# *Eucalyptus* in the British Isles*.*

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## Summary

Eucalypts have been planted successfully in Great Britain and Ireland since the mid nineteenth century. While most of the seven hundred species of eucalypts are not suited to the relative cold of the climate of the British Isles, trials in Britain and Ireland have shown that certain species and subspecies can grow successfully. Further, some eucalypts are the fastest~~rs~~ growing trees in the British Isles with mean annual increments of between 25 $m^3$/ha/year and 38 $m^3$/ha/year being reported. Rapid development of a wood biomass energy sector has encouraged a reassessment of the potential of eucalypts grown on short rotations as a source of energy. This article describes the history of eucalypts in the British Isles and their potential.

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## Introduction

Eucalypts~~,~~ have been widely planted, with an estimated 13 million ha worldwide (AFOCEL 2004). Of the seven hundred species (Poke et al, 2005), it is only a relatively small proportion that are adapted to temperate climates, such as that of the British Isles. If the position of British Isles in the Northern Hemisphere is compared with that of Australia in the Southern Hemisphere (Figure 1), it is apparent that only eucalypts from the extreme south of Australia and then those from colder areas, such as *Eucalyptus gunnii* (Hook. f.) and *Eucalyptus nitens ((Deane and Maiden) Maiden)* are likely to be suited to the British climate. Most of the *Eucalyptus* species in the British Isles have been introduced in a sporadic and speculative manner, without consideration of matching climates in their home ranges with those of parts of the British Isles. This has meant that the majority of species introduced have exhibited poor survival and growth. However, it is clear that there is a restricted range of eucalypts that will survive the extremes of cold and the frequency of unseasonal frosts that are part of the climate of the British Isles and further can also produce attractive yields. When examining the potential and site limitations of specific eucalypts, one difficulty is that they have only been planted in a limited number of locations and over small areas. Also, many of these plantings have established in collections in arboreta situated in parts of the British Isles with a milder climate.

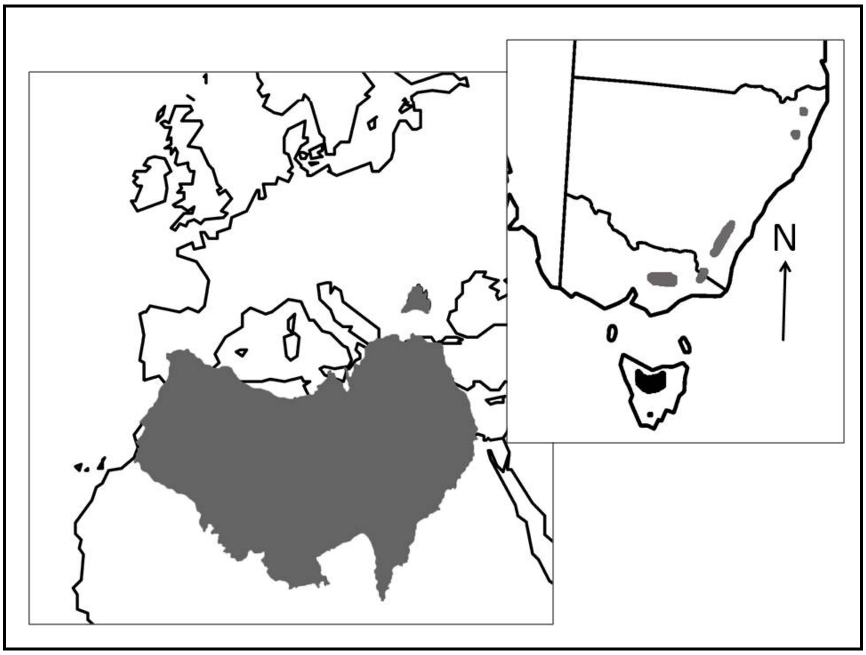


Figure 1 Main figure. Comparison of latitude and area of Europe and Australia (adapted from Turnbull and Eldridge1983). Insert on the top right. ~~and showing t~~The natural distribution of *Eucalyptus gunnii* ~~(black)~~ and *Eucalyptus nitens* ~~(grey)~~ in southern Australia are given in black and grey, respectively (Brooker and Kleinig 1990).

Eucalypts have certain traits that make them particularly suited to planting for biomass or bulk fibre production, such as rapid growth, broad site tolerances and moderate wood density. Interest in using eucalypts as a source of biomass for energy has increased in recent years in the British Isles, particularly in Great Britain. In Britain, incentives for adoption of renewable sources of energy, such as Renewable Obligation Certificates, promote the use of renewable energy sources and particularly biomass crops. Two recently proposed schemes supporting renewable energy in Britain are likely to have a positive impact on the financial viability of biomass as a fuel: the Renewable Heat Initiative (Pigot 2009) and the earlier Low Carbon Buildings Programme, both of which will support small-scale generation of electricity. Over 2009 there have been a considerable number of proposals for biomass power plants, including Drax power which is further developing its co-firing capacity and establishing dedicated biomass plants. It is estimated that by 2017 Drax will need 6.2 million tons of wood pellets or equivalent biomass per year (Forest Energy Monitor 2009). In Ireland the Biomass Energy Scheme supports planting of willow and *Miscanthus*, covering 50% of establishment costs (Bioenergy Site 2008), while support is also available for installation of facilities to produce electricity and heat from renewable sources through the REFIT (Renewable Energy Feed In Tariff) programme (Department for Communications, Energy and Natural Resources, 2009). This paper aims to provide a history of eucalypts in the British Isles, highlighting those species that are suited to the climate and productive enough to have potential as a source of wood fibre. It ends with a prediction of the future role of eucalypts in forestry in the British Isles.

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## The early history of eucalypts in the British Isles

Eucalypts were first introduced to Europe from material collected by Furneaux during Captain James Cook's second voyage to Australia in 1774. It is likely that the first species raised in Britain, at Kew Gardens was *Eucalyptus obliqua* (L'Hérit)~~.~~ from New South Wales (Aiton 1789). By 1829 *Eucalyptus globulus* (Labill.) was being cultivated in continental Europe, while by 1838 it had been introduced to the Scilly Isles (Martin 1950). There is some disagreement as to which was the first eucalypt planted in open air in Britain. Elwes and Henry (1912) describe *E. gunnii* as being the first species grown in Britain in the open, being a tree planted at Kew Gardens. This was 20 feet (6 metres) tall by 1865 (Smith 1880 in Elwes and Henry 1912). However, the first successful planting of a eucalypt is often attributed to ~~that planted by~~ James Whittingehame in East Lothian, Scotland probably in 1852 (Elwes and Henry 1912) ~~-~~from seed collected by James Balfour from Mount Wellington Tasmania, (University of Sydney, no date). The tree survived even the severe frost of 1894 and was still alive as a large tree in 1961 (MacLaggan Gorrie 1961). The identity of the tree has been debated, being identified as *Eucalyptus gunnii* (McDonald et al 1957), as a hybrid~~s~~, probably with *Eucalyptus urnigera* (Hook.f) (Elwes and Henry 1912, MacLaggan Gorrie 1961), or as pure *E. urnigera* (University of Sydney no date). Progeny of the Whittingehame eucalypts have been planted widely, including in Kew, London and Kingloch Hourn, Inverness, where they were still growing in good health in the 1960's (McLaggan Gorrie 1961). Trees from some other early plantings still survive in Britain. Purse (2005) describes the healthy condition of the remaining trees of a 1887 planting of *E. gunni,* at Brightlingsea, Essex. These were planted from seed sent from Argentina (Elwes and Henry 1912) and ~~-~~have survived many severe winters including that of 1962/1963 when the sea near the town froze (Purse 2005). In Ireland the first planting of eucalypts also dates from Victorian times and a large *E. globulus*, planted in 1856 was still alive in 1983 (Evans 1983).

During the 1870's and 1880's, the planting of *E. globulus* became fashionable in Europe, especially in the Mediterranean due to its fast growth and the mistaken belief that the tree and extracts derived from it had anti-malarial properties. This interest in eucalypts spread to the British isles and even *E. globulus*~~-~~, a relatively cold intolerant species, was planted and while generally not suited to the British climate one planted at Garron Tower, Northern Ireland still survived in 1961 (MacLaggan Gorrie 1961) Many other species were planted during the $19^{th}$ century and early $20^{th}$ ~~twentieth~~ century, and there were probably over thirty species in the British Isles at the beginning of the $20^{th}$ ~~twentieth~~ century (McDonald et al 1964). Plantings were particularly successful in warmer areas of Britain, such at Kilmun Arboretum in Argyll, where 21 species still grow succesfully (Evans 1980). Despite this interest, it is likely that in the $19^{th}$~~nineteenth~~ century, eucalypts were rare trees in Britain.

Over the decades of the $20^{th}$ ~~twentieth~~ century, there were many reports of the potential of eucalypts as a tree for wood production (Elwes and Henry 1912, Forbes 1933, McDonald et al 1964, Barnard 1968, Marriage 1971) particularly of the attractive growth rates that could be obtained. However these authors also noted the limited range of species that could survive the extremes of cold experienced in the British Isles. Some species were noted for their cold-tolerance; for example, a survey, undertaken after a particularly severe late frost in May 1935, that caused widespread damage to trees across Britain including native species, described certain species of eucalypt, notably *E. gunnii* and *Eucalyptus coccifera* (Hook f.), as being undamaged (Forestry Commission 1946).

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In Ireland important collections of eucalypts were established between 1908 and1910 at Mount Usher and nearby at Avondale Forest in County Wicklow and also in Northern Ireland at Castlewellan in County Down (Evans 1983). Between 1925 and 1961 experimental plots of eucalypts were established in Ireland and growth of several species was promising in the mild Irish climate, notably *Eucalyptus viminalis* Labill, *E. urnigera*, *Eucalyptus johnstonii* Maiden, *Eucalyptus*~~.~~ *delegatensis* RT Baker and *Eucalyptus dalrympleana* Maiden. A detailed presentation of results can be found in Neilan and Thompson (2008) and selected growth and survival data from a trial established in 1935 is presented in Table 1 to indicate the high growth rates that have been achieved.

Table 1: Growth of selected species and trial sites from plantings from 1935 at Glenealy, County Wicklow, planted at 1.8m x 1.8m spacing (Neilan and Thompson 2008). Notes: [1] “mountain” provenance as coastal provenance did not survive, [2] from a 1934 trial at the same site, with 11 year, 21 and 24 year results.

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| | **% survival** | **Height (m)** | | | **Dbh (cm)** | | |
|---|---|---|---|---|---|---|---|
| Species | 10 yr | 10 yr | 20 yr | 23 yr | 10 yr | 20 yr | 23 yr |
| *E. viminalis*[1] | 74 | 3.7 | 12 | 13 | 2.5 | 14.6 | 10.8 |
| *E. urnigera* | 96 | 4.8 | 16 | 18 | 3.8 | 14.6 | 12 |
| *E. johnstonii* | 98 | 7.8 | 18 | 21 | 7 | 12.1 | 15.2 |
| *E. delegatensis* | 100 | 4.9 | 14 | 16 | 5.1 | 14.6 | 15.2 |
| *E. dalrympleana* [2] | 100 | 4.9 | 14.8 | 17.5 | 7 | 15.2 | 17.8 |

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Other work in Ireland provided evidence supporting the use of eucalypts as fast growing sources of biomass. The quadrupling in price of oil in 1973 reinvigorated interest in wood as a potential fuel in Ireland. McCarthy (1979), reporting on two years of growth in a series of biomass trials across four sites in Ireland of conifers and broadleaved species, noted that the one eucalypt, *Eucalyptus johnstonii* Maiden. was a promising candidate for biomass production, except on a blanket bog site.

An assessment made in the 1976/1977 of amenity plantings on the Devon/ Dorset border, established between 7 and 30 years earlier provided interesting results on the merits of thirteen species of trees as a source of fuel wood (Marriage 1971). The trees tested included six eucalypts, *Eucalyptus cordata* (Labill.), *Eucalyptus delegatensis* (RT Baker), *Eucalyptus glaucescens* (Maiden & Blakely), *Eucalyptus gunnii, Eucalyptus macarthuri* (Deane & Maiden) and *Eucalyptus regnans* (F. Muell.). All of the eucalypts grew faster than the trees of other genera, including *Fraxinus excelsior*.L, *Nothofagus obliqua* (Mirb.) Bl., *Pinus pin*aster (Ait.), *Pinus radiata* (D. Don) and *Populus* X *robusta* (Schneid) (Marriage 1971). Indeed, Marriage (1971 p203) ends the article “in 10 years [eucalypts] will produce as much wood as ash in 30 years”.

In 1981 the Forestry Commission established a series of formal trials across nine sites (Figure 2, Table 2) to identify species and origins adapted to the British climate. Species included in these trials were selected on the basis of observations from plantings in arboreta, gardens and the few existing experimental plots (Evans 1980) that showed some eucalypts exhibited attractive attributes for production forestry, particularly:

- That they will attain large dimensions; growing to at least 20m in height

- And that they grow rapidly in their early years (1-2m height growth per year in the first ten years)

The species tested comprised sub-alpine species from temperate south-eastern mainland Australia and Tasmania.  The winter of 1981/82 proved to be one of the harshest in decades which was fortuitous in that it eliminated from consideration species that were not suited to the extremes of the British climate (Evans 1983; Evans 1986). The results supported previous observations that some eucalypts were sufficiently frost-hardy to survive extremely cold climatic events in the UK. In 1984/85 there was another severe winter and so by 1986 it was clear which species could be planted successfully in Britain (Evans 1986).  This eliminated a large number of potential species and seed origins but three species; *E. gunnii*, *E. pauciflora* ssp *niphophila* and *E. pauciflora* (Sieb. Ex Spreng.) ssp *debeuzevillei*  (Maiden L Johnson & D Blaxell) were noted to be sufficiently frost hardy for British conditions (Evans 1986). On the thre sites that were exposed to the coldest temperatures during the winter of 1981/82 (Alice Holt, Thetford and Wark) every species was killed except *E. pauciflora* ssp *debeuzevillei*, *E. pauciflora* ssp *niphophila* and *E. gunnii*. Further, the origins that had survived were the same, providing useful information on populations suited to the extremes of the British climate.

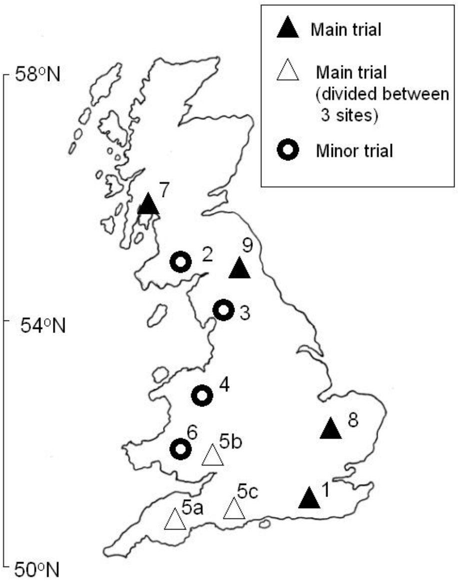


Figure 2: Sites of main eucalypt trials established in the 1980's in Great Britain.
1 = Alice Holt, 2 = Dalmacallan, 3 = Dalton, 4 = Dyfnant, 5a = Exeter, 5b = Tintern, 5c = Wareham, 6 = Glasfynydd, 7=Glenbranter, 8=Thetford, 9 = Wark. (Evans 1986)

| Site No. | Location | National Grid Reference | Region of Britain | Altitude (m a.s.l) | Minimum temperature (ºC) | |
|---|---|---|---|---|---|---|
| | | | | | Dec 1981 | Jan 1982 |
| 1 | Alice Holt | SU988303 | SE England | 60 | -14 | -19 |
| 2 | Dalmacallan | NX703964 | S Scotland | 320 | -16 | -19 |
| 3 | Dalton | SD453880 | Lake District | 65 | -12 | -12 |
| 4 | Dyfnant | SH940169 | N Wales | 500 | -11 | -13 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 5a | Exeter | SX882827 | SW England | 170 | -6 | -7 |
| 5b | Tintern | SO529052 | SE Wales | 222 | -12 | -16 |
| 5c | Wareham | SY883927 | S England | 30 | -10 | -12 |
| 6 | Glasfynydd | SN860228 | S Wales | 440 | -10 | -14 |
| 7 | Glenbranter | NS094965 | W Scotland | 140-220 | -11 | -16 |
| 8 | Thetford | TL800900 | E Anglia | 15 | -20 | -18.5 |
| 9 | Wark | NY794789 | NE England | 210 | -17 | -23 |

Table 2 Details of the trial sites established in the 1980~~'~~s and minimum temperatures in December 1981 and January 1982 (Evans 1986)

In 1985 a further set of trials was established across three of the original sites ranging from the lowlands of southern England to an upland site at Wark, near Kielder (Figure 2, Table 2) to test the growth and survival of snow gums; subspecies of *E. pauciflora* and a few other species, such as *E. camphora* (RT Baker), *E. perriniana* (F. Meull ex Rodway), *E. stellulata* (Sieb ex DC) and *E.viminalis*. These followed on from trials using large plots of *E. pauciflora* ssp *niphophila* and *E. pauciflora* ssp *debeuzevillei* ~~-~~that were established at four sites in 1983 and which had shown reasonable growth and good survival (Evans 1986).

During the 1980~~'~~s research was also conducted to investigate the potential of willows *Salix* spp), poplars (*Populus* spp), alders (*Alnus* spp) and eucalypts for biomass as short-rotation coppice. In trials established in 1981/82 yields of *E. gunnii* ssp *archeri* were comparable to the poplar and willow clones tested (Potter 1990). At a trial established at Long Ashton in 1986, yields from the *Eucalyptus gunnii* was far superior to the ~~Alder~~ alder (*Alnus rubra (Bong)),* the poplar clones and the willow clones (*Salix viminalis (L.)* Bowles Hybrid) in the experiment. Yields from *E. gunnii* ranged from 16 - 22 odt/ha/yr whereas willow, which was the next most productive material produced 7-8 odt/ha/yr (Mitchell *et al* 1993). The reason for the dismissal of eucalypts for short rotation coppice was the susceptibility to silverleaf disease **(***Chondrostereum purpureum* (Pers) Pouzar) following cutting of the stools**.** However the seed used to raise the seedlings of *E. gunnii ssp archeri* was from a single parent and it may be that narrow genetic diversity predisposed the stools to ~~successful~~ attack by this pathogen. It is known that reduced genetic diversity produces less adaptable trees; an investigation of selfing in *Eucalyptus* ~~.~~*globulus* showed poorer growth in the field when compared with individuals that arose from outcrossing (Hardner and Potts 1995). Growing eucalypts as single stems over longer rotations should reduce the damaging impact of silverleaf disease ~~through~~ since the trees ~~being~~ are being cut less frequently.

## The history of eucalypts in the British Isles since the 1980's

Following Evans' (1980, 1983, 1986) work, interest in eucalypts waned, and they were generally dismissed as trees unsuitable for meeting the objectives of production forestry in Britain. Evans (1986 p238) himself commented "until a specific need arises to maximise dry matter per hectare per year, further use of eucalypts … seems unlikely". The introduction of the Broadleave~~sd~~ ~~policy~~ Policy in 1986 favoured native trees and left no role for eucalypts in forestry; while production forestry remained centred on softwood species.

In 1992 and 1993 a new series of trials was established in Ireland, with *E. gunnii* and *E. delegatensis* planted in 1992 and *E. nitens* and *E. delegatensis* in 1993. In a review of eucalypts in Ireland, Neilan and Thompson (2008) report that growth in the trials has been excellent. The potential is illustrated by a comparison of adjacent stands at Cappoquin, County Waterford of *E. nitens* and Sitka spruce (*Picea sitchensis* (Bong.) Carr.), the most commonly planted softwood in Ireland (reference).

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**Commented [mm6]:** I do not understand the argument, since the point above was about selfing. Also, cutting in itself rejuvenate the stools which keeps them in a juvenile, i.e., more vigorous state.

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After 13 growing seasons *E. nitens* had attained a top height of 22.5m and dbh of 26cm, whereas S~~s~~itka spruce achieved a top height of 11.5m and dbh of 11 cm (Neilan and Thompson 2008). Furthermore, If growth after 13 years of *E. nitens* planted in 1993 at 2m x 2m spacing~~,~~ is compared with that from earlier trials, *E. nitens* shows a much greater diameter than that obtained at 23 or in some cases 46 years of age by the other species tested in the trials from the 1930~~'~~s. ~~attained at 23 or in some cases 46 years of age.~~

During the late 1990~~'~~s and early 2000~~'~~s a relatively small group of individuals and oranisations began to investigate the silviculture of eucalypts through small-scale plantings and trials. Companies such as Primabio and Forestry Business Services began to provide advice to private individuals and organisations interested in growing eucalypts for biomass energy. An article by Purse and Richardson (2001) described evidence of fast growth from a range of sites. They reported on a small replicated, privately owned trial, established on a reasonably exposed site at an altitude of 130m above sea level, north of Tiverton, Devon in 1993. Of the species planted *E. nitens* proved to be the most productive, while *E. dalrympleana* (Maiden), *E. fastigata* (Deane & Maiden) and *E. delegatensis* (RT Baker*)* also showed good growth (Purse and Richardson 2001).

Visits were also made by Purse and Richardson (2001) to eight of the Forestry Commission trials in southern England and as far north as Nottingham between 2000 and 2001. It was found that *E. gunnii* and *E. pauciflora* had survived well, while *Eucalyptus nitens* ~~(Deane and Maiden) Maiden~~ and *E. delegatensis* ~~(RT Baker)~~ showed poor survival but rapid growth. Comments were also made on the poor weed control in these trials observed during visits made in 1987. Purse and Richardson (2001) argued that competition between the eucalypts and weeds has reduced their growth and that the trials therefore underestimated the potential of eucalypts in the UK and that the competition would also have heightened damage by frost.

Concern about climate change and also energy security has raised awareness of a possible role for woody biomass as part of the means of meeting the energy needs of the UK (McKay 2006). This encouraged the development of a Strategy for England's Trees, Woods and Forests (DEFRA 2007) which largely ignored the potential of dedicated energy crops such as eucalypts, focusing instead on obtaining wood fuel from under-managed woodlands. It was initially individuals in the private forestry sector that ecognised a potential new role for eucalypts in Britain, grown rapidly on short rotations for energy and using high standards of silviculture (Purse and Richardson 2001). The approach adopted marked a change from the use of short rotation coppice (SRC) because the material produced is single-stemmed and the rotation was longer, being greater than ~~ten~~ 10 years and~~,~~ providing woody material of between 10 and 20 cm diameter at breast height (dbh) (Hardcastle 2006). The approach, known as short rotation forestry (SRF) differs also from SRC in that the material is capable of being harvested using conventional forestry harvesting machinery, whereas SRC is harvested using modified agricultural equipment.

In 2005 Nottinghamshire County Council embarked on an ambitious project to establish an energy forest at Daneshill, on the site of an old munitions works. This comprised a set of experiments and also operational plantings, covering an area of 30 ha. Trials included a species trial, a trial comparing line and intimate mixes of *E. nitens* and *E. dalrympleana* and a comparison of establishment methods. On the whole, early results have been encouraging, with *E. nitens* achieving a height of 8-10 m in four years and *E. gunnii* a height of 8-10 m height over five years (reference). Frost in the first year of planting meant that areas of *E. nitens* needed to be largely

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replanted but the *E. gunni* proved hardy and now there are some fine~~d~~ plantations of the species.

The increasing level of interest in *Eucalyptus* led to further reassessments of Forestry Commission trials from the 1980~~'~~s, such as one at Thetford and Glenbranter. The Thetford results showed the high level of cold tolerance of *E. gunnii*, which had grown and survived relatively well, while all *E. nitens* had been killed by the extremely cold winter of 1981/82 (Bennett and Leslie 2005). Findings from Glenbranter, an *E. gunnii* provenance experiment supported earlier results by Evans (1986) that showed that origins from Lake MacKenzie exhibited superior survival and growth to others (Cope, Leslie and Weatherall 2008). Most recently, a formal assessment of a snow gum trial in Chiddingfold, Surrey showed the main species tested, *E. pauciflora*, to have similar rates of growth to *E. gunnii* and as such, to be much slower growing than *E. nitens*.

Adopting some of the recommendations from a study by Hardcastle (2006), DEFRA supported a series of trials in England of SRF to collect data on establishment costs, yields and environmental impacts, while a similar series of experiments was funded in Scotland by Forestry Commission Scotland. In 2009 three trials sites were planted in England in Cumbria, Devon and Lincolnshire, predominantly with *E. nitens* ~~to collect information on growth rates, establishment costs and also environmental impacts~~. Experiments in Scotland have focused on ash (*Fraxinus excelsior* L.) as a potential wood fuel species (McKay pers comm. 2009). Smaller trials have also been established, for example a trial of SRF species, testing different eucalypts ~~against~~ species, ~~have~~ has been established between 2008 and 2009 at Drumlanrigg, ~~established~~ near Dumfries in 2008 by Buccleuch Estates, at the Penrith Campus of the University of Cumbria, and at Little Sypland, near Kirkubright by UPM Tillhill.

### The future for *Eucalyptus* in the British Isles

In January 2008 the European Union set a target reduction of 20% in greenhouse gas emissions by 2020, compared with levels in 1990 (Poyry 2008). As part of this target, the UK government aims to produce 15% of domestic energy from renewable sources, a ten-fold increase in current levels (Poyry 2008), while in Ireland, the target is a more modest increase to 7.4% of energy from renewable sources from the 2008 contribution of 4.1% (Sustainable Energy Ireland 2009). A study in the UK (TSO 2009) calculated that using biomass to produce heat is the cheapest way of increasing the proportion of renewable energy. Further, wood fuel is more attractive than some other sources of renewable energy as the technology that is already tried and tested and it has the capacity to meet peaks in demand for heat and electricity. A report on the role of forests in the UK on combating climate change estimates that emissions of as much as 7 MT $CO_2$ could be avoided by the substitution of fossil fuels with wood fuel (TSO 2009). The increase in the number of ROCs (Renewable Obligation Certificates) for energy generated from dedicated biomass crops and the announcement of a RHI (Renewable Heat Initiative) should make the use of woody biomass energy crops more attractive when producing heat. In Ireland the White Paper on sustainable energy (Department of Communications, Marine and Natural Resources 2007) states that combined heat and power, particularly using biomass will contribute 400MW of energy by 2010 and 800MW by 2020.

If woody biomass crops are to be used more widely as a source of energy in the UK and Ireland then eucalypts are likely to play an important role due to their high productivity. Evans (1980) considered *E. nitens* to be possibly the fastest growing tree in Britain and subsequent findings support this assessment, with reports of mean annual increments of 37 $m^3$/ha/yr at rotations of 8 years (Purse and Richardson 2001). Even slower growing species, such as *E. gunnii* are reported to attain mean annual increments of 25 $m^3$/ha/yr on rotations of 11-12 years (Jones pers. comm., in Purse and Richardson 2001).

In general there can be an inverse relationship between cold-tolerance of commonly planted eucalypt species and their growth rates, for example *E. nitens* is considerably faster growing than *E. gunnii* yet is also more susceptible to damage during cold periods, particularly those that are unseasonal. This is illustrated in Figure 3, which shows estimates of annual height growth and the minimum temperatures that can be tolerated when hardened by eucalypt species that have been planted successfully in Britain and Ireland. As such, it is crucial that our understanding of the site limitations of the different species is refined, particularly the risks from extreme climatic events, notably extremely cold winters such as 1963/4, 1981/2 and 2009/10. While there is evidence that a number of species have grown successfully across a range of plantings, to date *E. gunnii* and *E.nitens* are the two most widely established species under plantation conditions. *E. nitens* has proven to be the most productive of the species tested and is an obvious choice for warmer sites with good rainfall. It also has the attraction of being extensively planted elsewhere so its silviculture is well understood. However *E. gunnii*, although slower growing and palatable represents a lower risk to damage by climatic events as it can tolerate longer periods of more intense cold and also is little affected by waterlogging of soils (Kirkpatrick & Gibson 1999). A first attempt to define site requirements within EMIS (Electronic Management Information System) for SRF species, including eucalypts, has been made by Perks and Ray (in draft).

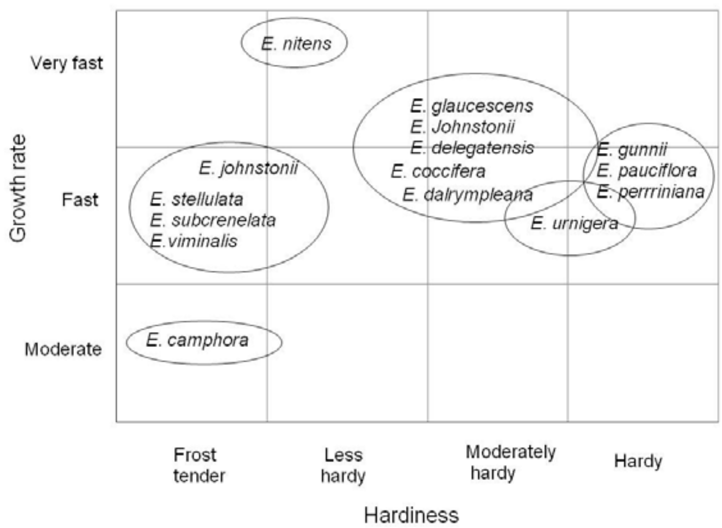


Figure 3: Height growth and minimum temperatures tolerated (when hardened) by different eucalypt species. Growth rates (height): very fast = >2 m/year, fast = 1.5m – 2 m/year and moderate = 1 m – 2 m/year.
Hardiness: less hardy = likely to survive long periods of –6 and short ones of –9ºC, moderately hardy = likely to survive long periods of –6 to –9ºC and short ones of –14ºC,

hardy = likely to survive long periods of –10 to –14$^{o}$C and short ones of –16$^{o}$C and very hardy = likely to survive long periods of –10 to –14$^{o}$C and short ones of –18$^{o}$C. Compiled from information from Brooker and Evans 1983, Evans 1986.

A considerable threat to the adoption of eucalypts more widely is the use of inappropriate genetic material. For several species there is clear evidence of differences between and within origins of cold-tolerant species (Evans 1986) and for some time using cold hardy origins has been recognised as being essential (Barnard 1968, Evans 1986). Evans (1986) describes superior origins of *E. nitens*, *E. gunnii, E. pauciflora*, *E. delegatensis*. However obtaining seed from sources well adapted to the UK climate has proven problematic, for example many of the remaining natural stands of superior origins of *E. gunnii* are found in national parks, which restricts opportunities for seed collection (Jinks pers comm 2009). Recent plantings have relied on nursery stock of unknown or less than optimum origins. There are however promising developments, with Maelor Nurseries importing seed of promising origin directly from Australia and bulking up material through vegetative propagation (Harun pers comm 2009).

The cold winter of 2009/ 2010 clearly highlighted differences in cold tolerance between individuals of *E. nitens* and is supported by the findings of earlier research, e.g., Evans (1986). It is interesting to note that 6-year-old *E. nitens* has survived relatively unscathed at Alcan plantings in Northumbria which were exposed to minimum temperatures of -15$^{o}$C (Purse pers comm. 2010). Variation in cold-tolerance within populations should be exploited. Those individuals surviving on particularly challenging sites might provide a source of material suited to the extremes of the British climate. Evans (1986) recommends this approach and noted that some individuals of *E. gunnii*, *E. pauciflora* ssp *debeuzevillei* and *E. pauciflora* ssp *niphophila* were capable of surviving -23$^{o}$C.

Also some species with intermediate characteristics of *E. nitens* and *E. gunnii*, i.e., faster growth than *E. gunnii* but more frost tolerant than *E. nitens* warrant further investigation. For colder sites, high altitude origins of *E. coccifera,* an unpalatable and frost-tolerant species are recommended for further consideration by Purse (2009a), who also considers *Eucalyptus glaucescens* (Maiden & Blakely), amongst other species, to have potential for biomass production in the British Isles. This species is being tested along with two provenances of *E. nitens* and one of *E. gunnii* in the DEFRA funded trials in England. Neilan and Thompson (2008) recommended *Eucalyptus johnstonii* Maiden as being a species worth of consideration for planting in Ireland. A trial in Exeter showed there to be significant differences in height growth between provenances of E. *johnstonii*~~,~~ (Evans 1986), making provenance selection ~~of origin~~ important.

A further priority is to develop best-practice recommendations for the establishment and management of suitable species. For some species such as *E. nitens* there is considerable information on its silviculture from other countries, while more limited information on growing *E. gunnii* in plantations is available from a planting programme in the Mid Pyren~~n~~ees (AFOCEL 2003).

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## Conclusions

Eucalypts have been ~~grown in the open~~ planted in the British Isles for over a hundred and forty years. Despite being planted over a relatively narrow range of sites and a restricted area, there are undoubtedly species that are sufficiently frost tolerant to survive severely cold winters across many areas of Britain. Fast growth across a range of sites has meant that many authors have recognised the potential of eucalypts for rapid wood production for pulp (Barnard 1968, Evans 1986) or biomass (Marriage 1977, Hardcastle 2006). There is however a pressing need to identify the potential of species other than *E. nitens* and *E. gunnii* and to define the site limitations and quantify the risk posed by climatic events of the various species. A further priority is to identify best practice in terms of establishment and tending for different species across a range of sites.

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### References

AFOCEL (2003) Information Eucalyptus, Itineraire technique et production. Fiche Information Eucalyptus No.2 - Avril 2003, AFOCEL 4pp.

AFOCEL (2004) Information Eucalyptus, Eucalyptus et environnement. Lettre d'information semestrielle eucalyptus. Numero 3, Vol. 2 Juillet 2004, AFOCEL, France 4p

Aiton, (1789) Hortus Kewensis, Volume 2. p157,scanned complete copy [online] Last accessed on 3 July 2009 at URL:
http://www.botanicus.org/item/31753000624103

Barnard, R.C. (1968) Eucalyptus. Quarterly Journal of Forestry, Vol LXII, No 4. p300-304

Bennett, C.J. and Leslie, A.D. (2003) Assessment of a *Eucalyptus* provenance trial at Thetford and implications for *Eucalyptus* as a biomass crop in lowland Britain. Quarterly Journal of Forestry. Vol 97 No 4 p257 -264

Benson, J.L (1994) Notes on the hardiest Eucalypts. Quarterly Journal of Forestry, Vol 88, No.3. P233-237.

Bioenergy Site (2008) http://www.thebioenergysite.com/news/2400/phase-3-of-bioenergy-scheme-announced

Brooker, M.I.H and Evans, J (1983) A key to the Eucalypts in Britain and Ireland with notes on growing eucalypts in Britain. Forestry Commission Booklet 50. HMSO, London. 31pp

Brooker, M.I.H and Kleinig, D.A. (1990) Field Guide to Eucalypts:.Volume 1, South-eastern Australia, Inkata Press, Sydney. 299pp

Cope, M.; Leslie, A.D. and Weatherall, A (2008) The potential suitability of provenances of *Eucalyptus gunnii* for short rotation forestry in the UK. Quarterly Journal of Forestry, Volume 102, Number 3. p185-194

Department for Communications, Energy and Natural Resources (2009) Renewable Energy Feed in Tariff, Additional, Categories [online] Last accessed on 23 January 2010 at URL:

http://www.dcenr.gov.ie/NR/rdonlyres/3B13ECAA-9351-41E0-8B44-7C02E98E4F50/0/AdditionalREFITcetegories.pdf

Department for Environment, Food and Rural Affairs (2007) The Strategy for England's trees, woods and forests [online] Last accessed on 24 January 2010 at URL: http://www.defra.gov.uk/rural/documents/forestry/20070620-forestry.pdf

Department of Communications, Marine and Natural Resources (2007) Delivering a sustainable energy future for Ireland. The Energy Policy Framework 2007 – 2020. Government White Paper. 68pp. [online] Last accessed on 11 January 2009 at URL: http://www.dcenr.gov.ie/NR/rdonlyres/54C78A1E-4E96-4E28-A77A-3226220DF2FC/27356/EnergyWhitePaper12March2007.pdf

Elwes, H.J. and Henry, A. (1912) The trees of Great Britain and Ireland. Volume 6. R and R Clark Ltd, Edinburgh. pp1612-1651.

Evans, J (1980) Prospects for Eucalypts as forest trees in Great Britain. Forestry Vol 53, No2, p129-143.

Evans, J (1983) Choice of eucalypt species and provenances in cold, temperate, atlantic climates. Collogue International sur les eucalypts au froid. AFOCEL. Nangis. p255-274.

Evans, J (1986) A Re-assessment of cold-hardy eucalypts in Great Britain. Forestry Vol 59, No2, p223-242.

Evans, J., Haydon, L. and Lazzeri, M. (1983) Propagating and planting eucalypts in Britain. Arboricultural Journal, Vol 7. pp137-145. (86)

Forbes, A.C. (1933) Silvicultural value of exotics in Ireland. Quarterly Journal of Forestry Volume XXVII, Number 1. p32-48.

Forest Energy Monitor (2009) The UK plans for a huge expansion in biomass power capacity. Investments and Technology, May 2009 [online] Last accessed 11 January 2010 at URL: http://www.forestenergymonitor.com/current_issue/free/UK_biomass_elec_invest_may09.html

Forestry Commission (1946) Spring Frosts, with special reference to the frosts of May 1935. Bulletin No. 18. HMSO, London. 111pp.

Forestry Business Services (2004) Nottinghamshire County Council, Daneshill Energy Forest. Formal Research. Draft report. 21pp. (92)

Forrest, M and Moore, T (2008) Eucalyptus gunnii: A possible source of bioenergy? Short communication. Biomass and Bioenergy. Vol 32, No 10. pp 978-980

Halliwell, B. (1974) Eucalyptus. The Arboricultural Association Journal 2. P197-204. (67)

Hardcastle, P.D. (2006) A Review of the impacts of short-rotation forestry. LTS International [online] Last accessed on 27 June 2007 http://www.forestry.gov.uk/pdf/SRFFinalreport27Feb.pdf/$FILE/SRFFinalreport27Feb.pdf

Hardner, C.M. and Potts, B.M. (1995) Inbreeding depression and changes in variation after selfing Eucalyptus globulus subsp. globulus. Silvae Genetica 44, p46-54.

Harun, I. (2008) pers.com. Nurseryman, Maelor Nursery, phone call of 17 July 2008 on importation of seed of superior origins.

Jinks, R. (2009) pers comm., Project Manager, Centre for Forest Resources and Management, Forest Research. meeting at Chiddingfold eucalyptus trial, 16 April 2009.

Kirkpatrick, J.B and Gibson, N (1999) Towards an explanation of the altitudinal distributions of three species of Eucalyptus in central Tasmania. Australian Journal of Ecology 24, p123-131.

Leslie, A.D. (2008) Short rotation forestry: goose that lays the golden eggs or dead duck? Forestry and Timber News, September 2008. p14,16h

Marriage, A. (1977) Fast-growing firewood. Quarterly Journal of Forestry, Volume71. P199-203.

Martin, D. (1950) Eucalyptus in the British Isles. Journal of the Royal Horticultural Society, Vol LXXV, part 5 p186-189.

McCarthy, R. (1979) The energy potential of forest biomass in Ireland. Irish Forestry Vol 36, No 1. p7-18.

McDonald, J: Wood, R.F.; Edwards, M.V. and Aldhous, J.R. (1964) Exotic Forest Trees in Great Britain. Paper prepared for the Seventh British Commonwealth Forestry Conference, Australia and New Zealand. Forestry Commission Bulletin No 30. Third impression with amendments. 67pp.

McKay, H (2006) Environmental, economic, social and political drivers for increasing use of woodfuel as a renewable resource in Britain. Biomass and Bioenergy 30, p308-315.

McKay, H. (2009) personal communication. Meeting at Northern Research Station, Forest Research on 20 October 2008.

McLaggan Gorrie, R. (1961) The Whittingehame Eucalyptus. Scottish Forestry, Volume 15, No 4. p218-219.

Mitchell, C.P.; Ford-Robertson, J.B. and Waters, M.P. (1993) Establishment and monitoring of large scale trials of short rotation coppice for energy. ood Supply research group, Department of Forestry, University of Aberdeen. 76pp plus Appendices.

Neilan, J. and Thompson, D. (2008) Eucalyptus as a potential biomass species for Ireland. COFORD Connects, Reproductive Material No.15. COFORD, Ireland. 8pp.

Perks, M. and Ray, D. (in draft) Eucalypt species cold tolerance assessment after initial freezing and application of expert knowledge for species suitability advice. Draft paper.  13pp.

Pigot, R. (2009) Renewable Heat Incentive is coming.  Forestry and Timber News, June 2009. p15.

Poke,F.S., Vaillancourt, R.E., Potts, B.M. and Reid, J.B. (2005) Genomic research in *Eucalyptus*. Genetica 125. p79-101.

Poyry, (2008)  Implications of the UK meeting its 2020 Renewable energy target. A report to WWF-UK and Greenpeace UK, August 2008[online] Last accessed on 27 December 2009 at URL:
http://assets.wwf.org.uk/downloads/poyry_2020renewablestarget.pdf

Purse, J.G. and Richardson, K.F. (2001) Short rotation single stem tree crops for energy in the UK- an examination with Eucalyptus. Aspects of Applied Biology, No. 65, 2001, Biomass and Energy Crops II, p.1-8

Purse, J.G. (2005) Brightlingsea's eucalypts - A brief summary by John Purse [online] Last accessed on 6 May 2009 at URL:
http://www.primabio.co.uk/docs/Brightlingseaeucs.pdf

Purse, J.G. (2009a) Notes on visit to FR St Clement 1 p53 eucalyptus trial, Truro, 12th March 2009, dated 20 March 2009. unpublished report. 5pp.

Purse, J.G. (2009b) Notes on visit to FR New Forest 38 p80 eucalyptus trial, 13th March 2009, dated 19 March 2009. unpublished report. 6pp

Purse, J.G. (2009) personal communication.  E-mail of 10 November 2009 with attached Excel spreadheet: CCF nitens_sept2009_summary.xls

Purse, J.G.(2010) pers comm.  RE: Eucalypts at Alcan, E-mail of 3 June 2010

Purse, J.G. (no date) Eucalyptus species with biomass potential for the British Isles [online] Last accessed on 1 July at URL:
http://www.primabio.co.uk/bm_sppbiomasspotential.htm

Sustainable Energy Ireland (2008)
http://www.sei.ie/News_Events/Press_Releases/BioEnergy_Release_Final.pdf

Sustainable Energy Ireland (2009) Energy Forecasts for Ireland to 2020. [online} last accessed on 27 December 2009 at URL:
http://www.sei.ie/Publications/Statistics_Publications/Energy%20Modelling%20Group/Energy_Forecasts_for_Ireland_to_2020.pdf

TSO (2009) Combating climate change: A role for UK forests. The synthesis report. The Stationery Office, Norwich.17pp.

Turnbull, J.W. and Eldridge, K.G. (1983) The natural environment of eucalyptus as the basis for selecting frost resistant species in Colloque International sur les eucalypts au froid, 26-30 Septembre 1983, Bordeaux, France, AFOCEL, Nangis. p43-62.

University of Sydney (no date) Critical revision of the genus *Eucalyptus*, Volume 2: Parts 11-20, *Eucalyptus urnigera*, Hook. f. [online] Last accessed 3 July 2009 at URL: http://setis.library.usyd.edu.au/pubotbin/toccer-new?id=mai.p00109v2.sgml&images=acdp/gifs&data=/usr/ot&tag=botany&part=69&division=div1