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Forest biomass for energy:

Current and potential use in Tasmania and a comparison with European experience

Report on the Sabbatical Project

Prof. Dr. Andreas Rothe

Hobart, July 2013

Biomass heat plant at the University of Applied Sciences, Weihenstephan, built in 2008.
850 KW thermal, 5000 m^3 forest residues replace 300 000 l heating oil every year and generates regional income. Total investment about 1 M AUD, calculated payback period about 5 years.

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PREFACE

This report is the result of a sabbatical project conducted from February to July 2013. The idea for this project dates back to 2011, when John Hickey (General Manager, Forest Management, Forestry Tasmania) visited Europe. In many European countries forest biomass is considered an important renewable energy source; its use has increased significantly in the last 10 years, it is politically supported by the public and all political parties and it is partly subsidised by governments. In contrast forest biomass use for energy is insignificant in Tasmania (as it is in the rest of Australia) and gets little political or public support although a significant amount of harvesting and processing residues are currently burnt in the open or dumped in landfills. This generated the idea to investigate the current and potential use of forest biomass for energy in Tasmania and compare that to Europe. Bavaria, the southeastern-most State of Germany was used as a case study comparison since the use of forest biomass for energy in Bavaria is commonplace and the area of forest and the management structure are comparable to that in Tasmania.

This study would not have been possible without the data and information received from forest companies, wood processors, consultants, governmental agencies and NGO’s. Appendix 8.1 lists the many people who contributed information. I am very grateful to all of them and I was very pleased to find such strong support for my work. I would also like to thank Forestry Tasmania for providing the infrastructure for this project and my home university for funding this sabbatical project.

My estimates consider a different use for low quality timber currently exported as woodchips and for residues burnt in the open or left on site. The calculations are based on the production levels agreed to in the Tasmanian Forest Agreement and do not include material arising from old-growth harvesting. The environmental standards applied are higher than those requested by best management standards for bioenergy production and would easily fulfill the requirements of all the European certification systems.

This report summarised the results from a more applied perspective. A second contribution for “Australian Forestry“, which is in preparation, will focus on the scientific aspects.

I hope that this study will contribute to a more realistic view of the potential for forest biomass use for energy production in Tasmania.

Prof. Dr. Andreas Rothe, July 2013

SUMMARY

The aim of the first part of this study (Sections 1-3) is to analyse the current use of forest biomass for energy in Tasmania and to estimate its future potential assuming a different use of forest residues and low quality timber. In the second part (Sections 4 and 5) the findings are compared to European experiences considering economic, ecological and social aspects. Based on published and unpublished data and information derived from interviews with the wood processing industry the current use of forest biomass is estimated to be about 400 000 bone dry t y^{-1} (about 700 000 green t y^{-1}), about 6.5% of Tasmania´s total energy supply. The prevailing use is domestic firewood (70%); a smaller faction is used for industrial heating, mostly by the wood processing industry for kiln drying purposes. The potential supply assumes land use as stated by the Tasmanian Forest Agreement, includes no material from oldgrowth logging and applies high standards concerning biodiversity and soil fertility. The estimates are conservative and include forest biomass from private and public forests including plantations, native forest regrowth and from wood processing. Based on the current practice in Central Europe, the estimates include 50% of the pulpgrade material which is currently exported as woodchips. Total potential biomass availability is estimated at 1.8 M bone dry tonnes y^{-1} (3.3 M green tonnes y^{-1}) corresponding to about 30% of Tasmania‘s total energy supply. The material is sourced predominantly from hardwood plantations with a smaller fraction (about 30%) coming from native forest regrowth. Since most of the plantations are under private management the bulk of the material comes from private land. About two thirds of the potential forest biomass for energy is pulpgrade quality, one third is forest or wood processing residues.

Compared to Europe the use of forest biomass for generating energy is very small in Tasmania. Countries with a comparable forest harvest per capita like Sweden or Finland generate about 30% of their total energy supply from forest biomass which compares to 6.5% in Tasmania. In Bavaria, a State in Germany with similar area of land and forest to Tasmania, more than 50% of a harvested tree is finally used for energy, in Tasmania only 14% is used. The biggest differences compared to Europe are the absence of biomass plants and the insignificant production of pellets in Tasmania. In Bavaria there are 700 operating biomass plants whereas Tasmania has only a handful. A greater use of forest biomass for energy could add up to 200 M AUD to the Tasmanian economy, predominantly generated in rural communities. It could also replace significant amounts of fossil fuels and contribute to climate change mitigation. In Europe the sensible use of forest biomass for energy attracts strong public and political support and is partly subsidised. Forest biomass is mostly used to produce heat or combined heat and power in small and medium size units which are very efficient. Biomaterial and biofuel production levels are still low but technology for their production is in constant development.

In contrast to the European situation the use of forest biomass gets little political support in Tasmania and is still strongly opposed by some environmental groups. It appears that the long ongoing conflict around harvesting in oldgrowth forests has prevented a realistic assessment of the possibilities of the use of forest biomass for energy. After the Tasmanian Forest Agreement oldgrowth harvesting has virtually ended and the future forest industries will be based on plantations and native forest regrowth. The bulk of the volume will be eucalypt which produces – similar to European hardwoods - more than 80% low quality timber. A better use of this low quality timber must be a key element when developing the future forest industry in Tasmania. While industrial use for pulp requires large scale operations the use of forest biomass for energy is possible at much smaller scales. Renewable forest biomass for energy could thus be an important component of Tasmania‘s future forest industry, make a significant contribution to local and regional employment and replace energy production from fossil fuels.

1 INTRODUCTION

Knowledge of the sustainable supply of feedstock is an essential part of understanding the potential of biomass for energy production. Several studies have already investigated the potential use of biomass in Australia. These studies were either relatively rough estimates covering large areas (whole of Australia), long timeframes (> 20 years) and a wide range of possible feedstocks (e.g. Farine *et al.* 2012) or detailed estimates for a potential consumer considering the area and feedstock for a special purpose (e.g. Wilson 2012). This study is unique in this regard in that it covers all forests in Tasmania available for harvesting, includes all biomass originating from forest management (native forestry, plantations, wood processing, and both public and private land) and focuses on the next three years. Using a short timeframe allows estimates to be based on the current situation instead of on more speculative assumptions of future development. In contrast to previous studies it also assumes that a fraction of the pulplogs (mostly sourced from plantations) is potentially available for energy use as is the current practice in Europe. Tasmania has – like the whole of Australia – a plantation estate which is still immature. Once more plantations reach maturity the potential volume of both solid wood and residues available for harvesting will increase. The supply estimates presented here for the next three years can thus be considered a minimum compared to that available in the longer term.

The use of biomass for energy has increased significantly in Europe over the last ten years and there exist ambitious plans for a further increase to achieve renewable energy targets. However, recent scientific literature has challenged the common view that biomass use for energy is *a priori* environmentally beneficial (e.g. Manomet Center 2010, Searchinger *et al.* 2009). The final assessment depends on the combustion technology used, on the amount of fossil fuel replaced, the use of the harvested products and the land management to produce biomass. Appropriate forest biomass use within sustainable forest management can significantly reduce carbon emissions, create regional economic benefits and produce other benefits such as decreased fire risk. Sweden and Finland, two European countries with a large forest resource produce between 25 and 30% of their final energy consumption from (mostly forest) biomass (AEBIOM 2012). This indicates that a different use of low quality timber and residues could significantly contribute to renewable energy in Tasmania, which has a low population density and a significant forest resource even after the Tasmanian Forest Agreement (Tasmanian Government 2013).

Although several studies have investigated the feasibility of individual biomass projects in the last ten years there has been no comprehensive overview of the current Tasmanian situation. To address this knowledge gap the current study aimed to:

i) quantify the current use and the sustainable supply of forest biomass for energy production in Tasmania; and

ii) analyse the economic, ecological and social context by comparing the findings to European experiences.

The results are intended to be a basis for further studies on the economic viability and technical aspects of biomass use, for policy development and for public discussion on the sustainable use of forest biomass for energy production.

2 METHODS

2.1 CURRENT USE OF FOREST BIOMASS FOR ENERGY

Estimates of the available volume of wood-processing residues are based on oral or written interviews with the major wood processing companies. The estimates for domestic firewood consumption are based on data from Driscoll *et al.* (2000), from Todd (2013) and on preliminary unpublished data from a wood-heater survey performed by the Tasmanian Environment Protection Authority during the winter of 2011. Supply of firewood from State forests was estimated using sales data provided by Forestry Tasmania and from private land using published data (Private Forests Tasmania 2012).

2.2 POTENTIAL SUPPLY OF FOREST BIOMASS FOR ENERGY FOR THE NEXT THREE YEARS

Calculation of potential supply is based on the following principles:

1. Conservative estimation of a minimum potential, i.e. using conservative figures for all underlying assumptions.
2. Land use and harvesting amounts as stated by the Tasmanian Forest Agreement.
3. Includes native forest regrowth harvesting ("native regrowth"), but no native forest oldgrowth harvesting ("oldgrowth").
4. Consideration of biomass supply from forest management (native regrowth, plantations) and wood processing residues only. Other forms of biomass (landscaping, waste wood, agricultural residues, municipal waste) are not included.
5. Higher standards are applied for leaving slash (soil fertility) and dead wood (biodiversity) than required by best management guidelines in Europe or North America (for an overview see Manomet Center 2010).
6. 50% of hardwood pulpgrade logs potentially available for energy production, based on Central European practice.
7. Conversion factors used:
   1 m^3 wood = 0.50 t dry weight (softwood)
   1 m^3 wood = 0.55 t dry weight (eucalypt)
   (density for native forest eucalypt logs is usually between 0.6 and 0.65 t m^{-3}, for plantation eucalypt logs it is usually between 0.5 and 0.6 t m^{-3}. Application of the plantation value to native forest regrowth is therefore a conservative estimate)
   1 m^3 wood= 1 t green wood
   (this factor varies according to species, origin of the wood and actual moisture content. For native eucalypt wood 1 m^3 is closer to 1.1 t green wood. The general 1:1 conversion is therefore a conservative estimate)
   Moisture content green wood: 45%
   Moisture content air dry wood: 15%
   Moisture content bone dry wood: 0%
   Energy content: 1 kg bone dry wood = 18 MJ (5 kWh)

Public native eucalypt:

The potential supply from native forest regrowth was calculated for two main forest groups 'Tall Native Eucalypt Forest' and 'Low Native Eucalypt Forest' based on harvest areas and volumes per area. The area of native forest regrowth harvested during the last three years (2009/10, 2010/11, 2011/12) was derived from the Forestry Tasmania operational database. Oldgrowth areas were subtracted from total harvested areas and a further 20% reduction was assumed in line with the Tasmanian Forest Agreement which included a significant increase to the reserve area (Tasmanian Government 2013). Available volumes per hectare were calculated using Forestry Tasmania's inventory database. This database only includes aboveground biomass of stems and course woody debris measured under bark, so bark, branches and leaves were not included. Biomass of stems and coarse woody debris for 56 forest classes and 21 inventory areas were bulked to area weighted averages for the two forest groups tall eucalypt forest and low eucalypt forest. These two forest groups have also been used for carbon studies (Moroni *et al.* 2010) and statistical reporting (Private Forests Tasmania 2012). The inventory database included harvesting fractions based on a visual assessment of the standing tree. 20% of the pulpgrade fraction was assumed to be suitable for peeler billets. Residues available for energy use were assumed to be 15% of total solid forest biomass (live standing volume, dead standing volume and downers decay class 1 and 2). The 15% value has also been used by Farine *et al.* (2012) and is based on the assumption that all small parts of less than 20 cm diameter are left on site to maintain nutrient sustainability and an important fraction of stemwood is left on site in order to provide enough material for continuity of coarse woody debris formation. More than 85% of solid coarse woody debris and 100% of decayed dead wood or dead wood with rot (decay class 3, 4, 5) was assumed to be left on site, which is significantly more than required by the 'Coarse woody debris (CWD) management prescriptions for fuelwood and commercial firewood harvesting' (Forestry Tasmania 2011). These management prescriptions require at least 30% of coarse woody debris to be retained on-site for biodiversity reasons. The 15% fraction for recovery of residue volumes is in accordance with field trials (Raspin 2009, Andrewartha 2003) which harvested between 13 and 17% of total forest biomass.

Private native eucalypt:

For private forests the potential supply of biomass was calculated using the published harvest figures of pulpwood and sawlogs for the same period, that is for 2009/10, 2010/11 and 2011/12 (Private Forests Tasmania 2012). The actual harvest was considered as a surrogate for assessing important factors influencing harvesting intensity on private land, especially technical restrictions (access) and willingness of owners to actually harvest timber. Since harvesting figures do not differentiate among forest class, proportions of 80% of low eucalypt forest and 20% tall eucalypt forest were assumed, derived from the spatial distribution of the forest types. Available biomass from residues was assumed to be 45% of pulpwood harvest using the same relationship as for State forests.

Hardwood plantation:

For hardwood plantations managed by Forestry Tasmania only thinnings and early clearcuts were considered since there will be little final clearcutting (< 3% of volume) in the next three years. Thinning and early clearcut areas and the corresponding harvesting volumes were available from FT's internal planning process (McKenzie 2012). Harvesting volumes included material >8-10 cm, all residues below this diameter were assumed to remain on-site in order to maintain nutrient sustainability.

Private hardwood plantations are almost entirely managed for pulpgrade material using short rotation periods (mostly 12-18 years). Recent harvesting has been dominated by the liquidation of the main plantation manager and does not reflect the longer term potential. Since significant areas of these plantations have reached maturity, the potential harvest was estimated by multiplying average annual clearcut area with pulpgrade volume per hectare. Due to the current management uncertainty an 18 year rotation period and a merchantable volume of 250 m^3 ha^{-1} were assumed. Both figures are conservative and include a certain loss of area due to natural losses (fire) or management decisions. Aboveground residues (bark, branches, leaves) account for about 25-30% of total biomass in eucalypt plantations (Perez *et al.* 2006). Only one third of these residues (corresponding to about 10% of standing biomass) were considered to be available due to economic and ecological restrictions (information from forest growers, Ghaffariyan 2012). The available residues consist mainly of breakage during harvest, bark and the lower stem logs too small to sell as pulpwood. All foliage, small branches and twigs were assumed to be left on site.

Softwood plantation:
For softwood plantations published production figures are available (ABARES 2012) for the last 10 years (2002-11) and these were assumed to remain constant in the near future. Available residues for energy were assumed to be 7% of the volume harvested for sawlogs and pulpwood (Ghaffariyan and Acuna 2012, information from forest growers). The recoverable material consists predominantly of breakage, dead trees and lower stem logs too small to sell as pulpwood. All small slash was assumed to be left on site for economic and ecological reasons.

Wood processing residues:
These estimates were based on oral or written interviews undertaken with representatives of the wood processing industry during May/June 2013. The participating companies (Appendix 8.1) are responsible for processing more than 90% of the current total harvest in Tasmania. The interviews investigated the amount of timber processed, the amount of residues generated, the current use of residues and the anticipated changes in the future. Based on the data gathered during the interviews the percentage of residues generated during processing as well as the percentage potentially available for energy use was calculated separately for the four categories: softwood sawmilling, softwood chipping, hardwood sawmilling/peeling and hardwood chipping. These percentages were then applied to the potential Tasmanian harvest in the near future using the same four categories. The future potential harvest was estimated using the amounts as stated by the 'Tasmanian Forest Agreement', the published harvest figures of the last three years in private native eucalypt forests and the plantation harvest already used for estimating residue fractions (see above).

3 RESULTS

3.1 CURRENT USE OF FOREST BIOMASS FOR ENERGY

Biomass plants

At present there are no operating biomass plants in Tasmania and no production of electricity using forest biomass. For the Southwood site near Huonville planning approval to build and operate a plant is in place but the project has not yet been realised.

Wood processing residues

The wood processing industry in Tasmania is currently undergoing major changes. While softwood processing volumes have been relatively constant over the last few years, hardwood processing has declined significantly. Total residues from wood processing was about 580 000 green tonnes in the last year, nearly 60% of this being softwood. While recovery rates during sawmilling are 50% or less, recovery rates from chipping or pulping are much higher. As the majority of the wood volume harvested is chipped or pulped the average recovery rate for all wood processed in Tasmania is about 80% and the amount of residues comparatively small. About 220 000 green tonnes of residues were used for energy, about three quarters of this for producing steam in order to kiln-dry processed timber. The remaining part was used for other industrial heating such as brick manufacturing, food processing or greenhouses or sold as domestic firewood.

Most of the residues not used for energy are sold as woodchips or used for landscaping purposes (mostly bark). An important quantity of residues (> 25 000 t y^{-1}) is currently not used at all and is put to landfills or just remains on site.

Pellets

The use of pellets is small and amounted to only about 1000 t in 2012. To date pellets used in Tasmania have been imported from Queensland or New Zealand but a small pellet plant using residues from the McKay Timber sawmill in Glenorchy will start operating shortly in order to supply the local market.

Domestic firewood

A significant amount of firewood is used for domestic heating purposes. Driscoll *et al.* (2000) conducted a comprehensive study of firewood use in Australia including a householder survey based on telephone interviews. They estimated a yearly consumption of 720 000 air dry tonnes in Tasmania, based on about 125 000 households using firewood with an average consumption per household close to 6 t y^{-1}. Todd (2001) estimated only 530 000 air dry tonnes for the same period which is indicative of the high uncertainty in these estimates. From 2000 to 2008 the use of firewood decreased significantly due to low tariffs for electric heating. From 2008 the use of firewood slightly increased again due to rising electricity and gas prices. In 2011 firewood consumption was estimated by Todd (2013) at 320 000 air dry tonnes per annum, derived from 28% of households using firewood as a main heating source with an average consumption of 4.8 t y^{-1} and 9% as a secondary source with an average consumption of 2.2 t y^{-1}.

The Tasmanian Environment Protection Authority (EPA) performed a woodheater survey during winter 2011 in eleven districts across Tasmania (EPA, unpublished). The survey covered nearly 150 000 households representing about 70% of Tasmania. The percentage of households using woodheaters as the main heating source varied from below 20% in urban areas to about 60% in rural communities. Based on the preliminary unpublished data provided by the EPA it is estimated that 60 400 households use woodheaters as their main heating source. This compares well with the 58 200 households assessed by the Australian Bureau of Statistics (ABS 2011). The EPA study didn't investigate the amount of firewood used per household but allows a rough differentiation between rural and urban areas. Assuming an average yearly consumption of 3 t per household in urban areas and 7 t per household in rural areas, firewood consumption as a main heating source was about 300 000 t y^{-1}. Adding households using wood as a secondary source and assuming a 10% error of estimates, total firewood consumption is estimated at between 290 000 and 350 000 t y^{-1}, nearly identical to the estimates from Todd (2013). The commercial use of firewood in hotels or pizza shops is estimated to be small and within the error of estimates for the private households.

The firewood market is highly unregulated and dominated by small private collectors. According to Driscoll *et al.* (2000) about 40% of firewood is collected directly by the consumer and the other 60% is bought mostly from small suppliers selling directly from the back of a truck. According to more recent estimates the amount of firewood bought commercially is about 50% (Todd, personal communication). Over 80% of firewood is obtained from private property and the contribution from State forests is relatively small. The harvest survey for private forests in Tasmania presented figures for firewood, which were only about 2500 t y^{-1} over the last 10 years (Private Forest Tasmania 2012). However, these figures were mainly industrial fuel wood and did not cover the prevailing domestic firewood harvest. The official firewood harvest from State forests covered by private collecting permits and commercial firewood sales was also small and amounted to only 21 500 t in the financial year 2011/12 (Clark 2013). Lacking comprehensive data it is currently impossible to make reliable estimates on the total firewood harvest.

In addition, significant illegal harvesting exists which is difficult to quantify. Moroni and Musk (2013) compared the amount of coarse woody debris in dry eucalypt forests along a 25 m strip along State forest roads and compared it to natural sites. Coarse woody debris is about 23 t dry weight ha^{-1} lower compared to natural sites resulting in an estimated removal of about 160 000 t dry weight (approximately 200 000 t) for this forest type only. This indicates that unregulated domestic harvesting removes significant quantities and potentially damages biodiversity values by diminishing habitat for species dependent on fallen logs (Driscoll *et al.* 2000, Grove and Meggs 2003). However, firewood collection concentrates on easily accessible areas which only account for a small part of the total area. Lacking studies on effects of firewood collection on a landscape level it remains an open question whether and to what extent firewood collection in fact influences biodiversity.

Total

Currently about 400 000 t y^{-1} of bone dry forest biomass (about 700 000 t y^{-1} of fresh biomass) are used to generate heat (Table 1). The corresponding energy equivalent of 7 PJ equates to about 6.5% of Tasmania`s total energy supply (109 PJ in 2010/11). The reduction compared to the 10% share reported for 2010-11 (DIER 2013) presumably reflects the reduced wood processing activities in the last few years, smaller differences could result from using differing conversion factors. Nevertheless forest biomass is still the second most important renewable energy after hydropower and its contribution is higher than windpower or solar energy (DIER 2013).

Table 1: Forest biomass used for energy.

	Mass kt y^{-1} (bone dry)	energy equivalent PJ*
domestic firewood	270	5
wood processing residues	120	2
total	**390**	**7**

*1 petajoule = 1 000 000 gigajoules.

3.2 POTENTIAL SUPPLY OF FOREST BIOMASS FOR ENERGY

3.2.1 NATIVE REGROWTH

Forest inventory assesses wood volumes, so in this section the data is presented in m^3. With the conversion factors assumed for this report 1 m^3 corresponds to 1 green t. The available amount of residues from ‘below pulpgrade’ and ‘solid dead wood’ is about 50 m^3 ha^{-1} in low eucalypt forest and 80 m^3 ha^{-1} in tall eucalypt forest (Table 2). The amount of ‘pulpgrade’ is about 110 and 190 m^3 ha^{-1} respectively. The assumed harvesting intensity is low with only 70% of available stemwood removed. All rotten dead wood as well as 88% of solid dead wood is left on site. The assumed harvesting intensity thus leaves a high degree of flexibility for economic, ecological and practical considerations during harvesting management.

Table 2: Volumes and harvestable volumes in State native eucalypt by forest group.

	Low Eucalypt			Tall Eucalypt		
	volumes m^3 ha^{-1}	harvestable m^3 ha^{-1}	left on site %	volumes m^3 ha^{-1}	harvestable m^3 ha^{-1}	left on site %
solid aboveground (without rotten dead wood)	320	216	32%	529	390	26%
sawlogs	30	30	0%	73	73	0%
peeler billets	28	28	0%	48	48	0%
pulpgrade	110	110	0%	191	191	0%
below pulpgrade*	65	38	42%	86	63	26%
solid dead wood*	87	10	88%	133	16	88%
(partly) rotten dead wood	106	0	100%	285	0	100%
total aboveground	**426**	**216**	**49%**	**815**	**390**	**52%**

*harvestable amounts from ‘below pulpgrade’ and ‘solid dead wood’ were assumed to be 15% of ‘solid aboveground volumes’, 80% of this is derived from residues below pulpgrade and 20% from solid dead wood. Lighter green areas show potential log grades for energy use. All figures refer to stem wood under bark (branches and leaves not included).

The area of eucalypt forest harvested on State forest was 6850 ha y^{-1} on average over the last three years, 1080 ha y^{-1} (about 15%) of this being oldgrowth. Assuming the full implementation of the proposed reserve system of 0.5 M hectares within the ‘Tasmanian Forest Agreement’ the available regrowth area over the next three years was estimated at 4400 ha y^{-1}, with about two thirds of this being in tall eucalypt forest and one third in low eucalypt forest. The annual harvest area is expected to decline by about 35% which corresponds to the decrease in the area of native eucalypt forest designated for production (550 000 ha before the TFA, 350 000 ha after the TFA). The potential supply from residues was estimated at 0.3 M m^3, the supply from pulpgrade 0.35 M m^3, total 0.65 M m^3 (Table 3). This corresponds to a harvesting intensity of potential energy wood of 1.85 m^3 ha^{-1} y^{-1} for the remaining 350 000 ha of multiple use eucalypt forests. The harvested area relates to a theoretical average rotation period of 80 years.

Table 3: Potential supply from State native eucalypt.

		Low Eucalypt	Tall Eucalypt	Total Eucalypt
regrowth harvesting after TFA	ha y^{-1}	1600	2800	4400
sawlogs+peeler billets	m^3 ha^{-1}	58	121	98
pulpgrade	m^3 ha^{-1}	110	191	162
residues (15% of solid biomass)	m^3 ha^{-1}	48	79	68
Total Volumes				
sawlogs + peeler billets	M m^3 y^{-1}	0.1	0.3	0.4
pulpgrade	M m^3 y^{-1}	0.2	0.5	0.7
pulpgrade available for energy (50%)	M m^3 y^{-1}	0.1	0.25	0.35
residues	M m^3 y^{-1}	0.1	0.2	0.3
total potential energy wood	**M m^3 y^{-1}**	**0.2**	**0.45**	**0.65**

Private forests:

The potential supply from private native forests is based on the amounts harvested over the last three years assuming a similar percentage of residues available for forest biomass for energy as in State forests (Table 4). Average harvesting in private native forests in the last three years (2009/10, 10/11, 11/12) was only 400 000 t y^{-1} (corresponding to about 400 000 m^3 y^{-1}), nearly 90% of this being pulpwood. These figures are much lower than those for the years prior to 2009, reflecting the currently difficult pulpwood market.

Table 4: Potential supply from private native eucalypt.

	M m^3 y^{-1}
pulpgrade	0.35
pulpgrade available for energy (50%)	0.18
residues available for energy*	0.15
total energy wood	0.33

*45% of total pulpgrade based on the relationship as in State forests.

The potential amount of biomass available for energy production was estimated at 0.33 M m^3 y^{-1} corresponding to a harvesting intensity of energy wood of 0.5 m^3 ha^{-1} y^{-1}. Total harvesting intensity including all log classes is about 0.8 m^3 ha^{-1} y^{-1}. This figure is low even for a low eucalypt forest type and shows that many private native forests are not managed intensively. Harvesting from private forests could be increased while still fulfilling best management guidelines. However, harvesting on private land strongly depends on access and on the intentions of the owner. Lacking meaningful information about these factors, future harvesting intensity on private land is difficult to predict.

3.2.2 PLANTATIONS

State forest hardwood plantation:

The total hardwood plantation area on State forest is about 55 000 ha. Forestry Tasmania has a full or partial equity in about 40 000 ha. The remaining 15 000 ha are considered to be within the private plantation estate. Due to the age class distribution of State forest plantations the amount of regular clearcuts is negligible. However, there is a significant area of plantations that are available for early clearcutting as they are not growing well enough to continue with the planned regime. The supply from thinning and early clearcutting areas on State forests is summarised in Table 5 (McKenzie 2012).

Table 5: Potential supply from State hardwood plantations.

	area ha y^{-1}	pulpgrade m^3 ha^{-1}	M m^3 y^{-1}
planned thinning in the next 3 years	1700	70	0.12
thinning catch up programme	1500	70	0.11
early clearcut areas	1500	100	0.15
total pulpgrade			0.38
pulpgrade available for energy (50%)			**0.19**

Private hardwood plantation:

The hardwood plantation estate under private management is about 190 000 ha (of which about 15 000 ha is located on State forest land). More than 50% of the hardwood estate was established and is operated under managed investment schemes. Assuming an 18 year rotation period and a pulpgrade volume of 250 m^3 ha^{-1} total pulpgrade harvest is estimated to be 2.65 M m^3 y^{-1}, with 50% of this potentially available for energy production. The residue fraction amounts to 0.35 M m^3 y^{-1} (Table 6).

Table 6: Potential supply from private hardwood plantations.

	M m^3 y^{-1}
pulpgrade total	2.65
pulpgrade available for energy (50%)	1.30
residues available for energy (10 % of standing volume)	0.35
total energy wood	**1.65**

Softwood plantation:

The 75 000 ha of softwood plantations in Tasmania produced an average of 1.2 M m^3 y^{-1} (16 m^3 ha^{-1} y^{-1}) of sawlogs and pulpgrade logs during the last 10 years with annual variation in production ranging from 0.8 to 1.3 M t y^{-1}. About 0.5 M m^3 y^{-1} were used as sawlogs. The bulk of the 0.7 M m^3 y^{-1} pulpgrade logs is used for mechanical pulp, a smaller fraction is sold to the mainland or is used for other industrial purposes. Harvesting residues potentially available for energy use are only about 0.1 M m^3 y^{-1}.

Plantations total:

The potential supply of biomass from softwood plantations is insignificant compared to that from hardwood plantations. Potential energy wood production from the 230 000 ha of hardwood plantations (State and private) is estimated to be 1.85 M m^3 y^{-1}, based on a potential total harvest of 3.4 M m^3 y^{-1} (Table 7). The average biomass harvest of 14.8 m^3 ha^{-1} y^{-1} is relatively low and reflects the current uncertainties following the collapse of the managed investment schemes and the fact that State forest plantations are still immature. A significant increase in harvesting from hardwood plantations is expected once the State-owned plantation estate matures.

Table 7: Potential supply from all plantations.

	pulpgrade available for energy M m^3 ha^{-1} y^{-1}	residues available for energy M m^3 ha^{-1} y^{-1}	total M m^3 ha^{-1} y^{-1}
State hardwood	0.20	0.00	0.20
private hardwood	1.30	0.35	1.65
private softwood	0.00	0.10	0.10
total	**1.50**	**0.45**	**1.95**

3.2.3 WOOD PROCESSING RESIDUES

Current changes in the forestry sector significantly influence the quantity of wood processed and thus the amount of processing residues. Based on the expected harvest after the implementation of the Tasmanian Forest Agreement and the recovery figures provided by the wood processing companies, the future amount of residues is estimated to be about 600 000 t y^{-1}, of which about 400 000 t y^{-1} is potentially available for energy use (Table 8).

Table 8: Wood processing residues potentially available for energy use.

	M t y^{-1}
softwood sawmilling	0.20
hardwood sawmilling/peeling	0.15
hardwood chipping	0.05
total	**0.40**

The residues potentially available for energy use consist of residues currently already used for energy, residues currently not used at all and a fraction of material currently sold as woodchips. The remaining residues are designated for non-energy producing purposes like landscaping (mainly bark) or further processing in the future (pulp, particle board).

3.2.4 FOREST BIOMASS TOTAL

The supply estimates are summarised in Table 9. The potential supply from forest and wood processing residues is estimated at 0.75 M bone dry t y^{-1} (1.35 M green t y^{-1}). Using only these residues, energy production could be nearly doubled compared to current levels (0.39 M bone dry t y^{-1}). The residues originate in nearly equal shares from wood processing, plantations and native forest regrowth harvesting. At present about 50% of the wood processing residues are used for energy generation, plantation residues are not used at all and the bulk of the native forest residues are burned in the open. About two thirds of the potential energy wood is pulpgrade material which is currently chipped and exported. At present an important fraction of the pulpgrade material is not used due to logistical and/or economic restrictions. Based on European experience it is assumed that 50% of the pulpgrade material is potentially available for bioenergy equating to 1.1 M bone dry t. About three quarters of total pulpgrade material originates from plantations, and one quarter from native regrowth.

Table 9: Potential supply of forest biomass for energy in Tasmania.

	pulpgrade total	pulpgrade for energy*	residues for energy	Total energy wood		energy equivalent
	M t (green)	M t (green)	M t (green)	M t (green)	M t (bone dry)	PJ
Native forests	1.1	0.5	0.5	1.0	0.5	9
Plantation hardwood	3.1	1.5	0.4	1.9	1.0	18
Plantation softwood	0.7	0.0	0.1	0.1	0.1	1
wood processing			0.4	0.4	0.2	4
total	**4.8**	**2.0**	**1.3**	**3.3**	**1.8**	**33**

* 50% of hardwood pulpgrade was assumed to be available for energy use, softwood pulpgrade was assumed to be used for processing only. 1 petajoule = 1 000 000 gigajoules.

The total potential supply of forest biomass for energy in Tasmania is estimated to be 1.8 M bone dry t y^{-1}. The corresponding energy equivalent of 33 PJ is approximately 30% of Tasmania's current energy supply (109 PJ in 2010/11, DIER 2013). A different use of the residues currently not used or burnt in the open and of low quality timber currently exported as woodchips could thus make a significant contribution to renewable energy production in Tasmania. Total potential supply of forest biomass for energy is expected to increase in the medium and long term due to a significant increase in hardwood plantation production. Long term supply from softwood plantations is expected to remain constant, while long term supply from native forest regrowth is expected to decrease slightly.

4 COMPARISON WITH EUROPEAN EXPERIENCES

At present biomass is by far the most important renewable energy source in Europe. In the 27 member nations of the European Union (EU27, population 500 M) biomass contributed 8.2% of total final energy consumption in 2010 or nearly 64% of European renewable energy (AEBIOM 2012). Forest biomass is the dominant feedstock contributing about two thirds of total biomass for energy production or about 50% of total renewable energy (Mantau 2010). Thus it is logical that the share of energy derived from biomass is closely correlated with the available forest resource (Figure 1). The most forested countries in Europe – Sweden, Finland and the Baltic countries (Latvia, Lithuania and Estonia) – generate between 20 and 30% of their total energy supply from forest biomass. Countries with a high biomass use despite a low forest resource such as Denmark mostly rely on agricultural residues. Despite the intensive and increasing use of forest biomass for energy, the standing volume of European forests increased 12% in the last 10 years and the current annual harvest is still well below the annual increment (Eurostat, SoEF 2011, quoted in AEBIOM 2012).

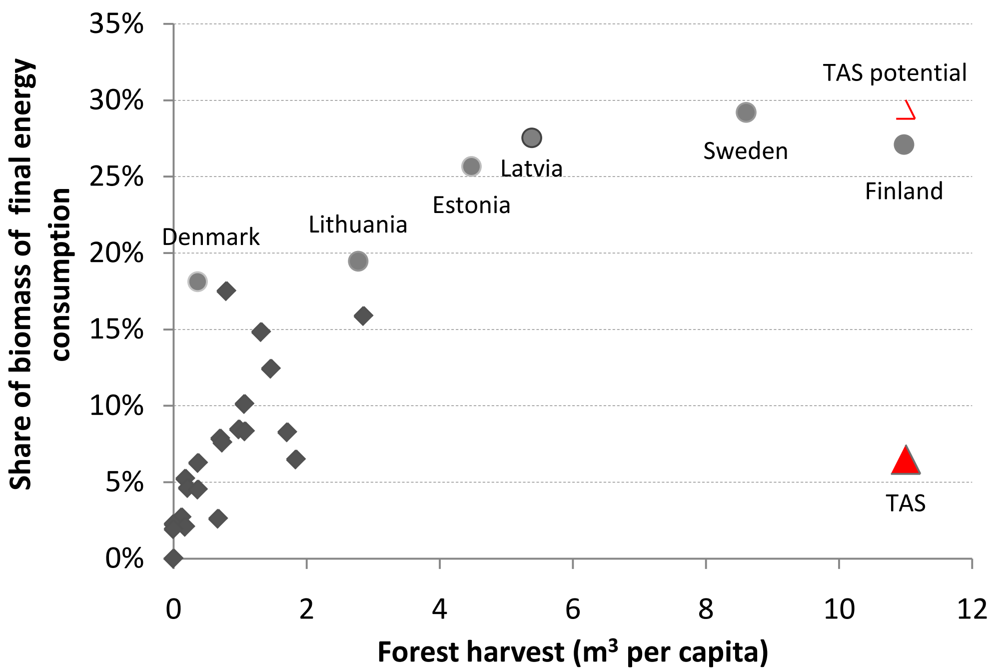


Figure 1. Share of biomass energy of final energy consumption in the 27 countries of the European Union (EU27). Red triangles show the current situation in Tasmania and the potential supply as estimated in this study.
Data Source (Eurostat, SoEF 2011, quoted in AEBIOM 2012).

In Tasmania the contribution of forest biomass to the energy supply is very small compared to the available forest resource. After the 'Tasmanian Forest Agreement' more than 50% of Tasmania's forests are not available for harvesting. Nevertheless Tasmania's potential future harvest per capita is still very high even on a worldwide scale. The very conservative figures used in this report (Table 9) indicate a future total harvest of pulpgrade and sawlogs/peelers of at least 5.5 M m^3 y^{-1} resulting from 1.5 M m^3 y^{-1} native forest regrowth, 3 M m^3 y^{-1} hardwood plantation and 1.2 M m^3 y^{-1} softwood plantation. The net production figure per capita of 11 m^3 y^{-1} (based on the population of Tasmania being 0.5 M) is similar to that in Finland, the most productive timber country in Europe and more than twice that in Canada (4–5 m^3 y^{-1} $capita^{-1}$), a country well known for its large forest industry. The calculated energy potential for Tasmania using wood processing residues, harvesting residues and low quality timber fits well with the European experiences and shows a real potential for future development.

There is a common misconception that the use of biomass is predominantly for electricity and transport fuel production (biodiesel, petrol substitutes). In fact, the dominant use in Europe is for heating. In 2010 75% of biomass in the EU27 was used for generating heat, 11% for electricity and 14% for biofuels (AEBIOM 2012). Biofuels are nearly exclusively produced using agricultural feedstock like maize or sugar beets. The generation of electricity from biomass is dominated by combined heat and power plants, with 64% of total electricity produced from solid biomass in combined heat and power plants in 2010 (AEBIOM 2012). More than 50% of the heat produced from biomass is used by private households. This sector is dominated by small scale heating, ranging from stoves of only a few kilowatts used for heating individual rooms, to boilers of up to 500 kW for bigger consumers such as schools or swimming pools. District heating, where a central biomass plant (usually between 100 – 1000 kW) is supplying heat to surrounding houses (often 20 – 100 units) has also significantly increased in the last few years. About one third of the heat generated is used for industrial heating, most directly for processing wood, for example drying of timber or paper.

A detailed analysis of the use of forest biomass for energy was performed within the scope of the EUWood Study (Mantau 2010). The current use of forest biomass in the European Union is dominated by classical firewood consumed in private households. The contribution of pellets has increased significantly over the last few years and now amounts to 7% of forest biomass used for energy; again most of this is used in private households. One quarter of the forest biomass results from wood processing residues, the most important quantity being black liquor from pulping. One quarter of forest biomass is used by heat and electricity producers, dominated by heat only or combined heat and power plants. In 2010 there were nearly 7000 heat and combined heat and power plants operating in the European Union (AEBIOM 2012). Biofuels from forest biomass are still in the trial stage and the operating pilot plants process very small quantities.

In Tasmania the current use of biomass for energy is even more dominated by domestic firewood. Besides the black liquor (which is not available in Tasmania as there is no chemical pulp manufacture) the main differences between Europe and Tasmania are the currently insignificant use of pellets and the absence of biomass plants (Figure 2).

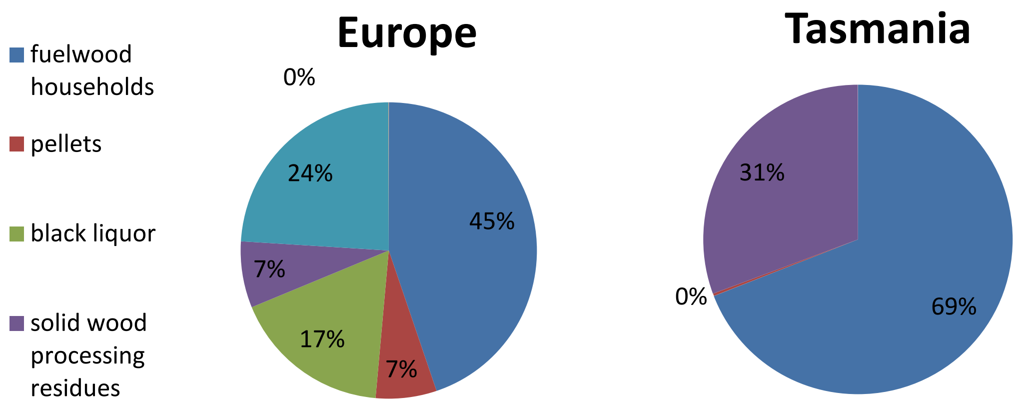


Figure 2: Use of forest biomass for energy production in the EU (346 M m^3) and Tasmania (0.7 M m^3). EU data from Mantau (2010), data for Tasmania this study.

Case study Bavaria

While a comparison based on European data gives a good overview it does not allow for a detailed analysis. Large scale data are inevitably approximate and reliable data on private households, which draw significant quantities from informal markets, are only available for some areas. Bavaria, a State located in the southeast of Germany, is used here for a case study comparison in order to get a more detailed picture. Bavaria is well suited since its size and forest management structure are very similar to that of Tasmania (Table 10). The use of forest biomass for energy is widespread in Bavaria and is typical of other regions in Central Europe. A detailed data set from a recently published report on the Bavarian wood energy market (LWF 2012) allows an in-depth comparison with Tasmania.

Table 10: Comparisons between Bavaria (Germany) and Tasmania (Australia).
Sources: Bavarian Ministry for Food, Agriculture and Forestry (2012), Forest Practices Authority (2012).

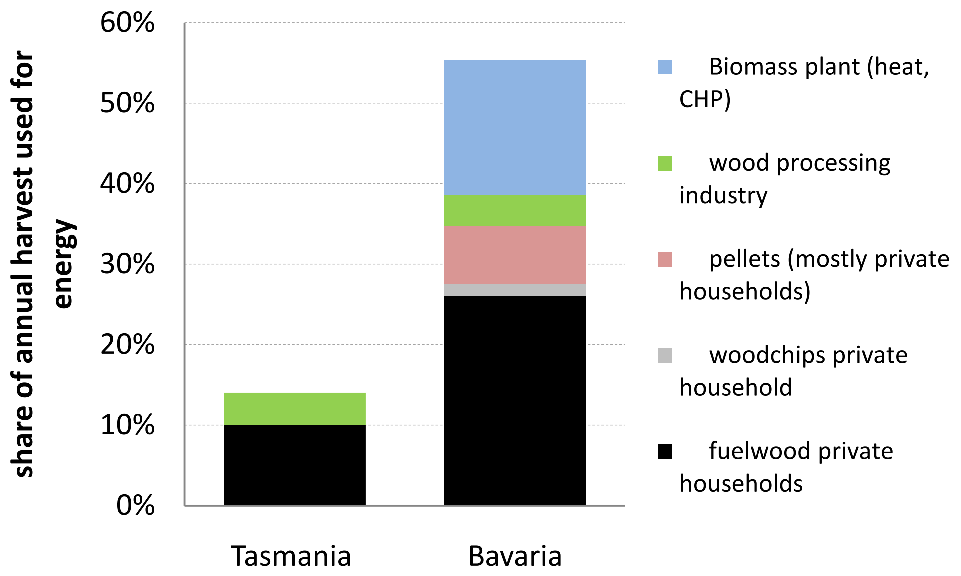
	Bavaria	Tasmania
People (million)	12.5	0.5
Land (million ha)	7.1	6.8
Latitude of capital city	48° N (Munich)	42° S (Hobart)
Forest area (million ha)	2.5	3.4
Forest available for wood production	2.4	1.2
Main forest type	Semi-natural spruce-beech forest	Natural and modified natural eucalypt forest
Wood production		
million cubic metres/year	15-20	5-6
cubic metres/capita	1.2-1.6	10-12
% private forest	57	30
Number of private forest owners	700 000	1400
Forest biomass for energy		
M cubic metres/year	10	0.7
% of total energy consumption	5	6.5

The average harvest in Bavaria was about 18 M m^3 y^{-1} over the last 5 years. On average, 10 M m^3 y^{-1} (55%) was used for generating energy. 4.7 M m^3 y^{-1} (27%) was used directly as energy wood (i.e. without further processing), nearly all as domestic firewood (Table 11, Figure 3). Nearly the same amount of energy wood originated from wood processing residues and waste wood. The production of pellets increased significantly in the last few years. Currently about 1.3 M m^3 y^{-1} of pellets are produced per year, nearly all of them from wood processing residues. The bulk of the utilisation of waste wood for energy production, accounting for 17% of the total harvest, takes place in special furnaces.

Table 11: Origin and use of forest biomass for energy in Bavaria and Tasmania.
Data for Bavaria from LWF (2012), Tasmania this report.

	Bavaria M m^3	Tasmania M m^3
Harvest total	18	5
wood for energy	10	0.7
coming from		
Firewood from forest	4.7	0.5
Woodchips from forest	1.4	0.0
Wood processing residues	2.0	0.2
Waste wood	1.9	0.0
used for		
fuelwood private households	4.7	0.5
woodchips private household	0.3	
pellets (mostly private households)	1.3	0.001
wood processing industry	0.7	0.2
Biomass plant (heat, CHP)	3.0	

Figure 3: Percentage of forest harvest used for energy
Data for Bavaria from LWF (2012), Tasmania this report.



In contrast to Bavaria, only 14% of the annual harvest was used for energy in Tasmania. Major differences between the two States are the absence of pellet production and biomass plants in Tasmania. The firewood use in Tasmania (about 1 green t y^{-1} $capita^{-1}$) is more than double that in Bavaria (0.4 green t y^{-1} $capita^{-1}$).

While the public perception is of huge biomass plants, the current reality in Bavaria is quite different. There are about 680 operating biomass plants in Bavaria, producing either heat or heat and power (Figure 4). Most of the plants are between 0.5 and 2 MW in size, corresponding to 1-10 t of biomass per year. Plants > 5MW (7% of all plants) mostly use waste wood or wood processing residues as their main fuel. The plants are quite evenly spread throughout the State and nearly all of the larger plants are located next to processing facilities. The distribution of plants keeps transport distances to a minimum which has economic and ecological advantages. This is often referred to as "Timber of short distances" (German: "Holz der kurzen Wege").

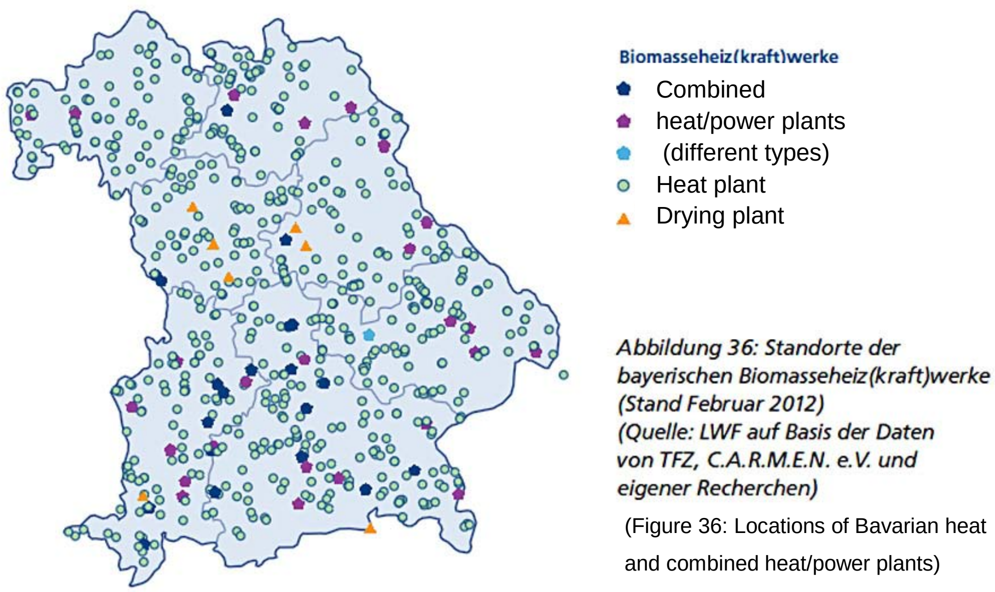


Figure 4: Biomass plants in Bavaria (land area similar to Tasmania) (from LWF 2012).

5 ECONOMIC, ECOLOGICAL AND SOCIAL IMPLICATIONS

5.1 ECONOMIC IMPLICATIONS

A detailed economic analysis is beyond the scope of this study. This section only highlights some important aspects.

5.1.1 BETTER USE OF FOREST HARVEST

The general aim of forest utilisation is to maximize the yield of high quality products such as sawn timber or veneer. However, the percentage of sawlog recovery strongly depends on the intrinsic properties of the different tree species. While softwood species with a long straight bole and small branches have on average a high sawlog recovery, the crown structure of hardwood trees with their much bigger branches leads to lower sawlog recovery and a high proportion of lower quality products. Sawlog recovery from Norway spruce, the dominant softwood in Bavaria was nearly 80% in 2011 while it was less than 20% from European beech, the dominant hardwood species (Figure 5). Sawlog recovery from Tasmanian eucalypt, also a hardwood species, is slightly higher than for Bavarian beech. The Tasmanian figures include peeler logs used for veneer production which enables higher recovery rates compared to sawmilling. However, the main difference between Tasmania and Bavaria is not the proportion of sawlog recovered but the significantly smaller amount of timber left on site and the higher proportion of energy wood recovered in Bavaria.

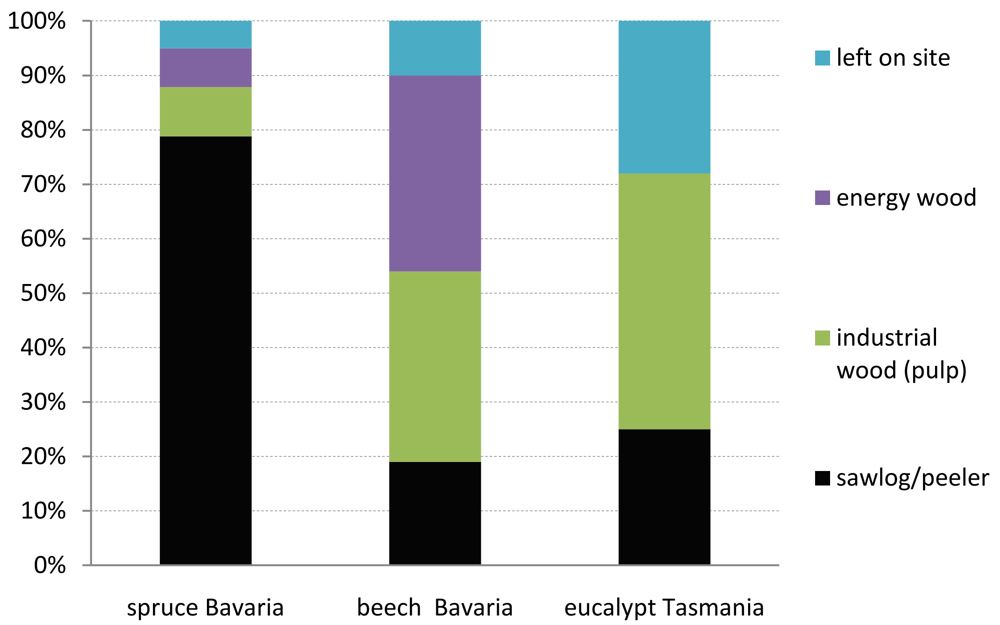


Figure 5: Log grades in the State Forests of Bavaria (2011) and Tasmania (2013)
Data for Bavaria from Statistisches Bundesamt (2013), Tasmania this report.

The small percentage of sawlogs recovered in eucalypt forestry is often criticised. The comparison with oak forestry in Bavaria may give an indication of realistic recovery rates. Oak is one of the most valuable timbers in Bavaria and high quality sawlogs are sold for between 250 and 1000 AUD m^{-3}. A high recovery of sawlogs and veneer logs has thus been the main target of forest management for more than 200 years. The recovery of high quality sawlogs from oak trees harvested in 2011 in the State forest of Bavaria was about 10% (not shown in the graph), total sawlog recovery from oak trees was about 30%. (Figure 6). Considering the losses during wood processing, only about 15% of the harvested volume finally ends up as a high quality product. The comparison with Tasmania may indicate some potential for better recovery of more valuable eucalypt log grades. However, from European experience and from the interviews with Tasmanian wood processors, a sawlog/peeler recovery above 35% is not realistic for eucalypt forestry (plantation and native) in the foreseeable future. Even under an optimistic scenario, more than 80% of a standing tree will end up as woodchips after processing, assuming that the waste from sawing is also recovered as chips.

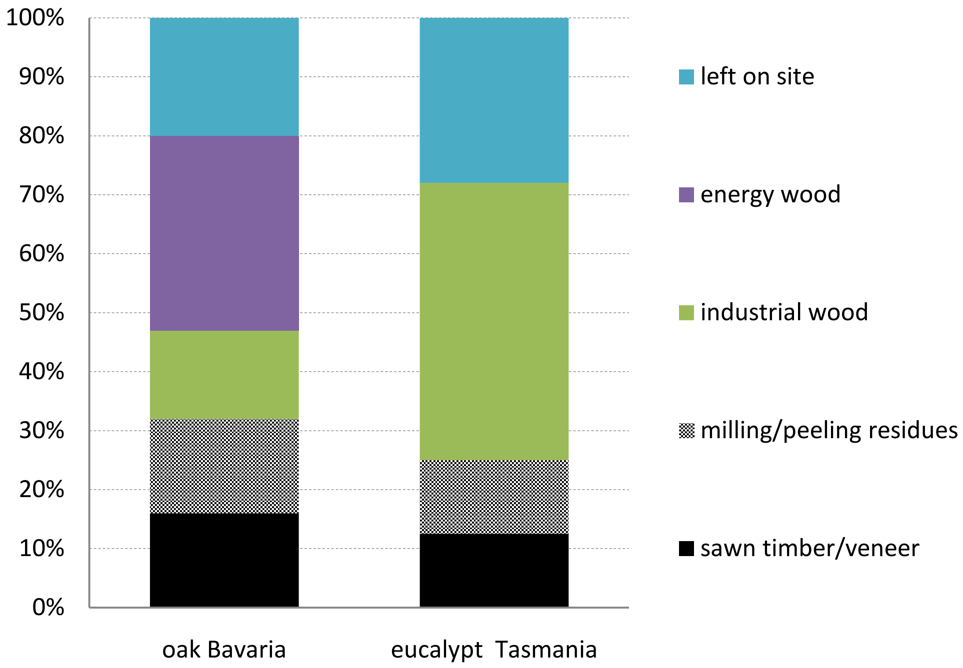


Figure 6: Log grades of oak in Bavaria (2011) and eucalypt in Tasmania (2013).
Data for Bavaria from Statistisches Bundesamt (2013), Tasmania this report.
Processing residues were assumed to be 50% of the log volume.

The development of alternatives to the current dependency on woodchip exports, and a shift to domestic processing, should be a key element of the future forest industry in Tasmania. Beside higher sawlog prices the main difference between current hardwood forestry in Tasmania and Bavaria is a strong and profitable energy market (80 AUD m^{-3} for hardwood energy wood) in Bavaria. The new energy market in Bavaria also increased prices for traditional log grades (pulp, particleboards) through competition. The market for energy wood also allowed better total recovery rates in Bavaria. While in Tasmania on average 30% of a tree is left on site (and often subsequently burnt in the open) the corresponding figure is only 10-20% in Bavaria.

5.1.2 ECONOMY OF BIOENERGY IN COMPARISON TO OTHER FUELS

In Europe there is a clear pattern concerning the economic viability of utilisation pathways for woody biomass:

heat > combined heat and power > bioproducts, bioelectricity

A sensitivity study on the maximum affordable price of biomass for different technologies in the US showed a similar pattern (Manomet Center 2010). While heat from biomass is competitive with other fuels, the production of bioelectricity or biofuels/biomaterials requires government support. Therefore forest biomass in Europe is mainly used for generating heat. In the last 10 years prices for woodchips, fuelwood or pellets increased less than those for fossil fuels and presently woody fuels are significantly cheaper per energy unit (Figure 7). Although the installation cost of wood heating systems is more expensive compared to fossil fuels the use of wood for generating heat is economically viable. The increasing use of pellet stoves in Tasmania is also driven by economic considerations (R. Douglas, personall communication). Modern wood heating systems are very energy efficient with an overall thermal efficiency >70%.

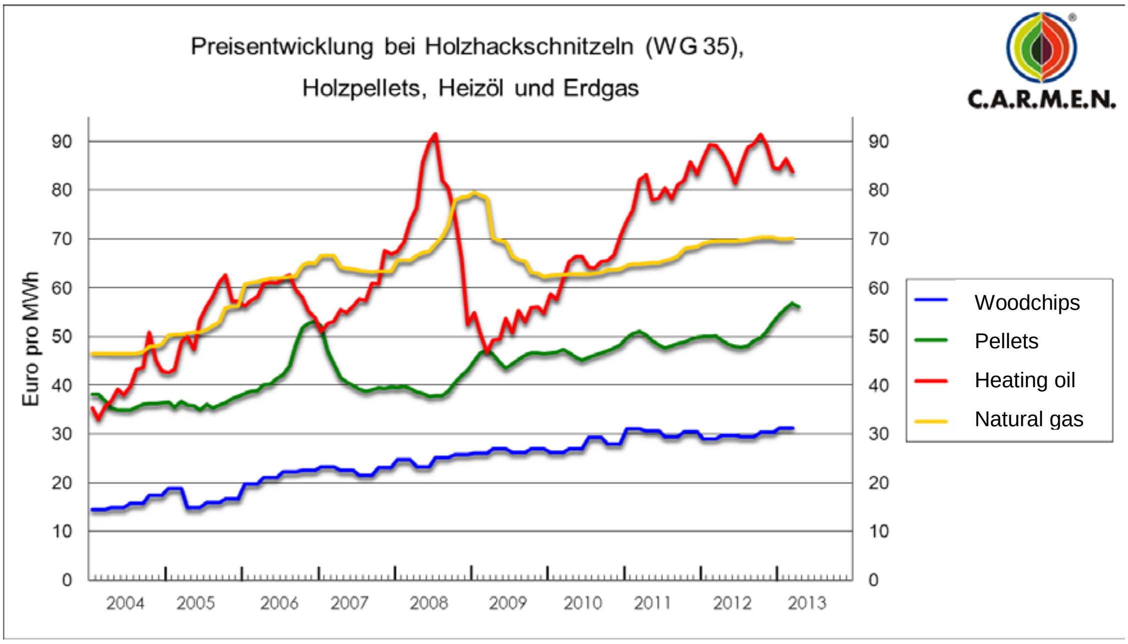


Figure 7: Development of prices for woodchips (35% wood moisture), pellets, heating oil and natural gas. (From C.A.R.M.E.N (Central Agriculture, Raw Material, Marketing and Energy Network, Germany), http://www.carmen-ev.de).

Although combined heat and power plants are more efficient (overall thermal and electrical efficiency around 80%) than heat-only plants, the generation of electricity from wood is more expensive than from fossil fuels due to the high installation costs. Electricity from biomass plants using forest biomass must be promoted by policy instruments like feed-in tariffs, tax incentives or energy tax exemption. In Germany electricity produced in combined heat and power plants using forest biomass is currently supported at 2.5 Eurocents/kWh (forest residues) or at 4 Eurocents/kWh (wood processing residues, waste wood) under Germany's renewable energy program (BMU 2012b).

The production of electricity alone using forest biomass is significantly less efficient (net electrical efficiency about 30%) compared to the combined heat and power production. It is economically inferior to the use of fossil fuels and must again be promoted by policy instruments. Currently there is intense discussion in Europe whether stand-alone electricity production from (forest) biomass should be supported within renewable energy programs. In countries where the financial support is linked with efficiency requirements (e.g. plant must use at least 50% of the co-produced heat), electricity-only plants using forest biomass are not viable.

The production of biofuels and biomaterials from woody biomass is currently an important area of research in Europe and will presumably be part of a priority research field within the upcoming European Research and Innovation Framework 'Horizon 2020'. However, production of such materials is still significantly more expensive compared to fossil fuel products and currently only subsidised pilot plants are operating. While this may change with the expected increase of fossil fuel prices, at this stage the chemical use of forest biomass is more an area of development rather than of large scale operations.

5.1.3 REGIONAL DEVELOPMENT

The value adding of wood utilisation increases with the level of processing in the following order:

Export of logs, woodchips < energy production < industrial use < sawn products

As shown above hardwood forestry produces high amounts of low quality timber and residues even when applying best practice forest management and wood processing. In addition to increasing recovery of sawlogs and engineered wood products, a future forest industry in Tasmania must also find new utilisation pathways for low quality wood. Around the world low quality wood is mainly used for pulp and paper, engineered wood products (mostly particleboards) and energy. Industrial use is usually considered to add higher value compared to use for energy production only (Pöyry Management Consulting 2012) and a high product recovery is desirable. However, pulp or engineered wood products are produced in a very competitive world market, mostly in huge plants processing enormous quantities of timber. The proposed Bell Bay pulpmill in Tasmania was intended to process about 4 M t y^{-1}. The lack of progress with this project makes it unlikely both from an economic and social point of view that such a production facility will be established in Tasmania. Lacking domestic processing facilities, all woodchips must be exported, which creates only a small income per tonne of wood processed and few jobs (West *et al.* 2012). The pulp market is also characterised by strong cyclical fluctuations and depends on the exchange rate of the Australian dollar. In addition the current structure with only two locations (Burnie, Bell Bay) for large scale woodchipping in Tasmania inevitably entails long transport distances.

Under these circumstances using wood for energy or producing pellets could be an attractive alternative. In contrast to the industrial use of woodchips, energy production can be performed at all scales starting from heating individual buildings (using less than 100 t y^{-1}) up to combined heat and power plants or pellet production facilities using more than 100 000 t y^{-1}. A decentralised network of biomass plants minimises transport distances and creates regional income for workers and forest owners. A recent study from the German Institute for the Economics of Forest Industries (Schweinle 2012) quantified the value adding of energy generation at 60 AUD t^{-1} (50 Euro t^{-1}), similar to the first step in other wood processing activities like sawmilling. A different use of the calculated available supply of biomass of 3.3 M t^{-1} y^{-1} could add up to 200 M AUD to the Tasmanian economy. Most of the income and jobs would be generated in local communities which is highly attractive from a regional development point of view. The German Institute for Ecological Economy Research calculated that a 5 MW biomass plant (using about 10 000 t y^{-1}) generates a local income of 45 M AUD (36 M Euro) and 45 full time jobs over a utilisation period of 20 years (Hirschl *et al.* 2010). This corresponds roughly to the domestic jobs created by chipping and exporting about 100 000 tonnes of wood. A different use of forest residues and low quality timber for generating energy could thus make a significant contribution to regional development in Tasmania. The assumption of this study where only 50% of the pulpgrade logs are utilised for energy production still leaves enough potential (> 2 M t y^{-1}) to establish an industry for engineered wood products.

5.2 ECOLOGICAL IMPLICATIONS

While biomass has been considered *a priori* environmentally friendly in the past, this view is increasingly being challenged. The final assessment depends on the land management to produce the fuel, on the combustion technology and the fuel replaced. While most of the concerns refer to land use changes such as clearing forests in order to produce biofuels from agricultural crops (e.g. Johnson 2009), forest biomass harvesting for energy production is increasingly under critical review. The main concerns address the possible negative effects on carbon budgets, biodiversity, soil fertility and air quality.

5.2.1 CARBON EFFECTS

The assessment of carbon mitigation effects of forests and forest management is highly complex from a scientific point of view. A complete assessment in the sense of a life cycle assessment would have to include carbon pools and fluxes in the forest, carbon effects of harvesting and processing operations, substitution and carbon storage effects of harvested wood products and possible effects of alternative land use. In addition the results depend on the temporal (short term vs. long term) and spatial (individual stands or landscapes) scales of consideration. Furthermore current knowledge is insufficient to allow for a reliable estimate of important components. For example the quantitative dynamics of soil carbon, which is more than 50% of total forest ecosystem carbon (Dixon 1994), is still the subject of intensive research and there is still a robust debate about the theoretical steady state of soil carbon storage (e.g. Reichstein *et al.* 2009). In the absence of reliable data, soil carbon changes are often assumed to be zero in the long run and are not considered in carbon budgets. Although considerable progress has been made in the last couple of years (e.g. Manomet Center 2010), complete life cycle assessments are still more a matter of scientific research rather than practical applicability.

The available data for Tasmania does not allow an exact quantification of carbon effects of forest management. There is no reliable data for soil carbon at a landscape level (especially when including the whole rooting zone), there is little data available for aboveground biomass beside commercial trees, the equilibrium carbon pool of unmanaged landscapes which is influenced by decadal or centennial disturbance regimes remains uncertain and long term effects can only be assessed using models that have high error margins (Moroni 2011, Dean *et al.* 2012). Therefore only some qualitative statements can be made here considering carbon pools and fluxes in trees and in harvested wood products. Harvested wood products are intended to be included in forest carbon accounting in the next commitment period of the Kyoto Protocol, although the exact accounting rules are still under negotiation (Wold 2012). The considerations here are based on a landscape approach and will use the terms “unmanaged landscape” and “managed landscape”. The term “unmanaged landscape” here refers to a forest landscape without active human intervention and consists both of oldgrowth forests and younger successional stages. The term “managed landscape” refers to harvested native regrowth and plantations.

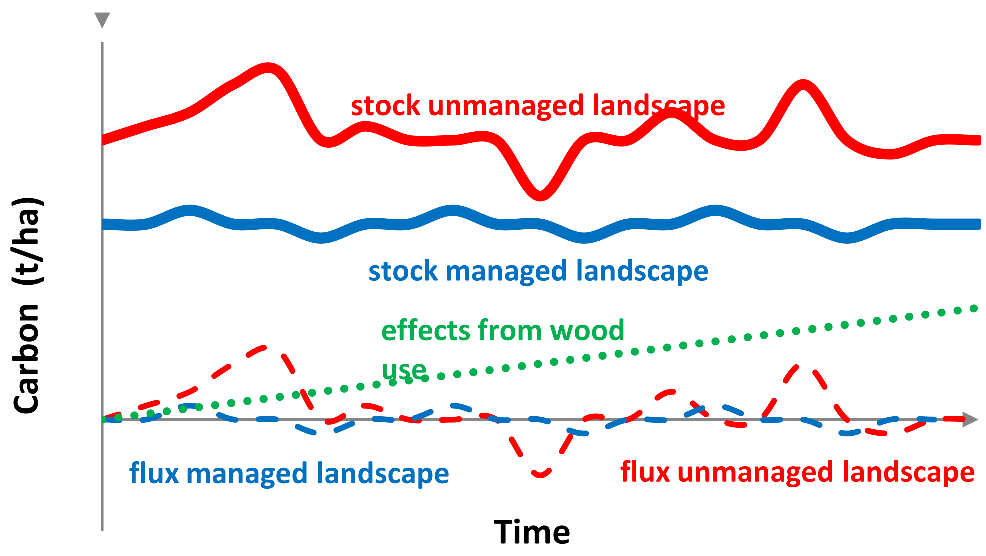


Figure 8: Schematic representation of carbon pools and fluxes in unmanaged and managed forest landscapes.

Figure 8 shows a schematic representation of carbon stocks and fluxes in unmanaged and managed landscapes. Unmanaged landscapes usually have higher carbon stocks than managed landscapes (for an overview see Moroni 2011) even when taking into account that there is a wide range of carbon densities according to vegetation type (Moroni *et al.* 2010). Although there are still open questions from a scientific point of view, net fluxes of unmanaged landscapes are assumed to be zero in the long term, as respiration equals assimilation (Mackey *et al.* 2013). The fluctuations result from natural disturbances like wildfire or pests (carbon source) followed by recovery periods (carbon sink). The net fluxes of sustainably managed landscapes (plantations or native forest regrowth) are also assumed to be zero because harvest equals assimilation. Due to the suppression of large disturbances and due to the smaller stocks the fluctuations are assumed to be smaller compared to those in unmanaged landscapes. In managed landscapes also the effects of the harvested wood products must be taken into account. This includes carbon storage in wood products and substitution effects when the harvested wood replaces fossil fuels or energy intensive materials like steel or concrete (for a discussion of these effects see Klein *et al.* 2013).

Due to the differing carbon levels of landscapes it is important to consider where harvesting takes place. Harvesting carbon dense mature oldgrowth forests releases carbon by reducing carbon stocks to the lower level of the managed landscape (Figure 9). In the graph this ‘carbon debt’ is simplified and shown for the first year, although in reality it is more complex. This ‘carbon debt’ is then gradually offset by the effects of the harvested wood products. However, depending on the assumptions (carbon pools of forests, harvest intensity, type of wood products) it takes several decades to centuries to ‘pay back’ this carbon debt. Converting oldgrowth forests to plantations follows the same principle: a reduction of carbon stocks (the amount depends on the type of plantation) is ‘paid back’ by storage and substitution effects of wood products (potentially higher than in native forests due to a higher productivity). The extreme example would be the conversion of oldgrowth forests to annual biofuel crops (e.g. sugar cane) with a high productivity but releasing large amounts of carbon during conversion. The missing consideration of these effects when harvesting oldgrowth forests is a common (and justified) point of criticism of accounting rules within the first Kyoto Protocol (e.g. Johnson 2009, Searchinger *et al.* 2009). Unless long timeframes of at least several decades are considered, it is beneficial to maintain unmanaged landscapes with high carbon stocks.

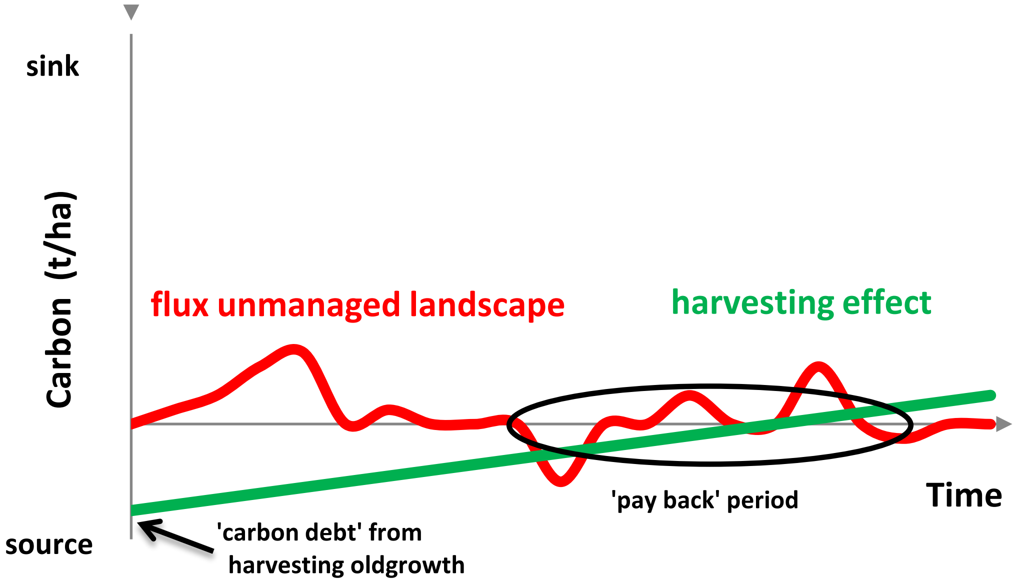


Figure 9: Schematic representation of carbon effects resulting from harvesting an unmanaged landscape.

The effects are different in a managed landscape. Harvesting reduces carbon stocks of individual stands but stocks in the landscape remain constant as long as the harvest is below increment (Figure 10). The question now is whether it is better to continue harvesting or to rebuild the higher carbon pools of the unmanaged landscape by conservation. Both continuing harvesting and conservation have positive effects for carbon mitigation, either by accumulating carbon in the forest (red line, referred to as 'regrowing unmanaged level' in Figure 10) or by storage and substitution effects of wood products (green line). An exact quantitative comparison of these alternatives is impossible due to the lack of data. However, the conservation effect will cease at some point in time when natural disturbance starts to offset carbon accumulation in the unmanaged landscape (referred to as 'natural equilibrium' in Figure 10). The harvesting effects will continue as long there is a substitution of fossil fuels and of products like steel or concrete with high embodied energy. Model calculations indicate that the differences between conservation and continuing management in native forest regrowth are small in the short term but harvesting is superior to conservation in the long term (Klein *et al.* 2013, Ximenes *et al.* 2012). In plantations continuing harvesting is normally superior to conservation even in the short term. The high production rates of plantations lead to high carbon mitigation effects via storage of wood products or substitution effects.

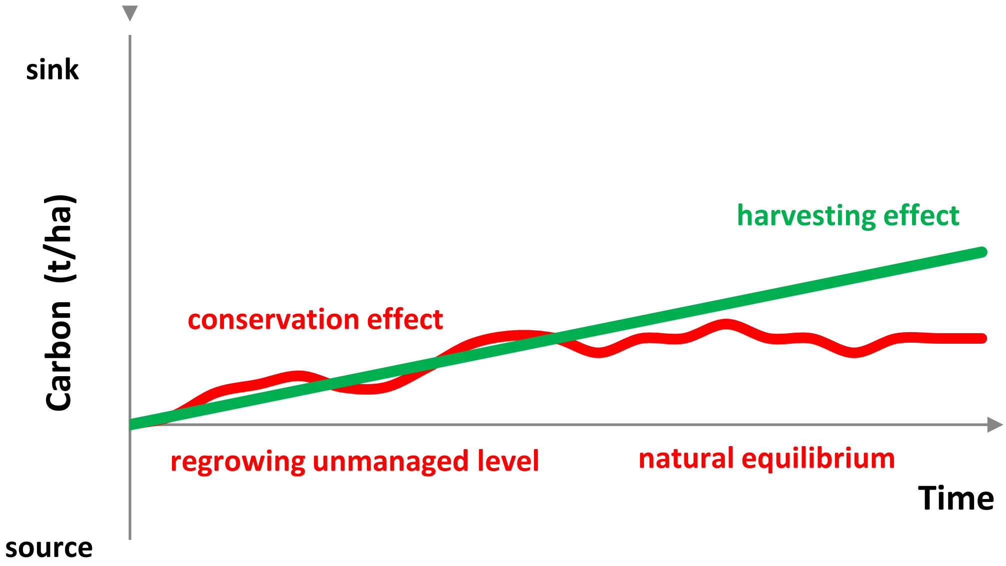


Figure 10: Schematic representation of carbon effects resulting from harvesting a managed landscape vs. conservation. The fluctuations of the red line result from natural disturbances such as fire, windthrow or pests.

Based on these considerations the use of forest biomass for energy will reduce carbon emissions, as long as carbon stocks of the landscape stay at least constant. This is usually the case when harvesting takes place in an already managed landscape (native forest regrowth or plantation). In Europe the small areas of remaining oldgrowth forests are all protected from logging and forest management is mainly based on native regrowth, to a smaller extent on plantations. Detailed forest inventories all over Europe document that carbon stocks of managed European forests are still significantly increasing despite intensive harvesting (Eurostat, cited in AEBIOM 2012). Under such circumstances the use of forest biomass for energy for heat or combined heat and power has significantly lower emission of greenhouse gases than the use of fossil fuels (e.g. German Ecological Institute 2010, cited in German Institute for Renewable Energies 2013).

For the supply estimates in Tasmania only harvesting in native regrowth and plantations was considered. The assumed harvesting intensity in native regrowth is about 1.3 m^3 ha^{-1} y^{-1}, significantly below the long-term increment of at least 2.5 m^3 ha^{-1} y^{-1} for native forest regrowth. This is derived from an average annual increment of at least 4 m^3 ha^{-1} y^{-1} in tall eucalypt forests (Forestry Tasmania 2009a) and at least 1.5 m^3 ha^{-1} y^{-1} in low eucalypt forests (Forestry Tasmania 2009b). The same applies to plantations since the assumed harvesting intensity in the plantations (about 15 m^3 ha^{-1} y^{-1}) is below average increment rates, which can be expected to be around 20 m^3 ha^{-1} y^{-1} (Neilsen 1990).

Carbon stocks of native regrowth and plantation forests in Tasmania will therefore still increase significantly despite harvesting in the near future, unless there are landscape level disturbances. Under these circumstances replacing fossil fuels with forest biomass derived from residues and low quality timber has carbon mitigation effects according to international accounting rules. Conservation also has carbon mitigation effects as long as forest ecosystems accumulate carbon. The comparison of harvesting vs. conservation strongly depends on the timeframe considered and on the potential of native regrowth to accumulate carbon. The available data in Tasmania does not allow a quantitative comparison. The rate at which conservation accumulates carbon is unclear and depends on natural disturbances with a random reoccurence. In Tasmania fires have a strong influence on the carbon storage of forest landscapes (May *et al.* 2012) and it is still an open question which forest type (eucalypt, mixed forest, rainforest) will finally develop in an unmanaged forest and how much carbon will be stored in the landscape (Moroni 2011).

5.2.2 BIODIVERSITY AND SOIL FERTILITY EFFECTS

The intensive removal of forest biomass can affect biodiversity and soil fertility. Dead wood (often termed coarse woody debris, or CWD) is a major habitat component of forest ecosystems and removing large quantities of CWD or not leaving enough biomass for generating new CWD will have adverse effect on a wide array of species such as birds, saproxylic beetles or fungi (Grove and Meggs 2003). Fine fractions of the tree such as the branches or leaves have significantly higher nutrient contents than the stemwood and the removal of whole trees (whole tree harvesting) extracts large amounts of nutrients which can deplete soil fertility and site productivity. Therefore the best management guidelines for biomass harvesting all include prescriptions for leaving sufficient CWD and slash on site (see Manomet Center 2010). Although the qualitative aspects are well understood there is still some uncertainty on the quantitative side. Even for intensively investigated European forests the proportion of CWD that must be retained in order to maintain biodiversity is not easy to quantify and depends on the species group under review (Müller and Bütler 2010). Whole tree harvesting studies in Scandinavia have documented long term negative effects on site productivity (Helmisaari *et al.* 2011) and have shown that the effects depend on a complex interaction between harvesting intensity, forest type and site factors.

Tasmania's native forests have some of the highest stocks of CWD in the world and its ecological value is well documented (Grove and Meggs 2003). Grove (2009) developed guidelines for CWD retention in native forest operations. The assumptions applied here with respect to harvesting intensity are based on those of Grove (2009) but are even more conservative in order to be on the safe side. For the removal of nutrient-rich tree components, a conservative approach was also applied. Since there is no quantitative data available for Tasmania both in native forests or plantations on how much material could be removed on certain sites without threatening soil fertility it was assumed that all fine material such as leaves, twigs, branches or bark (for all native eucalypts) was left on site and was not available for energy production.

These assumptions result in a much lower harvesting intensity than that found in comparable studies in Europe. Figure 11 shows the comparisons between Bavaria and Tasmania on a landscape level. While the exact figures will differ between European countries the general statements will remain similar, since all over Europe the area of forests not managed for wood production is comparatively small.

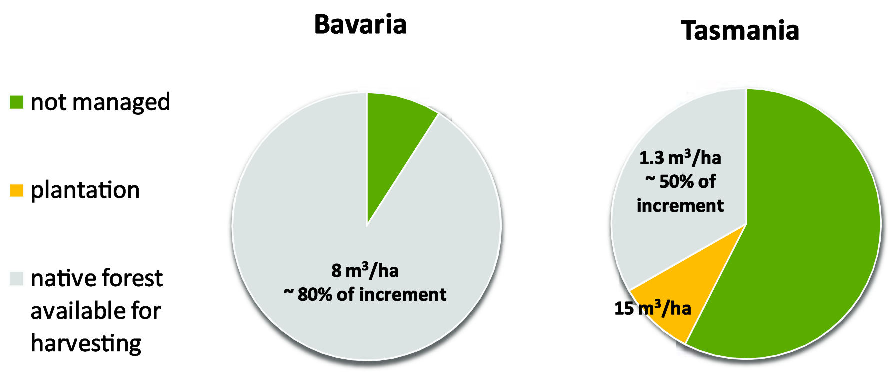
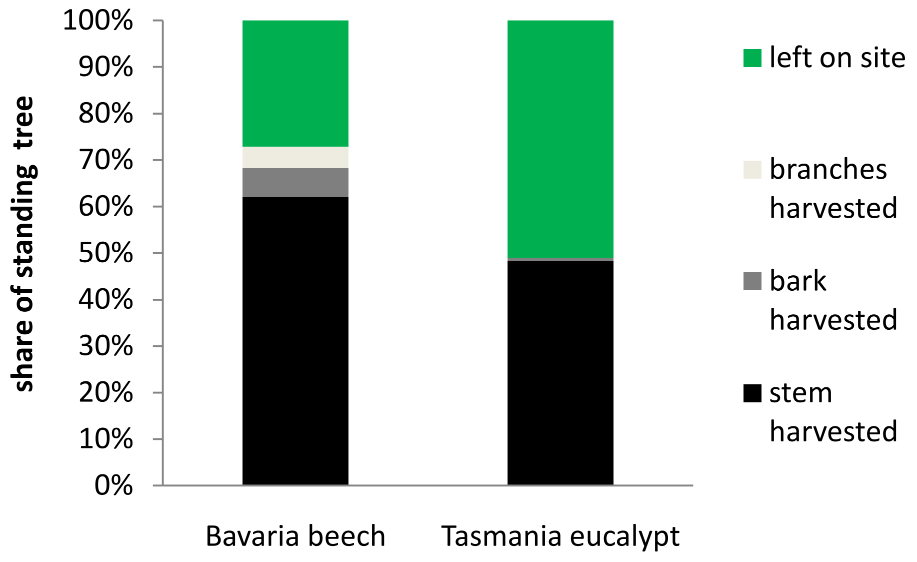


Figure 11: Comparison of harvesting intensity (landscape level) in Bavaria and Tasmania. Data for Bavaria according to Rothe and Borchert (2003), Tasmania this report.

In Bavaria about 10% of the total forest area is not managed, but only about 3% is in formal reserves. The other 90% of the forest area is managed intensively as native forest regrowth, harvesting about 80% of the increment over the long term. There are no intensive plantations managed with short rotation periods and large scale clearcutting. This compares to Tasmania where more than 50% of all forests are not managed for wood production after the ‘Tasmanian Forest Agreement‘. Within the native forest areas managed for wood production, which are predominantly regrowth forests, about 50% of the long term increment is harvested, significantly less compared to nearly all places in Europe. About 10% of Tasmania’s forests consist of plantations which are managed very intensively.

The assumed harvesting intensity at the stand level is also significantly lower than that in Bavaria (Figure 12). Even conservative estimates in Bavaria assume that about 70% of a standing tree can be harvested (Wilnhammer *et al.* 2013). The assumed intensity of harvesting in Tasmania is only 50% of the standing tree since all leaves, branches and bark (except small amounts which are not stripped off) as well as 30% of stemwood generally stay on site.



	Bavaria beech	Tasmania eucalypt
	assumed removal (%)	
leaves	0	0
branches	30	0
bark	90	10
stem	85	70

Figure 12: Comparison of harvesting offtake in native regrowth (tree level) in Bavaria and Tasmania. Data for Bavaria from Weis and Goettlein 2012, Tasmania: Ximenes *et al.* 2008 and this report.

The effects of forest biomass harvesting on biodiversity and soil fertility are closely related to the amount of biomass removed. The assumed harvesting intensities in this study are very low both on a landscape and stand level and leave more than enough biomass on site to meet guidelines for maintenance of biodiversity and soil fertility.

5.2.3 AIR QUALITY

A detailed air quality analysis is beyond the scope of this study and here only some general information on particulate matter is presented. The combustion of wood – like the combustion of other solid fuels – leads to the emission of particulate matter (PM), which can have adverse health impacts (Johnston *et al.* 2012). While there are still many open questions concerning the specific health effects it is clear that the combustion type has an important influence on emissions. While incomplete or low oxygen combustion has an increased health impact, continuously operating systems emit fewer and less toxic particles compared to basic stoves (Nussbaumer and Fong 2012). Emission and health effects decrease in the following order:

Burning in the open > old fuel stove > modern fuel stove > pellet stove > biomass plant

In Germany the strong increase of firewood use in small woodstoves has prompted concerns about particulate matter emissions and from 2015 there will be new, strict air quality standards for small private woodstoves (BMU 2012a). On the other hand modern pellet stoves and biomass plants have very low emission rates and fulfill the requirements of the strictest standards as set by countries such as Sweden, Germany, Switzerland or Austria (for Germany for example BMU 2012a). Tasmania's current practice is dominated by fuelwood combustion in more basic stoves and by burning in the open, both emitting a high amount of particulate matter per unit wood burnt. Compared to this the emissions from modern pellet systems of biomass plants would be insignificant (for examples see Nussbaumer and Fong 2012). If new systems are installed in place of some of the older style stoves or some of the open burning, then the overall emissions could even decrease.

5.3 SOCIAL IMPLICATIONS

The social context of forest biomass for energy has been investigated in a recent thesis 'Seeing the Forest for the Trees – Australian Forest Biomass for Energy – An Investigation of Understanding, Acceptance, Trust & Legitimacy' (Ulrik 2012). He writes that 'a lack of understanding and acceptance among important stakeholders' is a major constraint for forest biomass. The implementation of 'forest biomass for energy purposes in Australia has been overshadowed by disputes regarding Australian "native forests" – which has damaged social acceptance of forest biomass and discredited bioenergy in Australia'. He concludes that the lack of legitimacy is the main reason that implementation of forest biomass for energy in Australia is minimal compared to many European countries.

In Tasmania the long ongoing intensive controversy about native forestry ('No Greens', 'Save Tassie´s Forests') has certainly been a major constraint against using biomass for energy. All activities potentially dependent upon logging of native forests were opposed by the environmental movement. However, with the recent enacting of the 'Tasmanian Forest Agreement', virtually ending harvesting in oldgrowth, the situation could change. For the first time in the long ongoing conflict the environmental signatories of the agreement have given consent to (a much reduced) harvesting of native forests (nearly all of this regrowth) in return for reservation of additional large areas.

At this stage it remains an open question whether this will also change the attitude towards the use of biomass for energy. While the extreme wing of the environmental movement still fiercely opposes bioenergy (e.g. Markets for Change 2013) there are signs that the opportunities to use biomass with a strong community engagement could be supported by environmental groups. In contrast to industrial pulp or particleboard production, forest biomass for energy can be operated at small and medium scales. This could promote acceptability in Tasmania, which traditionally experiences difficulty in overcoming community opposition to large industrial projects. Ulrik (2012) also suggested regional biomass projects with a strong community license in order to develop a better understanding of the possibilities of forest biomass use.

Ulrik's suggestions correspond well with the experiences in Bavaria and all over Europe. Small and medium sized biomass plants have strong support from communities and in most cases also from environmental groups. The bigger the plants the more they are usually challenged. Some years ago the biggest biomass plant in Vienna was processing about 200 000 t y^{-1} of forest biomass. Recent plans in England are aiming at electricity plants using several millions of tonnes per year of forest biomass. In addition to efficiency questions of big electricity-only plants, there is an increasing social debate whether such large scale facilities are reasonable. In Germany the use of forest biomass for domestic heating and for small/medium sized heat or heat and power plants has a strong social licence and is supported by all major parties including the Greens. Due to the rapid increase (forest biomass use tripled in the last 15 years) there are increasing concerns that the use of forest biomass for energy may lead to an overexploitation of forest ecosystems and that too much wood is directly burned instead of producing wood products. The German Green party therefore recently requested regional plans for sustainable supply of biomass and a priority of wood products within the layout of renewable energy programs (Behm 2013). The key concern is that biomass harvest may drive forest management, similar to some Tasmanian concerns that biomass for energy would increase native forest harvesting. Therefore it is crucial to establish effective and transparent forest policy measures ensuring that only residues and low quality material is used within the already planned harvest in order to maintain social licence for forest biomass use in native forests.

6 CONCLUSIONS

After the Tasmanian Forest Agreement the total possible future forest harvest (sawlogs/peelers and pulpwood) in Tasmania is still at least 5.5 M m^3 y^{-1} (page 18), about three quarters of this sourced from plantations. The resulting harvest of 11 m^3 y^{-1} per capita is similar to that in countries like Sweden or Finland, well known for their strong forest industry. Since the softwood plantation estate is comparatively small, Tasmania's future forestry will mainly depend on eucalypt species. Eucalypt forestry inevitably produces a high proportion of low quality timber. Even best practice native hardwood forestry results in more than 80% of a standing tree finally ending up in material of woodchip quality, which is similar to the proportions from hardwood forestry in Europe. In eucalypt plantations grown for pulpwood the proportion of low quality timber is even higher. A Tasmanian future forest industry must therefore – besides trying to increase the yield of high quality products – work towards better use of woodchips that are currently exported and on a better use of residues that are not used at all.

Tasmania has a sustainable supply of forest biomass for energy of at least 3 M green t y^{-1}, which would be sourced predominantly from plantations, with a smaller fraction coming from native forest regrowth harvesting. About 70% of the potential energy wood comes from private forests, 30% from State forests. According to European experiences, the energy market could offer a viable alternative to industrial processing for pulp or particleboards. In contrast to industrial use which usually is performed at very large scales (the proposed Bell Bay pulpmill was designed for four million tonnes per year) energy production is performed at much smaller scales. In Central Europe even the bigger biomass plants or pellet production facilities only operate on a 100 000 t y^{-1} scale and the majority of plants are well below 10 000 t y^{-1}. The use of wood for energy production could add significantly more value compared to that of the current export of woodchips. The energy market is also more stable compared to the pulp market which is characterised by cyclical fluctuations. Even assuming production of 3 M green t y^{-1} for energy, this would still leave more than two million tonnes of pulpgrade eucalypt logs available to build an industry for engineered wood products.

Economics will decide the purpose for which the material is finally used. Based on European experiences heat from biomass is competitive with fossil fuels. It certainly makes sense to investigate the possibilities to use forest biomass for generating heat in private households, public facilities (e.g. schools, hospitals, pools) and industry in Tasmania. Combined heat and power plants are very efficient but still need financial support within renewable energy programs. The generation of electricity-alone from biomass is relatively inefficient. Hydro and windpower are better renewable alternatives for electricity production in Tasmania. The generation of biofuels, biomaterials or charcoal is still in the development stage. Since Tasmania has a big resource of low quality timber it should maintain a strong interest in the further development of these technologies. Due to Tasmania's small domestic consumption an important fraction of forest harvest must be sold to the mainland and/or also exported in future. The world market for pellets has developed strongly in the last 10 years and is expected to develop further in time (AEBIOM 2012). It would be worthwhile exploring the possibilities of producing pellets based predominantly on wood processing residues and maybe on plantation wood.

Forest biomass for energy is not a panacea but its sound use can make a significant contribution to renewable energy generation, climate change mitigation and regional economic development. Like all other forms of energy, forest biomass has its problems and should be used in a sensible way. This means in particular:

» No use of biomass from oldgrowth forests,

» Applying best management practices to leave enough material for biodiversity and soil fertility,

» Only using residues and low quality material directly for energy. In native regrowth maximizing the recovery of higher quality logs first and no biomass-only harvesting,

» Enacting adequate forest policy and planning instruments to ensure that biomass use is not driving forest management. The establishment of plants using material for energy or pellet production should be based on regional studies on the sustainable supply of feedstock,

» Using biomass in efficient small and medium size plants.

Coming from Europe with a limited availability of wood it is sometimes hard to understand how little economic and ecological advantage Tasmania is currently gaining from its large natural forest resource. It is also surprising that using forest biomass for energy gets so little political support despite its vast potential. It appears that the long ongoing conflict on harvesting in oldgrowth forests has consumed much of the social capital which would have been needed to develop a future forest industry and more effective use of renewable energies. Hopefully the ‘Tasmanian Forest Agreement‘ which virtually ends harvesting in oldgrowth forests is the starting point for a new era based on plantations and native forest regrowth. The development of a profitable and sustainable future forest industry based on these resources is challenging and will require significant commitment. The use of residues and low quality timber for energy could be an important part of this future industry.

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8 APPENDIX

8.1 LIST OF PERSONS WHO CONTRIBUTED DATA/INFORMATION

Name	Organisation/Company
Mohammad Reza Ghaffariyan	AFORA
Scott Arnold	ARTEC
Steve Barber	Barbers Sawmill
Dale Jessup	Branxholm Sawmill
Shawn Britton	Britton Brothers
John Raison	CSIRO
John Todd	Eco-Energy Options
Bill Wilson, Gary Brown, Sarah Whatley, Anthony Cook, Bob Hyde, Elzbieta Chelkowska	EPA Division, DPIPWE
James Neville Smith	FALCON
Sarah Munks, Amy Koch, Chris Grove	Forest Practices Authority
Mark Neyland, John Hickey, Martin Moroni, Michael Wood, Doug Massey, Marie Yee, Lachie Clark, Mike McLarin, Paul Adams, Peter Volker, Martin Stone	Forestry Tasmania
Sodum Gandhi	Greenworks, Australia
Jim Wilson, Darren Herd	Gunns Ltd (in Liquidation)
Rick Watson	Huon Valley Timber
Russ Sweeting	Longford Sawmill
Peg Putt	Markets for Change
Brett McKay	McKay Timber
David Dean	Morleah Millers
Arnold Willems	Norske Skog
Rob Douglas	Pellet Fires Tasmania
Ian Ravenwood	Private Forests Tasmania
Frank Strie	Schwabenforest
Greg Hickey	Ta Ann Tasmania
David Loone	Tasmanian Wood Panels
Vica Bailey	The Wilderness Society Tasmania
Kaine Arkley	Timberlands Pacific
Gary Harper	TimberLink Australia
Dario Tomat	Whetstone

8.2 PERSONAL BACKGROUND

Dr. Andreas Rothe is a Professor at the forest faculty of the University of Applied Sciences in Weihenstephan, Germany, the biggest+ forestry school at the Bachelor level in Germany (500 forestry students). In combination with the School of Forest Science of the Technische Universität München and the Bavarian State Institute of Forestry the faculty forms the Centre of Forestry Weihenstephan, the biggest forest research centre in Germany with a staff of about 400 people (www.center-of-forestry-weihenstephan.de). Dr Rothe teaches applied forest ecology and environmental resource management. He managed the faculty as dean from 2007-11 and has been the vice-dean since. He has a strong background in forest biomass and was responsible for establishing a new bachelor program in “Management of Renewable Energies” in 2008. Before joining the University Dr. Rothe worked for “Forestry Bavaria” for 15 years, including 5 years with the forest management department. He worked in native forest silviculture with Forestry Tasmania for 3 months in 2004 and has maintained contact with Tasmanian forestry ever since.