The Energy Potential of Forest Biomass in Ireland

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ABSTRACT

Wood has several important advantages over other biomass sources for energy production. Vigorous juvenile growth, low moisture content and the capacity to coppice are the ideal characteristics of species grown for this purpose. The Forest and Wildlife Service is participating in an EEC Energy Project with the aim of investigating the energy potential of forest biomass. The first phase of this project, consisting of growth trials of a range of woody species at four representative forest sites (western blanket bog, midland raised bog, old red sandstone podzol and drumlin-gley) was established in 1977. Plant spacing was narrower than that used in conventional forest management practice in order to increase productivity per unit area. Early results of plant survival and dry matter production from the growth trials indicate that, of the species being investigated, lodgepole pine, Sitka spruce and *Eucalyptus* are performing best. Above average forest land is required for satisfactory growth of species capable of coppicing and, of the four sites, only the drumlin-gley appears to fulfil this requirement. The possibility of direct seeding reducing the establishment costs of the successful, though non-coppicing conifers, is being tested. Preliminary results from these trials, of seedling emergence, are encouraging. Yields of forest biomass ranging from 25-40 tonnes dry matter/ha/year have been obtained on productive forest lands in the United States; this is a productivity almost competitive with coal at 1974 prices. Similar yields are possible in Ireland on comparable sites. Estimates of the possible energy contribution of forest biomass, as waste materials and as pure energy plantations, are made. It is postulated that the energy import demands of this country could be reduced by 27% based on 1977 imports and assuming the equivalent of half the total forest area were managed on a 20 year rotation.

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INTRODUCTION

The dramatic quadrupling of oil prices in 1973 had an alarming effect on the economy of most oil-importing nations. The Irish economy in particular suffered since we have a heavy dependence on imported oil, importing 75 percent of our energy requirements in the form of oil.(1) It is widely accepted that the 1973 crisis was no passing phenomenon; in other words, cheap oil is a thing of the past. Furthermore, the world's supply of oil is predicted to run out in the next 50 years. Other non-renewable sources of energy, such as coal and natural gas, also have limited reserves available.

Recognition of these harsh realities has activated urgent research into the use of alternative renewable sources of energy. Three options have been proposed in order to meet the energy shortage expected through unavailability of formerly plentiful and cheap sources of energy: (i) nuclear energy — this option is the subject of conflicting opinions on a worldwide scale; (ii) increased imports of coal — the disadvantage of this option for this country would be that it would again be placing an undue reliance on an imported source of energy, thus putting itself at the mercy of the whims of influences outside its control; (iii) renewable resources — included amongst this option would be such possibilities as solar and geothermal energy, wind and wave power, and biomass.

Renewal resources have considerable advantages: (i) renewability, (ii) abundance, and (iii) economy, and presumably this economy will become increasingly apparent as the non-renewable resources come nearer to full depletion and become economically inaccessible. Further discussion in this paper will be centred on the renewable resource biomass and specifically forest biomass.

THE FOREST BIOMASS CONCEPT

The term "biomass" refers to plant material and industrial waste, including forest wastes* and plantations grown specifically for the production of energy. (The latter are often referred to as "energy plantations").

The types of energy that can be derived from biomass include (i) direct heat, (ii) electricity generation, and (iii) liquid fuels. Forest crops have several advantages over agricultural crops for biomass purposes: (i) they can be put to other uses besides energy, (ii) they can be harvested throughout the year, (iii) they can be grown on poor or infertile sites, (iv) deterioration in storage is slow, (v) their fertiliser requirements are relatively small. It could also be said — and this also applies to some biomass sources other than wood — that the technology, workforce and materials are available for the development of this resource.

The main disadvantage of forest biomass is its bulky nature and therefore its high cost of transport. However, this might be offset by having the source of energy near to where it will be utilised.

* Wastes refer to tree stems less than 7cms in diameter, branches and needles.

The ideal species for use in biomass production would have the following characteristics: (i) it would be high-yielding in its early years of growth, (ii) it would have a low moisture content, and (iii) it would be capable of coppicing or sprouting. As regards the last it is unfortunate that the conifers in general do not fulfil this requirement. In addition, and perhaps more seriously, conifers at conventional spacings are not high-yielding in their early years, and rotations of at least 15 years would appear to be necessary for conifers if present spacings are to be used. Assuming continuance of the present trend in land use and the availability of only poorer land types for forestry, conifers are likely candidates for forest biomass. However, an awareness of the necessity for extensive forest biomass production may increase in the future to such an extent that land types normally denied to the forester may well be made available. If that is the case coppicing hardwoods would probably be the preferable species for biomass production. It behoves us therefore to have answers as to what species yield most on different land and soil types. In addition, research is needed to investigate the intensity of cultural practices required to maximise dry matter production. It is appropriate therefore that the Forest and Wildlife Service is participating in an EEC Energy Project which has these goals amongst its aims.

EEC Energy Project

Many bodies, such as the EEC, were prompted into major energy, research and development programmes following the oil crisis in 1973. Thus, the EEC initiated a wide-ranging programme in 1975 in which solar energy was to be one of the subjects for research. The Forest and Wildlife Service has undertaken involvement in the solar energy project entitled "Photosynthetic production of organic matter — choice and development of the most suitable energy crops for the different regions of Europe"(2). Our concern therefore will be the use of short rotation tree crops and forest wastes for the production of energy. The following are the objectives of the project: (i) to ascertain the likelihood of commonly grown species giving an economic yield on representative forest sites, (ii) to make projections as to the extent to which yields could be increased in order to obtain the maximum utilisation of solar energy, (iii) to determine the maximum output of utilisable energy per hectare and the proportion of national needs that will be supplied in this way.

The first phase of this project consists of a series of growth trials. These were established in Spring 1977 at four locations on representative forest sites (Table 1), that is western blanket bog (Ross Forest), midland raised bog (Tullamore Forest), drumlin-gley (Swanlinbar Forest), and old red sandstone podzol (Kilfinane Forest).

Table 1 — Site characteristics of growth trial locations

	Forest			
Characteristic	Kilfinane	Swanlinbar	Ross	Tullamore
Aspect	South	North	East	Nil
Elevation (m)	290	240	100	100
Slope	7°	3°	0.5°	Nil
Rainfall/yr (mm)	1000-1500	1,600 (Ca.)	1,250 (Ca.)	750 (Ca.)
Geology	O.R.S.	Carbonif. Sst.	Granite	Carbonif. Lst. Sst. and Shale
Great Soil Gp.	Podzol (Discont. iron pan)	Drumlin-gley	Blanket bog	Raised bog
Peat depth (m)	0.1-0.3	0-0.15	2.6	3.0 (Ca.)
Vegetation	Calluna-Molinia	Grass-Rush	Calluna-Molinia	Calluna-Eriophorum

Before planting, the sites were prepared to conform as much as possible to the normal forest management requirements (Table 2). At each of the four sites a range of species was planted (Table 3).

Table 2 — Site preparation for growth trials

Forest	Ploughing	Fertiliser
Kilfinane	Clarke S.M.B. tine plough (D6 tractor) — complete	500kg C.R.P. (14.5% P)/ha.
Swanlinbar	Clarke S.M.B. tine plough (D4 tractor) — complete	None
Ross	Cuthbertson S.M.B. (drainage) at 1.5m — Fiat 805	500kg C.R.P./ha.
Tullamore	Cuthbertson S.M.B. (drainage) at 2.0m — Fiat 655	500kg C.R.P./ha +250kg KC1 (50% K)/ha.

Table 3 — Species composition of growth trials

Species	Common Name	Age
Pinus contorta Doug. ex Loud.	Lodgepole pine	1+1
Pinus radiata D. Don	Monterey pine	1-year seedlings
Picea sitchensis Bong. Carr.	Sitka spruce	2+1
Alnus rubra	Red alder	1+1
Betula verucosa	Silver birch	1 u, 1
Eucalyptus johnstoni	Eucalyptus	1-year potted
Populus trichocarpa	'T' (Fritzi Pauley)	0+1
Populus tacamahaca x *trichocarpa*	'TT (32)	0+1
Castanea sativa Mill.	Spanish chestnut	1+1
Salix aquatica gigantea		
Salix dasyclades	Willow	Cuttings
Salix viminalis		

Planting was completed before the end of April 1977 at Ross and Tullamore and by mid-May 1977 at Kilfinane and Swanlinbar, apart from the *Eucalyptus* plants which were planted at the end of June 1977. The slit method of planting was used except in the case of the poplars (pit method), *Eucalyptus* (semi-circular spade method) and willows (unrooted cuttings were inserted directly into soil by hand).

Plant spacing was decided somewhat arbitrarily in the absence of guidelines (Table 4). However it was assumed that spacing narrower than that used in normal management practice would achieve better results in terms of dry matter production. The unavailability of suitable machinery to plough any closer than 1.5-2.0m on the peat sites dictated to some extent the spacing at Ross and Tullamore; that is, it would have been desirable to have the plough ribbons (i.e. the continuous sod removed to produce the furrow and upon which the trees are planted) closer than 1.5-2.0m in order to be able to plant at a narrow spacing across the ribbons. To make up for the plant number deficit across the ribbons extra plants were planted along the ribbons.

Table 4 — Plant spacing at growth trials (m)

Forest	Conifers, Eucalyptus	Willows	Other Hardwoods
Kilfinane	0.8 x 0.8	0.5 x 0.5	1.2 x 1.2
Swanlinbar	0.8 x 0.8	0.5 x 0.5	1.2 x 1.2
Ross	1.5 x 0.5	1.5 x 0.3	1.5 x 1.0
Tullamore	2.0 x 0.3	2.0 x 0.3	2.0 x 0.8

A randomised block design was used on the mineral sites and a completely randomised design on the peat sites. Plots were replicated three times except for *Eucalyptus* and willow at all sites and poplar and Spanish chestnut at the peat sites. The plant density of each species at the four sites are shown in Table 5.

Table 5 — Plant density of growth trials (plants/ha)

Species	Kilfinane	Forest Swanlinbar	Ross	Tullamore
Lodgepole pine	15,625	15,625	11,033	10,206
Monterey pine	15,625	15,625	11,033	10,206
Sitka spruce	15,625	15,625	11,033	10,206
Eucalyptus	15,625	15,625	11,033	12,022
Alder	6,400	6,400	5,785	5,897
Birch	6,400	6,400	5,651	5,405
Poplar 'T'	6,400	6,400	5,785	5,897
Poplar 'TT'	6,400	6,400	5,785	5,897
Spanish chestnut	6,400	6,400	5,785	5,897
Willow	34,225	34,225	19,354	18,144

Results and Discussion of Growth Trials Two Years After Establishment

Estimates of dry matter production two years after establishment of the various species at each site have been made (Table 7). These have been based on the number of surviving plants (Table 6) and a sampling of three trees per plot. The three sample trees were selected to represent (i) the mean height tree, (ii) the mean height tree plus one standard deviation, and (iii) the mean height tree minus one standard deviation.

It is clear from the survival assessments (Table 6) that several of the species, such as the poplars and willows, find the conditions of soil and/or climate unfavourable. The drumlin-gley site alone bears consistently high numbers of surviving plants. In general the species surviving best are: lodgepole pine, Sitka spruce, alder, birch and *Eucalyptus*.

Table 6 — Plant survival at growth trials (%)

Species	Kilfinane	Forest Swanlinbar	Ross	Tullamore
Lodgepole pine	98	89	99	95
Monterey pine	86	55	50	68
Sitka spruce	98	98	98	97
Eucalyptus	79	96	20	96
Alder	97	97	100	78
Birch	92	97	90	94
Poplar 'T'	92	100	10	0
Poplar 'TT'	94	100	70	0
Spanish chestnut	98	97	100	86
Willow	0	100	0	0

Table 7 — Above ground dry matter two years after establishment at growth trials (tonnes/ha)

Species	Kilfinane	Forest Swanlinbar	Ross	Tullamore
Lodgepole pine	0.82	0.17	0.64	1.37
Monterey pine	0.13	0.14	0.03	0.23
Sitka spruce	0.77	0.44	0.87	1.22
Eucalyptus	1.08	0.89	0.21	3.60
Alder	0.14	0.68	0.13	0.16
Birch	0.15	0.28	0.18	0.37
Poplar 'T'	0.37	3.79	0.03	0
Poplar 'TT'	0.33	1.08	0.21	0
Spanish chestnut	0.07	0.06	0.11	0.20
Willow				
S. aquatica gigantea	0	0.84	0	0
S. dasyclades	0	0.82	0	0
S. viminalis	0	0.65	0	0

Since these survival counts were conducted, severe frosts occurred in early January 1979 and wreaked havoc on the *Eucalyptus* in particular. It is uncertain if the plants will recover although some have been observed to have sent out shoots to take over from the damaged main shoots.

Whilst it is still too early to make projections as to the potential dry matter productivities of the various species it is apparent which species are likely to be in the forefront. Lodgepole pine and Sitka spruce are prominent at all sites except the drumlin; their relatively poor growth on the drumlin is surprising but they are expected to recover and may even grow very well on this site. *Eucalyptus* performed well on all but the blanket bog but it remains to be seen if this species recovers from the frosts mentioned above. If a frost-hardy *Eucalyptus* species were selected it seems that it would be a very promising candidate for biomass production. The poplars and willows succeeded only on the relatively fertile drumlin soil and where exposure was not excessive. The failure of the willows on all but the drumlin site might appear to be a severe indictment of the species. However, the willow species were the only ones that were planted as cuttings; perhaps survival and dry matter production would have been better if rooted plants were employed. Furthermore the planting of the willow cuttings was done later than desirable and they probably suffered as a consequence.

To the agriculturist the dry matter data of even the most successful species may not appear high. However, this is to be expected since forest trees in general are not productive in their initial growth. The mean annual increment (MAI) at normal spacing does not reach a maximum till after at least 15 years. Acceptable levels of biomass production might be achieved using rotations somewhat shorter than the age at which maximum MAI is reached. Dry matter production can be increased substantially by such devices as decreasing the spacing which would therefore allow a considerable shortening of rotations.

Given that only the drumlin site would be regarded as fertile it is not surprising that the coppicing species have not produced as much dry matter as the non-coppicing species on the other sites. Coppicing species, generally hardwoods, require fertile, unexposed sites and so favourable results could not realistically be expected for the hardwoods on the infertile sites. This is unfortunate since planting is one of the costliest items in stand establishment. In view of the relative success of the non-coppicing species, lodgepole pine and Sitka spruce, and assuming they have a potential for biomass production on the poorer forest sites, it was decided to investigate the possibility of reducing the establishment costs of these species by direct seeding. Accordingly, direct seeding trials were laid down at each site. Seeds of lodgepole pine and Sitka spruce were sown directly on to the ground surface in Spring 1978. The only site preparation carried out prior to sowing was the removal of coarse vegetation. The density of sowing was heavy, being similar to that used in forest nurseries, and so survival of even 25% of the emerging seedlings might be considered satisfactory for biomass production. More exact tolerable levels of seedling survival will not be known until more information is obtained about the plant spacing required for maximum yields. Preliminary results of seedling emergence are encouraging.

Yield Prospects from Forest Biomass

The EEC energy trials described above are not yet at a stage where we can answer the questions posed by the objectives of the project. The only conclusion that can be drawn from the trials so far is a tentative choice of the best species for each site. The big question is: Will productivity reach levels that will provide reasonable hope for further increases in yields through experimentation on fertilisation, spacing, species selection, etc.? Experience on some fertile sites in the U.S. has been that it is possible with present technology and expertise to increase yields from 10 to 15-fold through practice of short rotation forestry(3).

The viability of forest biomass as an alternative energy source can be gauged from experimental evidence gained in southeastern and northwestern U.S. where yields ranging from 25-40 tonnes/ha/year of above ground dry matter have been achieved so far(4,5). This level of productivity was almost competitive with coal in terms of 1974 coal prices(6). Given the spiralling increases in coal prices since 1974 it would be reasonable to assume that wood at such yields would now hold its own at least with coal and presumably will become increasingly competitive in time.

Is it possible for us in Ireland to achieve comparable yields? Conventional long rotation forests are composed of trees spaced too far apart, even in the most productive of our plantations, to give yields comparable to those reported in the U.S. In the absence of spacing trials (these are proposed for inclusion in the second phase of the EEC Energy Project) we are not in a position to be specific as to what yields are possible. However, reasonable estimates of potential yields are possible based on investigation of two small plantations of Sitka spruce. The first plantation is situated on a peaty gley in Drumkeeran Forest, Co. Leitrim and consisted of a bed of plants spaced 12cms apart both between and along rows. The yield of above ground dry matter reached 48 tonnes/ha after only three years following transplanting. The second plantation occurred in a private nursery on an acid brown earth in Carnew, Co. Wicklow, and the Sitka spruce plants here had been planted at a 27cm x 6cm spacing. The yield of above ground dry matter was more spectacular at this site reaching 88 and 90 tonnes/ha after only three and four years respectively following transplanting. Apart from the high yields obtained an interesting point about these data is that very little additional production is gained by waiting the longer time period. Perhaps these yields could be increased still further by utilising the best combination of resources available such as fertilisers and lime, weed and pest control, irrigation and even a different spacing. It has to be admitted that the yields mentioned above were obtained on above average forest sites and it may well be that energy plantations will require land of a quality not at present available to the Forest and Wildlife Service.

ENERGY PROSPECTS FROM FOREST BIOMASS

1. Forest Wastes

In 1978 total fellings (thinnings plus final fellings) amounted to about 1,055,000m^3, of which about 205,000m^3 represented waste material. Assuming a 50% moisture content (fresh weight basis) and 0.35 tonnes/m^3 dry material, forest wastes for 1978 amounted to about 36,000 tonnes dry matter. This is equivalent to about 18,000 tonnes oil equivalent or 26,000 tonnes coal equivalent, which would have represented about 0.3% of oil imports in 1978 or 3% of coal imports in 1978.* If total fellings for 1978 were used solely for energy purposes they would have been equivalent to 1.2% of oil inports or 12.6% of coal inports. National felling forecasts indicate substantial increases in volume of fellings each year rising to over two million m^3 by the year 2000(7); therefore it is possible to decrease our reliance still further on imported energy by utilising forest wastes, provided of course our energy requirements stayed relatively constant.

2. Energy Plantations

The present total forest land area in Ireland is about 330,000 ha. Let us assume an equivalent area to be managed on a 20 year rotation, capable of producing 10 tonnes dry matter/ha/year or 200 tonnes dry matter over the rotation. The area of forest due for harvest annually would be 330,000 ha $\div$ 20 years = 16,500 ha. Therefore the amount of dry matter available annually would be 16,500 ha x 200 tonnes/ha = 3.3 million tonnes dry matter/year. This would be equivalent to 1.6 million tonnes oil equivalent (MTOE) which represents 27% of the nation's energy import demand for 1977.

Whether this substantial reduction in energy imports could be sustained in the long term is unknown. It would depend on many factors, most of which would not be directly related to forest biomass production. Foremost amongst these would be the future energy demands of the country. It is estimated that the energy import demand will rise from 6.0 MTOE in 1977 to 16.0 MTOE in

* The conversion factors used were: 1 tonne wood = 0.49 tonnes oil equivalent and 1 tonne wood = 0.72 tonnes coal equivalent.

1990(1). If the projected contribution from forest biomass as stated above were to stay constant at 1.6 MTOE then this would represent 10% of the energy import demand for 1990, a considerable drop from the 27% envisaged for 1977. Thus the significance of the contribution of forest biomass to our energy requirements may well hinge on how people will respond to energy conservation measures they probably will be asked to adopt in the future.

SUMMARY AND CONCLUSIONS

The idea of using wood to produce energy does not meet with unanimous approval. However, with the costs of oil and coal escalating at a rate in excess of that for wood, the economics of the proposition should become more attractive in time.

The problems of disposing of timber products in periods of poor demand might be eased greatly if the product affected, say pulpwood, were diverted for energy production.

The growing of forests is a relatively efficient way of capturing and storing solar energy. The efficiency is increased if the lands suitable for the practice of intensive short rotation forestry using coppicing species are available.

There are two ways of producing forest biomass, firstly as forest wastes and secondly as pure energy plantations. A system of dual usage could be employed in which forests could be a source of conventional products such as sawlog, boxwood and pulpwood and also as a source of energy. This might be the best course of action on exposed and/or infertile forest lands. This would ensure maximum utilisation of the species that are likely to grow best on these sites, namely the non-coppicing conifers. Pure energy plantations would meet with greater success on more productive lands since these would support a wider range of species, including the highly desirable coppicing hardwoods.

Direct combustion may not be the most appropriate form of energy to produce from forest biomass. With continued improvements in chemical technology becoming available perhaps con version to other forms of energy, especially liquid fuels, might make a more substantial reduction in imported energy costs.

It is clear that much research and development work needs to be done before the full picture of the potential of forest biomass emerges.

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