SCIENCE & TECHNOLOGY IN SOCIETY

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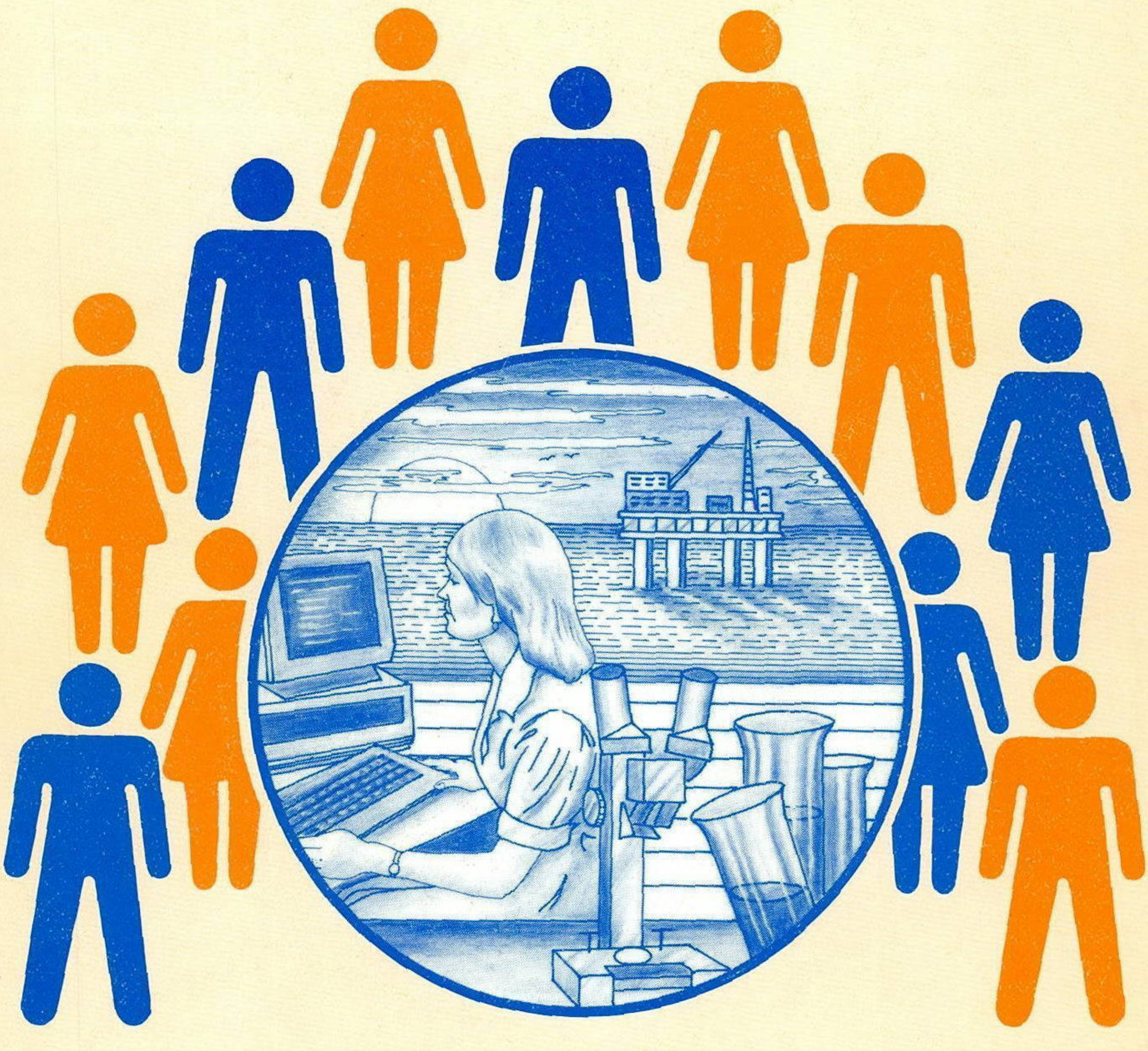

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SATIS

ABOUT SATIS

Science and Technology in Society units are designed to be used in conjunction with conventional science courses, particularly those leading to GCSE examinations. Each unit has links to major science topics as well as exploring important social and technological applications and issues.

The units are self-contained and generally require about 2 periods (around 75 minutes) of classroom time. Each unit comprises Teachers' Notes (blue sheets) and Students' materials (white sheets). Full guidance on use is given in the Teachers' Notes accompanying each unit, which also include background information and suggest further resources.

Each SATIS book contains ten units. The units are numbered in a system giving the number of the book followed by the number of the unit within that book. Thus the first unit in the first SATIS book is numbered 101.

In addition to the SATIS books, a general Teacher's Guide to the project is available, giving guidance on some of the teaching techniques involved as well as ideas for further activities.

Many people from schools, universities, industry and the professions have contributed to the writing, development and trials of the SATIS project. A full list of contributors appears in the Teachers' Guide.

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SATIS 2

List of units in this book

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Energy from Biomass

Contents: Reading and problem-solving exercises, including optional practical work, on the production of biomass energy.

Time: 2 periods or more, depending on number of parts attempted.

Intended use: GCSE Biology, Chemistry and Integrated Science. Links with work on photosynthesis, anaerobic respiration, fermentation, decomposition, combustion and fuels.

Aims:

- To complement work on photosynthesis, anaerobic respiration and fuels
- To show the range of technologies for biomass energy production, and some of the environmental problems encountered
- To develop awareness of the opportunities and problems involved in producing energy in developing countries
- To show some ways waste materials can be put to good use
- To provide opportunities to practise skills in problem solving.

Requirements: Students' worksheets No. 201. If practical work is attempted, apparatus will be needed, as described later.

The following background information may be of use.

Solid biomass fuels There is now considerable interest in certain fast-growing plants for biomass fuels. For example, in Kenya papyrus is grown as an energy fuel. One hectare of land can produce 32 tonnes of papyrus a year, compared with the 10 tonnes of grass produced per year by English pasture. Water hyacinth, a major nuisance which clogs up tropical waterways, can be grown on sewage lagoons. The plants purify sewage and produce a remarkable 712 tonnes of dry biomass per year from 1 hectare. Experiments are also being done with fast-growing seaweeds and with plants grown in CO_2-enriched greenhouses.

Liquid biomass fuels It is interesting to note that the Brazilian government blends the pure alcohol sold at pumps with a small percentage of petrol — apparently to prevent customers drinking it.

Biogas Students might be interested to hear about other anaerobic environments where biogas is produced — for example, in marshes and in the gut of animals, including humans.

Methane production in landfills (Q.3) is quite common. The enormous Fresh Kills landfill is New York State produces 20 billion cubic metres of gas a year.

General Biomass energy has many attractions, but also a number of drawbacks. An obvious problem is that energy crops may take land that is needed for growing food. It is worth noting that of the total material produced by photosynthesis, ten per cent would be needed to provide all the world's energy needs, while only 0.5 per cent is currently used for food. Since much of the world's biomass is in wild plants, grass and forest, to provide all energy needs by 'energy farming' would be a very major enterprise.

Fuel crops often require considerable energy *inputs,* and it is essential to ensure that their energy *output* is substantially in excess of this input. Input energy includes the energy used to manufacture fertilizers, to fuel farm machinery and to process the crops. The production of alcohol, for example, requires substantial energy at the distillation stage.

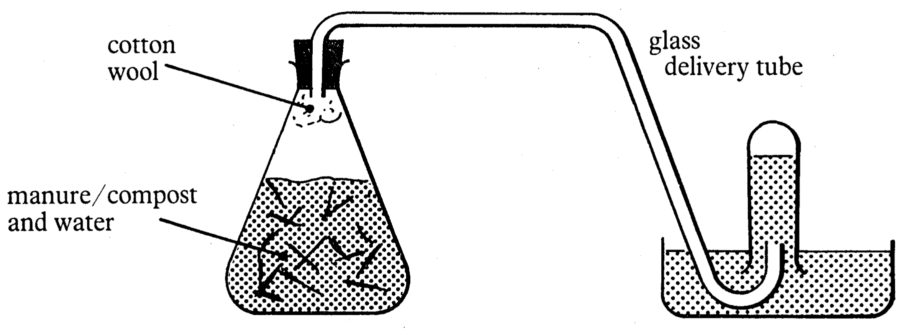
Activities and questions

The questions need not necessarily all be answered, though the Caramina problem is worth tackling as a useful way of drawing together the general information on biomass.

Practical work — Build your own biogas digestor

This problem-solving exercise is well worth attempting with all students at least as far as the design stage. Teachers will need to decide for themselves whether to allow the class to build their own digestors, the alternative being a demonstration one. The problems of an entire class handling manure or compost are obvious. In any case, **disposable gloves should be worn and equipment thoroughly cleaned afterwards.**

Many different designs are possible, the simplest and crudest being the one shown below.



Likely problems

1 *Temperature control* Keeping the 'brew' at a temperature of 30°C is tricky but vital. An electrically heated water-bath could be used, but is hardly appropriate technology. Students could be encouraged to devise solar heating arrangements — in summer, a position by a sunny window is enough to keep fermentation going, at least during the daytime. Thermal insulation can also be effective.

2 *Gas leaks* The small methane molecule diffuses rapidly, and the apparatus should be completely gas-tight. Rubber tubing should be avoided, though plastic tubing appears to be adequate.

3 *Blockage* It is possible for delivery tubes to become blocked by solid material which floats to the top of the 'brew'. This can cause a dangerous build-up of pressure, and can be prevented by using a cotton-wool plug positioned as shown in the diagram above.

Requirements

The apparatus required will of course depend on the design adopted.

A supply of compost or manure is needed: cow, horse and chicken manure all work well. Compost can be used, but will work much better if a little manure is added to ensure that plenty of bacteria are present.

Further practical work

Students could be given further practical problems relating to biomass energy, for example:

1 Design and carry out an experiment to make wood charcoal and collect the gas evolved.

2 Design experiments to make alcohol fuel from sugar.

Other resources

1 'Grow your own Energy', a *New Scientist* guide edited by Michael Cross, is a useful collection of information on the subject.

2 The Third World Science Project includes units entitled 'Methane Digestors' and 'Charcoal'. Available from: Third World Science Project, School of Education, University College of North Wales, Bangor, Gwynedd.

3 The Centre for Alternative Technology produces resource materials on biomass energy, and also has displays that can be visited at the centre in Wales. Centre for Alternative Technology, Machynlleth, Powys SY20 9AZ.

Acknowledgements Figure 3 supplied by United Nations Information Centre; Figure 8 from *Methane Digestors* (Third World Science Project).

ENERGY FROM BIOMASS

With fossil fuels running out, the world needs *renewable* energy sources — energy sources that are re-made as fast as they get used up. Plant material — called **biomass** — is a good renewable energy source. Biomass energy is particularly important in developing countries, which often do not have their own fossil fuels, and cannot afford to buy them.

How do we get energy from biomass?

Plants are able to trap the Sun's energy using the chlorophyll in their leaves. They use the energy to convert carbon dioxide and water to carbohydrate. This process is called **photosynthesis** (Figure 1).

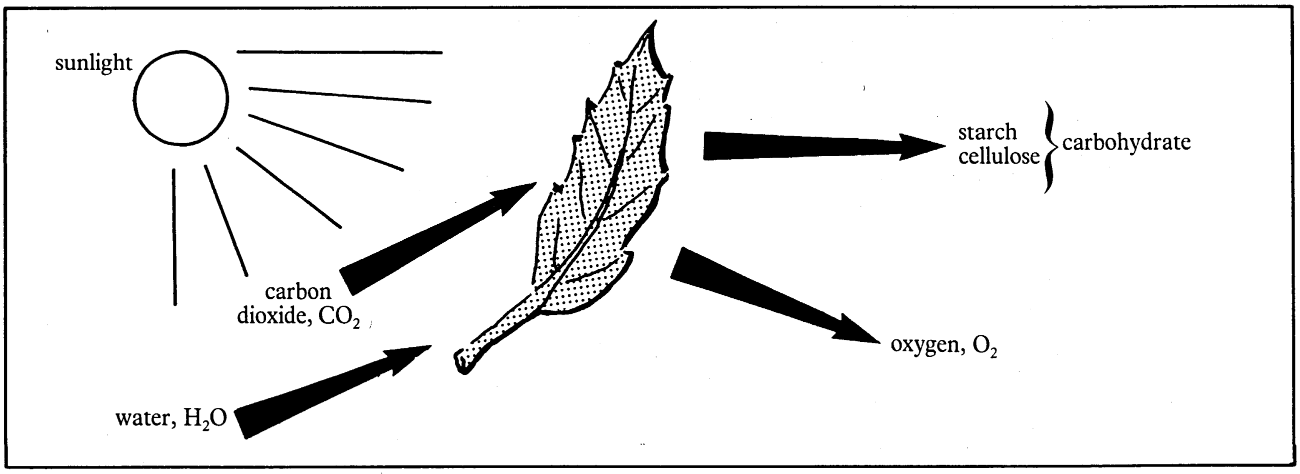


Figure 1 Photosynthesis

Carbohydrates like starch and cellulose store energy. When they are burned in air, this energy is released. A tenth of the energy stored by photosynthesis could provide all the world's energy needs.

Plant material, such as wood, can be burned directly as a fuel. It can also be turned to other fuels, which may be solid, liquid or gaseous (Figure 2).

Question

1 Tropical countries are generally better able to produce biomass fuels than cool countries like Britain. Explain why this is so.

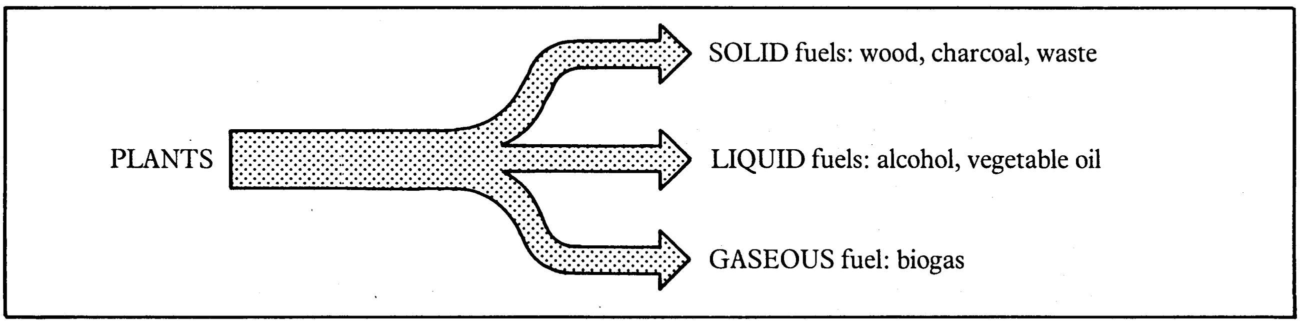


Figure 2 Biomass fuels can be solid, liquid or gaseous

Solid biomass fuels

Wood

Firewood is the oldest fuel of all. It is still the most commonly used fuel. Four out of five families in the developing world depend on wood as their main energy source. In some countries there is a serious shortage of firewood, because so many people need it. Women may walk 10 kilometres a day, five days a week, collecting firewood.

Question

2 *In Britain, wood-burning stoves and log fires are becoming popular. What problems could this cause?*

Figure 3 African women bringing firewood to their village

Firewood is a good renewable fuel, but there are problems if it is over-used. In many places, wood is cut from trees faster than new wood can grow. Eventually the trees will die. Where lots of trees are cut down and not replaced, serious soil erosion can occur.

Charcoal

Wood is heavy to carry about because it contains a lot of moisture. By heating wood without air present, the moisure can be driven out, along with flammable liquids and gases. Almost pure carbon is left, called charcoal. It is an excellent fuel which burns slowly and causes little pollution.

The traditional way of making charcoal is shown in Figure 4.

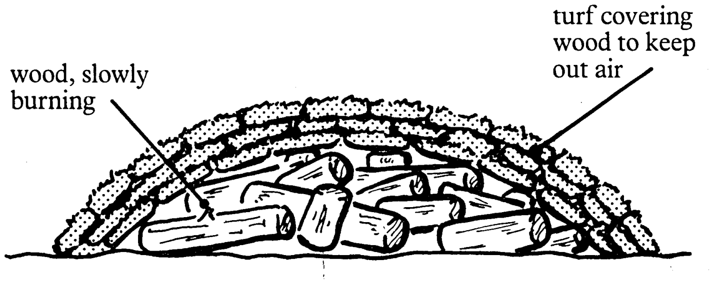


Figure 4 Making charcoal

In Britain we often use charcoal in barbecues. But it is the main fuel in some developing countries.

Waste

In Britain, 4.5 million tonnes of waste straw are burned by farmers each year. If the energy from the burning straw could be used, the farmers could supply all their energy needs from it. Household waste is also a good energy source. The problem is collecting these low-value waste materials and bringing them to the place where they are wanted. The energy used in collecting the waste could be more than the energy it provides when burned.

Question

3 **Landfill bioreactors** *are used to generate biogas from rubbish. Rubbish is tipped into a hole in waste ground, and allowed to produce biogas. (Figure 5).*

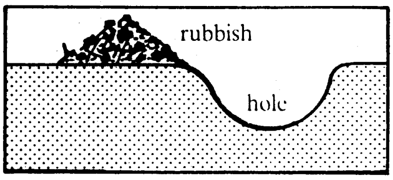


Figure 5

Draw a diagram to show the arrangement you would use to generate and collect biogas from a landfill bioreactor. What kinds of household rubbish would work best?

Liquid biomass fuels

Alcohol

Sugar cane is a fast-growing tropical plant. The sugar it provides can be fermented to make alcohol. Alcohol is an excellent liquid fuel which can be used instead of petrol in cars. It is often mixed with petrol to give **gasohol** (Figure 6).

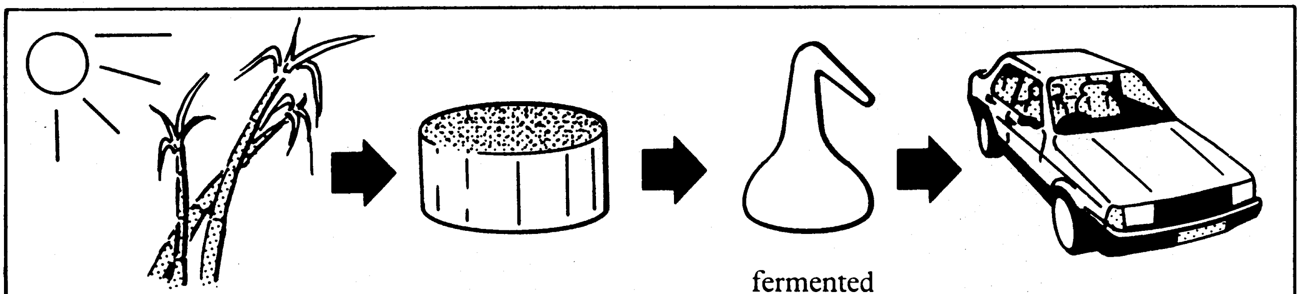


Figure 6 Making alcohol fuel

After the sugar cane has been crushed to remove the sugar, a woody material called **bagasse** is left. It makes a good solid fuel which can be used to provide heat for the distillation stage.

In Brazil, many cars now run on alcohol fuel made this way, and Brazil has plans to replace all petrol by alcohol.

Question

4 *For Brazil to replace all liquid fuels with alcohol, the country would need to use half its present farmland to grow energy crops like sugar cane. This means new farmland would be needed to grow enough food. The new farmland would have to be provided by clearing part of the Amazon jungle. What problems would this cause?*

Oil

Many plants produce vegetable oils — sunflower oil and peanut oil are examples. These oils could be used as fuels in the future. Engineers are trying to find ways of making diesel engines run efficiently using vegetable oils.

Biogas

When vegetable and animal matter rots in the absence of air, a gas is given off. This is **anaerobic respiration.** The gas is usually about 60 per cent methane, the rest being mostly carbon dioxide. This **biogas** is a good fuel, particularly for cooking, heating and lighting in the home.

Biogas is particularly easy to make on farms. Manure and waste vegetable matter such as straw are allowed to rot in a closed tank. The biogas is collected, and the solid material left behind is an excellent fertilizer. Figure 7 shows a typical **biogas digestor.**

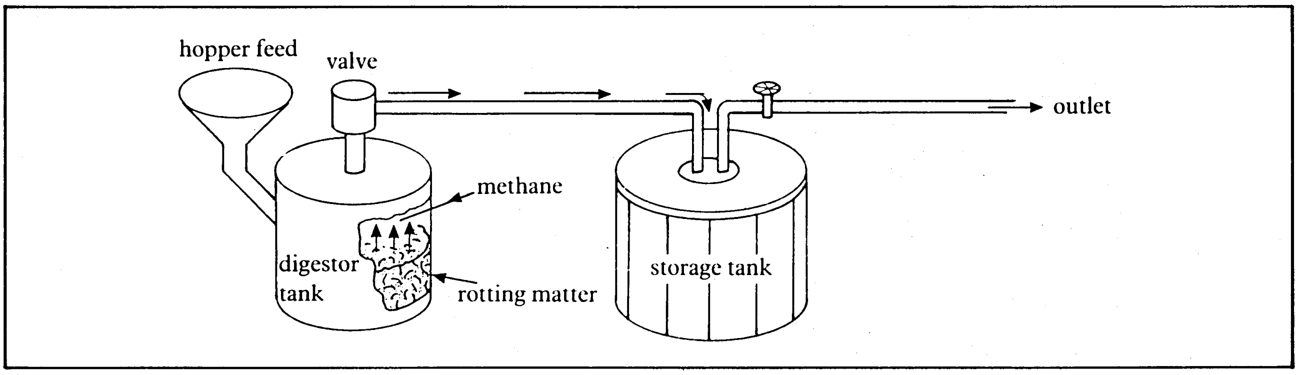


Figure 7 A biogas digestor

There are over 7 million biogas digestors in China, supplying energy for 35 million people. Often digestors are built in underground pits (Figure 8).

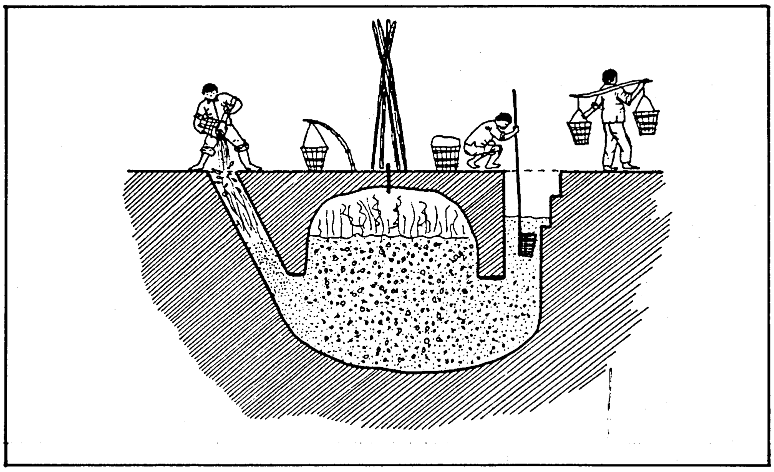


Figure 8 An underground biogas digestor

Question

5 Look carefully at Figure 8, then write a few sentences about it. What are the different people doing?

Farmers in Britain are beginning to use biogas too, for generating electricity and for heating. The gas can even be used instead of petrol to fuel cars.

A small biogas digestor will produce enough gas for a family. A typical small digestor would use the manure of five animals (cows and pigs) and some vegetable matter. A digestor like this would produce 2 or 3 cubic metres of gas a day.

One cubic metre of biogas will

- cook 3 meals for a family of 6, or
- drive a 3-tonne lorry 3 kilometres, or
- light a biogas lamp equivalent to a 60-watt bulb for 6 hours, or
- generate 1.25 kilowatt-hours of electricity.

Biogas is produced by bacteria. As they break down the rotting matter, the bacteria release methane. For good biogas production, the bacteria need to be warm — they work best at about 35°C. In tropical countries this is no problem, but in colder countries, some of the biogas has to be used for keeping the digestor warm.

Biogas digestors are simple to build, and you may get a chance to design and build your own.

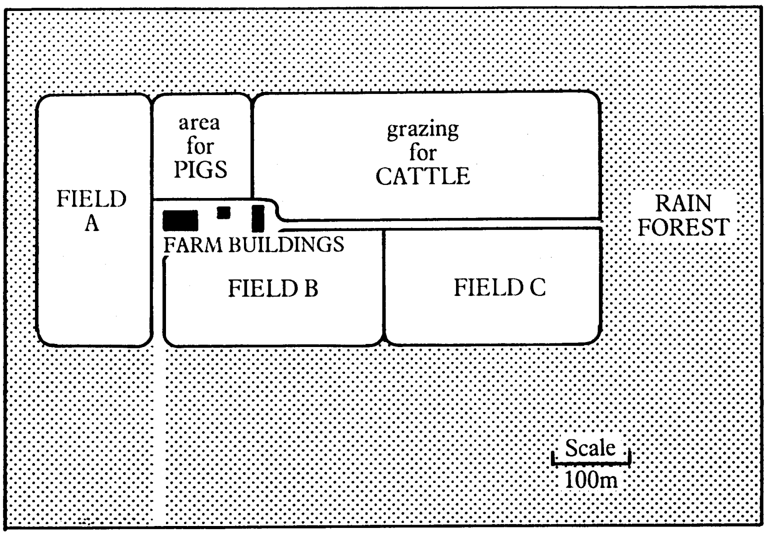


Figure 9 Caramina

Question

6 *Do you think biomass fuels will ever provide* all *the world's energy requirements? Explain your answer.*

Question

7 **The Caramina problem**
Caramina is a small farm built in a clearing in the Amazon rain forest (Figure 9). It has fertile, well watered soil and most crops grow successfully.

Two of the three fields are needed for growing maize. The farm's energy needs are as follows:

- *Lighting and cooking fuel for the farm buildings*
- *Fuel for the farm's small truck*
- *Electricity for the farm buildings.*

How would you provide all the farm's energy needs, using only *biomass produced on the farm or in the forest?*

Describe your plans, and redraw the map showing the crops you would grow and any new equipment you would need.

Build your own biogas digestor

Model biogas digestors are quite simple to make in the laboratory. Your task is to design a digestor that will produce and collect at least $10 cm^3$ of biogas from a sample of compost or manure.

You will need to bear the following points in mind.

1. The bacteria which produce the biogas work best at around 30°-35°C. This is a little below body temperature. If the temperature of the mixture drops below 20°C you will get very little biogas.
2. The bacteria need water. They work best when the compost is mixed half-and-half with water.
3. The methane molecule is small and can easily escape from apparatus unless it is completely gas-tight. Biogas can escape through the walls of rubber tubing unless they are thick.
4. Biogas does not dissolve in water.
5. As long as there is air in the apparatus, the bacteria will produce carbon dioxide, not methane. Biogas will start to be produced when all the air has been displaced from the apparatus. You will not get much biogas for a week or so.

Your digestor should use the kind of apparatus normally found in a science laboratory.

Draw a diagram to show your design. Your teacher may give you a chance to try it out by actually building the digestor.