Preface

In 1970, when the report by the Club of Rome, 'Limits of Growth', was published and discussed widely, it became obvious to everyone that the conventional forms of energy we use for our daily requirements, as well as many other important resources, are not inexhaustible. The energy shortage in 1973 demonstrated the necessity for discussing and evaluating alternatives to oil. The development of nuclear power is quite advanced in many countries and helps to satisfy a substantial part of the energy demand. But even power from nuclear fission is not unlimited. Moreover, heightened popular opposition to this form of energy and rapidly increasing costs compared to those incurred by earlier hydroelectric power plants may limit severely its further distribution. Therefore, the oldest form of energy used by mankind, solar energy, is becoming fashionable again. Actually, solar energy is not merely an alternative energy source; it is the only form of energy which is able to sustain life by giving food to all living organisms through the process of photosynthesis. Plants are able to convert sunlight into a chemical form of energy which serves as the energy source for all heterotrophs.

The amount of energy from the sun that reaches the surface of the earth is by several orders of magnitude higher than the world's energy requirement (approximately 10^{24} J versus 10^{20} J annually). However, the energy density of the solar radiation on earth is rather low (ca. 1 kW/m^2 at the vertical position of the sun). Therefore, a technical utilization of solar energy requires large absorbing areas. Such light absorbing areas are provided by nature in the form of plants covering the surface of the earth. The complex reactions of photosynthesis have converted sunlight into chemical energy for billions of years. Engineers constantly deny the energetic future of bioenergy and biomass based on the rather low efficiency of energy conversion of photosynthesis of about 0.1% worldwide. Actually, the conversion efficiency for fields and forests is in the range of 1–5%; the low figure is due to the fact that the light is usually not the limiting factor for the biomass yield and that large areas on the earth are not suited for plant production. Furthermore, it is often forgotten that biomass, the product of the photosynthetic energy conversion, is very stable and can be stored for a long period of time in contrast to heat that is gained from sun collectors or electricity from sun cells.

The present review, 'New trends in research and utilization of solar energy through biological systems' will be published in two issues of Experientia. We have tried to bring together the diverse ideas of many experts in order to give the reader an impression of the potentials in biological energy conversion. Many projects are still in the state of basic research, of laboratory size, and may never be realized on a large scale. Other projects, if not significant for the energy balance of the world as a whole, may prove to be important locally. Others, one hopes, may be of universal importance such as systems for producing biogas from wastes. The first issue deals with how solar energy is converted into biomass by higher plants and microorganisms. The latter may form especially interesting products which can be used, for example, directly as a fuel. The second issue will be concerned with biological procedures for converting the rather unhandy biomass into convenient forms of energy, with a large section devoted to anaerobic digestion yielding methane.

Solar energy through biology: fuels from biomass

by D. O. Hall

King's College, London SE24 9JF (England)

1. *Introduction*[1-6]

Hardly a day goes by without there being a news item warning us of the impending shortage of oil and what it is going to cost us - assuming we can get it! The belated realization that non-renewable liquid fuels are going to increase in price, and possibly even be rationed, is one of the main reasons why biomass is being looked into so seriously by so many of the developed countries. For the developing countries, the energy problem is as acute - if not more so. The 'woodfuel crisis' is revealing the long-term detrimental agricultural, social and economic consequences of deforestation.

The majority of the people in the world live by raising plants and by processing their products, but now, their governments - and most particularly the governments of developing nations - are confronted with the critical problem of maintaining and possibly increasing consumption without harming ecological systems. A more efficient use of existing biomass and energy alternatives upon which technology is solar- and wind-based is absolutely essential if the present trend of excessive biomass use is to be reversed. The biomass that provides a source of energy now can continue to do so in the future - but to what extent it will be able to contribute to the overall provision of energy will very much depend on the special economic and geographic circumstances within any given country, and the extent to which each country is capable of realistically assessing and planning for its energy requirements in the future.

The oil and energy problem of the last 8 years has already made a clear impact on the use and development of biomass energy. First, in the developing countries there has been an accelerated use of biomass as oil products have become too expensive or even unavailable. Second, in a number of developed countries large research and development programs have been instituted to establish the potential and costs of energy from biomass. Estimated current expenditure is over $100 million per annum in North America and Europe. While this work is still in its early stages, results look far more promising than was thought possible even three years ago. Finally, already in Brazil for example, (a country which currently spends over half of its foreign currency on oil imports), large scale biomass energy schemes are being implemented as rapidly as possible - the current investment is over one billion dollars per annum.

It is well-known that all our fossil carbon reserves are products of past photosynthesis. Photosynthesis is *the* key process in life and, as performed by plants, can be simply represented as

$$H_2O + CO_2 \xrightarrow[\text{solar energy}]{\text{plants}} \text{organic materials} + O_2$$

In addition to C, H and O, the plants also incorporate nitrogen and sulphur into the organic material via light-dependent reactions - this latter function is often not appreciated.

Where, in the past, photosynthesis has given us coal, oil and gas, fuelwood, food, fiber and chemicals, it now seems necessary to look at how photosynthesis fits into the biosphere and explore in what new ways solar energy conversion can become a source of raw materials in the future.

Most people are not aware of the magnitude of present photosynthesis: it produces an amount of stored energy in the form of biomass which is roughly 10 times the amount of energy which the world uses annually. Table 1 shows that the total amount of proven fossil fuel reserves below the earth is only equal to the present standing biomass (mostly trees) on the earth's surface while the fossil fuel resources are probably only 10 times this amount. This massive-scale capture of solar energy and conversion into a stored product occurs with only a low overall efficiency of about 0.1% on a world-wide basis, but because of