THE ENERGY OUTLOOK

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After the autumn of 1973 it dawned on the industrial countries that there are no cheap and inexhaustible energy reserves on earth. This realization was not merely the result of OPEC oil pricing policy; it sprang just as much from the changing real value of fossil fuel reserves, as computed from their efficiency, exploitability and availability. The energy-hungry industrial nations are exceptionally vulnerable these days because of their high per capita consumption and low self-sufficiency level.

Right up to our own era, fossil fuels have accounted for nearly all primary energy. One of them, coal, paved the way for the industrial revolution in the 19th century simply because it was available in large quantities and was easy to mine in some areas.

Coal largely dominated the European market up to about 1960. It then began to decline in the face of competition from oil, which enjoyed its real boom only after the Second World War. The use of natural gas developed much more gradually, however, mainly because solutions to the transport problem were long in coming.

Sharply rising energy consumption

Proven world reserves of fossil fuels alone, i.e. coal, crude oil and natural gas, amount to more than 8,000,000 million TCE (1 ton of coal equivalent — TCE — 7,000 Kcal), while annual world consumption was recently put at about 8000 million TCE. At first glance, then, there seems little cause to worry.

Unfortunately, though, several factors cast a cloud over this optimistic view of the world's energy picture. For one, there is the uneven distribution of fuel reserves and all of the political reprecussions that flow from it. The Soviet Union and Eastern bloc nations are sitting on the largest coal reserves, i.e. over half of the total. And the same countries possess 40% of the world's natural gas reserves, as against 23% for the Middle East. But then the Middle East does have the largest untapped oil deposits: roughly 60% of the world's proven reserves.

Besides territorial differences, there is also the chronological dimension. Estimates have it that the amount of energy used from the origins of humanity to the start of the industrial revolution, i.e. about 1850, was on the order of 35,000 million TCE. Which is about 4½ times the amount now consumed in a single year! From the mid-19th century up to the present about 350,000 million TCE was required. It can therefore be predicated, based on continuation of the same rate of growth, that humanity will consume between 7,000,000 and 14,000,000 million TCE between now and the year 2050!

Reserves for how long?

Though all of the world's coal reserves are estimated at 8,140,000 million tonnes, known and exploitable reserves total only 430,000 million tonnes. Based on the amount produced in 1974 this quantity would last another 200 years or so. In the case of oil, on the other hand, potential production (based on 1974 output) varies between 25 years, if one counts merely the proven reserves of the most important producer countries, and 85 years, if probable reserves are added. As for natural gas, known reserves would last another 55 years if the 1974 production level is maintained.

In view of the important position held by fossil fuels in aggregate energy consumption, it is clear from what has been said that their share will not start declining noticeably for many years. Even if we make the lowest possible estimate of worldwide consumption and the highest possible estimate of reserves, just a little over a century would be needed to use up every bit of those reserves. And this does not even take into account the uneven distribution of reserves and its repercussions, namely the exceptionally heavy dependence of certain countries on foreign energy sources and the risk that some deposits might remain unexploited for political reasons or for lack of the necessary financing.

Improving utilization efficiency

For a given amount of primary energy, the small fraction that can really be employed-the "useful energy" — is the part that counts. So it is necessary to differentiate between potential energy at the source and energy actually utilized at the point of consumption. On average, the latter is estimated to be about 37% of the former in the industrialized nations.

The obvious approach, then, is to work at improving this utilization efficiency — without trying to exceed certain limits set by the physical laws and technical circumstances involved. This is the most important and difficult task set for technological research. In quantitative terms, it certainly offers greater potential than the efforts to develop new sources of energy. But the latter are necessary as well if humanity wants to be sure of covering its energy needs on into the more distant future.

Solar energy

What are referred to as "new" energy sources can be listed under three main headings: solar energy, gravitation energy and nuclear energy. Though people have been aware of most of the new energy sources for years, their practical application has only now entered the realm of feasibility.

Table 1: Proven global energy reserves

Country or region	Coal in % of total	Oil	Natural gas
EEC	4	3	6
USA	28	8[1]	12
China	11	—	—
Comecon	54	9	41
Middle East and North Africa	—	63	23
Latin America	3	16	18

[1] USA plus Canada.

Source: United Nations Statistical Yearbook 1976.

Solar energy is by far the most abundant source available to humanity, and a virtually inexhaustible one to boot. Except for a few sporadic experiments without any practical consequences — the Genevan reseacher Nicolas de Saussure was the first to try out a solar collector, back in the 18th century — solar energy was virtually ignored until 1950/55. Only then was it taken up as an efficient way to generate electricity on board man-made satellites. Ultimately the 1973 energy crisis made the world conscious of the importance of solar energy, but the immense difficulties tied to its practical exploitation emerged at the same time. The earth's surface, which absorbs less than a billionth of the colossal amount of energy released by the sun in the form of radiation and elementary particles, receives the equivalent of the world's average annual energy needs many thousands of times over. But because it is spread out over such a large area, the intensity is much too weak to be able to serve industry. The variable intensity of solar radiation — depending on time of day, latitude and weather — can hardly be matched to steady industrial energy demand. But there do already exist a number of applications on a smaller scale that are tailored to very specific duties like the desalination of sea-water or the supply of hot water, heat and air conditioning in dwellings.

Opinions differ on cost. But most experts agree that the generation of electricity with photoelectric cells is not competitive with power plants based on fossil or nuclear fuels. The most promising project involves the launching of an orbital space station that would collect the solar energy for transmission to earth for conversion into electricity. The latest estimates indicate that the new energy sources — mainly solar energy in its various application forms, plus energy generated from geothermal sources, winds and tides — are expected to account for 0.25 to 1% of worldwide energy consumption by the mid-1980's It is possible that their importance will rise rather sharply thereafter and reach nearly 15% by the turn of the century.

Nuclear energy

The first projects for the peaceful utilization of atomic energy appeared after the war. Though industrial growth in this field began between 1960 and 1965, the true expansion phase came only after 1970. By 1974, nuclear energy was accounting for some 3% of world power generation. Of course, atomic energy can be obtained either by nuclear fission or fusion. Three different types of reactor are used for the fission process, depending on the fuel. The first category uses natural uranium as well as graphite and gas, and requires neither enriched uranium nor heavy water. The reactors with heavy water are particularly attractive because they require no enriched uranium and consume some 30% less fuel than those with light water.

The second category embraces reactors using enriched uranium. The big advantage of this process is that the reactors are smaller in size and simpler in design and have increased generating capacity. It made nuclear generation of electricity a commercial proposition.

This second category also includes the high-temperature reactors, which are of considerable interest for two reasons: their efficiency is very high and they can be used for industrial purposes besides power generation, e.g. in the chemical industry, the steel industry, industries working with high temperatures, for liquefaction of coal, and above all for the production of hydrogen. The third category is probably the most important, but at the same time the most controversial. It is the fast breeder reactor. From the operational standpoint this reactor is the most intriguing of all, because theoretically it permits 70 to 75 times as much energy to be extracted from a given mass of natural uranium than do the other reactor types. At the present state of the art, 30 to 35 times as much can already be extracted.

From the economic angle, size is a very important factor, which gives rise to a fundamental dilemma: profitability versus safety. The higher a plant's generating power, the greater the hazards in the event of an accident. The experts do not see eye to eye on ranking the different reactor types in terms of profitability; in addition, these rankings obviously change with time. Unlike the fossil fuels, uranium deposits do not happen to be concentrated in certain geographical areas. Known reserves are estimated to be 1.5 to 2 million tonnes. But it is feared that limiting construction to the classic reactor types would raise the spectre of fuel shortages fairly soon. Even under the most optimistic assumptions, the proven reserves that are exploitable at competitive prices will be exhausted around the year 2010 if the present reactor construction programme is adhered to!

Adoption of the fast breeder would probably extend the fuel supply further into the future, because thorium can be employed as an auxiliary fuel. Though nobody knows for sure how much of that element is contained in the earth's crust, total deposits are thought to be about triple those of uranium.

Thermonuclear fusion

The second atomic energy route is that of thermonuclear fusion. Precisely because of its virtually immeasurable potential, this process is the only realistic answer to future energy supply problems over the long range. The immense deposits of the required raw materials would last for several billion years based on 1975 consumption. Moreover, high utilization efficiency is possible.

Though themonuclear fusion is based on a very simple principle, its practical realization is something else again. Presumably it is true to say that the worldwide energy problem would be solved for good if the deuterium/deuterium fusion reaction were ever mastered. The reason is that the deuterium required for thermonuclear fusion is contained in water in the ratio of about one nucleus for every 6700 nuclei of hydrogen. This corresponds to 34.4g of deuterium per cubic metre of water, or the equivalent of 200 tonnes of crude oil. But everything is still up in the air, because nobody yet knows how to control the deuterium/deuterium reaction or how to convert the energy directly into electricity. Current efforts are centring on the deuterium/tritium reaction, which requires only one-quarter as high a combustion temperature and is therefore easier to put into practice. But tritium must be produced from lithium, the reserves of which are relatively unknown but thought to be quite small.

A thorny decision

We have reviewed the present situation in the energy field in very simplified fashion, leaving aside the important environmental protection angle. In view of incontrovertible facts like the inevitable depletion of traditional energy resources and uncertainty over the time span required to develop substitute sources of energy, our industrialized society is under pressure to make some decisions. Nor is this made any easier by the many questions still open. The quality of the substitute sources the technicians are able to come up with may depend partly on the amount of time we still have left, especially if preference is given to solar energy or nuclear fusion over nuclear fission. A superficial look at things might convey the impression that there is plenty of time to solve these problems. But as far as the industrial countries go, with their economies so heavily dependent on energy supplies from abroad, such an assumption would be fatal.

The time span between the initial planing of a project and its realization is often between 10 and 20 years. This makes it imperative to tackle such a project early enough. To estimate its urgency, a detailed investigation has to be made of the various factors contributing to energy demand. This means assessing demographic development, economic growth, individual industries and the potential for energy savings. International price levels and technological progress are, of course, very important as well, and the size of the future energy supply must be estimated. It must also be borne in mind that the opening up of new sources of energy involves not only expense for research, development and distribution, but also changes in infrastructure to permit utilization of the new source.

Outlook

Over the short term, the conventional, i.e. fossil, sources of energy will undoubtedly remain at the top of the list, though certain shifts are emerging: the relative importance of coal and natural gas will rise, that of hydroelectric power will stay level, and that of oil will decline. But oil will continue to play an important role, with a contribution substantially exceeding those of other energy sources. And the bulk of it will still be OPEC oil, though some of it will also come from other fields, such as the North Sea, Alaska, Mexico and numerous developing countries; the percentage accounted for by off-shore wells will rise.

During this period the impact of new energy sources will be slight. Nuclear fission will make gradual inroads, as will the use of solar energy for households. Unless huge new oil reserves are discovered, which would reduce the urgency of finding substitute energy sources, the classic sources will hold their percentages or slip off slightly. In that case, the importance of energy from nuclear fission and other sources, e.g. the sun, earth, wind and tides, will grow. Around the year 2000 the various sources can be expected to account for the following percentages: coal about 16 to 18%, oil 40% or more, natural gas between 18 and 22%, water power 5%, nuclear power between 15 and 18%, and other new sources less than 1%.

In the more distant future, on past the year 2000, everything will depend on scientific progress. Will we have mastered the technology required for nuclear fushion by then? Does science have some surprises up its sleeve? Could the energy of the future come from some as yet inconceivable source? It is easy to dream about such developments, but dreams are rarely reconcilable with the compulsions of hard reality.

Table 2: Breakdown of consumption by energy source

Country or region	Solid in % of total		Liquid		Gaseous		Hydro and nuclear	
	1960	1974	1960	1974	1960	1974	1960	1974
USA	24	20	43	44	31	33	1	2
EEC	69	26	27	54	2	18	2	2
Comecon	71	44	20	32	8	23	1	1

Table 3: Energy consumption and output per capita in 1974

Country	Consumption in kilo coal equivalents	Output	Net surplus or deficit
USA	11500	9900	—1600
Fed. Rep. of Germany	5700	2800	—2900
United Kingdom	5500	2900	—2600
France	4300	900	—3400
Italy	3200	500	—2700
Netherlands	6200	8500	+2300
Japan	3800	300	—3500
USSR	5300	6100	+ 800

Acknowledgements to Swiss Bank Corporation for reproduction of this article from *Prospects* 1979/2.