Bob Stanley

Cow dung and straw, made into cakes and dried, are a source of fuel in India: conversion of dung to biogas could produce the energy equivalent of 40 million tonnes of coal per year.

The so-called energy shortage has become perhaps the single most important factor in global affairs of the seventies. The need, or greed, for oil has tended to override established political and ideological differences, and has reshaped the world’s economy in only half a decade. The true have-nots now are those with no guaranteed supply of fossil fuels — and those who can no longer afford them. The only real rich are the oil rich.

Yet the great energy crisis that began with the OPEC oil embargo in 1973 may in retrospect turn out to be one of history’s black jokes. For while the poor get poorer and the rich scrabble desperately in some of the most hostile environments known to mankind in search of new sources of oil, abundant supplies of energy are to be found all around us — if only we care to look.


The abundant, and largely ignored, source of energy that is all around us can be described in one word — biomass. Biomass is the total amount of renewable organic matter on earth. It is a small proportion of the sun’s energy converted into chemical energy. It is the basis for the sustaining of all life on this planet. Biomass, in short, is the earth’s total complement of plants and animals.

The potential for energy production from biomass is perhaps best illustrated by the estimate that the amount of energy stored by the total biomass system in the United States in a year is equal to that country’s annual energy consumption. And the USA is the world’s leading energy consumer, gobbling up an amazing six times the world average.

The needs of the United States, which consumes more energy for air-conditioning than is needed for commercial purposes in the whole of China, are very different from those of oil-poor developing countries. And it is in these countries that the potential for the development of biomass energy is greatest.

Virtually all plants, including aquatic vegetation, are potentially capable of being converted into some form of energy. The three most promising sources of plant biomass (phytomass) for energy production are trees, agricultural crops and grasses, and aquatic plants. Given the basic research to determine which plants to grow, when and where, and the most efficient methods of producing energy from the various parts of the plants, it should be possible for many developing tropical countries to grow all the energy they need.

A study carried out in Ghana by the Georgia Institute of Technology estimated that a labour-intensive “energy-food” plantation of 40 000 hectares could produce annually the energy equivalent of 450 000 tonnes of coal, plus 50 000 tonnes of corn and 55 000 tonnes of peanuts. It would also create many new jobs.

The animal kingdom is a lot less efficient in converting the sun’s energy into useable form, principally because both men and beasts must first be “fuelled” with plant matter before they can work. Indeed, apart from a few relatively rare products such as fish oil and tallow, the only form of animal biomass used, or likely to be used for energy production is in the form of excrement.

This is a considerable contribution, however. It has been calculated that the dung produced annually by all the cattle in India, if converted to biogas instead of being burned, could produce the energy equivalent of about 40 million tonnes of coal per year. This is only a fraction, however, of the energy potential of the world’s forests.
Tree biomass

Trees are much the most important source of biomass for energy production. Because conventional forest inventory data do not concern themselves purely with energy production, they tend to be misleading, and estimates of the energy potential of forest biomass tend to be widely divergent. However, one conservative estimate puts the reserve of energy held by the world’s forests at about 20 times the current annual global consumption of energy from all sources. The annual rate of increment is estimated at five times the earth’s hydroelectricity potential — or a little more than the total consumption of fossil fuels in the boom year of 1974.

Ironically, most of this potential source of energy is far removed from centres of population. In fact, in many areas of the developing world, where wood and charcoal still provide 85 percent of the people’s fuel needs, the scarcity of fuelwood due to increasing population pressures is reaching crisis proportions. The first priority then, must be the proper management of the forest resource, in order to bring out its optimum capacity without destroying the resource or belabouring the land itself.

Natural tropical forests often contain more than 100 species on a single hectare, only a few of which are commercially useful. The harvesting of other, underutilized species for energy could actually improve the management of the forest. Similarly, undersized trees taken to thin out industrial or “man-made” forests would be readily adaptable to energy production. Such forest plantations at present represent a small percentage of the tropical forest, but their use is increasing rapidly.

Another system that may be particularly applicable in developing countries where land and labour costs are low, and sunshine and moisture are abundant, is the use of energy plantations. Experimental tree farms for energy production exist in a number of countries, including Nigeria and Malawi. Although hard data are not yet available, the potential is tremendous, particularly if research can help develop the species and techniques for rapid growth and maximum yield.

Such plantations might also be made to produce other products, such as oils, fruit, fodder, or rubber. Another alternative is the multiple-use energy plantation, with various tree and agricultural crop combinations. Again, a good deal of research is needed to fully understand both the techniques and the economic benefits.

One technique that has yet to be studied in relation to maximizing biomass production is the systematic pruning of branches. Lopping (removing lower branches) and pollarding (removing the upper part of the tree), are both carried out for various reasons in specialized kinds of wood production. Properly carried out, they could provide yet another means of maximizing yields from energy plantations.

Forestry wastes and by-products of plantations established for other specific purposes represent still another source of biomass energy. In some countries as much as 50 percent of fuelwood supplies now come from such residues as logging and mill wastes and the by-products of rubber or coconut plantations.

Whatever the energy situation in the future, it is likely that wood will continue to be the main source of fuel for hundreds of millions of people in the developing countries. Most of the technical knowledge required to improve supply, management, and energy conversion of the tree biomass already exists. The gap is in the application of that knowledge to specific situations.

Crops and grasses

Practically all the plant biomass produced by farmers around the world is a potential source of energy, whether the crop is grown for food, feed, or fibre. A substantial portion of the planet is still covered by grasslands, only a fraction of which are grazed by domestic animals. These too could be converted to useful energy.

Crop residues present more difficulties than do trees, however. First, energy production must compete with other uses such as fertilizer, feed, and a variety of industrial uses. Then the supply is also subject to the usual uncertainties of fluctuating demands for specific crops, and of course the weather. Nevertheless, there is considerable scope for increasing the contribution that agricultural wastes can make to the world’s energy supply, particularly in the Third World.

The study in Ghana referred to earlier estimated that residues from the country’s rice, coconut, and oil palm crops, combined with about the same amount of forestry wastes, could produce the energy equivalent of 1.45 million tonnes of oil in 1970 — more than doubling Ghana’s 1973 energy production.

Sugarcane and cassava are two of the most important major crops grown in the developing world, with a total yield, according to 1975 FAO statistics, of 645 million tonnes. Both are being used in Brazil to produce ethanol as motor fuel. According to Brazilian scientists, an energy strategy based on biomass is a natural course for Brazil with its huge land area and ideal climate for growth. It has been estimated that less than two percent of the land area could provide enough wood to replace all imported petroleum.

Cereal or grain straws are also a potential source of fuel. Annual straw yields per hectare in the USA range from 4.5 tonnes for wheat to as high as 27 tonnes for sorghum. Also in the USA it has been estimated that grasses grown on agricultural lands have a higher potential to produce biomass than do forest lands.

Millions of hectares of uncultivated grasslands are burned every year to dispose of dry vegetation and promote new pasture growth. The practice is both destructive and wasteful, and contributes to the spread of desertification in semi-arid regions — just those regions where wood fuel is in shortest supply. Yet the warm-season grasses such as Bermuda grass and Sudan grass have as great a potential for energy plantations as the most promising tree species.

More research in the developing regions is needed to determine the real potential of grass biomass, particularly on uncultivated lands. Studies on agricultural lands in the USA suggest that 100 000 hectares of grassland could produce as much energy as a 500-megawatt power plant.

Aquatic plants

Although aquatic vegetation contributes only about one-quarter of the world’s primary production of phytomass, the possibilities for a wide variety of uses are enormous, and largely untapped. Only very recently has some research begun into the huge potential of waterplant biomass for energy production.

Nowhere is that potential greater than in the warm waters of the tropics, where waterweeds are at their most prolific, and some species produce more biomass from a given area than any land plant. Most of the species useable for energy production are essentially a free crop — they require no seed, cultivation or fertilizer. And while in some countries aquatic plants are used to varying extents for food, feed or fertilizer, they are more commonly regarded as a nuisance, blocking waterways and even contributing to the spread of disease.

In fact, among fresh water plants the water hyacinth can contribute to health by removing pollutants from the water. Incredibly prolific in warm waters, the hyacinth grows so densely that it is possible to walk across floating masses of the plants — and they thrive on nutrients from domestic and agricultural wastes and sewage effluent. Daily yields of up to 500 kilos of dry matter per hectare have been recorded.

Egypt and Sudan have recently embarked on a dual-purpose project to keep the upper waters of the Nile clear of water hyacinths, and convert the resulting biomass harvest to methane gas by a process of fermentation. This process appears commercially promising. Harvesting is
simple, by mechanical or labour-intensive means, and each dry kilogram of water hyacinth (the freshly harvested plant is about 95 percent moisture) yields about 370 litres of biogas containing 60 to 80 percent methane. The sludge left over from the fermentation process makes a valuable fertilizer.

It may be possible to apply the same basic process to duckweeds, tiny water plants found worldwide that clustered in colonies on the surface of fresh water bodies. Having many similar properties to the water hyacinth, some species also have the advantage of a much higher dry matter content. Little research has yet been done on the biomass energy value of duckweeds, however.

Fresh water microalgae are also very efficient at fixing solar energy, and thus have a very high reproduction rate. They also purify water, and thrive on sewage effluent. If they are to be used for biomass energy production, however, they will have to compete for the demand for use as animal feed: their protein content runs as high as 60 percent.

Their ocean-going cousins are the giant California kelp, huge marine alga colonies that grow up to 65 metres in length. These usually do better in colder seas, although they are cultivated commercially in Japan, the Philippines, and Taiwan. The fact that some 70 percent of our planet’s surface is covered by oceans means that most of the sun’s energy falls on the seas. Farming the oceans for biomass is an area of research that has so far remained largely out of reach of the developing countries. It should not continue to be neglected.

**Getting the energy out**

The simplest and most direct method of obtaining energy from biomass is by burning it — even waterweeds can be burned if they are thoroughly dried. Burning biomass on an open fire is, however, the least efficient method of releasing this energy. Although relatively efficient compared to open combustion, the stove is still not a very good energy converter. And yet it is in precisely those areas of the world where fuel is most scarce that it is used most inefficiently.

Some plants — such as sugarcane, cassava, or waterweeds — lend themselves well to the production of gas by fermentation. This is a relatively simple, economical process that shows great promise. The fermentation process can also be applied to cattle dung, much of which is used as fuel at present — a practice that is not only enormously wasteful but is also harmful, as the smoke given off is damaging to the eyes.

Another promising conversion technique is pyrolysis — in which wood, or other lignocellulosic biomass, is heated in the absence of air to produce charcoal and various combustible liquids and gasses. Charcoal is a popular fuel in the developing world, and for good reason — it is lighter and easy to store, practically smokeless, and burns evenly. It is roughly four times as efficient as dry wood. Charcoal production from wood has been a common practice for hundreds of years. The technology is relatively simple and inexpensive, and can be operated on a small scale. Much of the technology now used in developing countries, however, is inefficient since it wastes the by-products of pyrolysis such as methanol and acetic acid. More efficient techniques have been developed, primarily in the USA, and developing countries could likely benefit from the new technology.

In recent years there has been a revival of interest in gasification — in which pyrolysis results in the complete conversion of wood or other biomass into a combustible gas. This gas may be converted to methane as a substitute for natural gas, or to methanol (wood alcohol), which may be used as motor fuel. While most of the research is now being carried out in the industrialized world, it may have important implications for the developing world in the not-too-distant future.

The production of biogas by fermentation of animal and vegetable wastes is a technology that has been developed in the developing countries. Only very recently have scientists in the industrialized nations begun to show an interest — presumably because of the “energy crisis”.

Family-sized biogas plants first came into widespread use in India in the 1950s in an effort to make a cleaner and more efficient use of cattle dung. The program really took off with additional government support in this decade, and today there may be as many as 100,000 plants. Most are in domestic use for cooking and lighting, but some larger units are operated by cooperatives, government, or industry. One Indian study has estimated that the value of the fertilizer obtained is in itself greater than the cost of producing the biogas. Thus, the system is economically sound, in addition to other benefits such as a cleaner, healthier environment.

**The future of biomass**

Biomass as a source of energy for the rural areas of the developing world has many advantages including low cost, reduction of waste, environmental improvement, and above all, self-sufficiency. The technology for growing, harvesting and converting biomass for energy production is still in its infancy, and the prospects are good that systematic research will bring rapid improvements. But what stimulates biomass energy research in the industrialized nations is the prospect of economic gain. Such large-scale commercial applications are unlikely to be of much relevance to the needs of the average Third World village.

Bringing village-scale biomass energy to the developing world will require research and development at the local level. It will also need the support of both donor agencies and governments if the full potential of home-grown energy is to be made available where it is most needed.

The information used in this article is taken from Energy from biomass for developing countries, a state-of-the-art report prepared for IARC’s Board of Governors by J.G. Bene, H.W. Beall, and H.B. Marshall. The report has been published for limited circulation in IARC’s Manuscript Report series.

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A charcoal and wood market in Africa. Charcoal is four times as efficient as dry wood and the technology of its production well-suited to developing countries.