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# The future of upland Britain

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# 34 Future possibilities for fuel cropping in upland Britain

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## INTRODUCTION

Without exception all governments see the solution to perceived energy problems principally in highly capital intensive developments of coal, nuclear power and lower quality reservoirs of oil, not only to replace existing supplies, but also to provide for planned growth in demand. The capital intensity of these projected developments is orders of magnitude higher per delivered unit of energy than traditional direct fuel technologies (Lovins, 1976; Carosso, 1975), and of such a scale that many observers, such as the strategic planners of the Shell Group in London (Lovins, 1976), have concluded that no major countries outside the Persian Gulf can afford these centralised high technologies on a scale large enough to run a country.

A general acceptance of this fact of life would rapidly induce an ethos for the very careful use of remaining energy resources and the conservation of capital and materials. Parsimony would not be a formula for translating finite energy resources into inexhaustible energy supplies and ultimately all fossil-reservoirs of hydrocarbon would be phased out as energy sources. There would be mounting pressure to devise technologies for the capture of the various manifestations of natural energy flow ie the tides, the wind, hydropower and the sun. Fuel cropping is a potential energy source deserving conscientious research.

## FUEL CROPPING

Wood growing is one of the most energy efficient means of capturing energy. Although agriculture offers gross annual yields equal to or in excess of those which may reasonably be anticipated from silviculture, due to agriculture's requirement for annual management and harvesting it is energetically inferior. In present-day forestry employing relatively intensive silvicultural programmes, approximately 5% of the harvested energy is consumed in harvesting and management (Jaatinen, 1976; Nilsson, 1976; Smith & Johnson, 1977); this compares favourably with other present-day energy technologies. Aside from harvesting the biggest potential energy consumer in silviculture is nitrogen fertilisation; the second is mechanical site preparation (Smith & Johnson, 1977).

On a dry weight basis, the heat values of wood range from 18.5 to 21 MJ/kg compared with 42 MJ/kg for No 6 fuel oil, 31.5 MJ/kg for bituminous coal and 43 MJ/kg for natural gas (Sarkanen, 1976). Resinous conifers and woods with significant oil content, such as cedars, give higher heating values such as 21 MJ/kg for Ponderosa Pine and 22.5 MJ/kg for Western Red Cedar (National Academy of Sciences, 1976). Freshly cut wood has a high moisture content (40 to 50% on a dry weight basis) which reduces the heat value by as much as 70%; a kilogram of wood with a calorific value of 20 MJ/kg would yield 14 MJ at 15% moisture content (National Academy of Sciences, 1976). The net heat value of freshly cut wood is usually about 7 MJ/kg and it would be very highly desirable to refine seasoning techniques for the parsimonious removal of moisture close to the point of harvest.

Although wood has a lower calorific value than coal and petroleum, it is nevertheless fairly attractive as an energy source which can be economically shipped a considerable distance (Table 1). A 5 000 mile (3 107 km) sea journey with road and rail links at each end would consume less than 10% of the delivered energy.

Table 1
TRANSPORTATION COSTS FOR WOOD

| | | |
|---|---|---|
| Rail | (1) | 0.43 MJ/tonne-km |
| Road | (1) | 1.80 MJ/tonne-km |
| Waterway | (1) | 0.44 MJ/tonne-km |
| Marine | (2) | 0.16 MJ/tonne-km |

1 tonne dry wood $\equiv 19.5 \times 10^3$ MJ

Sources: 1 Hirst & Moyers (1976)
2 Leach & Slesser (1976)

Should fuel cropping in Britain prove a viable practice, then due to a continuing pressure for good quality agricultural land, it would be obliged to exploit the less productive land area, which in general means the uplands. It is quite possible that limited forestry developments may be introduced into lowland areas, possibly to the mutual benefit of silviculture and agriculture, but the contribution to a national energy supply would be small compared with that emanating from the uplands; agricultural waste and organic waste in general may provide a significantly larger contribution than lowland forestry (Moorcroft, 1974) *Spartina anglica* grown on Britain's intertidal mud-flats has been proposed as a fuel crop (Heslop-Harrison, 1975). Unfortunately the area is limited at 12 000 ha (Ranwell, 1967) and there are the energy costs of annual cropping to contend with.

Forestry in Britain currently provides pulp and structural material, and at present there are large importations of these commodities. In some future semi steady-state economy there may be considerable scope for moderating this demand, particularly in an economic system converted to conservation and recycling practices. The energy costs of producing timber are low compared with steel and aluminium (1.5 GJ/tonne compared with 9.6 GJ/tonne for steel and 60 GJ/tonne for aluminium (Zerbe, 1971) ) making it an attractive structural material, although demand for fuel crops is not automatically at variance with this demand for structural timber and pulp; the scope for recycling pulp and timber is large and ultimately discarded pulp and timber could contribute to fuel stocks.

## SILVICULTURE AND TREE IMPROVEMENT

Britain is well placed to consider the potential for growing trees for fuel. We have one of the most favourable climates in the temperate regions for tree growth and many years of experience in overcoming the problems posed by our exposed upland planting sites with their often degraded soils. However, while land available for afforestation remains largely restricted to the uplands the possibilities for exploiting the systems of intensive culture based on broadleaved tree species of the type devised recently in the US (McAlpine *et al*, 1967; Szego *et al*, 1972; De Bell, 1972; Rose, 1977) will be small. Such systems, involving coppicing, short rotations and frequent routine management require sheltered sites on good to medium soils and with good access if the returns are to justify the costs (although these constraints may relax in a different economic climate). Of course if better land became available for afforestation then there is every reason to believe that similar increases in yield over those obtained by conventional forestry methods could be achieved here as in the US trials. Even on the poorer sites it might be worth considering trial plantations of species such as red alder *(Alnus rubra)* which has been found to produce exceptional yields (average in British Columbia 38 dry tonnes/ha/year) under widely varying site conditions elsewhere.

Improvements in yields of conifer crops, which are likely to remain the major forest type in most of upland Britain, could be substantial as a result of existing and predicted research advances in tree physiology and tree breeding. Until recently tree breeders have been severely handicapped in their aims by the long life-cycle of forest trees and the frequency of juvenile periods which may extend for the first 10-30 years of life and during which flowering may be scarce or totally absent. It has often been necessary to graft scions of older trees on to seedling rootstocks in order to bring selections together for crossing. A further complication is that many mature trees or grafts do not flower annually.

Considerable progress has been made recently in identifying factors affecting flowering, and in some cases techniques are now being developed for reliable stimulation of heavy flowering under field conditions so that controlled fertilisation and seed production can be effected on a regular basis (Longman, 1975). In some species rooted cuttings have been induced to flower in glasshouses and growth chambers soon after potting up, thus allowing precise control by the tree breeder. Early flower induction in birches is being used in Finland for large scale crossing to produce improved seed (Lepistő, 1973) and it is estimated that by 1985 birch cultivars will be producing 100% more timber than the unimproved species. There is no reason to doubt that similar improvements can and will be achieved in other forest tree species.

At a more controlled level than those already described, tissue culture offers the possibilities of even greater advances. It is already possible to raise plantlets of a number of broadleaved and coniferous species from young embryos and from bud primordia and nodal stem cuttings on defined artificial media (Winton, 1970; Sommer *et al,* 1974, 1975; Brown & Sommer, 1975). It should soon also be possible to raise plantlets from single somatic cells in liquid culture so that within a few years we will be able to clone or reproduce vegetatively many of our forest trees *en masse.* This opens up the possibility for producing any number of the best of these species as and when required. Of course such developments must be used carefully and adequate precautions taken to ensure reasonable genetic variability in our forests if the pest and disease problems associated with monocultures in other crop plants are to be avoided. However, similar risks have been an acceptable part of fruit production for many years.

Tissue culture offers additional advantages to those of rapid cloning just discussed. The genetic base can be broadened by: selecting for advantageous mutations in cultured cells; and by controlled artificial hybridization (Winton *et al,* 1974; Brown, 1976). If reliable methods could be developed for screening gametic (haploid) plantlets for vigor, disease and pest resistance and other desirable traits, much of the need for expensive and time-consuming field trials of the conventional type might be removed. Promising genotypes could be recovered from cultures and used in subsequent breeding programmes to obtain hybrid vigor. Such hybrids could then be mass produced by cloning. Again, it will soon be possible to hybridize cells from different species and even perhaps from different genera together followed by plantlet production and screening for desirable traits.

It will be seen that the future for fuel cropping in the uplands looks brighter than some present analyses may suggest. The potential for increased yields as a result of tree selection, tree breeding and modified management procedures are considerable, doubling of present yields being quite conceivable in the short term for some species with the possibility of considerably greater improvements.

## ENERGY CONVERSION

In general all techniques for upgrading fuel quality into more portable and more convenient forms incur energy penalties (Maugh, 1972; Goldstein, 1975) of about 50% or more eg conversion to methanol and ethanol or oil by pyrolisis. Conversion to electricity incurs a 70% penalty for remote power stations where the improved efficiency of combined heat and power cycles cannot be exploited. It will therefore be advantageous wherever possible to use wood in its original form eg wood-burning stoves, boilers and power-stations.

## YIELD AND ENERGY BUDGET

The general yield class of Sitka spruce grows at about 11 tonnes/ha/year (Busby, 1974) if suitable allowance is made for complete tree utilisation (Keays, 1974). Let us, for the sake of demonstration in the following exploratory arithmetic, estimate that the silvicultural and tree improvements mentioned above will double this yield to 22 tonnes/ha/year.

Let us make the following assumptions about potential forest area so that the maximum yield from tree fuel cropping can be ascertained. Suppose that a combination of population decline and enhanced agricultural husbandry will, in say 100 years, permit all land between the 120 m and 600 m contours to be occupied by forests. The very approximate area of this land is about 6 000 000 ha (based on a computer summation for England and Wales (Ball & Williams, 1977) and visual assessment of the relative contribution of Scotland and Northern Ireland).

Table 2 indicates the magnitude of energy capture for potential renewable energy sources.

Ryle (1977) has hypothesised that a British economy could function on an annual energy budget (electrical equivalent) of $2.1 \times 10^9$ GJ, albeit by introducing quite radical changes in the manner in which society is organised, particularly in the sphere of eliminating wasteful practices. Although $2.1 \times 10^9$ GJ is only about 20% of existing gross consumption, when used carefully in association with heat pumps, combined heat and power converters and superior

## Table 2
## CAPTURE OF RENEWABLE ENERGY SOURCES

| | | |
|---|---|---|
| Hydropower | (1) | $0.13 \times 10^9$ GJ (electrical) |
| Windpower | (2) | $0.96 \times 10^9$ GJ (electrical) |
| Solar collectors | (2) | $0.3 \times 10^9$ GJ (electrical) |
| Fuel cropping | | $2.5 \times 10^9$ GJ (thermal) |
| Organic waste | (3) | $0.3 \times 10^9$ GJ (thermal) |
| Total | | $1.39 \times 10^9$ GJ (electrical) |
| | | $2.8 \times 10^9$ GJ (thermal) |

Sources: 1 Mackillop (1972)
2 Ryle (1977)
3 Author's estimate of all organic waste at 50% conversion efficiency.

insulation, it is equivalent to a large fraction of present-day energy consumption. Furthermore fuel crops could make a major contribution.

It may be generally believed that there is little urgency to perfect silviculture for fuel cropping, because our reserves of coal are expected to last some hundreds of years at existing extraction rates. Public acceptance of the notion that land is one of our most valuable long-term resources, may, however, produce pressures which discourage the despoiling of remaining productive land, especially if there are practicable and demonstrated, sustainable alternatives. Perhaps it is not too soon to explore the potential of fuel cropping in the uplands.

## REFERENCES

Ball, D F & Williams, W M (1977) *The Uplands of England and Wales — Land characteristics and classification.* Bangor: Institute of Terrestrial Ecology.

De Bell, D S (1972) Potential productivity of dense young thickets of red alder. *Forestry Research Note, Crown Zellerbach,* No 2.

Brown, C L (1976) Forests as energy sources in the year 2000. *Journal of Forestry,* 74, 7-12.

Brown, C L & Sommer, H (1975) *An atlas of gymnosperms cultured in vitro: 1924-1974.* Macon: Gainesville Forestry Research Council.

Busby, R J N (1974) *Forest site yield guide to upland Britain.* Forestry Commission Forest Record, 97. Edinburgh: Forestry Commission.

Carosso, M et al (1975) *The energy supply planning model, PB-245 382 and PB-245 383.* Springfield, Va: National Technical Information Service, Bechtel Corporation.

Goldstein, I S (1975) Potential for converting wood into plastics. *Science,* 189, 847-852.

Heslop-Harrison, J (1975) Reforming the cellulose economy. *New Scientist,* 266.

Hirst, E & Moyers, J C (1973) Efficiency of energy use in the United States. *Science,* 179, 1299-1304.

Jaatimen, E (1976) Energy accounting in forestry. In: C O Tamm (Ed.) Ecological Bulletins No 21, *Man and the Boreal Forest.* Copenhagen: Swedish National Science Research Council.

Keays, J L (1974) Full-tree and complete-tree utilisation for pulp and paper. *Forest Products Journal,* 24, 11.

Leach, G & Slesser, M (1973) *Energy equivalents of network inputs to food producing processes.* University of Strathclyde.

Lepisto, M (1973) Accelerated birch breeding in plastic greenhouses. *Forestry Chronicle,* 49, 172-3.

Longman, K A (1975) Tree biology research and plant propagation. *Proceedings of the International Plant Propagation Society,* 25, 219-236.

Lovins, A B (1976) Energy strategy: the road not taken? *Foreign Affairs,* 55, 65-96.

MacKillop, A (1972) Low energy housing. *The Ecologist,* 2, No 12, 4-10.

Maugh, H T (1972) Fuel from wastes: a minor energy source. *Science:* 178, 599-602.

McAlpine, R L, Brown, C L, Herrick, A M & Ruark, H E (1967) 'Silage' sycamore. *Forest farmer,* 26, 6-7.

Moorcroft, C (1974) Plant power. *Architectural Design,* 44, 18-29.

National Academy of Sciences (1976) Fuel from biomass. In: *Renewable Resources for Industrial Materials.* Washington: National Academy of Sciences.

Nilsson, P O (1976) The energy balance in Swedish forestry. In: C O Tamm (Ed.) Ecological Bulletins No 21, *Man and the Boreal Forest.* Copenhagen: Swedish National Science Research Council.

Ranwell, D S (1967) World resources of *spartina townsendii (sensulato):* economic use of *spartina* marshland. *Journal of Applied Ecology,* 4, 239-256.

Rose, D W (1977) Cost of producing energy from wood in intensive cultures. *Journal of Environmental Management,* 5, 23-35.

Ryle, Sir Martin (1977) Economics of alternative energy sources. *Nature,* 267, 111-117.

Sarkanen, K V (1976) Renewable resources for the production of fuels and chemicals. *Science,* 191, 773-776.

Smith, D W & Johnson, E W (1977) Silviculture: highly energy efficient. *Journal of Forestry,* 75, 208-210.

Sommer, H & Brown, C L (1974) Plantlet format in pine tissue cultures. *American Journal of Botany,* 61, supplement 5, 11.

Sommer, H, Brown, C L & Kormanik, P P (1975) Differentiation of plantlets in longleaf pine (*pinus palustris* Mill.) tissue culture in vitro. *Botanical Gazette,* 136, 196-200.

Szego, G C, Fox, J A & Eaton, D R (1972) *The energy plantation.* Intersociety Energy Conversion Engineering Conference. Seventh Conference Proceedings, Paper 729168. San Diego, California.

Winton, L (1974) Shoot and tree production from aspen tissue cultures. *American Journal of Botany,* 57, 904-909.

Winton, L, Parham, R A, Johnson, M A & Einspahr, D W (1974) Tree improvement by callus, cell and protoplast culture. *Journal of the Technical Association of the Pulp and Paper Industry,* 57, 151-152.

Zerbe, J (1971) *Forest Products Journal,* 21, 16.

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