Use of short or medium rotation forests of eucalyptus species can provide a biomass resource in the medium term, to supplement residues and other material from plantation pine forests, building to a large scale supply of biomass for bioenergy beyond 2025.

Promising resources and systems for producing bioenergy feedstocks

Eucalypts
New Zealand

IEA Bioenergy

IEA BIOENERGY Task 43:2011:01

Eucalypts, New Zealand

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Summary report

Key Messages

Radiata pine is likely to remain the primary species for timber and bioenergy purposes in New Zealand. However, other species also have a role to play, not only in domestic firewood production, but also as a feedstock for bioenergy plants which may be relying on other providers for material.

Currently, the preferred species currently planted for production of short fibre pulp are *E. fastigata* (North Island) and *E. nitens (South Island)*. These species are also likely to be part of any bioenergy forest plantations.

Further research is required to widen the data base on alternative species for bioenergy production. In particular, there is a need to evaluate species that have high wood density and high to moderate volume growth rates for biomass purposes.

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Cover picture – Eucalyptus nitens, Southland, New Zealand

EXECUTIVE SUMMARY

New Zealand has an abundant supply of softwood from extensive (1.75 million ha) of plantation forests, 89% of which is *Pinus radiata*. This resource has an uneven age class distribution leading to peaks and troughs in log and biomass supply.

In order to build on this supply and to get a more evenly distributed biomass / bioenergy resource, forests grown on an intermediate length rotation (10 to 15 years) are required. Achieving a consistent supply of biomass will be fundamental to attracting investment in bioenergy infrastructure.

Whilst building this resource could be done with *Pinus radiata* it has a comparatively slow early growth rate in its typical rotation length (28 to 32 years) and other species which have more rapid early growth need to be considered.

There have been a number of trials of *Eucalyptus* and other hardwood species over a number of years and a wide range of sites. Some of these species have been grown on a commercial basis, with varying success.

Here we present a summary of the data from these trials and conclude the species with the most potential for biomass production from short to medium rotation (10 to 15 year rotations) are *Eucalyptus fastigata* in the North Island and *Eucalyptus nitens* in the South Island.

Growing costs (estimated at $28 per tonne) are similar to those for longer rotation softwood plantations. Whilst the rotation is much shorter the establishment costs are higher due to higher planted stockings, and the harvest volume is reduced.

Harvesting costs are also expected to be similar to those for current conventional logging ($25 tonne for ground based logging and $32 per tonne for cable systems on steep terrain).

Transport costs will be the same as for current log transport ($18 per tonne assuming an average transport distance of 75 km) as the same infrastructure will be used.

Further species and siting trials are required to refine the siting / species matching and broaden the species options.

INTRODUCTION

Considerable biomass research has been conducted in New Zealand, particularly the partitioning of material from radiata pine (*Pinus radiata*) trees. However radiata pine is not regarded as a preferred biomass species for purpose-grown energy crops because of its slow initial growth rate compared with some other introduced tree species (*Eucalyptus* and *Acacia*) which perform well in New Zealand conditions.

Despite these species limitations pine residues are likely to provide the bulk of feedstock for any bioenergy system in New Zealand in the short term, because of the size of the radiata pine resource, approximately 1.6 million hectares (89% of the ~1.75 million hectare plantation forest estate) and the subsequent volume of in-forest residues (approximately 2.0 million cubic metres (0.84 million odt) per annum.

Interest in alternative species to radiata pine for bioenergy are based on the fast initial growth rate of species from several hardwood genera, and the strategic need for a purpose grown bioenergy crop as part of a bioenergy system.

There is also some concern over the mono-cultural nature (and associated biological risks) of New Zealand's current plantation forest estate. Some of these genera, particularly *Eucalyptus*, have been established to produce short fibre pulp in New Zealand. In recent years *E. nitens* has been the species most commonly planted. Other species planted, largely for pulp fibre production are *E. fastigata* and *E. regnans*.

Background

Hardwood biomass research in New Zealand has been conducted sporadically since the early 1980s, with the most effort in the mid 1980s. Research on SRC willow has been pursued since 2005.

In the 1990s researchers at Forest Research (now called Scion) conducted biomass studies on *E. saligna*, *A. dealbata* and *E. nitens*. Nearly all the early evaluations were one-off studies of forest stands and as such have seldom represented stands designed for optimum biomass production.

Studies more relevant to energy forests have also been conducted, such as the *E. saligna* study based on sampling from a Nelder spacing trial at age 9 years. This has provided an excellent analysis of the effect of spacing on productivity.

Massey and Lincoln Universities have also conducted a range of biomass studies. Massey University has established long-term bioenergy trials, including a coppicing study superimposed on a Nelder trial with *E. saligna*, and repeated harvest of a species trial. At Lincoln University, biomass evaluations have been conducted on *E. ovata* and *E. nitens* Nelder trials.

Researchers involved in effluent studies have also conducted studies on biomass productivity.

Commercial plantations of *Eucalypt* and *Acacia* species have been sporadic, one the more successful has been the *Eucalyptus nitens* plantations in Southland and Otago, which are grown on a rotation of approximately 15 years, with the market being hardwood chip (for export).

Drivers for Short Rotation Forests - Eucalypts

New Zealand's timber harvest is almost exclusively (99.9% of 21 million cubic metres, 2009) from plantation forests of introduced species (*89% Pinus radiata*). We have good national datasets on area, age class, regimes, yields and replanting intentions and so it is possible to look ahead at least 30 years and predict with confidence the volume of timber available for harvest. An estimate of volume by log-grades and the amount of harvest residues is also possible. What a simple look at this data (Figure 1) tells us is that we face a large increase in harvestable volume over the next 10 to 15 years, followed by a decline.

Given the rotation ages currently used, planting more *Pinus radiata* grown on a 28 to 30 year rotation will not be able to fill in the decline in supply post 2025. However, eucalypts or similar fast starting species grown on 15 year rotation would be able to make a contribution to fibre supply post 2025, assuming planting was start in the next year or so.

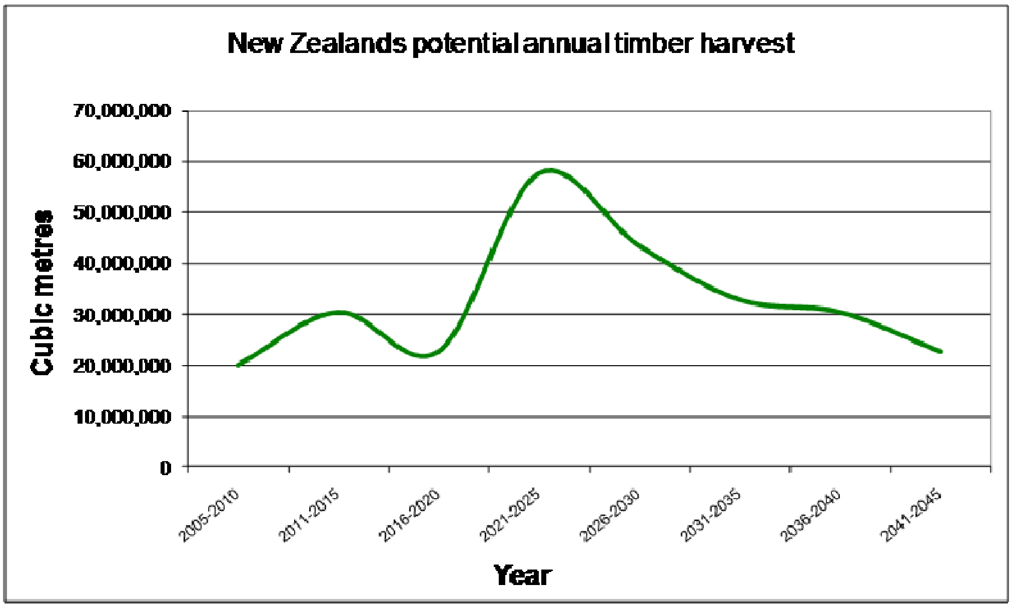

Figure 1.Potential national wood supply, New Zealand, 2005 to 2045

Growth rates

Considerable growth and yield information has been collected in New Zealand for the main species grown for short fibre pulp requirements, particularly *E. nitens*. This has been used to develop a preliminary *E. nitens* growth model incorporating New Zealand and Tasmanian data (H. McKenzie pers. comm., 1998).

A national series of *E. nitens* regime trials to evaluate stocking effects, planted in 1990, are also providing excellent data for the Forest Research/Industry Management of Eucalypts Co-operative (Figure 2).

Figure 2. *Eucalyptus nitens* regime trial, age 14 years, Otago, New Zealand

Data from one of these trials in the Central North Island shows that at age 7 years, across a stocking range of 2400 - 1100 stems/ha, total stem production can range from 297 - 194 m^3/ha, equivalent to mean annual increment values of 42 - 28 m^3/ha/yr. These figures indicate why *E. nitens* is considered the main candidate for short fibre pulp production and for bioenergy in New Zealand. In cold regions of other temperate countries where *E. globulus* is less successful, *E. nitens* has also become a favoured species. However, commercial scale plantings of E nitens in the Bay of Plenty regions were not successful, with many stands suffering from insect and fungal attack after they moved to adult foliage at around age 6 to 7. The consequence of theses attacks is very poor health and growth. Therefore the preferred Eucalypt species in the North Island are *E. fastigata, E. regnans, E. saligna and E. maidenii* (Nicholas and Hall 2009).

Recent harvests of *E. Nitens* in Southland have shown final crop volumes of 260 to 270 m^3/ha (at age 14 to 16), indicating a mean annual increment (MAI) of 17 to 18 m^3 per ha. Whilst this may not appear high, the crop was grown to maximise stem volume for chip production rather than gross biomass and this is the MAI at age 15.

In New Zealand the most common species grown, *Pinus radiata* would have an MAI of 22 to 26 m^3 per ha at age 28 to 30 and at age 15 the MAI would likely be similar to that of the *E. nitens* , depending on the management of the stocking.

To date, little information has been collected for other bioenergy species in New Zealand, including *Acacia* species and poplars.

Short rotation coppice (SRC) willows have been trialled (now age 4) and productivity data is developing from biomass sampling. Indicative productivity levels on favourable sites are 17 to 18 odt per ha per annum. On less favourable sites (cooler or with limited summer rainfall) productivities of 10 to 12 odt/ha per annum are more likely.

Summary of Eucalypt Biomass Studies

The published reports on eucalypt biomass production in New Zealand are summarized in Table 1. A wide range of stand ages and species have been assessed.

Biomass studies incorporating time or spacing variations have been established for two species, *E. saligna* and *E. regnans*. However, for *E. regnans* the studies were based on stands which had been thinned for pulp production rather than stands designed for maximum productivity for bioenergy purposes.

Nearly all this data, is from one-off studies which come from different sites, have different spacing, and different management regimes. These studies have also tended to reflect the favoured forestry species at the time rather than reflecting interest in bioenergy.

The data in table one shows a range of *Eucalyptus* species and sites that have MAI's that are high in comparison to industry standards.

The site pictured in figures 3 and 4 is an *E. maidenii* stand. It received municipal waste water from underground pipes, providing irrigation and nutrition.

Table 1. Eucalypt biomass studies (* coppice, ** Initial planting density)

Species	**MAI #** **odt/ha/yr**	**Age** **yrs**	**Stocking** **stems/ha**	**Volume** **m³/ha**	**MAI** **m³/ha/yr**	**Reference #~**
E. saligna	21	2.6	5000	-	-	1
E. saligna	15	3.2	6013	-	-	1
E. saligna	16	8	829	-	-	1
E. saligna	17	9	1064(1111**)	214	24	2
E. saligna	18	9	1383(1457)	238	26	2
E. saligna	20	9	1807(1924)	264	29	2
E. saligna	21	9	2366(2551)	292	32	2
E. saligna	23	9	3088(3380)	321	36	2
E. saligna	24	9	3990(4444)	345	38	2
E. saligna	24	9	5127(5827)	362	40	2
E. saligna	20	9	6206(7694)	325	36	2
E. fastigata	15	4	7250	-	-	1
E. regnans	15	4	2050	103	26	1
E. regnans	27	7	1850	371	53	1
E. regnans	30	10	1075	537	54	1
E. regnans	21	13	1300	542	42	1
E. regnans	26	17	1250	854	50	1
E. nitens	20	4	6470	-	-	1
E. nitens	15	5	1675	-	-	1
E. nitens	14	6*	1317(4873)	-	-	1
E. maidenii	28	4	3000	196	49	3

~ 1. Shula *et al.*, 1989; 2. McKenzie & Hay, 1996; 3 Nicholas unpublished

Figure 3. One of the most productive eucalypt bioenergy sites assessed in New Zealand, Waihi Beach, Western Bay of Plenty, *E. Maidenii*

Figure 4. Inside a *E. maidenii* bioenergy crop, age 4 years, Bay of Plenty, New Zealand.

In 2009 a review of species productivity (Nicholas and Hall) was carried out using the national data set derived from the Permanent Sample Plot (PSP) system. Through a combination of stem volume growth and wood density, an estimate of potential productivity (and a ranking) of each species was derived from averaging the top five PSP sites for the species with data available, the top ten *Eucalyptus* species were identified (Table 2). *Pinus radiata* (based on the best productivity (pre-harvest) is competitive with all Eucalyptus species. It should be noted that these figures represent the likely maximum productivity, not the average that occurs.

Table 2. Potential bioenergy species profiles, ranked by stem wood biomass productivity

Species	Stem volume MAI m^3/ha/yr	Basic wood density (kg/m^3)	Stem wood oven dry tonnes/ha/yr	Mean Age of Plots
P. radiata	60.1 - 63.8	420	25.2 - 26.8	19
E. fastigata	46.0	500	23.0	12
E. nitens	42.5	520	22.1	8
E. regnans	45.7	460	21.0	17
E. saligna	33.8	610	20.6	8
E. maidenii	31.4	561	17.6	8
E. botryoides	23.7	620	14.7	4
E. globoidea	19.8	630	12.5	14
E. delegatensis	24.5	470	11.5	15
E. pilularis	15.9	580	9.2	11
E. muelleriana	13.6	550	7.5	12

Of particular note from Table 2 is that despite the very high productivity rates for *Pinus radiata*, these volumes are achieved at a much greater age than for *E. Fastigata* and *E nitens*.

The top three eucalypt species are all similar in productivity, and a key to maximising productivity is matching species to sites and good management.

Whilst the *Pinus radiata* productivity is high across a range of sites it should be noted that the Eucalyptus species tend to grow faster at an earlier age and are hence more suitable to a short rotation bioenergy crop.

Data from some *Eucalyptus* stands pre and post harvest was gathered (Hall and Nicholas 2003) in the Central North Island (Kinleith forest) and is summarised in Table 3. These stands were grown for short fibre pulp. The lower productivity rates than those in Table 2 reflect the productivity achieved on typical forests sites.

Table 3. Stand biomass from 3 *Eucalyptus* crops, Kinleith forest

Species	Age	TSV* m^3/ha	Stems per ha	Stem Residue m^3/ha	Branch Residue m^3/ha	Total biomass m^3/ha	MAI m^3 ha p.a.	Basic Density Kg/m^3	ODT/ ha/ pa
E. fastigata	19	425	560	7.6	14.5	439.5	23.1	500	11.55
E. fastigata	19	425	560	7.8	13.3	438.3	23.0	500	11.50
E. regnans	22	668	460	12.2	17.2	685.2	31.1	460	14.31

* TSV = total standing volume

Regime Options

Many of the Eucalypts species do not coppice consistently or well enough to consider SRC.

The high stockings required at planting to get large volumes of biomass at age 3 or 4 are cost prohibitive when replanting is required at every harvest. For these species, which have rapid early growth, a regime that falls between SRC and the traditional 28 to 30 year regime used in pine plantations is the one that may offer the best compromise. This is particularly so when biomass production is the goal, rather than larger diameter saw-log production.

These regimes would be typically variations on the following;

- initial stocking 1250 stems per ha
- no thinning
- 15 year rotation

Productivity would be expected to be 18 to 22 m^3/ha per annum, depending on the site and the species. Piece size at harvest would be 0.2 to 0.3 m^3. Trees of this size would be harvested by either highly mechanised systems off rolling terrain, or small hauler systems with motor manual felling and mechanised processing at landing on steeper terrain. *E nitens* has a basic density of ~520 kg per m^3.

Costs

Growing

Growing costs are likely to vary considerably by site, but will be in the order of $28 per m^3.

Harvesting

Harvesting costs will be similar to logging of conventional forests, with a step change in costs between ground based ($25 per m^3) and hauler systems ($32 per m^3). Small mobile haulers are likely to be used.

Transport

Transport would use conventional logging trucks (gross vehicle mass 44 tonnes, payload 29 tonnes), and so cost would be the same as current log transport, which are estimated to be $18 per tonne (or m^3 of) logs, assuming an average transport distance of 75 kilometres.

Total

Total delivered costs would be;

- Rolling terrain / Ground-based / mechanised = $75 per m^3
- Steep terrain / Hauler / semi mechanised = $82 per m^3

Ultimately, the choice to adopt a particular species or regime will be based on its ability to deliver the required type and volume of biomass at acceptable cost to a particular site.

CONCLUSIONS

Radiata pine is likely to remain the primary species for timber and bioenergy purposes in New Zealand. However, other species also have a role to play, not only in domestic firewood production, but also as a feedstock for bioenergy plants which may be relying on other providers for material.

Currently, the preferred species currently planted for production of short fibre pulp are *E. fastigata* (North Island) and *E. nitens (South Island)*. These species are also likely to be part of any bioenergy forest plantations.

Further research is required to widen the data base on alternative species for bioenergy production. In particular, there is a need to evaluate species that have high wood density and high to moderate volume growth rates for biomass purposes.

Future Research

An important element of biomass production from an energy forest is the influence of species selection, tree spacing and rotation length on stand productivity across a range of sites.

These are also important in economic evaluations which bring together the impact of initial spacing, growth rate, and time on financial return.

A major element of biomass productivity is species selection and site matching. Eucalypt species tend to be favoured because of their fast initial growth rate and ability to generate high stem wood volumes at an early age. However, more research is required to match species to site specifically for energy production. Health issues, particularly for eucalypt and acacia species, warrant careful evaluation before any large planting programme is initiated.

Another aspect of energy forests is that of sustainability. The effect of the total nutrient values of material grown and removed from the site, and how this influences long-term productivity, is unknown for most eucalypt species. This needs to be understood before the long-term sustainability of biomass production can be determined.

However, there is extensive information from long term site productivity trials on *Pinus radiata* stands that give good indications of the likely impacts. These are summarised (Payn 2008) as: *"With appropriate management maintenance of long term site productivity is attainable within NZ's plantations. This will also apply to new short rotation energy forests. Basic and long term research findings support these conclusions and have enabled continued improvement in site management practices".*

Further in some of the older plantation forests, some sites are on their third rotation and growth data shows higher productivity with each rotation. Some of this is from improved tree breeds and management but it does indicate that long rotation (25 to 30 years) forest crops can be taken off the same site without undue adverse effects.

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IEA Bioenergy

IEA Bioenergy is an international collaboration set up in 1978 by the IEA to improve international co-operation and information exchange between national RD&D bioenergy programmes. IEA Bioenergy's vision is to achieve a substantial bioenergy contribution to future global energy demands by accelerating the production and use of environmentally sound, socially accepted and cost-competitive bioenergy on a sustainable basis, thus providing increased security of supply whilst reducing greenhouse gas emissions from energy use. Currently IEA Bioenergy has 22 Members and is operating on the basis of 13 Tasks covering all aspects of the bioenergy chain, from resource to the supply of energy services to the consumer.

IEA Bioenergy Task 43 – *Biomass Feedstock for Energy Markets* – seeks to promote sound bioenergy development that is driven by well-informed decisions in business, governments and elsewhere. This will be achieved by providing to relevant actors timely and topical analyses, syntheses and conclusions on all fields related to biomass feedstock, including biomass markets and the socioeconomic and environmental consequences of feedstock production. Task 43 currently (Jan 2011) has 14 participating countries: Australia, Canada, Denmark, European Commission - Joint Research Centre, Finland, Germany, Ireland, Italy, Netherlands, New Zealand, Norway, Sweden, UK, USA.

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