

In 1973 the Academy of Science suggested that Australia should aim at producing half its annual requirements for liquid fuels from vegetation by the year 2000. As these requirements are expected to more than double by then, the target is a figure somewhat greater than our present oil consumption. That's a vast amount of fuel—the equivalent of 20–30 thousand million litres of oil.

The suggestion was one of the recommendations made in an Academy report on solar energy research in Australia. Methods exist now for turning material from plants into liquid fuels, but whether it will prove possible to achieve such an enormous output is far from certain. Two CSIRO scientists, Mr Jim Siemon of the Division of Chemical Engineering and Dr Geoff Gartside of the Division of Chemical Technology, have recently looked into some of the possibilities and problems.

There are many good reasons for making fuel from plants. For one, oil is running out. If the equipment that it powers including nearly all forms of transport is to keep running beyond the next few decades, alternatives have to be found. Oil can be made from coal, but coal reserves also have their limits. Fuel from plants, which gather solar energy as they grow, should be available for as long as the earth supports vegetation.

Another point that may prove important is that use of this fuel will not add to the carbon dioxide content of the atmosphere. It will only put back into the air the amount that the plants took out during their growth. The worry with the present growth in carbon dioxide concentrations due to the vast output from coal, oil, and natural gas burning—is that it could produce changes in climate by trapping more heat near the earth's surface.

But large-scale use of fuel from plants also has its drawbacks. The fact that land needed for fuel crops could otherwise be used for growing food and fibre is probably



Mr Siemon.



the biggest of these. Just how much land will be needed per litre of fuel remains unclear, but certainly millions of hectares will have to be set aside if the Academy's target for the year 2000 is to be met.

Another problem could be a very big fertilizer requirement. The ingredients of some fertilizers, notably phosphates, cannot be recycled with current technology. If supplies become unavailable, production of fuel from plants must plummet. But that problem should not arise for a long time—probably for centuries (see 'Phosphorus and feeding the world', *Ecos* 8).

# Wood to ethanol

One of the most promising possible fuels is ethanol (ordinary alcohol), which can be made from all plants. Mr Siemon, in a project for the CSIRO Solar Energy Studies Unit, has looked into the poss-

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# Can we grow our fuel?

ibility of producing large amounts from eucalypt forest plantations. An ethanolfrom-wood process operated commercially in Germany during the 1950s, and Mr Siemon based his calculations on its performance record.

In this process, the wood is first chipped and dried. Hydrochloric acid is added to convert the wood's cellulose into a mixture of sugars, which are then separated out from the acid. Finally, in a fermentation process, yeast breaks the sugars down into ethanol and carbon dioxide.

The process requires heat and, if this was supplied by burning conventional fuels, would consume more fuel than it produced. But the heat could also be supplied by burning by-products from the process with additional wood. Mr Siemon calculates that the amount of wood needed for heating would be nearly double the amount fed through the ethanol process. Something like three times more fuel would then come out than was used in harvesting and chipping the wood, building machinery, and so on.

When he looked into the prospect of meeting the Academy's goal for liquid fuel production—which in energy terms is  $10^{18}$  joules, about half Australia's total energy consumption in 1970—Mr Siemon worked on the assumption that ethanol would be used in blends with petrol for the foreseeable future. Ethanol has only 62% of petrol's energy content, but experiments suggest that well-tuned engines perform as well on blends with up to 25% ethanol as on straight petrol. So, if used in such blends, ethanol and petrol can be regarded as equivalent fuels.

Working from that starting point, Mr Siemon calculated that a production rate of 21 · 2 million tonnes of ethanol a year would meet the Academy's target—if the ethanol was blended with petrol and each litre made the same contribution as a litre of petrol. On its own, however, that



The forecasts for the year 2000 are by Mr Roger Morse, CSIRO's Director of Solar Energy Studies. They assume that oil will be unavailable locally by then and will not be imported; liquid fuels will come from coal and vegetation.

amount of ethanol would go only 62% of the way towards meeting the target.

# Can we do it?

More than 200 million tonnes of wood would have to be harvested and processed each year to produce all that fuel. Is that possible in Australia? Native forests and plantations produce less than 10 million tonnes a year now, and the figure is expected to rise to only about 14 million tonnes by the year 2000. The expansion needed to reach the target for fuel is enormous.

Mr Siemon looked at what would be involved in achieving that output from plantations of eucalypt trees. In plantations in India, Portugal, and Italy, one fast-growing species, the southern blue gum, has given stem wood yields ranging from 15 to more than 30 tonnes per hectare per year, and in Victoria stands of another species, the mountain ash, have given annual yields as high as  $22 \cdot 6$  tonnes per hectare. These compare with average yields of  $5 \cdot 8$  tonnes per hectare per year expected from our pine plantations at the beginning of next century, rising to possibly 15 tonnes when all plantations reach full productivity. The maximum yield of sawn timber logged from vigorous native forests is about 2 tonnes per hectare per year.

Mr Siemon assumed that fertilizers would be used in wood-for-ethanol plantations, and based his calculations on



an estimated average annual stem wood yield of 12.5 tonnes per hectare. Taking into account the branches and leaves useless if trees are harvested for timber, but as good as stem wood for ethanol production—the total yield comes to 19 tonnes per hectare per year.

On these figures, 17 production complexes, each with a 740 000-hectare plantation and a factory turning out 4000 tonnes of ethanol a day, would meet the target. The total plantation area would be 13 million hectares.

A recent study by Mr Henry Nix of the CSIRO Division of Land Use Research came up with an estimate of nearly double that area—25 million hectares—as the amount of arable land in Australia not farmed now. If plantations for fuel could be kept within those 25 million hectares, food production and our existing native forests would not be disturbed. But only detailed assessment could determine how much of that land would be suitable.

What would the ethanol cost? Mr Siemon's calculations, based on 1974 price levels, suggest a price at the pump, including tax, of about 44 cents per litre (\$2 per gallon), which could drop with improved technology to 33 cents per litre. These prices compare with an estimate, at 1974 coal prices, of about 16 cents per litre (75 cents per gallon) for petrol from coal. But oil-from-coal can only be a temporary solution to the problem of keeping up liquid fuel supplies, and coal prices have risen sharply since 1974.

# Fertilizer

Ethanol from trees also cannot provide an indefinite solution unless ways are found to recycle the phosphorus used in fertilizers. Mr Siemon estimates that 13 million hectares of eucalypt plantations would need 80 000 tonnes of phosphorus in fertilizers each year. That's about onethird of Australia's 1971–72 consumption rate. At the phosphorus demand rate predicted for the year 2000, the known usable reserves in Australia and its main outside sources—Nauru and Christmas Island—have a lifetime of a little more than 400 years.

In his study, Dr Gartside looked more generally at methods that have been proposed for making large quantities of liquid and gaseous fuels from plant material. Some of his conclusions are decidedly pessimistic. One is that 46 million hectares of forest plantations rather than the figure of 13 million hectares calculated by Mr Siemon—would be needed to produce enough ethanol to reach the Academy's target.

A large part of the difference between the two estimates arises from the fact that Dr. Gartside based his calculations on the amount of ethanol needed on its own to reach the target. The starting point for Mr Siemon's calculations, which effectively reduced the target by two-fifths, was described earlier. Other factors are involved too.

The scientists looked at different woodto-ethanol processes, but arrived at similar figures for the proportion of the energy content of the wood made available in ethanol. Mr Siemon's figure is about 20% and Dr Gartside's a somewhat lower 13%. They assumed different productivity figures for the eucalypt plantations. Mr Siemon used a stem yield of 12.5 tonnes per hectare per year, giving a whole-tree yield of 19 tonnes, while Dr Gartside worked from a more modest total yield figure of 10 tonnes per hectare per year.

As plantations on the scale envisaged are quite unprecedented, only rough estimates of their potential productivity are possible. But undoubtedly a very large amount of land would be needed.

### Alternatives

Keeping the area that has to be planted as small as possible is obviously vital, so high yields are essential. Dr Gartside looked at cassava, a high-yielding tropical crop, as another possible source of ethanol. But he found that harvesting and processing the crop required more energy than was available in the ethanol produced. His calculations for ethanol production from sugar molasses gave a similarly disappointing result.

An alternative way to obtain fuel from plant material is to break it down by pyrolysis-heating in the absence of air. This produces a liquid similar to heavy fuel oil, an inflammable gas, and char. Calculations by Dr Gartside indicate that, if the gas and some of the char are burnt to provide heat for the process, considerably more energy comes out in the liquid product than has to be supplied from other sources to produce it. His calculationsdone for elephant grass, cereal straw, and domestic garbage as the feedstocksuggest that further studies of cost and yield would be worth while. Pyrolysis may prove decidedly more productive than the ethanol process.

Liquid fuel can also be produced by hydrogenating plant material—building up its hydrogen content in reactions at high temperatures and pressures. This again produces a form of oil. Laboratory



tests overseas indicate that hydrogenation gives a greater fuel yield than pyrolysis, but consumes more energy. Even less research has been done on this process.

A well-known way to make fuel from organic matter is to ferment it in the absence of air, producing methane (the principal ingredient of natural gas). Garbage and sewage can be fermented this way, and so can crop material. Dr Gartside's calculations indicate that a given amount of plant material can yield three times more energy through this process than as ethanol. But the product is a gas, and the need to find substitutes for natural gas is not as urgent as the need for oil substitutes.

Wastes converted into liquid or gaseous fuels could supply part of our energy need, but only a very small part. Dr Gartside estimates that the straw left over when Australia's wheat crops are harvested could provide a net energy yield equivalent to 3% of the Academy's liquid fuels target and that forestry wastes could supply a similar amount. But the energy used to collect and transport the wastes has to be deducted from those figures, and we haven't any other waste products that could make comparable contributions.

# With coal

While he is pessimistic about the prospects for producing liquid and gaseous fuels just



Cars on the production line substitutes for petrol will be needed quite soon.

from plant material in quantities matching existing or expected use rates, Dr Gartside believes plants could play a valuable role in extending the life of fossil fuel reserves.

For example, if coal was used to supply the energy needed for the wood-to-ethanol process, this could be regarded as a way of converting coal to liquid fuel. The ethanol energy output would be about 60% of the coal energy input, a conversion rate similar to that achieved by turning coal directly into liquid fuels. Processing costs and product quality would probably determine which coal-to-liquid route was more desirable.

Cassava, and other starch crops, would give still better conversion rates. The plantation areas needed for these processes would be less than half those required if coal was left out of the equations.

Methane production by this indirect method seems quite a good prospect. If coal supplied the energy needed to process the plant material, the methane produced would contain twice as much energy as the coal used. That's more than three times the energy output from the direct conversion of coal to methane. The extra energy comes, of course, from the plant material.

Dr Gartside calculates that a million hectares of a high-yielding tropical crop such as elephant grass would yield enough methane to meet the much-mentioned Academy target. That may be worth remembering when natural gas supplies begin to falter, although the target is for liquid rather than gaseous fuels. When coal starts to run short, another set of answers will be needed.

# More about the topic

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