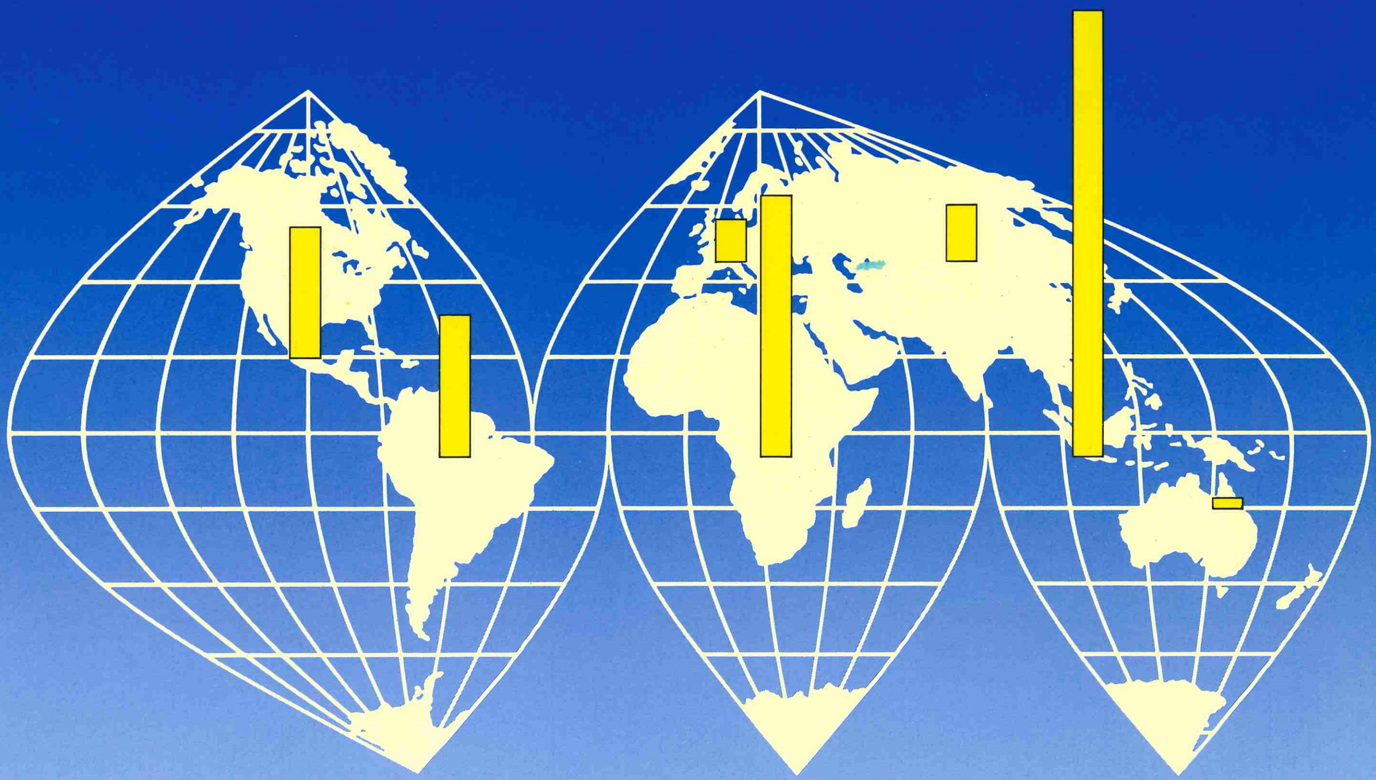
Synthetic fuels and renewable energy



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Synthetic fuels and renewable energy

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World map: Bartholomew's re-centred sinusoidal projection featuring world fuelwood consumption. Copyright John Bartholomew & Son Ltd (reproduced with permission).

Energy for the future

Over 90 per cent of the world's energy demands are currently met by non-renewable resources of which oil contributes about half. Oil price rises in 1979 focused attention on the need to develop a range of alternatives to what was perceived as a rapidly dwindling energy resource.

Since then the decline in oil prices and the slow-down in the growth of energy demand have affected the development of even the most promising candidates. Even before this price fall, many options that were competitive relied on special local circumstances. Immediate prospects are therefore limited except where local factors outweigh the cost disadvantage. Nevertheless, it is by pursuing commercial opportunities now and in the near future that the valuable experience needed for further development will be gained.

By the early part of the next century the world's population is likely to have grown by two billion people from around five billion at present. Most of the increase will be in the developing countries. Demand for transport fuels in the developing world could almost double by the end of the first decade of the next century. In addition, urbanisation in many developing countries is expected to increase the need for clean, convenient energy in industry and in the home. In rural areas of some developing countries a heavy reliance on biomass – firewood, agricultural and animal waste – has already resulted in deforestation and soil erosion. There will therefore be increasing pressure to find more efficient ways of using biomass, as well as more extensive use of alternatives such as solar energy.

In OECD countries the long term effects of investment already made in energy conservation may be expected to continue to dampen future energy demand, even if the level of energy prices does not provide an incentive for further conservation.

Efforts to limit the effects of combustion of fossil fuels on the environment, especially in OECD countries, is expected to continue. This will affect the choice of fuels and attention will be paid increasingly to quality as well as the availability of energy sources.

Conventional energy resources, notably the fossil fuels – oil, coal and gas – and nuclear energy are expected to continue to meet the bulk of world energy requirements during the remainder of this century and well into the next. However, the task of replacing oil resources is likely to become increasingly difficult and expensive and there will be a growing need to develop clean, convenient alternatives. Initially these will supplement and eventually replace valuable oil products, especially as transport fuels.

Many potential energy options are as yet unknown or at very early stages of research and development. New energy sources take decades to make a major global contribution. Sustained commitment is therefore needed during the remainder of this century to ensure that new technologies and those currently at a relatively early stage of development are available to meet energy needs in the next century.

Strategies to satisfy energy needs in the next century are likely to include:

- Finding replacements for conventional oil, primarily for transportation. In general, these are likely to be synthetic liquid fuels derived from raw materials such as coal, natural gas, oil shale and tar sands. The resource base of these materials is considerably greater than that of conventional oil.

- Development of new technologies to convert relatively plentiful supplies of energy into convenient, environmentally acceptable forms.

- Further development of renewable energy resources such as biomass, solar, wind, tidal, wave and hydropower. In some cases these will be large scale projects involving major capital investment; in others the emphasis will be on low-cost alternatives for use in rural areas.

- New methods of energy conservation.

The following sections focus on two of the many areas of activity – synthetic fuels and renewable energy resources – in which Shell companies, among others, are helping to ensure that energy demands can be met during the early part of the next century.

Synthetic fuels

In 1985 oil satisfied some 40 per cent of the world's primary energy needs. Fuels with similar properties can be derived from raw materials other than crude oil and are referred to as synthetic fuels or synfuels.

Coal, natural gas, oil shale and tar sands/heavy oil – constitute over 90 per cent of estimated world ultimate recoverable fossil fuel reserves (Figure 1). Biomass, a non-fossil, renewable resource, is also a potential raw material; its use is outlined in the next section.

A number of processes are already available, and others are being developed to convert these materials into convenient forms to meet consumer needs. The amount of potential hydrocarbon, and also the ratio of hydrogen to carbon, which must eventually be matched to that of the desired fuel, are important factors in synfuel conversion (Figure 2). There are two main process routes.

The syncrude route

Adding hydrogen to, or removing carbon from, tar sands, oil shale or coal to make syncrude is the major cost. Conversion efficiency is also an important cost factor: this is typically 60-80 per cent, but upgrading to improve product quality can reduce this by some 10-15 per cent. The processes differ, depending on the raw material.

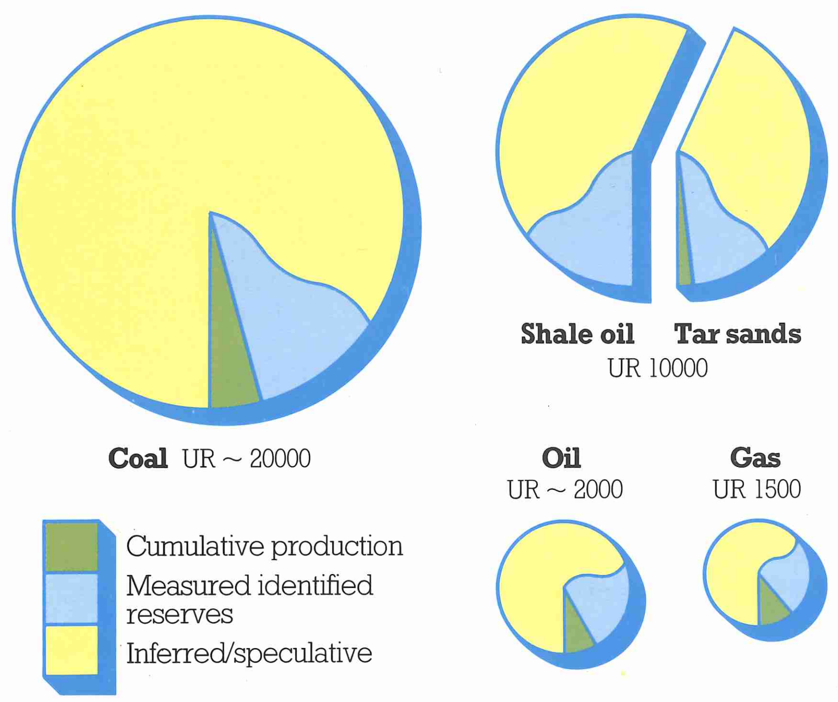
Tar sands are often extensions of heavy oil deposits. Some of the technology used to extract and upgrade them can be considered commercially proven. Shell Canada's Scotford refinery, which went on-stream in 1984, was the first refinery capable of processing syncrude exclusively from tar sands.

Oil shale consists of sedimentary rock containing organic matter. Major oil shale deposits occur in the United States and Australia with smaller deposits in a number of other countries. It is turned into syncrude by heating the shale in retorts at around 500°C and extracting the liquid. However, the energy remaining in the rock may well exceed the energy content of the shale oil produced, so efficient energy recovery is required. A number of projects are being considered, mainly in the United States and Australia, but only around 10 000 bdoe were actually produced in 1985. The USSR and China are also operating oil shale projects.

Coal has a relatively low hydrogen content. Extensive research has been carried out on direct coal liquefaction by the addition of hydrogen at high temperatures and pressures. Second-generation processes based on this research are being developed improving the technologies first used during World War II. However, at present, such projects are only at the demonstration phase. It is unlikely that large scale projects will be developed before the next century, except for strong strategic reasons.

1 Fossil fuel resources

Estimated World ultimate recoverable reserves



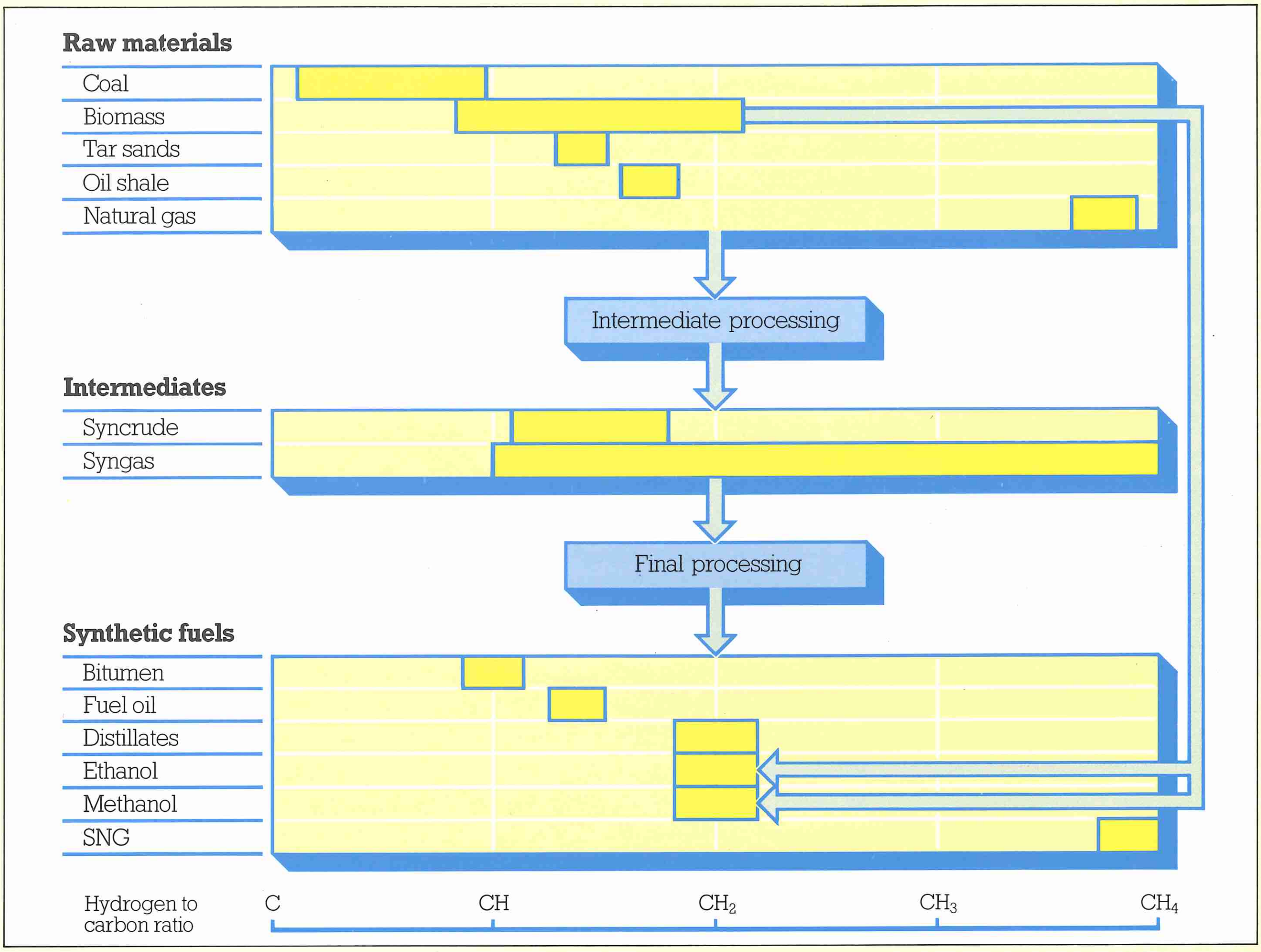
UR = ultimate economic recovery (barrels of oil equivalent × 10^9)

The syngas route

Indirect conversion of coal to synthesis gas (Syngas), followed by hydrocarbon synthesis, can be a more economic route to liquid fuels. Examples are the Mobil methanol-to-gasoline process in New Zealand and the Shell Middle Distillates Synthesis Process. A number of coal gasification/liquefaction plants based on well-established technology, for example the SASOL plants in South Africa, are already operating. Second-generation gasification processes have advanced to commercial or large-scale pilot plant stage, for example the Shell Coal Gasification Process (SCGP) plant in the United States that will come into operation during 1987.

Natural gas can also be converted into liquid fuels using the Syngas route. Biomass can be used to produce a range of synthetic fuels, either via conversion into an intermediate liquid or Syngas, or directly by fermentation into alcohols.

Hydrogen, one of the components of syngas, also has potential as a fuel. Its main advantage is that the combustion product, water, is non-polluting.



2 Making synthetic fuels

Interest has been expressed in a 'hydrogen economy' in which hydrogen is piped directly to industrial/domestic users or liquefied for transport. However, the high cost of producing hydrogen from syngas, or alternatively, by the electrolysis of water in a fuel cell make such developments unlikely until well into the next century.

Status of synfuels

In 1986, output of liquid synfuels was around 400000 bdoe, or less than one per cent of world oil production.

Product costs depend on the resource and process used and are higher than present oil prices. Local circumstances or strategic factors can offset a cost disadvantage to some extent but large-scale synfuel production will be unlikely until oil prices are significantly above early-1987 levels. Activity has shifted to projects that can be developed on a small scale, or where modular extensions are possible, for example in-situ tar sands recovery.

This situation contrasts sharply with events immediately after the rise in oil prices in 1979 which prompted support for synfuel development, mainly for strategic reasons. Much of the initial activity was in the United States where the Synthetic Fuels Corporation (SFC) was established in 1980 with a $88 billion budget and a programme to produce two million b/d of synfuels by 1992.

Falling oil prices, the large Strategic Petroleum Reserve and a growing budget deficit all contributed to a decision taken in 1985 to discontinue the SFC. By this time the SFC had paid out only $34 million with commitments of 1.5 billion in support of projects with a capacity of 22000 b/d. Existing commitments are expected to be honoured.

Emphasis in the United States can be expected to move towards diversification of synfuel technology rather than volume production. One area that remains relatively buoyant is coal gasification for combined cycle power generation in applications where environmental advantages can be demonstrated.

There is support for synfuel projects in a number of other areas including Europe, Canada and Japan. In Europe most of the activity is concentrated on coal conversion technologies in the Federal Republic of Germany.

Given the long lead times needed for large scale synfuel projects, the immediate priority is to ensure that the technology is established so that synfuels can make a global contribution to supplement and replace conventional fuels as the need arises.

Biomass

About as much energy is stored in living plants at any time as is contained in all the proven reserves of coal, oil and gas combined. Biomass is the collective term used to describe plant matter and also derivatives such as residues from forests and crops, animal wastes and the organic content of municipal and domestic solid waste.

About two-thirds of the world's land surface can support extensive biomass. Currently only 15-20 per cent of this area is under cultivation producing in energy terms roughly the equivalent of the world's annual energy consumption. However, as this cultivated area also has to support food production and timber, there is potential competition to the use of biomass for fuels.

Small scale biomass

Over half of the world's population currently relies on wood for cooking and heating. Wood is also a source of energy for industry. Since 1970 fuelwood consumption has risen by 2 to 3 per cent a year and was estimated at 1.7 billion cubic metres in 1984 equivalent to 8 million bdoe (Figure 3).

Developing countries in particular use fuelwood, in some cases getting 90 per cent of their energy from this source. However an estimated 1.3 billion people cannot obtain enough fuelwood. Dwindling supplies in rural areas and high fuelwood prices in urban centres force families to spend disproportionate amounts of time and money on fuelwood, and also mean lower standards of living. Social, cultural and economic factors frequently prevent the widespread use of alternatives.

Satisfying the increasing energy needs of a rising population in this way is contributing to a number of ecological problems. Deforestation of tropical soils leads to erosion and degradation of the soil, rendering the land unsuitable for agricultural crops. Where fuelwood is scarce, the use of animal waste as a fuel rather than as a fertilizer reduces agricultural efficiency.

Meeting the growing needs for cheap, efficient energy in rural areas of developing countries, while at the same time avoiding major ecological problems is a challenge to the widespread future development of biomass for energy. Initiatives to develop the efficient use of biomass fall into three broad categories.

Increasing resources: yields can be improved by choosing appropriate crop species and by the selective development of high-energy crop strains using techniques such as genetic engineering. Plantations of high yielding species, developed for use as a fuel source, reduce the need to exploit natural forest. Shell companies, among others, are investigating such techniques, as well as ways to maximise productivity by adopting efficient forest and plantation management, carefully developed fertilizer regimes and selective replacement of vegetation.

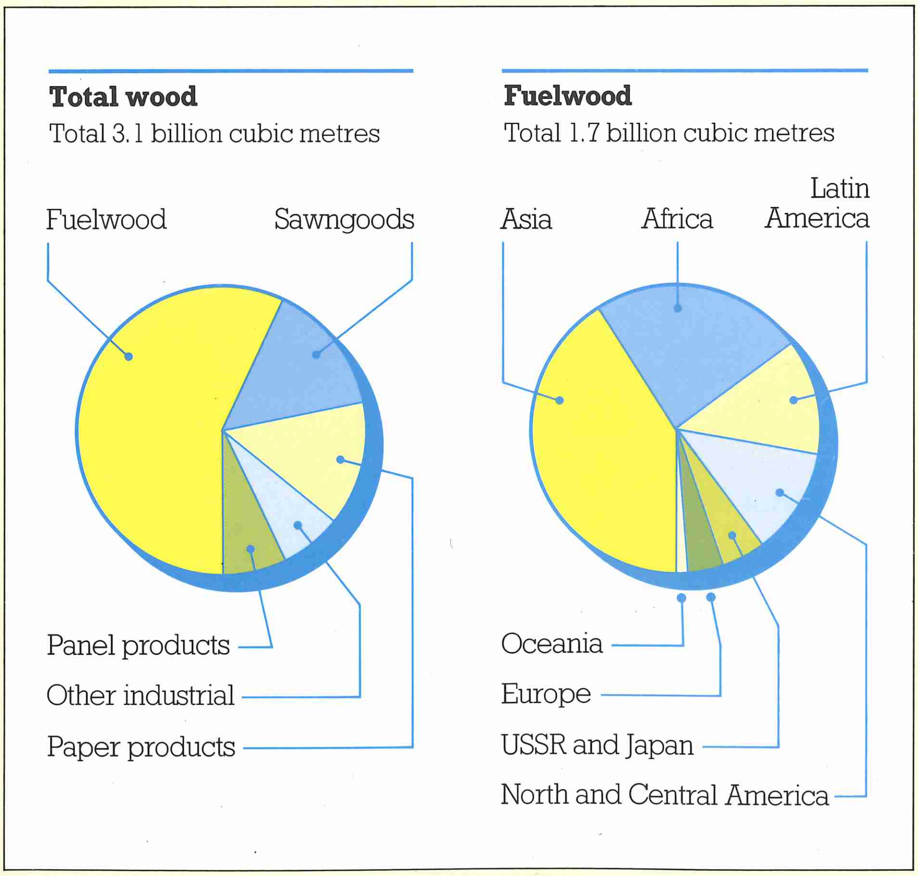
Upgrading: techniques are available to make better use of biomass produced (Figure 4). The most common method is to upgrade the energy value of the fuel, for example, the production of charcoal from wood. Although charcoal is more convenient, considerable energy is lost during upgrading. Wood waste can be upgraded physically by densifying it into pellet form; such pellets are used as a solid fuel for industrial steam-raising in North America and Europe. A Shell company is operating wood pelletisation plants in Canada.

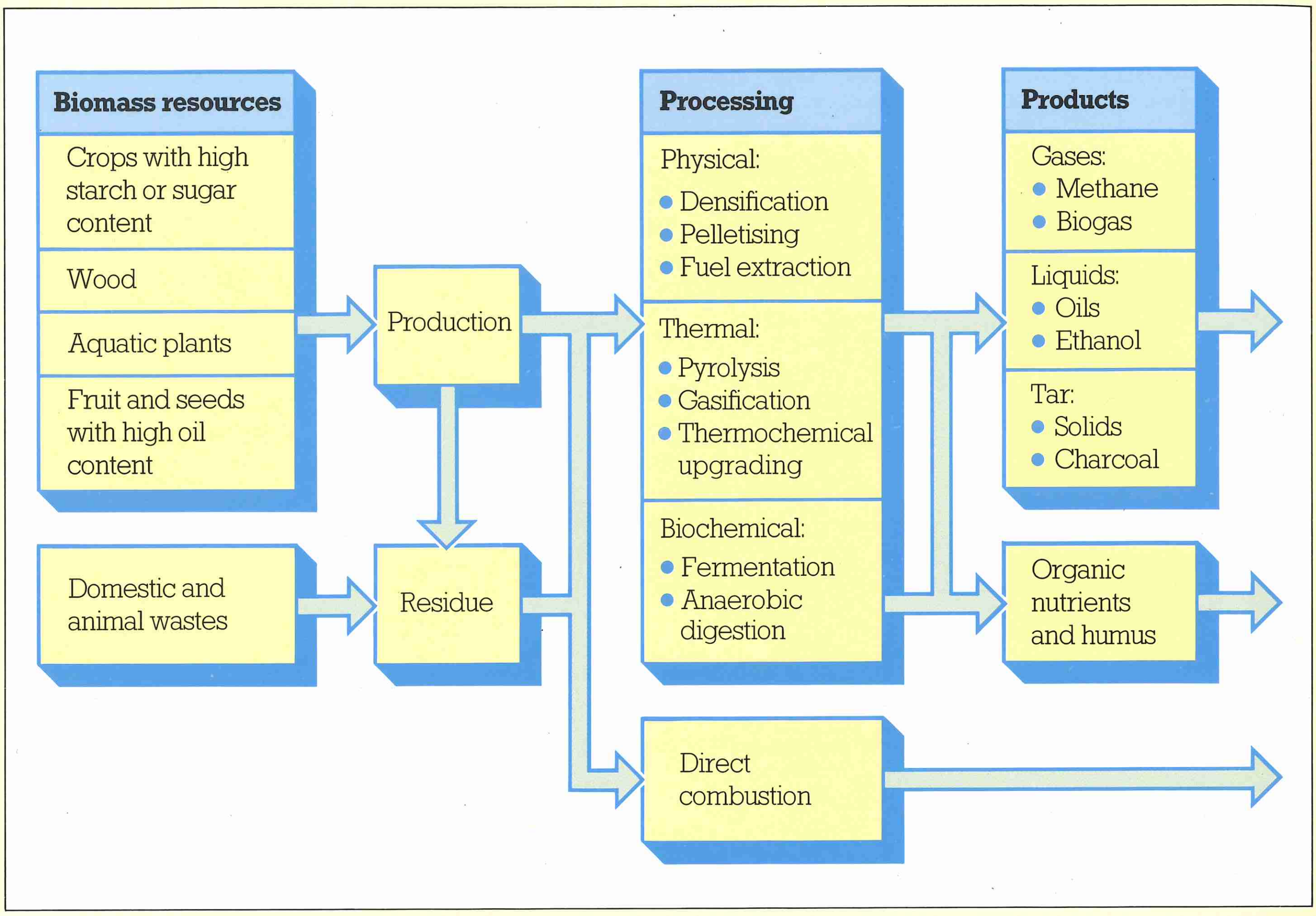
Chemical methods can also be used. In biogas units the biochemical action of micro-organisms – a process known as anaerobic digestion – breaks down biomass and animal waste into a fuel and fertilizer. This is widely used in India and China. Larger versions are being developed to provide fuel for local electricity generation, with small wood-based co-generation facilities an attractive option to provide heat and electricity.

Improving efficiency: combustion efficiency has also been improved by the development of new wood- and charcoal-burning stoves. Research is continuing aimed at producing low-cost, highly reliable biogas generators and stoves to improve energy efficiency of local biomass resources.

One of the main priorities is to ensure that, as well as being efficient,

3 **World wood consumption 1984**





4 **Upgrading biomass**

the technologies are also appropriate to local needs with high reliability, long life and low cost. Although small scale use of biomass is unlikely to make a major contribution to global energy demand, its efficient use could improve the standard of living of two billion people in the developing world.

Large scale biomass

The rise in oil prices at the beginning of the 1980s prompted a number of governments to investigate ways of turning readily available biomass resources into liquid fuels.

The most notable example to date is Brazil's major fuel-alcohol programme, started in 1975 after the oil price rises in 1973/74, in which sugarcane juice is fermented to provide alcohol fuel for some two million vehicles. The programme was supported by a range of financial, fiscal and legal incentives. Other developing countries such as Kenya and Malawi have also introduced alcohol fuels, albeit on a much smaller scale.

At around $50 a barrel of oil equivalent, the cost of alcohol is higher than the price of comparable oil products. The main attraction is the use of indigenous products sold in local currency rather than imported oil priced in dollars.

Despite Brazil's achievements, immediate prospects for expansion have been dealt a blow by the fall in oil prices during 1986. Current indications are that the programme will continue in Brazil, but commitments for future expansion have been curtailed at present.

Immediate prospects for large scale biomass projects depend on local circumstances: the energy situation, the need to reduce energy import bills, the availability of infrastructure in rural areas and, most important, government attitudes to encouraging technological development and providing incentives as part of a co-ordinated energy programme. Environmental considerations, for example a need to use low-sulphur fuels, can also increase the attraction of biomass-derived fuels.

In the longer term the outlook could be improved by new technological developments. Although still at the exploratory stage, a number of routes are being investigated to provide a range of oil-like products. One way is to extend the range of potential biomass feedstocks. By using cellulosic feedstocks, instead of sugar cane, it should be possible to produce ethanol and gasoil less expensively from more abundant wood products.

An alternative line of research is concentrating on more efficient fermentation; for example, continuous processing based on innovations in biotechnology could replace current batch techniques and increase ethanol production. Other routes include pyrolysis, gasification and thermochemical upgrading to produce synthetic fuels on a large scale (Figures 2 and 4).

Solar energy

It is estimated that every year the earth's surface receives about ten times as much energy from the sun as is stored in the whole of the world's fossil fuel and uranium resource base. This is equivalent to 15000 times the world annual energy demand. Despite this enormous potential, only a tiny fraction is used.

Technology to harness some of the sun's energy is based on two quite different principles – solar thermal systems and photovoltaic cells (Figure 5).

Solar thermal

In solar thermal systems sunlight is absorbed and transformed into heat which can be extracted using a heat transfer medium, for example water. Systems can be designed to operate over a range of temperatures, with high temperature systems being more sophisticated and expensive.

Relatively simple units are generally satisfactory for such low temperature applications as domestic water heating, swimming pools and crop drying. Such systems are fairly widespread even in the relatively cooler climates of Northern Europe. For higher temperatures parabolic mirrors are usually used to concentrate sunlight. These can be further enhanced by using tracking systems to produce temperatures over 300°C. High temperature systems can be linked to a conventional turbo-generator arrangement to generate electricity indirectly.

Solar thermal systems are technologically well-developed, and in some cases costs have been substantially reduced during the past five years. However, it is becoming increasingly difficult to further reduce the manufacturing costs of simple flat plate collectors. Nevertheless, future savings can be expected from improvements in the overall design of systems and the use of new materials.

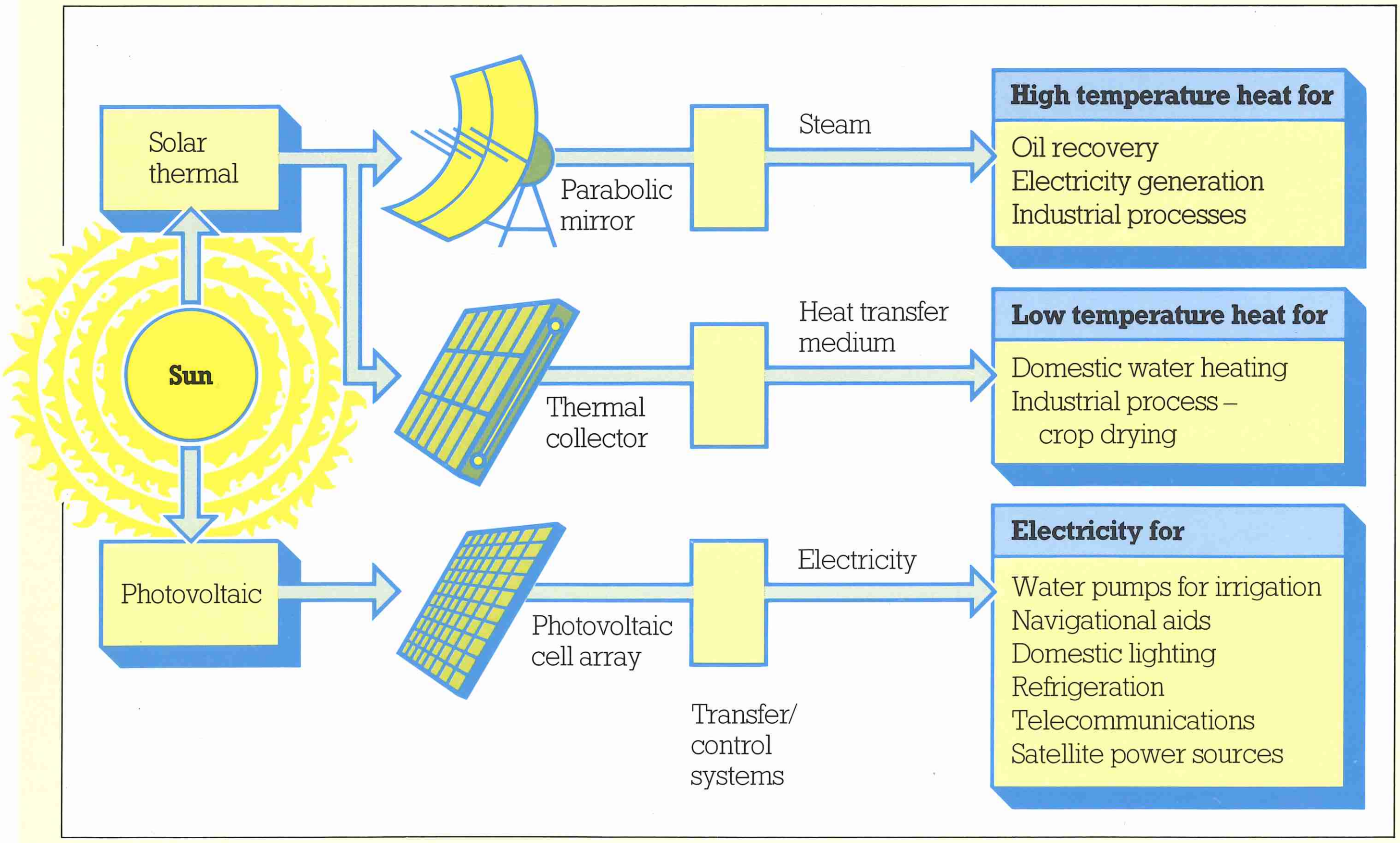
There is still considerable scope for more widespread use of solar thermal systems in a range of applications in a number of countries. Prospects for larger scale systems depend on trends in costs of conventional energy, but more use of domestic systems could be made in sunny areas.

Photovoltaic cells

The photovoltaic cell converts sunlight directly into electric current by generating a voltage differential in a semi-conductor. Cells are connected to each other, packaged in a protective seal and sold as 'modules'. The voltage and power output of a module depends on the size and number of cells. Modules can be further aggregated into panels and arrays for use in higher voltage applications.

The power output of a photovoltaic system varies with the intensity of the sunlight hitting the solar cells. Output increases from zero at night to a peak

5 **Solar energy systems**



around midday, decreasing as sunset approaches (Figure 6). The peak output is known as the 'watts peak' (Wp) of the system and is the most common method of rating. The considerable changes in output mean that for practical purposes batteries are frequently used to even out the load, the batteries being recharged during the periods when output exceeds the load requirement.

First generation photovoltaic cells, based on single crystals of silicon, are well established and have been used to power most satellites. During the past ten years costs have been reduced by a factor of 20, opening up a wide range of additional applications, mainly on a small-scale in remote locations. Examples are electrically driven water pumps for irrigation, railway crossings, telecommunications, cathodic protection for corrosion prevention and as a power source for battery chargers.

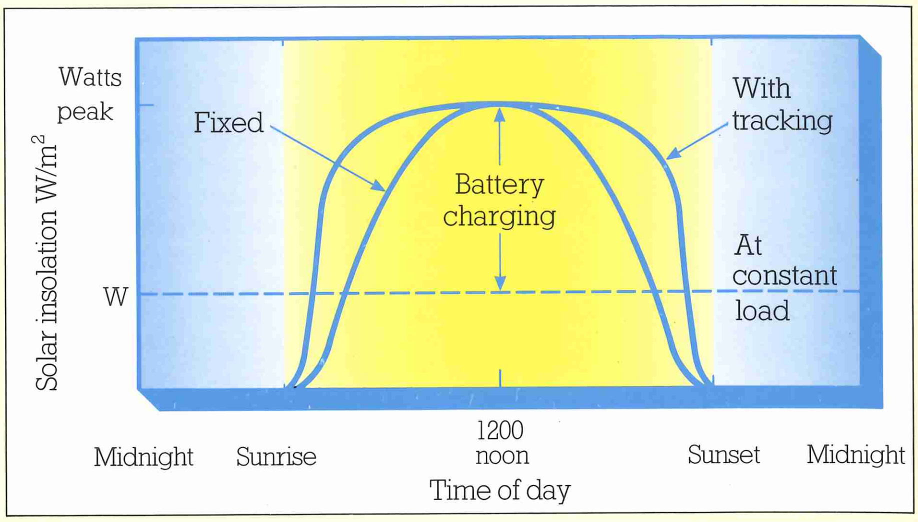
Recent innovations have further reduced costs through new production techniques using polycrystalline silicon or amorphous silicon – a thin film of non-crystalline silicon applied to a glass substrate – which is used extensively in calculators and toys. Unfortunately these techniques also reduce efficiency and this has limited their use in large scale applications.

Cost reductions have stimulated a major growth in photovoltaic module supplies from well under one megawatt peak (MWp) in 1976 to an estimated 27 MWp in 1986. Japan has become established as the world's largest supplier (Figure 7). Since 1983, falling oil prices have probably contributed to limiting the rapid growth rates seen during the late 1970s and early 1980s.

Further reductions in cost are becoming increasingly difficult to achieve. This, coupled with the relatively low current level of oil prices, makes it difficult to assess immediate prospects for photovoltaics. Nevertheless, there is still considerable scope for technological innovations to bring down costs in the longer term.

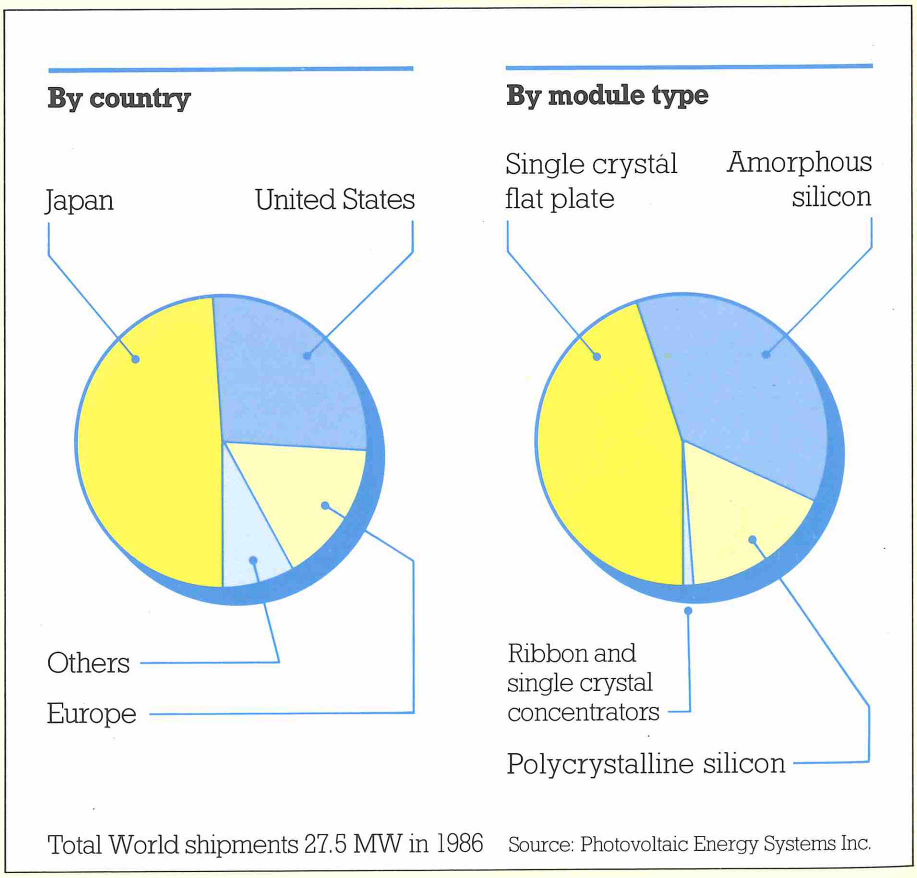
Expansion is likely in low-power applications, for example toys and calculators, but energy requirements for this very large and diverse consumer market will remain relatively small in global terms. Similarly small-scale applications in remote areas may be expected to grow. In both cases photovoltaics are already competitive with other energy sources.

For large scale systems the picture is less certain. If the efforts being put into technical innovations to reduce costs and improve efficiency are successful, there may be scope for the use of photovoltaics for large scale electricity generation. In the meantime, as with solar thermal, the search will continue for new applications in which photovoltaics can compete on the basis of their advantages of low maintenance and operating costs, especially where conventional fuels are expensive or unavailable.



6 **Watts peak-load relationship**

7 **Photovoltaic module shipments**



Other renewable energy sources

A number of other renewable energy options are available (Figure 8).

Water-based systems

Hydropower is used to generate 25 per cent of the world's electricity. Large hydropower stations of up to 7000 megawatts (MW) are generally built in remote areas with little or no local demand. The long overhead power lines required are expensive and have significant transmission losses. Considerable investments are required, due to their size and remoteness, and with lead times up to 10-15 years these power schemes tend to be difficult to plan and develop. Large hydropower stations are relatively clean but their environmental impact can be considerable and sometimes detrimental. A service life of some 50 years is common, with low operating cost the main attraction.

The drive for utilisation of local resources and energy efficiency has prompted interest in smaller (1-5 MW) and micro (smaller than 1 MW) stations. Over the past few years the trend has been to design standard small hydro machines. These are easy to transport and install in remote areas, where reliability and ease of operation are essential.

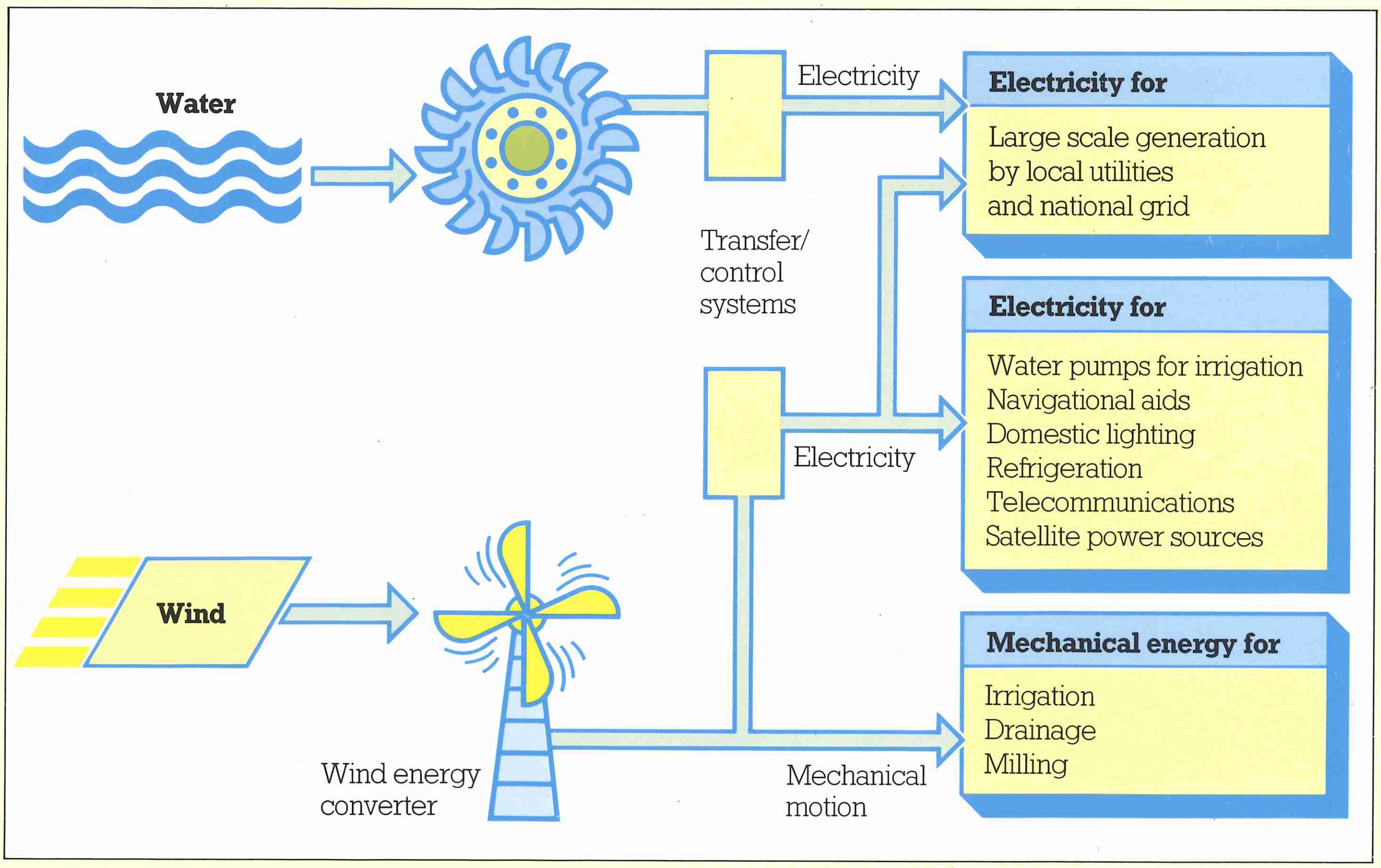
By 1985 a total hydropower capacity of 300 gigawatts (GW) had been installed. Considerable resources are still available for further development of both small and large hydropower schemes and, as a result, their contribution towards energy supplies for electricity generation may be expected to rise in the future.

Tidal hydropower is similar to conventional hydro-electricity schemes except that the head of water is obtained from the rise and fall of the tide. A barrage, for example a dam, is constructed and large turbines are driven during the flow and ebb of the tide. Ideal locations for such systems which can provide large power outputs are scarce, the two best unexploited sites being the Severn estuary (United Kingdom) and the Bay of Fundy (North America).

The cost of electricity from tidal power is comparable to that from coal-fired power stations. Because the tidal pattern does not always coincide with demand, this is best used in conjunction with a storage system, for example pumped storage, or as part of a network. Widespread commercial applications of tidal hydropower seem unlikely this century.

Wavepower uses the oscillating motion of the sea to move floating devices and thereby generate electrical power either directly or indirectly. For the system to be effective it must be in a difficult environment with high installation and transmission costs. The

8 Water and wind based systems



very nature of the system makes demand/load matching difficult. The current economics of wavepower systems have discouraged research and further investment.

Wind-based systems

Windmills have been used for centuries to extract energy from the wind. Modern systems incorporating sophisticated technology derived from aeronautical and electrical engineering have little in common with the traditional windmill. This form of energy can, however, only be considered as supplementary except where some form of storage is available.

Systems can be broadly classed as:

Stand alone – used to provide mechanical energy to drive irrigation pumps or similar equipment, or to generate electricity for local use. In remote areas without grid connections, specially designed wind generators can satisfy local domestic electricity requirements while providing scope for new developments, such as making ice to preserve foodstuffs.

Grid-connected – tend to be large, with a number of linked wind turbine generators forming part of a large electricity network. Recent projects in California comprise some 10000 wind turbines with a combined output of around 1000MW, equivalent to a large conventional thermal power station. During the past few years large wind turbines with ratings of 500KW to 700KW have been successfully operated. Improvements in equipment efficiency, availability and lower equipment cost have contributed to a general reduction in the cost of electricity to 10-20 US cents per kilowatt-hour (KWh) in 1985.

Marine systems – for ship propulsion. Modern sail-assisted ships are designed from the outset as complete energy-saving units capable of making the greatest possible use of sails to complement their engines. These range from simple fixed systems to computer systems measuring wind speed and direction to adjust the sails to the optimum angle.

At present wind energy systems are competitive with conventional generating facilities in remote areas with reasonable winds. Their prospects will depend on further reductions in investment costs and improvements in efficiency.

The scope for technological development is limited compared with solar photovoltaic. Nevertheless, environmental cleanliness, renewability of the energy source and the short lead time required for installation favour wind power, although noise from the generators can cause local problems. Relative economics and future potential will also be influenced by electricity pricing policies, particularly the buy-back rates offered by utilities for wind generated electricity.

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