THE PROSPECTS FOR THE UNCONVENTIONAL ENERGY SOURCES IN BRITAIN WITH PARTICULAR REFERENCE TO SOLAR ENERGY

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SUMMARY

While it is technically feasible for Britain to achieve a small but significant contribution from unconventional energy sources by the year 2000, several factors may well militate against this. One of them is Britain's favourable indigenous energy situation.

RESUM

Si és tècnicament factible a la Gran Bretanya d'aconseguir una contribució energètica petita, però significativa, amb fonts d'energia no convencional cap a l'any 2000, hi ha un bon nombre de factors que se li poden oposar ben bé. És molt i molt important la situació favorable d'energia natural de la Gran Bretanya.

The rise in oil prices since October 1973 has led to much controversy over the prospects for the new energy sources in Britain. Their advocates are usually outside the traditional fuel supply industries and government, and have tended to make optimistic claims on future contributions to the UK's energy balance. They point out that the level of R & D expenditure on such sources is a minute proportion of total energy R & D funding, and that higher resource commitments are necessary to ensure that the technologies are adequately proven for use when fossil fuels become scarce and expensive. On the other side *the fuel supply industries argue* that the capital costs of the new technologies are high, and that they are unsuitable for widespread application. It is very difficult to decide between the various claims and counterclaims, because there are very few real facts known about the economics of these new technologies, and in some cases there are doubts whether they will work efficiently on a larger scale.

A number of factors combine to make the evaluation of the new technologies difficult. At current levels of fuel prices, many of them are uneconomic. Their economic viability in the future, together with the decision on whether to allocate significant quantities of R & D funds to their development, depends crucially on long-term movements in fuel prices in the longer-term. It is necessary to depend on judgements on these longer term fuel prices.

The technical development of these sources in the future is also far from certain, and so any evaluation tends to be speculative. It is difficult to assess the effect that larger unit production (economies of scale effect) will have on costs, for example, and to what extent lower unit costs will result from the learning curve effect of long production runs of standardised equipmens.

The choice of rate at which to discount the future flows of costs and benefits arising from the project is also crucial, particularly for projects which have high capital costs and long lead times. In the public sector in Britain a test discount rate of 10 % is used to evaluate all capital investment projects. This is to a large extent an arbitrary rate, and a lower rate (which might reflect more accurately the Social Time Preference) would immediately improve the prospects for long term, highly capital intensive projects, like the construction of a tidal barrage (see below).

There is a tendency, too, when evaluating the unconventional energy sources to compare them with existing alternatives, and nuclear power (as an «expandable» source, not subject to depletion) is frequently chosen as the reference case in situations where the output of the non-conventional alternatives could be in the form of electricity. This is not a fair comparison as the current status of nuclear power is the result of major R & D expenditures in the past, which has not been the case with the newer technologies. It is important to decide whether any such comparisons are meaningful.

A number of dificulties arise when commercial introduction of such technologies is considered. The newer technologies often have no institutions responsible for promoting them in the fuel supply sector. The fuel industries themselves have ingrained technical and management philosophies which tend to act as forces to preserve the status quo. They are also, in some cases in the public sector, ruled by statutory obligations determined in the early postwar period (a very different energy supply situation) which are not necessarily suitable in the changing circumstances, and which can act against the introduction of non-conventional sources.[1]

To the extent that the prices prevailing in the energy market do not reflect the future scarcity values of the fuels then there would be a tendency for sub-optimal investment to take place in the non-conventional energy sources.[2] This is particularly applicable to those technologies, like solar water heating and windpower which depend for their introduction on individual decisions by the consumer.

A number of the new technologies will require back-up supplies from the gas and electricity industries reflecting the variability in supply — from season to season, day to day, and day with night. In the direct applications of solar power, in particular, the peak incidence of radiation does not coincide with peak consumption demands, and only limited progress has so far been made on long-term heat and energy storage. Although their utilisation would lead to

1. In Britain the electricity supply industry is statutorily obliged to produce electricity at minimum cost which may mitigate against schemes where substantial joint benefits result.

2. Gas prices have been low relative to competing fuels since 1967, and there has been much debate on whether prices should be raised to reflect long-run marginal costs.

fossil fuel savings they could also lead to greater margins of spare capacity in back-up fuel industries, with the consequently higher capital costs reflected in higher prices.

BRITAIN'S CURRENT ENERGY SITUATION

Before considering the more detailed prospects for the individual sources in Britain's future energy balance it is important to consider the current energy situation in Britain — the context in which the non-conventional energy sources will be competing for scarce R & D funds, and attempting to demonstrate their commercial viability.

TABLE I

UK's INLAND CONSUMPTION OF PRIMARY FUELS (mtce)

	1960	1970	1973	1975
Coal	196.7	154.4	131.3	118.1
Oil	65.5	145.6	159.4	134.4
Natural Gas	0.1	17.6	43.5	54.5
Nuclear/Hydro	2.6	12.0	11.9	12.7
TOTAL	264.9	329.6	346.1	319.7

SOURCE: Department of Energy, Digest of Energy Statistics.

In 1973, as Table I shows the UK's primary energy requirements were met 46 % from oil, 38 % from coal, 13 % from natural gas, and 3 % from nuclear and hydro-electric power. This was significantly different from the situation prevailing in 1960, and reflected the increasing penetration of cheep Middle Eastern and African crudes in the 1960's, the supplies of natural gas landed from the UK sector of the North Sea from 1967 onwards, and the growth of a small but significant nuclear power component. In 1969 the first oil discoveries were made in the UK sector of the North Sea, and these were due on-stream in the mid-1970's promising self-sufficiency by 1980. In this situation Britain was able to look forward to a relatively diversified primary fuel supply with little net reliance on energy imports.

The higher oil prices improved the prospects for North Sea oil developments and for the other fuel industries, in particular coal which had a price advantage. There was considerable uncertainty, however, on price elasticities, and the scope for inter-fuel substitution.

In the period 1974-6 a number of measures were taken by the British government to ensure a diversified and secure energy supply base in the future.[3] In July 1974, a £1400 million investment programme was announced to increase production in the coal industry from about 120 million tons in 1975 to 130-150 million tons in 1985; a substantial exploration programme was also initiated. Also in 1974, a contract was signed to purchase natural gas supplies from the Norwegian sector of the Frigg field (which lies on the boundary line between Norway and Britain) in addition to supplies from the UK sector. Together with other contracts signed for gas supplies from the British sector the supply in 1980 will be double that in 1973, and will represent 23-25 % of UK primary energy consumption.

The development of the nuclear power component had received a set-back with technical and administrative difficulties on the Advanced Gas Cooled Reactors initially ordered in 1965, and due to enter service from 1970. Lower than anticipated growth rates in the 1960's, due in part, to the «gas effect» (the competition from cheap natural gas in particular markets) meant that despite late commissioning of the AGR's, the generating authorities enjoyed a substantial margin on spare capacity (exacerbated by a rund of mild winters). In 1974 the government agreed a programme of 4000 MW of Steam Generating Heavy Water Reactors (SGHWR's). There are now considerable doubts whether these will be built as the result of surplus capacity in the electrical supply industry and the high costs involved in building such a small programme.

In addition to these measures priority was attached to the rapid development of North Sea oil resources and an energy conservation programme was introduced. Taking account of all these factors leads to the conclusion that Britain might well be in a energy «glut» situation in the 1980's. This might lead to complacency towards the need to secure longer term energy supplies and to attitudes on the development of the unconventional sources, and present a disincentive to te conservation of energy (though this obviously would depend on the prevailing level of energy prices).

3. These developments are covered in greater depth in J. H. CHESSHIRE, A. J. SURREY *et al.*, «Energy Policy in Britain - A Case Study of Adaptation and Change in a Policy System», in *The Energy Syndrome: Comparing National Responses to the Energy Crisis*, ed. L. N. Lindberg, Lexington Books, to be published, April 1977.

ENERGY R & D IN BRITAIN

In Britain before 1973 the emphasis in R & D work on energy was clearly oriented to nuclear power, with a very small level of expenditure on the non-conventional sources as Table II shows. For the UK, in 1973 only 4.3 % of public energy R & D funding was spent on the development of new primary sources of energy. Of this majority went on fusion power; only £376,000 was spent on R & D on all applications of solar power. 68 % of total public funding of energy R & D was on nuclear fission power (a total of £55 m.). Over half of this was being spent on the development of the Fast Breeder Reactor which since 1965 had accounted for a cumulative expenditure of £218 m., 40 % of total civil nuclear R & D over this period. This experience broadly reflects the R & D priorities of a number of other developed countries as demonstrated by their relative levels of R & D spending, and this is also shown in Table II.

Because of the very long lead times associated in general with R & D on energy technologies, the need for a strategy to guide R & D was recognised after the oil «crisis» and this led to the publication, in June 1976, of a discussion document entitled «Energy R & D in the United Kingdom» which was released through the Advisory Council on Reseach and Development for Fuel and Power.[4] ACORD is responsible for reviewing the research programmes of the nationalised fuel and power industries. It is chaired by the Chief Scientist at the Department of Energy (who is also incidentally Deputy Chairman of the United Kingdom Atomic Energy Authority) and it advises the Secretary of State for Energy.

The ACORD document was based on the premise that the downturn of indigenous oil and gas production —perhaps in the last decade of this century— could lead to the creation of an energy gap unless technologies had been developed by then to fill it. A number of scenarios on energy requirements were constructed, and all but one (the «limit-on-nuclear» view of the future is the exception) predicted a major expansión of nuclear power as the only way to fill the potential «energy gap». The major priorities for research emerging from the document were for nuclear power, and the most controversial area in Britain today has been the proposed development of the Fast Breeder Reactor.[5]

4. «Energy R&D in the United Kingdom. A discussion Document», *ACORD*, June 1976.
5. See, for example, J. SURREY, J. CHESSHIRE and N. DOMBEY, «The hazards of rushing to build a nuclear fast reactor», *The Times*, 28th June, 1976.

TABLE II

PUBLIC FUNDING OF ENERGY R & D IN 1973: THE UK COMPARED WITH USA, FR GERMANY, FRANCE AND THE NETHERLANDS
(MILLION UNITS OF ACCOUNT,[1] PERCENTAGES IN BRACKETS)

	UK		USA		FR Germany		France		The Netherlands	
Fast Breeders	73,5	(39.2)	264.5	(38.6)	72.2	(29.5)	75.7	(29.7)	20.0	(55.2)
High Temperature Reactor	10.5	(5.6)	7.4		71.2	(29.1)	13.2	(5.2)	1.1	
Proven Reactors	21.6	(11.5)	30.1	(4.4)	8.7	(3.6)	39.6	(15.5)	0.3	
Exploration and extraction of uranium and thorium	0.2		2.9		?		0		?	
Other nuclear R & D	21.2	(11.3)	112.6	(16.4)	48.9	(20.0)	31.5	(12.3)	8.4	(23.2)
Total nuclear fission power	127.0	(67.7)	417.5	(60.9)	201.0	(82.0)	160.0	(62.7)	29.8	(82.3)
Developing indigenous fossil fuels	10.8	(5.8)	28.1		5.8		34.2	(13.4)	0.4	
Coal Gasification	0		37.8	(5.5)	4.5		0		0.1	
Coal Liquefaction	0.5		11.2		?		0.1		0.1	
Hydrogen Fuel	0		?		?		1.0		0.1	
Process Uses of Nuclear Energy	0		?		11.8	(4.8)	0.2		?	
Other	0.6		?		0.6		?		?	
Total: Substitute Fuels	1.1		49.0		16.9		1.3		0.3	
Fusion	7.2	(3.8)	76.3	(11.1)	18.3	(7.5)	9.8		2.1	
Geothermal	0		4.5		0.1		0.6		?	
Solar	0.8		4.1		0.3		0.9		0.3	
Other	0		?		?		0.1		0.1	
Total: New primary energy sources	8.0		84.9		18.7		11.4		2.5	
Transport and storage of enery	10.0	(5.3)	?		2.1		20.1		0.9	
Energy utilisation	24.1	(12.8)	32.8	(4.8)	0.3		19.7		1.3	
Other[2]	6.6	(3.5)	73.3	(10.7)	0.2		8.6		1.0	
GRAND TOTAL	187.6	(100.0)	685.6	(100.0)	245.0	(100.0)	255.3	(100.0)	36.2	(100.0)

1. 1 European Unit of Account=£0.47=$0.98=DM3.215=F Fr5.88=Guilders 3.355.
2. Includes R&D on environmental protection & energy systems studies.

Sources: Inventory of R&D on Energy in the Public Sector, EEC (XII/648/74), 1974; US data derived from Annex 1; J. SURREY and W. B. WALKER, «Energy R&D - a UK perspective», *Energy Policy*, June 1975.

The alternative energy technologies were also considered in this R & D overview, and its conclusions emphasised the importance of undertaking R & D to establish their ultimate potential and economic practicability. But a view commonly expressed about the document is that it is nuclear orientated. It pays lip service to the principle of conservation, and the development of alternative energy sources, but one doubts wheter these will be major priority areas. The danger that a major resource commitment to nuclear power will in fact prevent necessary R & D work on utilisation technologies and the less conventional energy sources has been the cause for much concern.

In connection with the ACORD document, the Energy Technology Support Unit[6] has made estimates of the potential contribution of the unconventional energy sources to Britain's longer-term energy requirements. ETSU has estimated that their contribution could reach 45 million tons of coal equivalent in the year 2000 (or 13 % of *current* energy consumption) given «a successful conclusion to a vigorous R & D programme on each of the sources, resulting in approximate economic parity with the more conventional energy sources». The contributions anticipated from the individual sources, together with ETSU's assessment of the ultimate potential for growth beyond 2000 are given in Table III.[7]

The uncertainties, both technical and economic, associated with forecasts of this nature, are substantial. There is no guarantee that adequate R & D support will be forthcoming, or that all technologies will be supported. Whether or not economic parity with other

TABLE III

Source		Form of use	Approx. Annual mtce	Ultimate Potential for Growth beyond 2000
Solar (1)	Solar heating	heat	5	large
(2)	Fuels from plants	fluid fuel	3	uncertair
Geothermal		heat	4	modest
Wind		electricity	6 *	small
Tides		electricity	3-10 *	small
Waves		electricity	15 *	very large

* Assuming about 30 % overall efficiency of electricity production and distribution.

6. ETSU was formed in 1975 to advise the Secretary of State for Energy on the new energy technologies.

7. W. MARSHALL (Chief Scientist to the Department of Energy), Keynote address to the Symposium on Renewable Sources of Energy, at the Royal Society of Arts, London, 16th June 1976. The proceedings are available from the Royal Society.

energy sources could be achieved depends crucially on the prices and prospects of the other fuels, and the progress of R & D programmes on other technologies like the Fast Breeder Reactor. The table probably selves no other purpose than demonstrating today's official/scientific perceptions of the relative potencial of the newer energy sources, and very little significance should be attached to the numbers themselves.

This paper is not the place to comment in detail on the content and approach of this attempt at evaluating an R & D strategy for the energy sector, although we have commented on it elsewhere.[8]

Final decisions still have to be made on many aspects of the UK's energy R & D programme. It will be important to identify those research areas where Britain should make a major individual contribution, with a view to export markets, as well as home demand. In other areas collaborative ventures, some with the EEC and IEA may be one way of ensuring British participation in new technologies at relatively low cost. In other cases the decision will be to maintain a watching brief on technical developments abroad, to permit sensible licensing agreements to be concluded once the technology is proven. But it is important to emphasise that the document, in its major priorities, represents the views of important and influential groups in the energy field, and that in comparison the advocates of the unconventional energy sources have considerably less access to resources and influence.

THE INDIVIDUAL UNCONVENTIONAL ENERGY SOURCES

The rest of the paper will briefly consider the unconventional energy sources which may have some potential in Britain —wave-power, tidal power, geothermal power, direct solar applications, and wind power.

Wave-power

The prospects for the utilisation of wave-power are regarded most favourably in the ACORD document. The most suitable area of British coastline identified is off the north-west coast of Scotland. It is anticipated that the wave generators would be situated

8. C. M. BUKLEY and J. H. CHESSHIRE, «UK energy resources - some key issues», *Chemical Engineer*, September 1976.

several kilometres offshore. Using an extraction efficiency of 25 %, it is assumed that half the present UK requirements for electricity might be generated in a stretch of ocean extending about 1000 km., if the most favourable sites were used.[9] It is estimated that the average power density along the UK west coast is 80 kw/metre.[10]

Although subject to significant seasonal variation wave power has the advantage that the potential peak level of energy generation coincides with peak electricity demand in the winter months, and thus avoids the mismatch which is a disadvantage of the direct use of solar energy. The ideal site for the establishment of these wave generators is, however, far removed from major centres of demand, and substantial system expenditure would be necessary.

Two important British innovations to extract the energy from the waves are currently being investigated. The Salter «duck» consists of a rocking boom with a front surface that rises and falls with the water of an oncoming wave, but which does not disturb the water behind. Cockerell has developed a connected series of rafts which have piston-operated pumps at each joint, and which progressively extract the energy of a wave as it moves down the line.

Government support for further research has been given initially of £ 1 m. over two years. The prospects at this stage are very uncertain on technical feasibility, as well as costs. The scale of the equipment would be large, and there would be problems of anchoring it in open seas; much thought needs to be given to the means of transferring the energy produced to the shore (as electricity, for example, or hydrogen) and on to the final consumer. There are potential environmental impacts, too which need careful analysis.

Tidal power

In the Severn estuary there is one of the most suitable tidal power sites in the world with a high tidal range, and the potential for output capacities of between 1000 MW(e) and 5000 MW(e).[11] Proposals for a two reservoir system, which would permit storage, and enable electricity supplies to be tailored to demand have been advanced. The barrage is seen as a means of complementing the preferably constant output mode of thermal generating plant.[12]

9. ACORD, *op cit.*
10. I. GLENDENNING and B. M COUNT, «Wavepower», in Royal Society of Arts, *op. cit.*
11. ACORD, *op. cit.*
12. T. L. SHAW, «Tidal Power» in Royal Society of Arts, *op. cit.* Reprinted in the *Chemical Engineer*, September 1976.

Tidal schemes have been considered in the past, and more recently studies of the potential of hydro power have been undertaken by the Central Policy Review Staff and the Advisory Council on Research and Development for Fuel and Power. They concluded that the costs were unlikely to be competitive with nuclear power in the future. The capital costs of the venture are estimated variously from £1000 m.-£2500 m. (SHAW) to £4000 m. (ACORD), and tidal power is the prime example of a project which suffers from the use of an arbitrary 10 % test discount rate.

The government has not sanctioned the necessary expenditure to undertake a feasibility study, but further studies are being planned to examine some of the technical uncertainties surrounding a scheme of this nature (including the problems of barrage closure, and of environmental impacts).

Geothermal power

A preliminary assessment of the prospects for geothermal energy in the United Kingdom has been undertaken by the Energy Technology Support Unit.[13] They concluded that the geological uncertainties associated with the size and quality of the geothermal heat that exists in Britain were large, and that the major priority was to undertake an extensive geological survey of promising geothermal areas.

The average heat flux in Britain seems to be close to the world average (0.06 Watts/square metre). A number of examples exist of warm springs, with a discharge temperature of about 50°C, but the major area of interest surrounds hot rock technology. Hot rocks, often granite, are at higher than normal temperatures because of the presence of local heat sources, but lack sufficient permeability to permit water circulation. Two areas, in Durham and Cornwall, appear promising, and it is suggested that deep holes be drilled into impermeable rock with a higher than average thermal gradient, and that water be pumped down one hole, and returned to the surface via another, after ensuring that adequate opportunity existed for heat transfer.

The economics of the proposals are uncertain as are the markets for final use (likely to be for local low-grade heat, rather than for electricity production).

13. J. D. GARNISH, «Geothermal Energy: the case for research in the United Kingdom», *Energy Paper*, No. 9, HMSO, 1976. See also W. BULLERWELL, «Geothermal Energy: Geophysical and Geological Aspects», Royal Society of Arts, *op. cit.*

Solar power

The possible direct applications of solar power are numerous, and substantial research programmes are being undertaken throughout the world. The US expenditure on solar energy R & D in 1976 is estimated at £35 m., and expenditure on Japan's Project Sunshine in 1976 is estimated at £18 m.[14] In Britain in 1973 expenditure on solar research was £376,000, the government is in the middle of finalising a research programme for the next four years costing £1 m. per year.[15] There will also be a British contribution to EEC research in this area.

The annual solar input to the United Kingdom is about half of that in the United States, and Australia. A large component of the solar radiation is in the diffuse form (fig. 1) and there is substantial variation in solar radiation levels from season to season, from day to day, and from day to night (fig. 2). The North-South variation is particularly pronounced in the winter months. These factors mitigate against its widespread utilisation in applications which require regular direct solar radiation, but mean that there may be major potential applications in space and water heating.

The technology required for water-heating applications is well-known, and there have been numerous applications in the United Kingdom.[16] Widespread penetration of water heaters depends primarily on their cost effectiveness, which will tend to occur with higher fossil fuel prices and cost benefits deriving from large scale production. The ACORD document estimated that under present-day conditions, a reduction in the installed cost of solar domestic water heaters by a factor of three would be required to achieve cost effectiveness.

Space-heating applications are being investigated at a number of locations, details of which are given in the UK-ISES publication. Better house design will improve the effectiveness of utilisation of solar energy, and to a large extent the penetration of solar heating in space heating applications depends on the rate of turnover of the housing stock (c. 2 % per annum).[17]

The major problem which is currently being researched is of long-term heat storage to overcome the mismatch between the inci-

14. UK Section of the International Solar Energy Society (UK-ISES), «Solar Energy: a UK assessment», May 1976.
15. *New Scientist*, 13 January 1977.
16. UK-ISSES, *op. cit.* Also, J. C. McVeigh, «Developments in Solar Energy Utilisation in the United Kingdom», ISES, Los Angeles, 1975.
17. ACORD, *op. cit.*

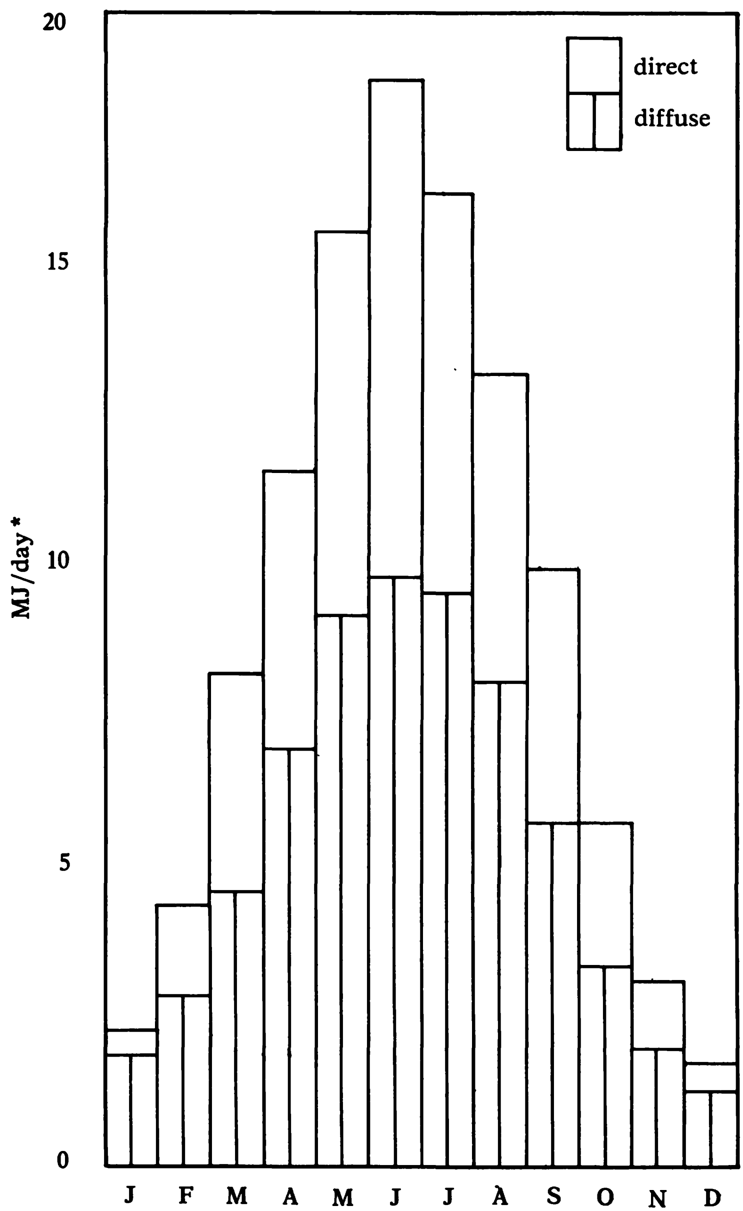

FIGURE 1

SOURCE: J. C. McVEIGH, «Developments in Solar Energy Utilisation in the United Kingdom», ISES, Los Angeles, 1975.

* MJ = Mega-Joule.

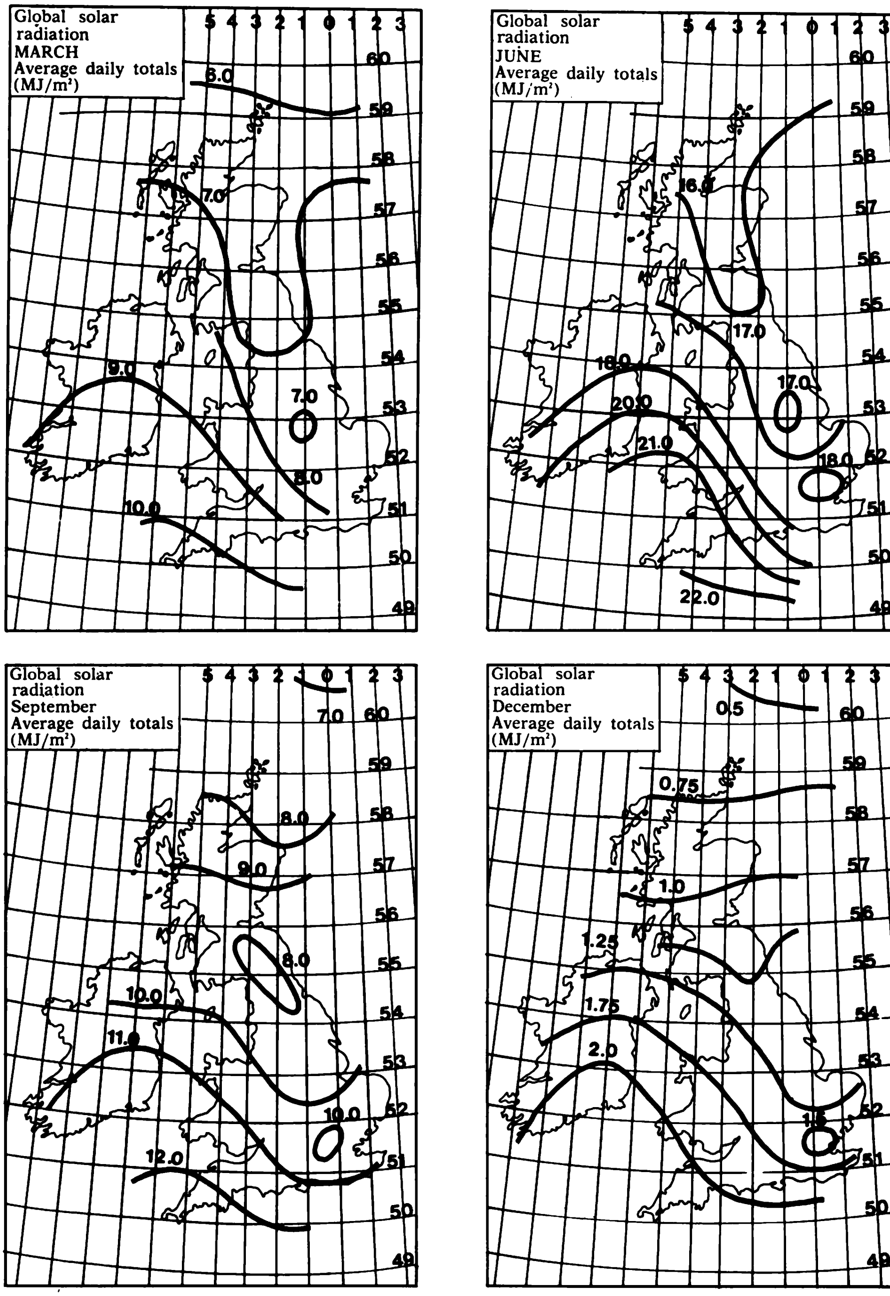

FIGURE 2. Monthly mean global irradiation for March, June, September, and December (MJ/m²).

dence of solar radiation and the requirement for heating, and although substantial progress is being made a satisfactory solution has not yet been achieved.

These two applications are likely to be most important in the domestic sector which accounts for about one quarter of UK energy consumption (see Table IV below).

TABLE IV

	m. therms							
	1960		1970		1973		1975	
Industry	21315	42.3	24689	42.6	25790	42.3	21951	39.3
Domestic	14425	28.5	14643	25.3	14917	24.4	14073	26.3
Transport	8812	17.4	11186	19.3	12876	21.1	12261	21.9
Others (inc. agric.)	5943	11.8	7435	12.8	7451	12.1	6959	12.5

SOURCE: Department of Energy, Digest of Energy Statistics, HMSO, 1976.

Within the domestic sector the Building Research Establishment [18] has estimated that 64 % of a typical household's energy consumption was devoted to space heating, 22 % to water-heating, 10 % to cooking, and 4 % to TV, lighting, etc. The technical potential for the use of solar energy in these applications is therefore considerable. Studies by ETSU given in the ACORD document show that with vigorous exploitation, but without the need for a major breakthrough in technology nor a major disturbance in lifestyles or institutions, solar energy in the domestic sector could contribute to UK energy supplies at up to the following levels:

	Year 2000	Year 2025
Domestic Water Heating	3 mtce	6 mtce
Domestic Space Heating	3 mtce	9 mtce

The International Solar Energy Society, not unsurprisingly, have more optimistic forecasts.[19] They assume, for example, that if 25 % of the domestic thermal load could be met by solar power then 6.2 % of UK 1972 gross consumption could be accounted for by solar energy. Savings of 10 % of gross industrial consumption and 12½ % in the «other users» category would lead to a 12 % saving of gross UK 1972 consumption (ie. 35 mtce), by 2020.

18. Building Research Establishment, «Energy Conservation: a study of energy conssumption in buildings and possible mean of saving energy in housing», 1975.
19. UK-ISES, *op. cit.*

These are highly optimistic figures for the possible applications of low grade solar heat. Great uncertainties surround the prospects for the other more «direct» applications of solar power (as opposed to indirect applications like wind power) ie. photovoltaics, biomass fuels, and photochemical applications, all of which are admirably described in the UK-ISES publication. Considerable research is being devoted to these areas internationally, and there is great interest in te UK. ETSU see prospects for the utilisation of biomass fuels in the year 2000.

Photovoltaics are the most advanced area of research, but unit costs are still very high, and only application in remote or difficult sites with no mains supply are regarded as being currently economically feasible, although mass production could certainly lead to lower costs.

Wind power

The utilisation of wind power does have the advantage that as an energy source it is at its peak at about the same time as maximum consumer demand and so avoids the mismatch between the peaks encountered in solar heating applications. But it is a very variable source of supply, and whether used as a supply source for the central electricity authorities, or for household supplies at a more local level, would require back-up supplies unless important technological breakthroughs are made in storage techniques.

The Central Electricity Generating Board have identified a few hill top sites where large wind generators could be installed to feed power into the grid, but they point out the visual disamenity of large wind generators in these sites, and prefer to treat the technology as an insurance standby should there be unforeseen developments in other elements of their supply system (for example nuclear power).[20]

At a local level a number of small (200 W to 2 kW approximately) wind generators have been installed,[21] and bigger units are being developed in Britain. A major potential application is foreseen in home heating[22] (using underfloor concrete stores, for example) as well as in mechanical applications (eg. pumping), which would lead to significant fossil fuel savings.

20. ACORD, *op. cit.*
21. J. C. McVeigh, *op. cit.*
22. H. Sharman, «The Future of Wind Generation in Britain», Royal Society of Arts, *op. cit.*

CONCLUSIONS

While it is technifically feasible for Britain to achieve a small, but significant contribution from unconventional energy sources by the year 2000, a number of factors may well militate against this. Paramount is Britain's favourable indigenous energy situation which may lead to an energy «glut» over the next 15-20 years. Britain is therefore unlikely to be first country to develop and exploit these new technologies. Institutional factors, referred to earlier, may also act to reduce their penetration, as well as current pricing policies (especially of the gas industry) which do not accurately reflect long-term scarcity values.

Increased R & D funding seems justified in the light of the longer term energy uncertainties, including the risk of social and political constraints on the long-term build-up of nuclear power.

Given the wide range of new energy sources there is a strong case for agreed international specialisation and collaboration on R & D on particular energy sources according to comparative advantage and national priorities.