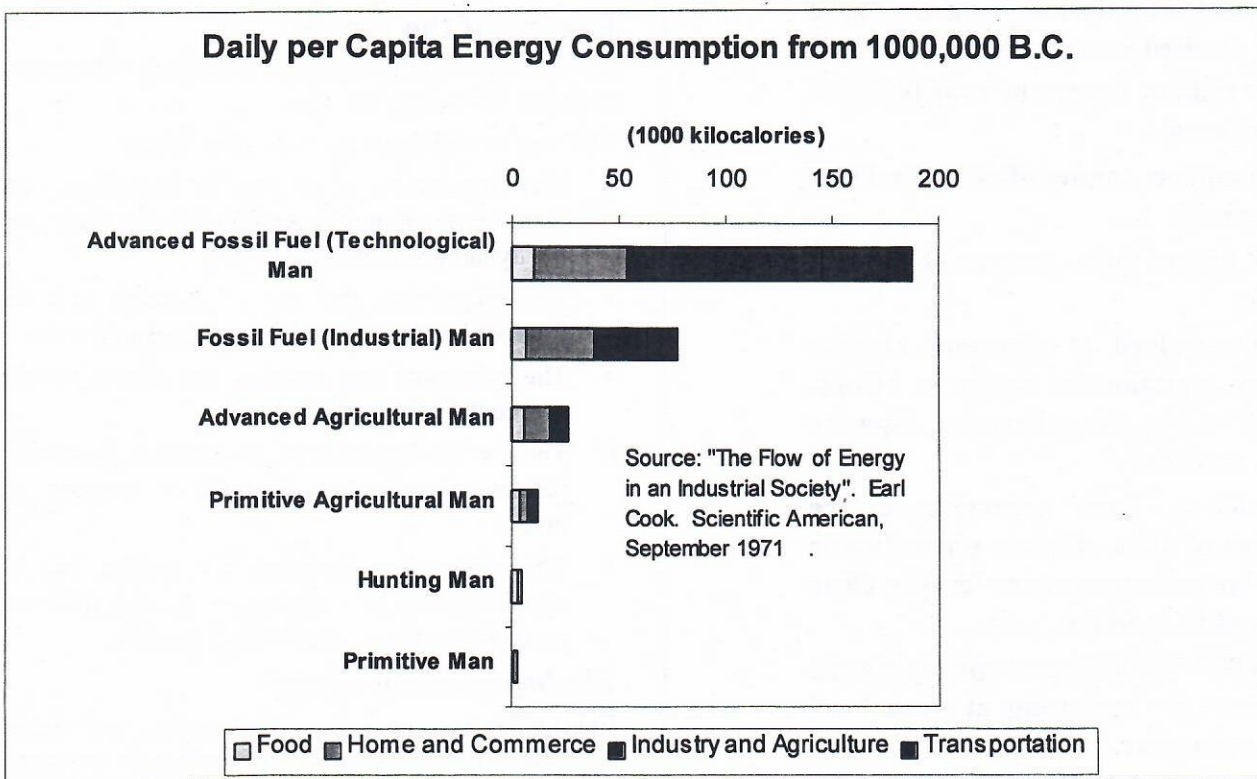


Figure 2: Daily per capita Energy Consumption from 1,000,000 BC to the Present Day

Magnitude of Energy Use:

Figure 2, which charts the per capita growth in energy consumption from Primitive to Advanced Technological Man, shows that, during this progression, the per capita consumption of energy has increased about 100 fold. This is as though each of us today is consuming the same amount of energy as 100 of our primitive ancestors, or, that each of us has

essentially 100 slaves.

Figure 2 also illustrates why there is currently, and likely will be for some years, a rapid increase in the global consumption of energy. As underdeveloped societies, which are somewhere between Agricultural and Industrialized Man, become urbanized and industrialized they approach the energy consumption of Technological Man.

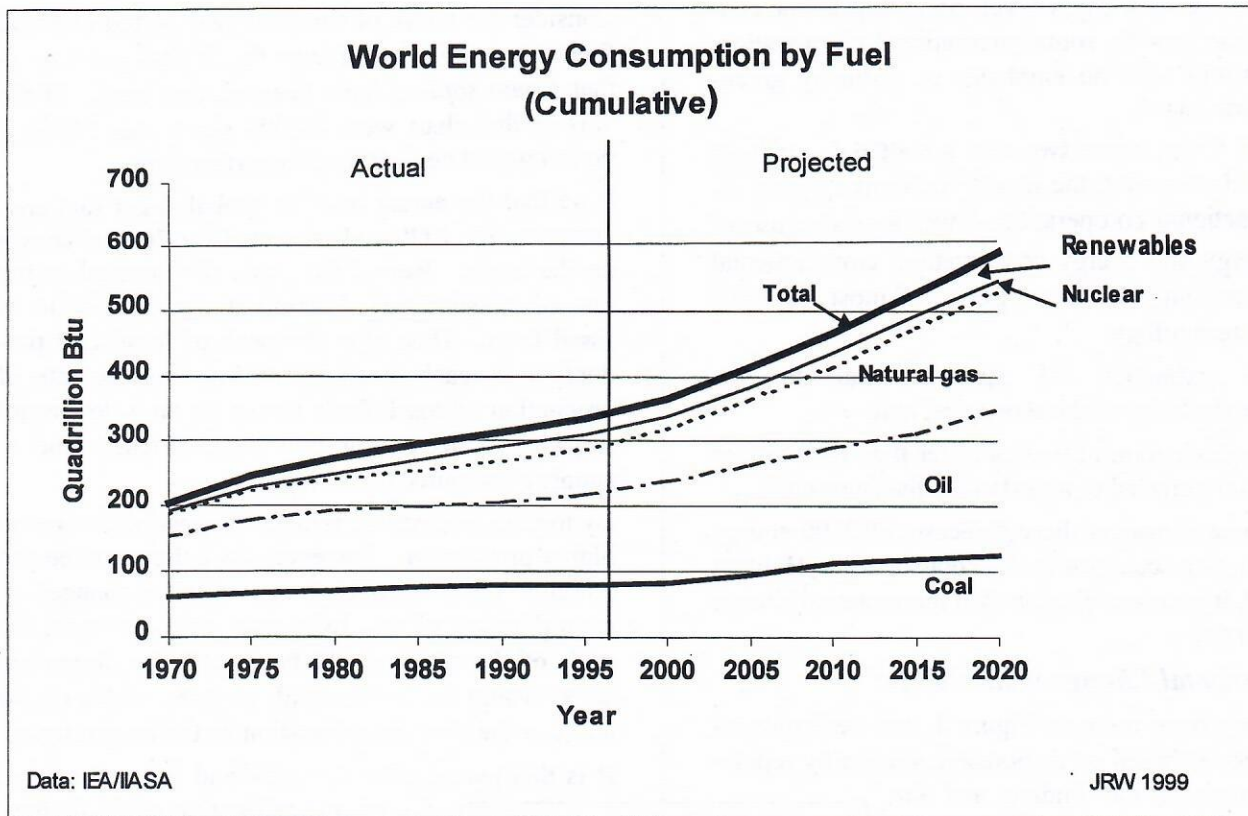


Figure 3: Cumulative World Energy Consumption by Fuel

Figure 3 depicts the current and foreseeable global consumption of energy. Its important features are:

- the current level of global energy consumption of about 360 QUAD per year. This is equivalent to the energy content of 128 million rail cars of coal, or, with 100 cars per train, of about 3500 coal trains per day. That is two and a half coal trains each and every minute some place in the world. This quantity of energy almost defies comprehension.
- today about 90% of the energy that the world is using comes from the burning of fossil fuels.
- nuclear and renewable sources of energy are almost insignificant compared to the fossil fuel sources.
- there is a tremendous rate of increase in the consumption of energy as shown by the slope of the line - about 12 QUAD per year. This rate of increase means that there will be a replication every eight years, somewhere in the world, of the energy infrastructure of North America.

- most importantly, due to the massiveness and the momentum of the current energy supply regime coupled with the enormous rate of increase in the demand for energy virtually nothing can be done to significantly change the pattern of energy supply and consumption within the next 20 years, when the level appears almost certainly to be about 600 QUAD per year, close to double of that today.

When thinking about the energy situation for the future we need to extend this graph out for another 100 years, until about 2100. When we do that, and contemplate alternative energy scenarios in order to decide on the form of future energy supply system, we come to several global energy consumption scenarios.

- 1900 Quad, a continuation of today's unfettered approach to energy with about a **six-fold** increase from today's level, assuming high world economic growth, high technological development, and no emphasis on reducing greenhouse gas emissions;

- 1500 Quad, a middle course, about a **four-fold** increase of today's level, assuming lower economic growth, some international co-operation, but still with no emphasis on reducing greenhouse gases;
- 850 Quad, about **two and a half** times today's level, assuming the ideal conditions of great international co-operation, lower intensive use of energy and energy conservation, environmental protection, and, development of most appropriate technology.
- the extinction of species vital to the sustainability of the ecosphere, and,
- the production of wastes faster than they can be either recycled or absorbed by the ecosphere.

When one considers these forecasts of 2100 energy consumption scenarios in the context of the Hubbert "spike", it becomes obvious that monumental change is inevitable.

Monumental Change is Inevitable:

Referring once more to Figure 1, the derivation of this spike is based on responsible studies by reputable groups of the finding and the depletion of finite nonrenewable resources. The area under the spike represents the total assessed fossil fuel reserves and resources. The mathematics of the bell-shaped curve is used to fit it to the curvature of actual recorded energy consumption.

On the premise that fossil fuels can be treated as normal nonrenewable resources, the curve depicts the probable time and the magnitude of the peak production of all fossil fuels, as well as the likely duration and amount of fossil fuel supply beyond that peak.

This type of crude analysis assists in dealing with uncertainty in the estimates of recoverable resources. It also focuses attention on the downward rate of supply after the peak rate of production has been passed. That is, if it transpires that recoverable resources are significantly greater than the estimate used, the effect would be to move the down side of the curve to the right, increase the peak, but only move the peak to the right about half that amount. All of the problems of dealing with the effect of decreasing rate of production would still have to be

faced but at a slightly later point in time.

Consider the width of this 200 year period of fossil fuel consumption relative to the 20,000 years or so that *Homo sapiens* have been on this earth. If the axis of this chart were 20,000 years, this 200-year period would be a rather thin vertical line.

Note that the actual level of global fossil fuel consumption for 1990 and projected for 2020 is shown on the curve. Before the peak, the demand or the rate of consumption determines the production of fossil fuels. Then after the peak of fossil fuel production is reached, about 2045 or so, the rate of production of fossil fuels would be on a downward slope of a decreasing rate of production due to supply or resource limitations.

By forcing production, it might be possible to sustain higher production. However, since the resource and therefore the area under the curve is not changed by attempting to sustain high rates of production, the peak of the chart would be raised, the downward slope would be more rapid, and the width of the curve or the time for exhaustion would be shortened.

It is this period after the peak and this prospect of decreasing production of fossil fuels that is an issue of great concern.

During this period of decreasing production of fossil fuels the actual global demand for energy will still be increasing, as was noted during the discussion of Figure 1. Therefore, the increase in non-fossil fuel sources must simultaneously meet the growing energy demand and also provide for the replacement of the fossil fuel infrastructure. Consequently, during

the decline in fossil fuel production, we could need about 25 Quad per year of new energy sources. That amounts to about 800 nuclear power stations, or the equivalent in renewable sources, every year somewhere in the world; that is two or three every day. Such a rate of construction of new energy supply facilities, even on a global scale, is almost beyond comprehension.

This requirement may be eased if decisions are made to restrict the use of fossil fuels well before the peak is reached in order to reduce the emission of greenhouse gases. Such a move would somewhat extend the duration of fossil fuel usage, and more importantly would produce some momentum in the re-

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The real issue is how soon we make the decision to phase out fossil fuels (because of the both the greenhouse gas emission problem and the inevitable transition to other fuels). Or will we wait until the decreasing resources force us to make the change, with all of the chaos that usually occurs when changes have to be made rapidly and under duress?

Momentum

Working against a decision to phase out fossil fuels by choice are tremendous forces of momentum tending to maintain the ongoing energy supply regime. The momentum factors include:

- the sheer magnitude of the fossil fuel infrastructure;
- the unrelenting increase in the demand for energy;
- which in turn is due to the growing population from currently close to 6 billion, to 10 plus billion in 2100;
- the gradual and accelerating economic development of the underdeveloped nations;
- the trend to urbanization, from currently about a 50/50 split to about 80% urban and 20% rural in 2100;
- the industrialization that occurs with economic development; and,
- consumption of energy to reduce the adverse effects that are created by the use of energy.

These factors act with a compounding effect to produce a tremendous momentum, and a seemingly insurmountable barrier to any attempt to deliberately change the composition of the primary sources of energy. One factor that is working to relieve this momentum is the gradual reduction in the intensity of use of energy in advanced industrialized nations due to both advanced reduced energy consumption technology and deliberate efforts at energy conservation where such action makes sense both economically and environmentally.

Inertia

While the momentum tends to keep the status quo, the inertial factors conspire to slow down or impede the build up of forces that could bring about decisions and action to phase out fossil fuels. The inertia factors include:

- the lack of comprehension of the enormity of the energy issue and its momentum;

- the lack of recognition of the inevitability of a phase out of fossil fuels;
- the lack of recognition of the 50 year or so gestation period before there can be any significant change in the composition of the primary energy sources;
- the strong anti-nuclear sentiment, particularly in North America;
- the faith that there will be an easy technological solution;
- the faith that there will be more fossil fuel resources than currently forecast by reputable authorities;
- a superficial and seductive understanding of what would be involved with trying to rely on renewable resources such as wind and solar as the principal sources of prime energy;
- energy deregulation, which will encourage the type of free market forces that could lead to the high energy consumption levels noted previously for 2100, will encourage the lowest cost producer, and also would make it more difficult for there to be government control of the energy infrastructure, just at the time when there is going to have to be major changes in the entire scheme of energy affairs;
- the decision and implementation delays due to the time required for the generation of a consensus that there is a problem;
- the development of a consensus as to what is the nature of the problem;
- the development of options for addressing the problem;
- the development of a consensus as to which option(s) would be most likely to succeed;
- the taking of decisions and legislating policy for the selected option(s);
- the time for implementation to take effect, again referring back to the 50 year gestation period.

These problems of future energy are not just emerging at this time. King Hubbert⁴ in the late '40s first produced this "spike" type of analysis, and in the early '60s applied that analysis to forecast that the domestic production of oil in the USA would peak in 1968, which in fact did occur. The problems were recognized 45 years ago with a "spike" in Harrison Brown's "The Challenge of Man's Future"⁵. They

were extremely well analyzed and reported by IIASA in "Energy in A Finite World" in 1981. They have been discussed in at least two special editions of Scientific American, the latest in 1990. There is a strong consensus in the energy community, based on this type of analysis, that the peak of conventional oil production will occur about 2010. The issue was well explored by the International Energy Agency in 1992 with the report "Global Energy"⁶. The subject has again been well analyzed recently by IIASA and the World Energy Council⁷, but that analysis did not assess the full implications of the inevitable phase-out of fossil fuels as has been done herein.

Challenge:

The present generation and the next two or three generations face three profound challenges with respect to energy.

- There is the challenge to find the means to continue to reap the benefits that mankind has enjoyed from its use of energy. While doing so, the adverse effects that have been generated due to mankind's ability to produce, transport, use and control energy must be eliminated or at least substantially reduced.
- Within the time frame of the next two or three generations the consumption of fossil fuels will peak resulting in an inevitable gradual change in the primary source of our energy. That inevitable change could be hastened by decisions to reduce the consumption of fossil fuels in order to reduce the emission of greenhouse gases.
- To satisfy the two previous conditions requires contending with the tremendous momentum of the energy juggernaut due to both its mind-boggling magnitude and its unrelenting rate of growth. At the same time the inertia and complacency, which inhibit mankind from facing the realities of the problem and developing a sustainable global energy supply, must be overcome.

If these challenges are not picked up and dealt with

within the next two or three generations, the indications are that the subsequent generations will be faced with a chaotic energy supply situation which could lead to a breakdown in the social order.

The authors hope that this introduction and overview has provided a context against which the problems related to individual sources of energy may be considered in greater detail.

Notes and References:

1. *Global Energy: The Inevitable Transition (Part 1)* by J. R. Whitehead (CACOR Proceedings 1.3, June 1992)

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2. M. King Hubbert, *Science* Vol. 109, Feb 4, 1949

3. "Global Energy Perspectives" IIASA/World Energy Council, Cambridge University Press, 1999
International Energy Outlook, 1999. International Energy Agency, 1999

4. loc. Cit

5. *The Challenge of Man's Future* by Harrison Brown, Viking/Compass, 1954.

6. loc. cit.

7. loc. cit.