# The Potential Contribution of Irish State Forests to the Supply of Energy

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## SUMMARY

This paper estimates what the energy-supply of a hypothetical conventional State forest of 360,000 ha would be if it were totally composed of Sitka spruce, Yield Class 14 on a rotation of 50 years. The data base is small and results are, therefore, tentative. Nevertheless, it appears that a large forest estate might be able to supply an equivalent amount of energy as used by its potentially dependent forest industries. Whilst the annual supply of energy to the total national budget appears to be modest, the long term contribution would be accumulative because of the renewable nature of the source. It is felt that two aspects should now be examined: (1) the role dry matter might have in the country's forests, as an alternative measure to volume alone and (2) the approach research should adopt in relation to biomass investigations.

## INTRODUCTION

When fossil fuel energy is cheap and abundant, the search for alternative sources of power tends to be less active than in periods when it is expensive or scarce. Supply deficits have been experienced on a large scale during the Second World War which produced many innovations to overcome them. Between 1974 and 1982 the world suffered dramatic price increases in crude oil that were followed by the establishment of programmes to create alternative power sources. Ireland has experienced all of these trends and may be on the verge of a period of relatively cheap and abundant fossil fuel, if indications about finds materialise into commercially productive oil wells. Does this mean that research related to renewable power sources will become less important in the near future? Hopefully not. Fossil fuel deposits have a limited life span which renewable sources of energy would help to extend. In the long term future, the world is likely to be forced to shift its dependency from non renewable sources to alternatives as the former are depleted. The sooner this transition is prepared for, the easier will be the changeover.

IRISH FORESTRY, 1983, Vol. 40, No. 2: 98-109.

Relatively little information is available to describe the contribution that productive forest land could make to the national energy supply under current management techniques. This paper attempts to evaluate the biomass potential of conventional State forests using available data and certain assumptions which are outlined. Sitka spruce (*Picea sitchensis* (Bong.) Carr.), which covers about 50% of State forest land, was used for this evaluation, because more dry weight information exists for this species over a greater range of tree sizes than for any other.

Embraced under the term 'conventional forests' are those that are managed in the traditional way, through silvicultural techniques designed mainly for the production of industrial wood rather than energy.

## BASIC DATA

Basic data consisted of individual tree volumes and biomass components which were used to create a series of equations. These were employed, with selected plot data, to obtain biomass and volume on an area basis. Biomass/volume ratios were then worked out and used to convert a selected British Forestry Commission volume yield table to a biomass yield table, on the basis of which yields from a hypothetical forest estate were calculated. Details are given below.

### *I COMPILED INDIVIDUAL TREE EQUATIONS*

Equations that predict dry weight for components of individual trees, based on easy to measure variables like DBH (diameter breast height) and H (total tree height), are widely used. These equations may be local, regional or national. If the regression coefficients of two equations are shown not to be statistically different, then the data may be combined and a new formula drawn up to cover the geographic range of both.

In the case of Ireland, a comparison of this type is thought to be premature for conventional forests, because too few data exist. It was assumed, in this paper, however, that available information could be combined to obtain equations that reflect, to some degree, the biomass of standing Sitka spruce trees within the country. This assumption, and the fact that the samples were not chosen at random from the population, invalidates any statistical measure of error. However, in the absence of adequate data the approach taken here should be seen as a preliminary step in determining the biomass potential of Irish State forests.

Eighteen weighed sample trees were available from previous studies (Carey and O'Brien, 1979, and Carey, 1980). A further 14 trees were selected for biomass determination in order to include a wider variety of site types. Table 1 gives details of stand and site charisteristics of sample tree locations.

Several equations were then created:

*(1) Biomass Equations*

Five equations were compiled, using the 32 sample trees. The type of equation or model employed is known as 'Schumacher and Hall' in volume table construction and has the following format:

$$\text{Log Ye} = a + b\,(\text{Log DBH}) + c\,(\text{Log H})$$

where: Ye is the estimate of individual tree component biomass
DBH is the diameter at breast height in cm
H is the total height of the tree in m
a, b and c are regression coefficients
Log is Logarithm to base 10.

Equations were compiled for: total overground biomass (TOOG) and component biomass of the complete stem overbark (TOSO); branches-with-needles (TOBN); merchantable stem to a top diameter of 7cm (STMO); and total slash (TOSL). The latter is defined as TOOG less STMO. The regression coefficients are shown below:

| Component | Regression Coefficient | | |
|---|---|---|---|
| | a | b | c |
| TOOG | –1.185263 | 1.897357 | 0.691947 |
| TOSO | –1.453427 | 1.708470 | 1.002647 |
| TOBN | –1.464177 | 2.375586 | –0.070251 |
| STMO | –1.595717 | 1.851189 | 0.946490 |
| TOSL | –1.149487 | 2.046517 | 0.071603 |

(2) *An Equation for Estimating Percentage Bark by Weight*, was compiled for stems of Sitka spruce to a top diameter of 7cm over bark.

It is:

$$\text{Ye} = 23.97362 - 0.52344\,(\text{DBH}) + 0.00652\,(\text{DBH})^2$$

where: Percent bark $= 100 \times (\text{Sin}^2\text{Ye})$
DBH = Diameter at breast height (cm)

Table 1: Stand and Site Characteristics of Sample Tree Locations.

| Characteristic | Glenmalure | Glen Imaal | Cloosh Valley | Camolin | Curraghmore |
|---|---|---|---|---|---|
| Age (years) | 33 | 50 | 25 | 46 | 48 |
| Yield Class ($m^3$/ha) | 14 | 20 | 22 | 12-13 | 17-18 |
| Density (trees/ha) | 3,760 | 468 | 2,540 | 1,075 | 825 |
| Geology | Mica schist and granite | Granite and shale | Granite | Ordovician shale | Silurian shale |
| Soil | Peaty gley-blanket peat | Peaty podzol | Brown podzolic | Brown podzolic | Brown podzolic |
| Elevation (m) | 350 | 250 | 100 | 300 | 180 |
| Mean Annual Rainfall (mm) | 2,115 | 1,225 | 2,000 | 860 | 1,370 |
| Mean Daily Air Temp ($^oC$) | 7.6 | 8.5 | 7.7 | 7.8 | 9.3 |
| Number of samples | 8 | 10 | 10 | 2 | 2 |

The equation was derived from 18 trees and they are the same as those used in compiling biomass estimates for Sitka spruce in: Carey and O'Brien, 1979, and Carey, 1980.

*(3) Volume Equations*

These were compiled using the basic data (32 trees) for the biomass component equations.

They are:

$$Ye(1)=4.265123+1.954895\ (\text{Log DBH})+0.921085\ (\text{Log H})$$

$$Ye(2)=-4.407932+2.099353\ (\text{Log DBH})+0.863421\ (\text{Log H})$$

where: Ye(1) is log of total stem volume overbark
Ye(2) is log of volume overbark to 7cm top diameter

DBH is Diameter breast height (cm)
H is Total tree height (m)
Log is Logarithm to base 10.

*II PLOT DATA*

The mean yield class for State forests is about 14 $m^3$/ha/yr, while for Sitka spruce alone, it is close to 16. In this study it was decided to use the overall mean yield class of the country (14) in order to predict roughly the dry weight production of the total forest estate, assuming it was composed wholly of Sitka spruce.

Nine pure Sitka spruce compartments were selected; these were separated in age, by 5 year intervals, beginning at 14 years. The compartments, which were fully stocked, had a yield class of 14 according to inventory data, a minimum area of two hectares and a normal thinning status. They were located in the Wicklow/Wexford area. A point was selected at random on a map of each chosen stand. A circular plot of 0.05ha was established within the plantation in relation to the selected point on the map. All trees were counted and all DBHs equal to 7cm and over were measured. A minimum of 8 trees were sampled for total height, including the two largest DBH trees.

For each plot surveyed the following were used as input data into a computer programme:

(1) the total number of trees greater than or equal to 7cm

(2) the mean basal area of the plot

(3) the DBHs, with the total heights of sampled trees

(4) the biomass-component equations

(5) the volume equations and

(6) a table of bark percentages by stem categories, derived from the bark equation.

The programme calculated the dry matter of the following on a per hectare basis for each plot: total overground, total stem, total branches and needles, stem to 7cm, and the total slash, using the biomass component equations. The weight of merchantable bark per hectare was estimated using the bark table; stem volumes to tip and 7cm were worked out with the volume equations.

For each plot the total stem dry matter per hectare was divided by the estimated volume to 7cm and the resulting factors were used to convert the Yield Class 14 yield table (in Forestry Commission booklet No. 34, Page 131) into a total overground biomass table (Hamilton and Christie, 1971). This was done by multiplying the volume-to-7cm by the factors for the same or next closest year. The result is shown in Table 2.

It was only possible to estimate biomass of thinnings in one case and this was shown to have the same proportion of total dry matter/volume to 7cm as the standing volume. Based on this it is assumed that all thinnings and standing volumes have the same proportions for any selected year.

Yield per hectare, for selected components, was estimated by multiplying the total overground biomass (Table 2) by the appropriate percentage weight as found in the plots. These weights were then converted to tonnes of oil equivalent (TOE) to calculate total forest energy yield (Table 3). A conversion factor of 0.37 TOE/tonne of dry matter was assumed (Lunny, F. 1981. Personal communication. National Board for Science and Technology).

*Potential Biomass Yields from Fully Productive State Forests*

If the Forest and Wildlife Service (FWS) continue to plant at the rate of 6,000 to 8,000 hectares per year, the total area of productive State forest will exceed 360,000 hectares by the early 1990s. Based on Table 3 and assuming an average planting programme of 7,200 ha, we have estimated the energy flows from a fully productive estate of this size (i.e. one which has reached maximum sustainable yield; Figure 1). The study assumes a coniferous forest of Sitka spruce on a rotation of 50 years, yielding an average of about 14 cubic metres of commercial wood or 7.1 tonnes of total overground dry matter per hectare per year. It would, in theory, be permissible to remove 0.94 (MTOE) in perpertuity, from the forest estate of which total residues would constitute about 46% (0.43 MTOE).

Table 2: Total Overground Dry Matter (TOOG) Production for Yield Class 14 Sitka spruce.

| Age | Main Crop after Thinning | | | | | Yield from thinnings | | | Cumulative Production | | MAI | Age |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Top Ht. | Mean Diam | Basal Area | TOOG | No. Trees | Mean Diam | TOOG | No. Trees | Basal Area | TOOG | TOOG | |
| yrs. | m | cm | $m^2$ | tonnes | | cm | tonnes | | $m^2$ | tonnes | tonnes | yrs. |
| 15 | 6.2 | 8.3 | 18.0 | 27.7 | 3331 | — | — | — | 18.0 | 27.7 | 1.8 | 15 |
| 20 | 8.8 | 10.6 | 23.7 | 51.4 | 2681 | 12.5 | 19.2 | 650 | 31.7 | 70.6 | 3.5 | 20 |
| 25 | 11.5 | 13.0 | 23.9 | 70.4 | 1809 | 12.8 | 31.7 | 872 | 43.2 | 121.3 | 4.9 | 25 |
| 30 | 14.3 | 16.1 | 26.3 | 100.0 | 1299 | 14.0 | 30.8 | 510 | 53.4 | 181.7 | 6.1 | 30 |
| 35 | 16.9 | 19.4 | 29.0 | 126.6 | 982 | 16.0 | 28.6 | 317 | 62.5 | 236.9 | 6.8 | 35 |
| 40 | 19.3 | 22.6 | 31.2 | 147.8 | 780 | 18.6 | 26.4 | 202 | 70.2 | 284.5 | 7.1 | 40 |
| 45 | 21.5 | 25.6 | 32.8 | 173.3 | 639 | 21.3 | 26.1 | 141 | 76.8 | 336.1 | 7.5 | 45 |
| 50 | 23.4 | 28.3 | 34.2 | 170.9 | 545 | 23.8 | 20.7 | 94 | 82.4 | 354.4 | 7.1 | 50 |
| 55 | 24.9 | 30.7 | 35.6 | 191.3 | 483 | 26.0 | 17.6 | 62 | 87.2 | 392.4 | 7.1 | 55 |

Table 3. Yield of Selected Components in Tonnes of Oil Equivalent (TOE)/ha for Sitka spruce, Yield Class 14, on a Rotation of 50 Years.

TOOG: Total overground dry matter (DM)
STMO: DM of merchantable stem to top diameter 7cm overbark
STMU: DM of merchantable stem to top diameter 7cm underbark
TOSL: TOOG less STMO.

TOE/ha removed

| Age | TOOG | STMO | STMU | TOSL | Merch. Bark |
|---|---|---|---|---|---|
| 20 | 7.1 | 4.2 | 3.8 | 2.9 | .4 |
| 25 | 11.7 | 7.1 | 6.5 | 4.6 | .6 |
| 30 | 11.4 | 7.3 | 6.7 | 4.1 | .6 |
| 35 | 10.6 | 7.0 | 6.5 | 3.6 | .5 |
| 40 | 9.8 | 6.9 | 6.4 | 2.9 | .5 |
| 45 | 9.7 | 7.0 | 6.5 | 2.7 | .5 |
| 50 | 70.9 | 53.2 | 50.3 | 17.7 | 2.8 |

Assumption: There are 0.37 TOE/tonne of dry matter.

Table 2 indicates that mean annual biomass increment would culminate at 45 years, whereas the British Forestry Commission yield tables for yield class 14 show that volume increment reaches a maximum after 50 years (Hamilton and Christie, 1971). The discrepancy is somewhat suspect. It may be due to a tendency of the original equations to underestimate the total biomass of the older selected plots. It was decided to use the more conservative estimate of 7.1 t/ha/year of overground material with a rotation of 50 years, which is closer to the volume rotation of maximum mean annual increment. This production appears reasonable when compared to other estimates made for conifers on peatlands (McCarthy and Keogh, in press).

The total potential residues (0.43 MTOE) made up of slash and bark from all thinnings and the clearfell, and residues from industrial production, would amount to 2% of the projected primary energy demand of the Republic for the year 2000 (i.e. 18 MTOE; Kavanagh and Brady, 1980). By this time the FWS estate should be approaching normality. Clearly, only the satisfaction of a small part of the national annual primary energy demand is possible from the conventional forest. But as national energy consumption is likely to fluctuate in the foreseeable future, it is somewhat misleading to compare a fixed annual output with an ever changing demand. It may be more fruitful to consider that part of the country's energy budget the conventional forest could satisfy constantly.

In Figure 1, the amount of energy consumed by the forest industry is calculated at 0.37 MTOE. This is based on the assumption that the total raw material calculated to be available (0.77 MTOE) requires the same proportion of energy in conversion as the industries of the ECE region of the mid 70s (Prins 1979) and that the structure of the industries are alike. If all available residues from industrial conversion were used (0.11 MTOE), it would be necessary to obtain a further 0.26 MTOE in order to satisfy the demands of the industries. This could, in theory, be obtained from the forest residues (thinnings, clearfell and bark: total 0.32 MTOE), leaving a surplus of 0.06 MTOE. In other words 81% of the forest residues would need to be extracted: the feasibility of doing this would depend on site fertility levels and terrain, as well as financial considerations.

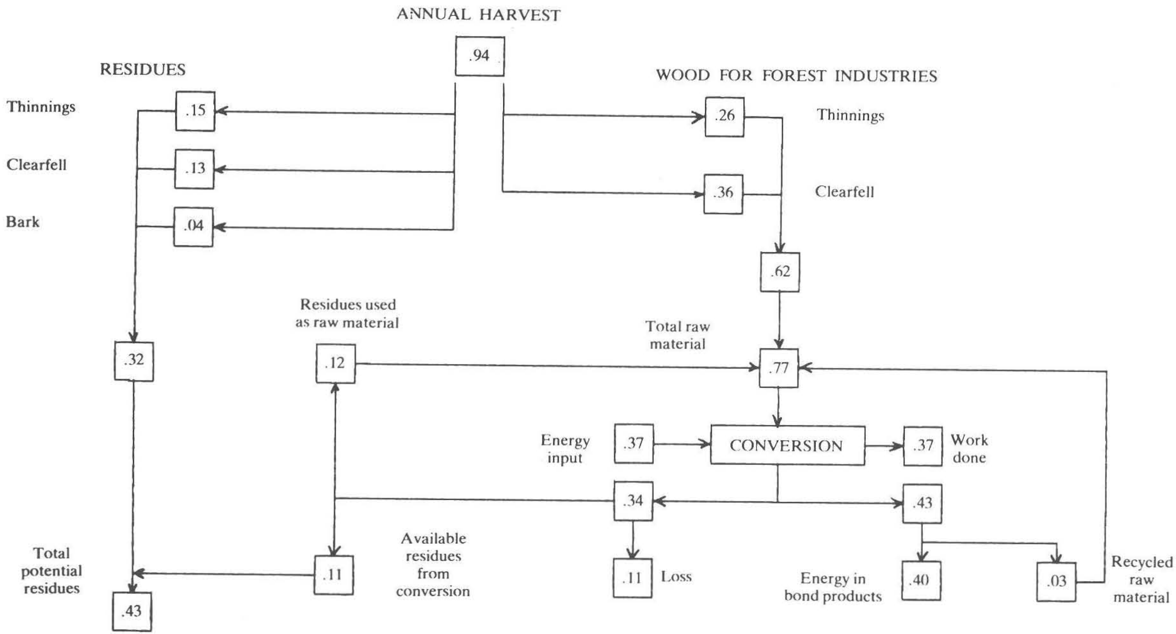
In summary: it seems that it might be possible to supply in perpetuity, from the forest base, irrespective of its size, an amount of energy equal to that consumed by the potentially dependent forest industries, assuming that they have a like structure and similar efficiencies as those of the ECE region during the mid 70s. While the potential yields from conventional State forests seem modest compared to the total annual primary energy demand for the Republic at the beginning of the next century, they are not insignificant when considered over long periods. In an interval of 30 years, an industry consuming 0.37 MTOE/year would use up the equivalent of a small oilfield of 70 million barrels. An oilfield of this size, producing 50,000 barrels per day, would provide 50% of Ireland's oil requirements for about 4 years.

## Discussion

It has been pointed out that the amount of forest biomass data, originating from conventional forests in this country is small. These have been used to compile equations and make estimates of standing biomass that should reflect, to some degree, the potential energy production of Irish State forests. However, it is clear from the exercise that extra data are needed if more reliable predictions are to be made.

We feel it is time to re-evaluate the role dry matter might have in the management of the conventional forest and the approach research should adopt to produce the necessary basic information.

Figure 1: Potential Overground Harvest per Year from a Conventional Forest Estate of 360,000 hectares of Sitka spruce, Yield Class 14, on a Rotation of 50 years.




Figures are in millions of tonnes of oil equivalent (MTOE).

Dry weight provides not only a measure of potential energy within trees or stands but may be employed to evaluate the nutrient balances of forest ecosystems or enhance understanding of crop responses to silvicultural treatments in a better way than volume alone. A total crop assessment is possible with dry matter, whereas volume is confined to the stem because of the impracticability of measuring the volumes of branches, leaves and other parts of the tree. On the other hand it is relatively expensive to obtain basic dry matter values for individual trees.

It would be worthwhile to attempt to construct national or regional equations for the major species with the objective of compiling biomass yield tables. These tables would enable inventories and forecasts to be constructed on a weight basis which would provide necessary data for planning the utilisation of forest residues. They would also allow crop nutrient balances to be drawn up to identify stands which would be in danger of excessive nutrient depletion if residues were harvested.

From dry matter yield tables, it would be possible to obtain a more accurate estimate of the potential sustainable production of primary energy from the forest estate, than is now available. This production we think, should be seen in terms of satisfying a definable part of the nation's energy demands and suggest that the amount of energy used by the potentially dependent forest industry could be a guide. The next step would be to explore the feasibility of extracting and converting the residues. In this context, it might be worth concentrating research on assessing whether or not it would be possible to supply energy directly to the forest industries. In order to accomplish this it would be necessary to formulate co-operative projects, involving both the forestry and engineering professions.

The approach suggested would lead to a greater efficiency in the exploitation of the State forest resource and may produce an almost self-sufficient forest industrial sector in terms of energy and raw material supply. The industry should, in turn, be able to provide the country with much of its industrial wood needs for the forseeable future.

## Acknowledgements

Acknowledgement is expressed to the Research Foresters who assisted with the field work: Mr. W. B. Luddy, Mr. W. F. Collins and Mr. J. I. Kilbride.

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