Use of Solar Energy

Although most of the papers under this heading were presented in sessions dedicated to the different forms of energy conversion, the importance of the topic ensured its mention in several other lectures dealing with the transport and storage of energy and with energy research strategies.

In his plenary address P. Aigrain reviewed the subject at a popular level, giving a realistic, if not pessimistic assessment of what appears feasible. Solar energy, globally extremely abundant but very diffuse and therefore difficult to utilize, constitutes much more than the energy we need until sun and life are gone. The conversion of this energy is a fruitful field of investigation for the physicist, but some present-day claims appear to be wildly exaggerated. It is also false to assume that the use of sunlight is free from thermal pollution. Large surface solar collectors with their absorptivity higher than the surrounding desert would effectively lower the albedo of that part of the globe and could cause climatic changes. The answer may lie in painting the unused parts of the desert white, perhaps in a zebra pattern, to compensate for the greater heat absorption, but one could do that also to compensate for excess heat from other power conversion systems. Within the next generations there will doubtlessly be a tremendous increase in the uses of solar energy but nothing spectacular should be expected. Because solar energy is so intermittent and unevenly distributed the biggest problem is storage, the cost of which largely exceeds that of solar energy conversion if a reasonable degree of energy availability is desired. The best long-term solution is likely to be conversion into chemical products where the cost of storage is not large.

Four general categories of solar energy utilization can be distinguished :

(i) for special applications, e.g. in space telecommunications and satellites where energy cost is an insignificant part of the whole and competitiveness is not a problem.

(ii) for general use in isolated areas. Development is likely to be slow and an economic solution will probably lie in photochemical conversion.

(iii) for feeding energy to electric power networks — only realizable in the very distant future, if ever.

(iv) for water heating or pumping.

The last is the only category not requiring the production and storage of electrical energy and hence the prospects of its rapid development are good. Solar water heaters are already competitive in France at today's electricity charges and so is pumping in arid regions lacking dense electric power networks.

Numerous types of thermal collector are already available, which make use of different degrees of solar concentration by orientation or solar tracking motion. Absorbers can also be rendered spectrally selective, but the combination of concentration and selectivity is unlikely to be thermally efficient because of the higher collector temperatures. On the other hand, focusing of solar energy on photovoltaic devices used for pumping will improve the efficiency. Aigrain firmly shelved as science fiction the idea of going into space to convert solar energy into electricity and then to microwaves for beaming to earth and subsequent reconversion. Even if precise pointing of the aerials could be achieved and safely maintained, there is likely to be considerable thermal pollution from the unavoidable side lobes.

Water as an ideal medium for storing low-grade heat, such as solar energy at between 40 and 90°C, was also mentioned by D.J. Schröder in his talk on thermal energy storage. A latent heat storage plant using KF-H_2O is effective in the short term but sedimentation caused by gravity will result in deterioration. Eutectic fluoride systems with their high values of heat of fusion offer great possibilities for high-grade heat storage, perhaps in tropical regions.

As far as conversion is concerned, F.P. Califano talking on the photovoltaic effect pointed out that monocrystalline Si solar cells can now be produced with conversion efficiencies close to the theoretical optimum, at around 15 %, but their cost is still very great : \$ 1500 - 2000 per m^2 representing \$ 15,000 - 20,000 per kW. Technical problems, such as the improvement of mobility in Si and the reduction of surface and series resistance losses, remain to be solved and the use of polycrystalline materials, e.g. CdS-Cu_2S, and of Si grown in ribbons may help to bring down the price. It was also encouraging to hear from P.T. Landsberg in a short report that effective use of solar cells is possible even under cloudy skies. Efficiency was shown to rise with the change from bright, direct sunlight to diffuse conditions and lower incident energy.

The photochemical aspects of solar energy conversion were reviewed by M.D. Archer. A suitable photochemical reaction should be capable of providing compact and long-term storage of solar energy. Operational limitations of the process and desirable properties of materials were discussed. Whereas in thermal conversion all photons may be absorbed and converted to heat, quantum processes such as those described make use of a narrow absorption band. Although the photochemical energy collection efficiency may be relatively high, the production efficiency and, hence the overall efficiency, tend to be very poor because the chemical products cannot be easily separated and a " back reaction " will occur. The decomposition of water and the reductive fixation of CO_2 were among other processes considered and the role of electron transport in photosynthesis was illustrated.

Photosynthesis was also the theme of G. Forti who, thanks to the advances of physics in the observation of nanosecond events, was able to give a detailed description of this ancient process which, while converting electromagnetic into chemical energy and ensuring plant growth, manages to keep the O_2 level constant to suit man's requirements.

The long-term importance of photochemical utilization of solar energy in comparison with other forms of quantum utilization was emphasized by G. Stein. Developing nations that lack skilled manpower and whose population is dispersed are primarily in need of viable sources of chemical energy, and in about 20 years photochemical systems may well become competitive with photovoltaic devices. The latter could be made more cheaply by restricting their absorption spectrum to a band of 600 nm where most of the incident energy lies — but the major expense in the system is still battery storage. The best photogalvanic systems have an overall efficiency of only 0.1 % and also require storage. Photoelectrochemical devices, such as those based on rutile or platinum for water decomposition, produce chemical fuel suitable for storage but they are very inefficient and productive only below 400 nm. The main cost in all the devices mentioned lies in the manufacture of large active surfaces — but at least it can be said that they perform !

The search for a homogeneous photochemical device capable of producing chemical fuel is only beginning. Europium and samarium have been used to evolve H_2, but they are such rare substances that the findings are of purely academic interest. Organic materials and the use of isomerization remain to be studied. In all this, man must not attempt to imitate the results of natural evolution such as biological photosynthesis. But the study of biological and biochemical processes could well lead to the development of a practical device based on the photofixation of CO_2 in a non-biological system, perhaps 15 to 20 years from now.

With so much theory and speculation being devoted to the solar energy problem its impact on everyday life now should not be forgotten. Take black beans, for instance. J. Meyer reporting on solar energy investigations in Brazil showed that his young research group had followed the rule that science in a developing country should be closely related to general activities there. The drying of black beans is an essential part of their food economy, and it is worth remembering that 30 % of the foodstuffs in the tropics perish because of the lack of correct treatment. So they developed a solar collector of 8-10 m^2 in area connected by a ventilating system (so far electrically powered) to the silo full of beans. With a potential solar input of about 800 W/m^2 during six hours a flow of 400 m^3/hour of dry air between 16 and 30°C can be produced ensuring rapid drying without risk of damaging the fruit. A similar system may be developed for the drying of fish.

In considering solar energy in its relations to our habitat J.K. Page dealt with conditions prevailing at higher latitudes, particularly in the UK not exactly renowned for high solar input (1975 excepted). Because the supply of solar energy and demand are controlled by meteorological factors and are grossly mismatched at high latitudes, other sources of energy have to help out. Therefore thermal storage and the prevention of heat losses are important criteria which unfortunately appear to have been ignored by many modern architects although simple peasants already had some good ideas on the heat conservation of buildings. Well informed collaboration between architects and solar technologists is thus essential. The magnitude of the task becomes clear when it is realized that the solar heat input in the UK ranges over two orders of magnitude between a good day in summer and a bad day in winter. The summer surplus should be adequate to cover winter needs, if only a good storage technique could be devised. For short-term storage the use of heavy thermal mass building materials is helpful, but even more important is the conservation of energy in buildings, at present largely lost by bad ventilation and insulation. With better insulation internal heat sources, such as even the occupants at 100 W per person, could make a bigger contribution. Ideally windows should become valves allowing radiant energy to penetrate and preventing heat from escaping, and their orientation can have a considerable regulating effect. For the solar house of the future research should go into developing high-efficiency collectors to provide sufficient energy at high latitudes with overcast sky by using thermal siphoning with radiatively selective absorbing surfaces and the suppression of convection losses. The recovery of energy from waste water either directly or by heat pump could also be of economic benefit.

About ten years ago St. George's School at Wallasey, England, was constructed incorporating some of the above principles such as window orientation, thermal insulation and thermal storage in the building materials so that most of the heat can be obtained directly from the sun without auxiliary collectors. The school has since operated successfully on the energy from the sun, the children (and teaching staff) and electric lights, without the use of additional fossil fuel for heating. Stepping out from the crowded lecture theatres at Magurele into the bright warm sunshine with which the Conference was appropriately blessed all the week, one wondered, had the splendid modern conference building been equipped in line with the aims of solar technology, what surplus energy could have been produced by the sun and all those speakers and participants, if only the problem of storage were solved.

W.S.N.

Transport and Storage of Energy

Energy strategies can depend as much on distribution and manipulation as on the availability of particular primary sources. From predictive studies, taking into account these factors, C. Marchetti deduced that, at least in the USA, the fuel most likely to be affected by any big increase in nuclear power capability was gas rather than oil or coal. Extending predictions still further into the future he forecast a rapid decline in nuclear energy usage in favour of solar energy around the year 3050 !

While admitting that mankind has no real influence on the availability of primary sources of energy, our influence on the means of transporting and using energy was paramount. The ease of transporting a particular form of energy affected the scale of the plant for producing it and, therefore, the economics which could be achieved by the use of larger plants, and fewer plants, an example being the growth in size of electric power plants and their relative decline in numbers as the ability to transmit electricity over large distances has improved. While geographical factors have played a major part, it can be seen that the ability to transport oil has grown apace with its use. Natural gas if available in adequate quantities could become a world commodity — dispensed from a few very large fields with ease and economy by pipeline, and stored locally in the many geologically favourable underground sites.

The ease of transporting a particular form of energy really determines whether the strategy is many power sources situated close to the points of consumption or a few large ones supplying very large areas whilst the technology of energy transport is bounded by fundamental physical and economic constraints. The practical distance limit of transmission for each form of energy determines the optimum size of the power plant, e.g. hot water: 2 km 0.2GW, electricity: 100 km 1GW; hydrogen: 1000 km, 100 GW; ADAM/EVA (nuclear generated methane): 2-3 x 10^3 km, 10^3 GW; Oil: 10^4 km, 2 x 10^3 GW (typical oil field).

Electricity Transmission

Developments arrived at improving the efficiency of electricity transmission (A. Rocher) are pointing towards UHV overhead transmission, improved conventional, cryogenic and superconducting cables underground. A key issue in this is the cost, which depends on the cable loading requirements.

For electrical power transmission in excess of 500 MW per cable, super-