BIOMASS AND BIOENERGY 80 (2015) 162–172

Available online at www.sciencedirect.com

ScienceDirect

http://www.elsevier.com/locate/biombioe

Research Paper

Current and potential use of forest biomass for energy in Tasmania

Andreas Rothe [a,*], *Martin Moroni* [b], *Mark Neyland* [b], *Matthias Wilnhammer* [a]

[a] *Faculty of Forestry, University of Applied Sciences Weihenstephan-Triesdorf, Hans-Carl-von-Carlowitz-Platz 3, 85354, Freising, Germany*

[b] *Forestry Tasmania, GPO Box 207, Hobart, 7001, Tasmania, Australia*

ARTICLE INFO

Article history:
Received 20 April 2015
Accepted 22 April 2015
Available online

Keywords:
Forest biomass
Feedstock supply
Tasmania
Firewood
Forest residues

ABSTRACT

Although Tasmania, Australia's southernmost state, has a large forest resource per capita there is no reliable information on the potential use of harvest residues, low quality logs or processing residues for energy production. In order to address the current knowledge gap we: i) quantified the current use and the potential sustainable supply of forest biomass in Tasmania, ii) compared those results with the use of forest biomass in Bavaria, a comparable state in Southeast Germany, and iii) analysed the low Tasmanian production of energy from forest biomass considering economic, legislative and social drivers. The current use of forest biomass for energy (400 kt y^{-1} of bone dry material) represents about 6% of Tasmania's total annual energy supply. The potential supply of forest biomass for energy production is estimated at 1800 kt y^{-1} of bone dry material equivalent to about 30% of Tasmania‘s current total annual energy supply. In contrast to Bavaria and other European countries, forest bioenergy production is small in Tasmania relative to the available resource and could be more than quadrupled from a resource availability perspective. A weak domestic market for energy wood leading to low prices, the lack of political stimuli and a low social acceptance are likely key factors. As a strong increase in market prices for forest biomass is unlikely, political incentives are necessary in order to increase the use of forest biomass. Addressing social acceptance will be a prerequisite for the success of initiatives or legislation to achieve this potential.

* *Corresponding author*. Tel.: +49 8161 71 5970; fax: +49 8161 71 4526.
E-mail addresses: andreas.rothe@hswt.de (A. Rothe), martin.moroni@forestrytas.com.au (M. Moroni), mark.neyland@forestrytas.com.au (M. Neyland), matthias.wilnhammer@hswt.de (M. Wilnhammer).
http://dx.doi.org/10.1016/j.biombioe.2015.04.021

1. Introduction

Tasmania, Australia's southernmost state, has a large forest resource per capita. Although about half of the 33 000 km^2 total forest area is reserved the total annual harvest is still at about 5 hm^3 (1 hm^3 = 1 000 000 m^3) of timber corresponding to 10 m^3 $capita^{-1}$ [21]. In the past the majority of this harvest has been from native forests but in the future plantations will become the main source of timber. The bulk of the plantation estate in Tasmania and in fact throughout south-eastern Australia has been planted over the last 15 years, and whether it is managed for pulpwood or solid wood products this estate is currently some years from maturity. As the plantation estate matures, the potential harvest may increase [19].

The use of forest biomass for energy is comparatively small in Tasmania and restricted to domestic firewood and some industrial heating plants. Substantial uncertainties exist regarding the current use and the sustainable future supply of forest biomass feedstock for energy production in Tasmania. The last officially published figures on firewood use date back over 14 years [16] and a comprehensive study on industrial biomass use for energy production is not available. Several recent studies have investigated the potential use of biomass for energy 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. Refs. [14,19]) or detailed estimates for a potential consumer considering the area and feedstock for a special purpose (e.g. Refs. [23,63]). There is no reliable information on the potential Tasmanian forest biomass for energy feedstock originating from forest management covering both public and private land.

In contrast to the situation in Tasmania, the use of biomass for energy has significantly increased in Europe over the last twenty years [20]. Sweden and Finland, two European countries with a large forest resource per capita, currently produce between 25 and 30% of their final energy consumption from (predominantly forest) biomass [4]. The increasing use of forest biomass for energy was stimulated by rising prices of fossil fuels and political support for renewable energy. As a consequence, the public and scientists are increasingly concerned about overexploitation of forests and strong competition between the material and energetic utilisation of wood from forests. Therefore several wood supply estimates have been conducted producing a comprehensive view of the wood supply potential for bioenergy production at the European (overview see Ref. [20]), individual nation and region within nation level (e.g. Refs. [30,32,62]).

In order to address the current knowledge gap about forest biomass for energy in Tasmania we undertook a study that:

i) quantified the current use and the sustainable potential supply of forest biomass for energy production in Tasmania,
ii) interpreted those results in comparison to Bavaria (a comparable state in Germany) and
iii) analysed the differences considering economic, legislative and social drivers.

In this study the term "forest biomass" refers to all woody biomass generated directly by forest management (split logs, other low quality logs, harvesting residues) and wood processing (e.g. shavings, sawdust, woodchips).

Tasmania can be seen as a case study for a region, where the use of forest biomass is marginal compared to the available forest resource. The results are intended to foster a better future utilization of forest biomass and wood in general, and to inform forest policy development and public discussions.

2. Material and methods

2.1. *Current use of forest biomass for energy*

Estimates of the volumes of wood-processing residues used for energy were based on oral or written interviews undertaken with representatives of the wood processing industry during May/June 2013 [44]. Between them, the participating companies were responsible for processing more than 90% of the total harvest in Tasmania at that time. The estimates for domestic firewood consumption were based on data from Driscoll et al. [16]; which were updated by Todd [56] and on unpublished data from a wood-heater survey performed by the Tasmanian Environment Protection Authority during the winter of 2011. Firewood consumption was estimated by multiplying the number of households using firewood as a main heating source with an average household consumption of 4.8 t y^{-1} of air dry material and by multiplying the number of households using firewood as a secondary heating source (where firewood is used as a supplement to a different primary heating source) of 2.2 t y^{-1} of air dry material.

2.2. *Potential supply of forest biomass for energy*

The potential supply of forest biomass for energy in the short term (over the next three years) was calculated separately for low quality logs and harvesting residues resulting from forest management of both native forest regrowth and plantations, and from wood processing residues (woodchips, shavings, sawdust). Material from oldgrowth harvesting was not included due to the low public acceptance of such harvesting and since oldgrowth harvesting is a very small proportion of the total harvest following signing of the Tasmanian Forests Agreement Act in 2013.

2.2.1. *Native forest regrowth*

For State forests the potential supply of low quality (pulpgrade) logs and harvesting residues 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. 'Tall' forests are defined as those over 34 m in height whilst 'low' forests are those from 8 to 34 m tall, in accordance with past practice [36,52]. Non–eucalypt species were not considered since they comprise <5% of the annual harvest. Future rates of harvest were based on the area of native forest regrowth harvested during the 2009/10, 2010/11, and 2011/12 Australian financial years (1 July – 30 June) derived from Forestry Tasmania's operational database. Forestry Tasmania is a government business enterprise charged with managing the production of timber from the State controlled production forests.

Oldgrowth areas were subtracted from total harvested areas and a further 20% reduction was assumed in line with the Tasmanian Forests Agreement Act 2013 which included a significant increase to the reserve area. Volumes per hectare were calculated using Forestry Tasmania's inventory database. Bark, branches and leaves were considered most likely to remain on site and were not included in the biomass for energy estimates. Biomass of stems and coarse woody debris for 56 forest classes and 21 inventory areas were averaged for the two forest groups 'Tall Eucalypt Forest' and 'Low Eucalypt Forest' (see Ref. [44] for further details). Harvest residues available for energy production were assumed to be 15% of total solid forest biomass, which includes live standing volume, dead standing volume and downed dead wood decay class 1 and 2 [28]. The 15% fraction has also been used by Ref. [19] and is based on the assumption that all <20 cm diameter solid forest biomass is left on site to maintain site nutrient levels and a significant fraction of >20 cm living biomass and 85% of dead solid biomass is retained on site in order to provide enough material for continuity of coarse woody debris formation. Recovery of 15% of harvest residue volumes is consistent with field trials where 13–17 % of total solid forest biomass was removed [5,41]. These trials assessed the economic recovery of fuelwood, and generally only pieces that were large enough to be collected using a forwarder were included; this varied with distance from landing, with a higher proportion of material collected close to the landing, and less from further away. In addition to harvest residues we considered 50% of pulpgrade logs to be available for energy production, based on current practices in Germany concerning hardwood utilisation [51].

For private forests the potential supply of low quality (pulpgrade) logs was calculated using published harvest rates for pulpwood for the 2009/10, 2010/11 and 2011/12 financial years [39]. Again 50% of pulpgrade logs were considered to be available for energy production. Available biomass from harvesting residues was assumed to be 45% of pulpwood harvest using the same relationship between harvesting residues and pulpwood as for State forests.

2.2.2. *Plantations*

For hardwood plantations under public management only thinnings and clearfells before mean rotation age were considered since there will be little mean rotation age clearfelling (<3% of harvesting volume) in coming years. Thinning and early clearfell areas and the corresponding harvesting volumes were available from internal planning processes of Forestry Tasmania.

Private hardwood plantations are managed almost entirely for pulpgrade material using short rotations (mostly 12–18 years). Since significant areas of these plantations are mature, the potential harvest was estimated by multiplying average annual clearfell area with estimated harvest volume per hectare. We conservatively assumed an 18 year rotation age and a stemwood volume of 250 m^3 ha^{-1} [12]. Aboveground residues (bark, branches, leaves) account for about 25–30 % of total biomass in eucalypt plantations [38]. Only one third of these residues (corresponding to about 10% of standing biomass) were considered to be available for biomass energy production due to economic and ecological restrictions ([26]; personal communication from forest growers). As for the assumptions for native forest regrowth, we considered that 50% of plantation hardwood pulpgrade logs could be available for biomass energy production.

Future harvest rates for softwood plantations were based on average harvest volumes for the period 2002–2011 during which time harvesting rates have been relatively constant [2]. In contrast to the assumption for hardwood material we assumed that pulpgrade softwood is only used for industrial purposes (current practice) and would not be available for energy. Available harvest residues for energy were assumed to be 7% of the merchantable volume of sawlog and pulp logs ([25]; personnel communication from forest growers). All small slash (<8–10 cm) was assumed to be left on site for economic and ecological reasons.

In many regions worldwide an important fraction of wood is salvage harvested following natural disturbances like fire, windthrow, snow or pathogens, especially in conifer forests [47,49]. Salvage cutting of timber can make a significant contribution to biomass for energy because this material is often not suitable for alternative uses. Fire is the dominant natural disturbance in Tasmania's eucalypt forests. However, few fires have occurred at a landscape scale since the 1930s and trees and burned forests contain large quantities of charcoal that makes them unattractive to harvest and process, particularly for paper making. Furthermore most native eucalyptus forests readily recover following wildfire. Hence, salvage operations in Tasmania are minimal and were not specifically included in our calculation.

2.2.3. *Wood processing residues*

The potential volumes of wood processing residues were estimated based on oral or written interviews undertaken with representatives of the wood processing industry (see 2.1). Interviews gathered data on the amount of timber processed, the amount of residues generated, the current use of residues and anticipated changes in future residue use. 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 volumes expected in the next 3 years using the same four categories.

2.2.4. *Conversion factors*

The estimates for the current and potential use of forest biomass for energy are in part based on volumes and in part on mass where different materials have different water contents. We used the following conversion factors to allow estimated energy content to be presented using the common units of energy per kg of bone dry wood:

1 m^3 wood = 0.50 t of dry mass (softwood),
1 m^3 wood = 0.55 t of dry mass (eucalypt),
1 m^3 wood = 1 t wood (green),
Water mass fraction of green wood: 45%,
Water mass fraction of dry wood: 15%,
Water mass fraction of bone dry wood: 0%,
Energy content: 1 kg of bone dry wood = 18 MJ (5 kWh).

Table 1 – Forest biomass used for energy in Tasmania.

	kt y^{-1}	kt y^{-1}	Energy equivalent
	(green)	(bone dry)	PJ
domestic firewood	490	270	4.9
wood processing residues	220	120	2.2
total	710	390	7.0

3. Results

3.1. *Current use of forest biomass for energy*

Currently about 400 kt y^{-1} of bone dry forest biomass are used for producing energy in Tasmania (Table 1). This is equivalent to about 6% of Tasmania's total primary energy supply (110 PJ in 2012/13, [10]). All of the biomass is used for generating thermal energy; there are no facilities for producing electricity from biomass. Domestic firewood for heat production is the dominant use of forest biomass for energy, accounting for about two thirds of the total amount. Nearly one third of the total amount is derived from wood processing and is used for non-domestic heating, predominantly for kiln-drying of processed timber. Smaller amounts are used for other industrial heating, particularly during brick manufacturing, food processing or heating greenhouses. The production of wood pellets is negligible in Tasmania. About two thirds of processing residues are used for industrial (woodchips) or landscaping purposes (mostly bark). A significant quantity of processing residues (>20 kt y^{-1} of bone dry material) is currently not used for energy production or industrial/landscaping purposes and is placed into landfills or left on site.

3.2. *Potential supply of forest biomass for energy*

The potential supply of forest biomass for energy production in Tasmania is estimated at 1800 kt y^{-1} of bone dry material (Table 2). About 40% of this material (700 kt y^{-1} of bone dry material) is derived from harvest and processing residues. Using only these residues, bioenergy production could be nearly doubled from the current 400 kt y^{-1} of bone dry material. The residues originate in nearly equal quantities from plantations and native forests regrowth. 1100 kt y^{-1} of bone dry material (corresponding to about 60% 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. About three quarters of total pulpgrade material originates from plantations, and one quarter from native forest regrowth.

The potential supply of 1800 kt y^{-1} of bone dry material corresponds to an energy equivalent of 33 PJ or approximately 30% of Tasmania's current energy demand (110 PJ in 2012/13, [10]). Residues currently left in the landscape to decompose or burnt in the open and low quality logs currently exported as woodchips have the potential to make a significant contribution to renewable energy production in Tasmania. The above estimates are conservative and can be regarded as a minimum potential since all underlying assumptions (e.g. conversion factors) are conservative and other forms of woody biomass (landscaping, waste wood) are not considered here. In addition we assume higher standards for retention of slash to maintain soil fertility and retention of dead wood for biodiversity than required by best management guidelines in Europe or North America (for an overview see Ref. [59]). The above estimates of potential energy production are expected to remain relevant for several years until 2020. The 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. Comparing Tasmania with Bavaria

4.1. *Forestry and forest industry in Bavaria and Tasmania*

This section presents a case study comparison by contrasting Tasmanian results with data from Bavaria, a southeast German state. The comparison allows an accurate interpretation of our results and an in-depth analysis of relevant drivers. Bavaria was selected due to similarities in Tasmania in area, contribution of forest biomass to total energy consumption and the proportion of forest management between

Table 2 – Potential supply of forest biomass for energy in Tasmania.

	Pulpgrade total	Pulpgrade for energy[a]	Residues for energy	Total energy wood		Energy equivalent
	kt (green)	kt (green)	kt (green)	kt (green)	kt (bone dry)	PJ
Native forests	1050	500	450	950	500	9
Plantation hardwood	3050	1500	350	1850	1000	18
Plantation softwood	700	0	100	100	50	1
wood processing			400	400	200	4
total	**4800**	**2000**	**1300**	**3300**	**1800**	**33**

[a] 50% of hardwood pulpgrade was assumed to be available for energy use, softwood pulpgrade was assumed to be used for processing only. Figures rounded to 50 kt.

Table 3 – Comparisons between Bavaria (Germany) and Tasmania (Australia). Sources [7,21].

	Bavaria	Tasmania
People (million)	12.5	0.5
Latitude of capital city	48° N (Munich)	42° S (Hobart)
Land (km^2)	71 000	68 000
Forest area (km^2)	25 000	34 000
Forest available for wood production (km^2)	24 000	12 000
Main forest type	Semi-natural spruce-beech forest	Natural and modified natural eucalypt forest
Wood production ($hm^3\ y^{-1}$)	15–20	5–6
Wood production ($m^3\ y^{-1}\ capita^{-1}$)	1.2–1.6	10–12
Forest biomass used for energy ($hm^3\ y^{-1}$)	10	0.7
Fraction of total energy supply generated from forest biomass (%)	5	6

the public and private sectors (Table 3). Additionally, recent comprehensive data is available on the domestic market for biomass used for energy in Bavaria [24]. The use of forest biomass for energy is widespread in Bavaria which is typical for many European countries (Fig. 1) where the share of energy derived from biomass is closely correlated with the available forest resource. In the 27 member nations of the European Union biomass contributed 8.2% of total final energy consumption in 2010 or nearly 64% of European renewable energy [4]. Two thirds of total biomass for energy production or about 50% of total renewable energy [33] was from forest biomass.

Despite Tasmania and Bavaria having a comparable forest area, there are significant differences between the two states in industry configuration and markets. Bavaria is located in the heart of Central Europe and is characterized by a high population density (175 people km^{-2}) leading to a strong domestic market for wood products and bioenergy. There are more than 1000 sawmills processing annually 11.5 hm^3 wood and about 20 plants for engineered wood products (veneer, plywood, particle boards, chemical pulp, mechanical pulp) processing annually about 4 hm^3 wood.

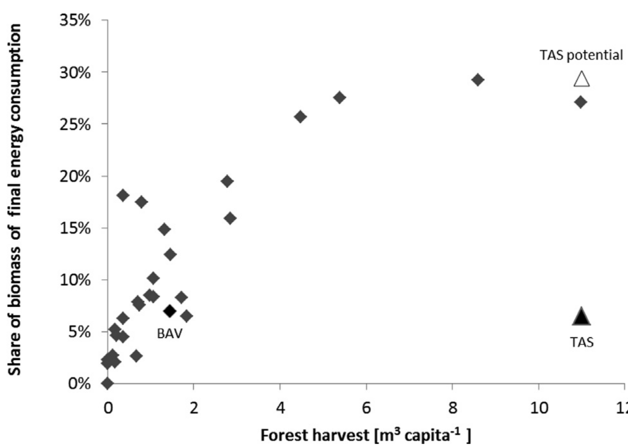

Fig. 1 – Share of biomass energy of final energy consumption in the 27 countries of the European Union (EU27) and the German state Bavaria (bold). Triangles show the current (filled) and potential (empty) use in Tasmania as estimated in this study. Data Source [4].

The current revenue of the wood processing industry is estimated at 13.2 billion € [43]. Transport distances are usually below 100 km and most of the timber produced in Bavaria is locally processed. About one third of the raw timber is exported to neighbouring states of Germany or other countries, the import of raw timber from other states or countries is about half of the exported amount. In summary the calculated fraction of timber processed in Bavaria relative to the harvest from Bavaria's forests is between 80 and 90%.

Tasmania is an island located off the south east coast of the Australian mainland with a low population density (7 people km^{-2}). Market countries with a high population density and wood demand such as Indonesia, China or Japan are about 8000 km from Tasmania. There are 61 individual forest processing businesses in Tasmania, most of them very small operations. The four largest volume businesses processed almost 90% of Tasmania's forest harvest [48]. Transport distances are generally <100 km, except for low quality logs from southern Tasmania that must be transported closer to 200 km to northern Tasmania following the recent closure of the southern port facility. The majority of sawlogs enter the domestic market (>90%) but their fraction of total harvest is less than 20%. The majority of the wood produced is low quality hardwood nowadays mostly originating from plantations. Currently almost all low quality hardwood logs are exported as chips into China and Japan, where the main processing takes place.

4.2. *Comparison of forest biomass resource utilization*

In Tasmania the fraction of total energy supply generated from forest biomass (6%) is only slightly higher than in Bavaria (5%) although the annual harvest per capita is about sevenfold higher in Tasmania (Table 3). Only 14% of the annual Tasmanian harvest is used for generating energy. Biomass for energy is dominated by domestic space heating with firewood and a smaller fraction is used by industrial boilers producing heat (Fig. 2). However, there is no biomass plant in Tasmania and pellet production is only just beginning. Quantities are small and the production of pellets from sawdust which commenced in 2014 is expected to expand to produce 800–900 t y^{-1} of pellets in 2015/2016. Although the

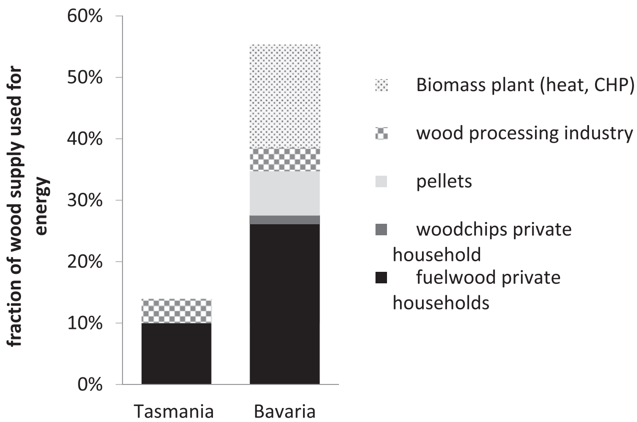

Fig. 2 – Fraction of wood supply used for energy in Tasmania and Bavaria. Data for Bavaria from [24]; data for Tasmania as estimated in this study.

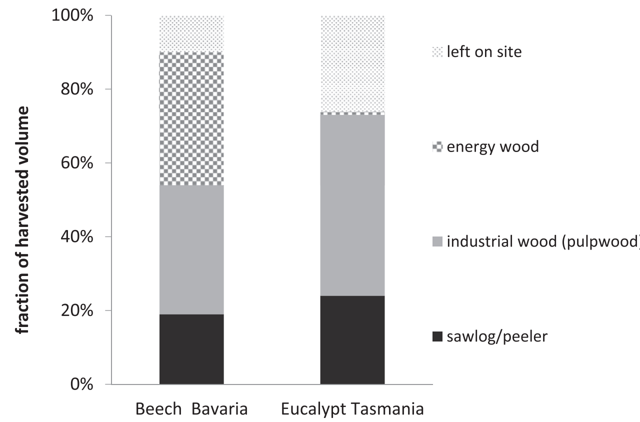

Fig. 3 – Beech and eucalypt log grades in the State Forests of Bavaria (2011) and Tasmania (2010/11).Total volume: beech 0.8 hm^3, eucalypt: 3.3 hm^3.

relative firewood consumption in Tasmania (about 1 t y^{-1} $capita^{-1}$ of green wood) is more than double that of Bavaria (0.4 t y^{-1} $capita^{-1}$ of green wood), only 10% of the annual Tasmanian harvest is used as fuelwood for private households due to the low population density. In Bavaria 55% of the annual harvest (18 hm^3 y^{-1} over the last 5 years) was used to generate energy. 27% of the wood supply was used directly as energy wood (i.e. without further processing), largely as domestic firewood with a small proportion of woodchips. Nearly the same amount of energy wood originated from processing residues and waste wood from used wood products. Significant amounts of pellets are produced from processing residues and are mostly used for heating private households. The 680 biomass plants in Bavaria (mostly between 0.5 and 2 MW in size) use 17% of the available wood supply with waste wood being the dominant feedstock. The harvesting of log grades explicitly referred to as energy wood in Tasmania is insignificant compared to Bavaria even when taking into account considerable illegal harvesting [35]. Only 1% of total harvest from State forests in Tasmania is firewood sold through firewood collecting permits and commercial firewood sales compared with 36% of beech harvest from State forests sold directly as energy wood in Bavaria (Fig. 3). In Tasmania the total demand for firewood is small and about 25% of the harvested tree remains on site. Most of this material is burnt in the open during regeneration burns that are undertaken to prepare a seedbed for the next crop [22]. In Bavaria only 10% of the harvested tree is left on site to decompose. While the available resource of forest biomass for energy is extensively utilised in Bavaria our estimates indicate that forest biomass production could be more than quadrupled in Tasmania from a resource availability perspective. The potential fraction of total energy production in Tasmania from forest biomass energy of 30%, as estimated in this study, is consistent with current circumstances in European countries with a large forest resource per capita (Sweden, Finland, Latvia, Lithuania and Estonia) indicating this potential is realistic (Fig. 1).

4.3. *Comparison of economic, legislative and social drivers for forest biomass utilization for energy production*

4.3.1. *Prices for energy wood*

There is currently no Tasmanian market for energy logs and the fraction of timber explicitly sold as energy wood is insignificant. Tasmanian prices for low grade pulp-logs and firewood are ≤ half Bavarian prices, and Tasmanian prices for woodchips from processing are below Bavarian prices (Table 4). In contrast prices for wood pellets are significantly higher in Tasmania than in Bavaria. This is due to the small volume of the pellet market in Tasmania (<10 kt y^{-1}) and the lack of a large scale pellet production facility in Tasmania. The Tasmanian demand for firewood is small relative to the annual harvest and firewood collecting permits for private use are priced close to zero. Due to the low demand, firewood prices are determined by transport and labour costs for preparation with the price of the raw material itself being low

Table 4 – Comparison of prices (€ t^{-1}) for forest biomass used for energy between Bavaria and Tasmania.

	Bavaria	Tasmania
Hardwood energy logs (roadside)	65	[a]
Hardwood collecting permit (private use)	30	3
Hardwood pulplogs (roadside)	65	25[b]
Firewood air dry (delivered)	200	120
Forest woodchips	80	[a]
Woodchips from processing (mill door)	110	80
Wood pellets (retail)	300	430

Prices for logs sold in the forest refer to 1 t green material (first three rows), all other prices to 1 t dry material. Prices without VAT, conversion: 1$AUD = 0.80 €.

[a] Currently there is no market for energy logs/forest woodchips in Tasmania, energy logs/forest woodchips would be priced as for pulplogs/processed woodchips.

[b] 15 Euro has been added to stumpage prices for Tasmania to cover felling, snigging and stacking at roadside.

and having little effect on price. Due to the low Tasmanian population density a significant rise in local firewood prices is unlikely. The theoretical maximum consumption of domestic firewood - assuming that all 200 000 Tasmanian households [3] use fuelwood as a primary heating source and consume 5 t y^{-1} equals, at most, 20% of the annual harvest. In addition there are few industrial heating plants and no biomass plants generating municipal heat in Tasmania which would increase the demand for, and hence potentially the price of, firewood, low quality logs and woodchips. Furthermore, there is no domestic demand for hardwood chips from an industry such as pulp and paper making. As a consequence prices of low quality pulpgrade logs, firewood, and woodchips are determined by their industrial use on the world market.

In contrast to Tasmania there is a strong domestic demand for energy wood in Bavaria, especially from hardwood species. Since 2005 there has been a strong increase in demand for energy wood and currently about 60% of the total beech harvest (2.5 hm^3 y^{-1}) is explicitly sold as energy wood. The demand results predominantly from private households using fuelwood. In addition there are more than 600 biomass plants processing about 3 hm^3 y^{-1} [24]. Due to the strong demand, prices for energy wood have nearly doubled in the last 10 years [13]. This has also entailed a significant increase in prices for industrial wood, since industrial users such as particleboard plants or pulpmills compete for the same resource. Only a low proportion of low quality logs is exported to other countries, and between 2010 and 2013 Bavarian roundwood imports and exports were about the same. As a consequence prices for low quality industrial logs and energy wood (firewood, woodchips) are dominated by the domestic market rather than the world market. Even within Bavaria there are strong differences with firewood prices next to urban agglomerations about one third higher compared to rural areas [55].

4.3.2. *Legislative framework*

Within the Renewable Energy Target (RET) scheme the Australian Government aims to ensure that 20 per cent of Australia's electricity comes from renewable sources by 2020. The RET scheme primarily focuses on solar and wind systems but electricity generated from biomass including wood residues has been recognised under the RET scheme. In 2012 wood residues originating from native forestry were excluded from the RET scheme by the former Socialist-Green coalition due to concerns concerning native carbon effects after native forest harvesting, a position the current conservative federal government plans to reverse. Since the origin of wood residues is often unclear this change had an important impact on forest biomass projects. Another major impediment concerning forest biomass for energy is missing incentives within the RET scheme for other forms of energy such as thermal heat, since electricity usually is not the most efficient use of forest biomass [59]. In Tasmania government funding of forest biomass for energy has been negligible in the past and there is no operating biomass plant producing electricity or heat. All private stoves and furnaces are also operating without public subsidies.

For Germany, an increase in the share of renewable energy to 18% is foreseen by 2020 [11]. A set of legislative frameworks and promotional instruments governs renewable energy development [9]. The Renewable Energies Act aims to increase the share of renewable electricity production to 35% of total production by 2020 and includes a guaranteed feed-in remuneration for power producers. The subsidies are collected via a nationwide, standardized apportionment which currently amounts to 6.24 € kWh^{-1} consumed [50]. In order to support the planned expansion of the use of bioenergy for heat production from 10% to 14% the Market Incentive Program for renewable energies also promotes biomass use. For example, a new installation of a pellet boiler, wood chip or split log boiler is subsidized up to the value of 3500 € [6]. Exact data on the total amount of subsidies in Bavaria concerning biomass are not available, but a breakdown of nationwide subsidies [1] to Bavaria according to population equals 760 million € of public subsidies in 2013.

4.3.3. *Social context*

The social context of the use of forest biomass for energy in Australia has been investigated in detail by Ref. [58]. Disputes concerning harvesting in “native forests” have damaged the social acceptance of forest biomass and discredited bioenergy in Australia. According to [58] the lack of understanding and acceptance among important stakeholders is the main reason that implementation of forest biomass for energy in Australia is minimal compared to many European countries. It may also explain why forest biomass from native forests is not promoted in Australian renewable energy programs. The controversy surrounding native forest harvesting has been especially intense and long-lasting in Tasmania [31,45]. Environmental NGO's such as the “Wilderness Society” or “Markets for Change” fear that the use of forest biomass for energy will increase native forest harvesting and therefore fiercely oppose the promotion of this energy source. Even government agencies are quite critical about the intensive use of fuelwood [18]. Currently there are signs that environmental groups may support regional biomass projects with a strong community engagement. Although this may help to develop a better understanding of the possibilities of forest biomass use, such regional projects can only process small quantities due to the small Tasmanian population.

In Bavaria and the rest of Germany the use of forest biomass currently has a strong social license, except from individual local protests following “not in my backyard” interests. There are many regional and community initiatives supporting biomass use within renewable energy targets. The German Federal Ministry of Food and Agriculture promotes the use of bioenergy via so-called bioenergy villages and bioenergy regions which illustrate the benefits of bioenergy use, particularly biogas and wood [8]. However, there are signs that scientific concerns about the trade-offs of biomass harvesting (overview see Ref. [20]) are gaining in importance and there is an increasing discussion about the optimal intensity of forest management also in Bavaria [53]. Key areas of discussion are the preservation of minimum coarse woody debris amounts, maintenance of soil fertility and the percentage of forests without active management. Nevertheless environmental NGO's are not specifically addressing forest biomass use at present [60]. Main reasons may be the trade-off between promotion of renewable energies (a major goal of environmental NGO's) and a reduced harvesting intensity as well as the widespread use of fuelwood also by environmentalists.

5. Discussion

In contrast to Bavaria and elsewhere in Europe, the use of forest biomass for energy is low in Tasmania and could be more than quadrupled from a resource availability perspective. Domestic demand for forest biomass for energy is low in Tasmania and the bulk of the forest harvest is exported as pulpwood to other countries. Thus prices for low quality logs are dominated by international pulpwood prices. In contrast to the Tasmanian situation, bioenergy use significantly influences prices for low quality timber in many regions worldwide [29,42]. Due to the increasing demand for forest biomass feedstock for energy production prices for energy wood reached or surpassed prices for industrial wood in many parts of Europe leading to strong competition between both uses. While for the European market a further uptake in fuel wood demand and therefore increasing prices is expected [20] a significant domestic increase for Tasmania is unlikely. Therefore larger quantities of forest biomass could only be sold on the world market, e.g. as pellets. In this case prices for forest biomass for energy must be equal or higher compared to pulpgrade material in order to make it an attractive alternative for forest owners. In the past world market prices for energy wood (pellets, woodchips) were not high enough to absorb significant quantities of Tasmanian timber and up to now no investor has been willing to invest in bigger bioenergy projects.

Public subsidies would be an option to foster the use of forest biomass for energy under marginal economic conditions. In the European Union the increasing supply of renewable energies is a major political goal and the aim is that by 2020, more than 20% of final energy consumption shall be supplied by renewable energies according to the Renewable Energy Directive 2009/28/EC. The use of (forest) biomass is considered a major component of renewable energies especially for producing thermal energy or combined thermal and electrical energy. As a consequence European countries have been supporting the use of (forest) biomass though the intensity varies across the European Union. Beside different renewable energy targets and minimum obligations for bioenergy per country, European member states have introduced different tax exemptions, investment grants and feed-in tariffs [54]. In the last few years the intensive system of public support in the European Union has experienced increasing criticism for economic (financial burden, too much wood directed at bioenergy instead of solid wood), ecological (environmental trade-offs) and social (competition with food production) reasons [20] and this may influence the corresponding policy. The increase of renewable energies is also a major political goal in Australia. However, the Renewable Energy Target (RET) scheme of the Australian Government with a 20% target for renewable sources for Australia's electricity by 2020 primarily focuses on solar and wind systems. Concerning forest biomass for energy Australia is much more conservative than Europe and corresponding public subsidies have been insignificant up to now. One reason is that the demand for heat (the main application for biomass) is much lower in Australia due to a low population density and a warmer climate. Furthermore there is an intensive discussion about potential negative ecological effects connected with an increased use of forest biomass, e.g. concerning carbon effects of biomass use [15,34] or potential tradeoffs concerning water quality or biodiversity [40]. Similar discussions are reported from other continents [57,59] and it seems clear that this has an impact on the social license of forest biomass for energy and as a consequence on public subsidies.

The relatively low social license of forest biomass for energy is certainly a major impediment to more intensified use of forest biomass for energy in Tasmania. Even the domestic use of firewood has been under debate because of potential adverse effects on coarse woody debris [27]. Nevertheless the use of domestic firewood still has a positive reputation and is an important part of the Tasmanian lifestyle. However, all ideas concerning an intensified use of forest biomass (biomass plants, export) are facing intensive opposition, since there is a strong fear that intensified use of forest biomass might intensify native forest harvesting. Here the long-lasting Australian conflict on native forest harvesting seems to influence even the use of forest residues for energy [58]. In Europe the use of forest biomass for heating has a strong social license. Domestic firewood has a centuries-long tradition and is an important part of the rural lifestyle especially in Central and Northern Europe. The strong emotional link of people with "their" firewood may explain why potential negative effects of intensive firewood use do not receive attention from environmentalists. Also small/medium sized biomass plants are usually supported by communities and in many cases by environmental stakeholders. The bigger the biomass-for-energy plants the more they tend to be challenged. Especially large-scale electricity generation is often criticised by the public, especially when there is no combined use of heat and power and energy efficiency is low. Apart from the opposition against individual big biomass plants practical conflicts concerning the use of forest biomass are rare, although there is increasing scientific discussion on this topic [17,37,46].

Tasmania has a significant forest resource which is currently not fully utilized. Lacking domestic processing facilities, all woodchips must be exported, creating small incomes per ton of wood processed and few jobs [61]. Initiatives to improve this situation should consider better wood utilization in general rather than focusing only on forest biomass for energy. In the last 10 years several so called "cluster-initiatives" were started in different German states aimed at fostering value adding for the whole forest sector. Also in Tasmania several attempts were made to improve wood utilization from native forests, including peeling for export and the production of Laminated Veneer Lumber. However, all further attempts must consider the specific properties of eucalypt timber as a hardwood species. The fraction of high quality log grades is inherently lower in hardwood species than in softwood species, where sawlog recovery may be as high as 80% of the tree volume (Fig. 4). The comparison with oak forestry in Bavaria may give an indication of realistic recovery rates. Oak is one of the most valuable German timbers

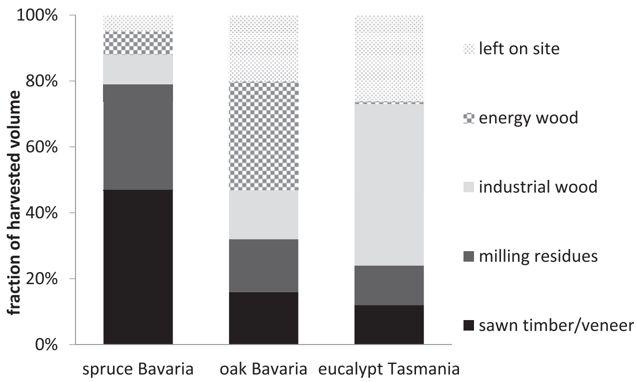

Fig. 4 – Log grades in the State Forests of Bavaria (2011) and Tasmania (2010/11).Total volume: spruce 3.5 hm^3, oak 0.1 hm^3, eucalypt: 3.3 hm^3 Fraction of residues during sawmilling/veneer production was assumed to be 50% for hardwood species and 40% for softwood species.

and high quality sawlogs are sold up to more than 1000 € m^{-3}. A high recovery of sawlogs and veneer logs has been the main target of forest management for more than 200 years. The recovery of high quality sawlogs and veneer logs from oak trees in the State forest of Bavaria is about 10%, total sawlog recovery is about 30%. Hence only about 15% of the tree volume finally ends up as sawn timber/veneer when losses during wood processing are considered (Fig. 4). The comparison with Tasmania indicates some potential for better recovery of more valuable eucalypt log grades. However, 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 tree volume will end up as low quality products. 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. According to European experiences the better use of forest biomass for energy could make an important contribution to the value of the whole forestry sector.

6. Conclusions

In contrast to Bavaria and other countries in Europe, forest bioenergy production is small in Tasmania relative to the available resource. A weak domestic market for energy wood, the lack of political stimuli and a low social acceptance are likely key factors. Due to the low population density in Tasmania, a strong increase in market prices for forest biomass is unlikely in the near future. Therefore political incentives are necessary in order to increase the use of residues and low quality timber for energetic purposes. Besides small regional biomass projects, the export of processed material such as pellets or torrefied wood may offer opportunities to better utilize the resource. Addressing social acceptance will be a prerequisite for the success of initiatives or legislation to achieve this potential.

Acknowledgements

We are grateful to Christina Schumann and a long list of forest companies, wood processors, consultants, governmental agencies and NGO's contributing information to this work. We thank anonymous reviewers for intensive, substantial comments. Andreas Rothe would like to thank the University of Applied Sciences Weihenstephan-Triesdorf and Forestry Tasmania for supporting his sabbatical project.

REFERENCES

[1] 50 Hertz transmission GmbH, Amprion GmbH, Transnet BW GmbH, Tennet GmbH. EEG-Mengentestat 2012 auf Basis von WP-Bescheinigungen. Angaben zu Stromeinspeisemengen und Vergütungen nach EEG. Berlin. 26.07.2013. Available from: www.netztransparenz.de/de/file/2012_EEG-Jahresabrechnung_.pdf [accessed 13.05.14].

[2] ABARES (Australian Bureau of Agricultural and Resource Economics and Sciences). Australian forest and wood products statistics: September and December quarters. Canberra: released 06.06.2013: Australian Government Department of Agriculture, Fisheries and Forestry; 2012. Available from: http://www.daff.gov.au/abares/publications [accessed 13.05.14].

[3] ABS (Australian Bureau of Statistics). 1304.6-Tasmanian key indicators, MAR. released 22.03.2011. 2011. Available from:, http://www.abs.gov.au [accessed 13.05.14].

[4] AEBIOM (European Biomass Association). European bioenergy outlook 2012. Brussels: European Biomass Association; 2012. Available from: http://www.aebiom.org/wp-content/uploads/file/AEBIOM%20Statistical%20Report/AEBIOM_European%20Bioenergy%20Outlook%202012sv.pdf [accessed 13.05.14].

[5] Andrewartha R. Integrated fuelwood harvesting trial SX128E. Hobart: Forestry Tasmania; 2003 [Internal Research Report].

[6] BAFA (Federal Office for Economic Affairs and Export Control). Förderübersicht Biomasse (Basis-, Innovations- und Zusatzförderung (Richtlinien vom 11.03.2015), Bonn: Bundesamt für Wirtschaft und Ausfuhrkontrolle. Available from: http://www.bafa.de/bafa/de/energie/erneuerbare_energien/biomasse/publikationen/uebersicht_bm.pdf [accessed 31.03.15].

[7] Bavarian Ministry for Food. Agriculture and Forestry. Bayerischer Agrarbericht 2012. Munich: Bayerisches Staatsministerium für Ernährung, Landwirtschaft und Forsten; 2012. Available from: www.agrarbericht.bayern.de [accessed 13.05.14].

[8] BMELV (Federal Ministry of Food and Agriculture). Bioenergie in Regionen. Berlin: Bundesministerium für Ernährung, Landwirtschaft und Verbraucherschutz; Nov 2012. Available from: http://mediathek.fnr.de/media/downloadable/files/samples/b/r/brosch_regionalbroschuere.web.pdf [accessed 16.02.15].

[9] BMWi (Federal Ministry for Economic Affairs and Energy). Informationsportal Erneuerbare Energien. Berlin: Bundesministerium für Wirtschaft und Energie. Available from: http://www.erneuerbare-energien.de/[accessed 13.05.14].

[10] BREE (Bureau of Resources and Energy Economics). 2014 australian energy update. Canberra: Australian Government Bureau of Resources and Energy Economics; July 2014. ISSN 2203–8337.

[11] Bundesregierung (Federal Government). Das Energiekonzept – Beschluss des Bundeskabinetts vom 28. Berlin: Presse und Informationsamt der Bundesregierung; September 2010. Available from: http://www.bundesregierung.de/ContentArchiv/DE/Archiv17/_Anlagen/2012/02/energiekonzept-final.html [accessed 13.05.14].
[12] Candy SG. Growth and yield models for eucalyptus nitens plantations in Tasmania and New Zealand. Tasforests 1997;9:167–94. Available from: http://www.forestrytas.com.au/publications [accessed 31.03.15].
[13] CARMEN. (Central network for Agrarian feedstock marketing and energy). Preisentwicklung bei Waldhackschnitzeln - der Energieholz-Index (Version: March 2014). Straub Cent Rohst Marketing- Netzw e.V; 2014. Available from: http://www.carmen-ev.de/infothek/preisindizes/hackschnitzel [accessed 13.05.14].
[14] Crawford D, Jovanovic T, O'Connor M, Herr A, Raison J, Baynes T. AEMO 100% renewable energy study: potential for electricity generation in Australia from biomass in 2010, 2030 and 2050. Newcastle Australia: CSIRO energy transformed flagship. 04 September 2012. CSIRO Report EP-126969.
[15] Dean C, Wardell-Johnson GW, Kirkpatrick JB. Are there any circumstances in which logging primary wet-eucalypt forest will not add to the global carbon burden? Agr For Meteorol 2012;161:156–69.
[16] Driscoll DA, Milkovits G, Freudenberger D. Impact and use of firewood in Australia. Report to Environment Australia. Canberra: CSIRO Sustainable Ecosystems; 24 November 2000.
[17] Eckerberg K, Sandström C. Forest conflicts: a growing research field. For Pol Econ 2013;33:3–7.
[18] Environment Australia. Regulatory impact statement: national approach to firewood collection and use in Australia. Canberra: Australian Government Department of the Environment; 2001. Available from: http://www.environment.gov.au/resource/regulatory-impact-statement-national-approach-firewood-collection-and-use-australia-5 (accessed 10.02.15).
[19] Farine DR, O'Connell DA, Raison RJ, May BM, O'Connor MH, Herr H, et al. An assessment of biomass for bioelectricity and biofuel, and greenhouse gas mitigation in Australia. GCB Bioenergy 2012;4:148–75. http://dx.doi.org/10.1111/j.1757-1707.2011.01115.x.
[20] Ferranti F. Energy Wood : a challenge for European forests. Potentials, environmental implications, policy integration and related conflicts. Joensuu: European Forest Institute; 2014. EFI Technical report 95.
[21] Forest Practices Authority. State of the Forests Tasmania 2012. Hobart: Forest Practices Authority, Available from: http://www.fpa.tas.gov.au/__data/assets/pdf_file/0009/82872/State_of_the_forests_Tasmania_2012_report.pdf [accessed 13.05.14].
[22] Forestry Tasmania. Stewardship report 2011-12. Hobart: Forestry Tasmania; October 2012. Available from: http://cdn.forestrytasmania.com.au/uploads/File/pdf/pdf2012/stewardship_report_2012.pdf [accessed 13.05.14].
[23] Freyer R. Tasmanian's state forest residue wood flow prefeasibility evaluation for Licella Pty Ltd. Hobart: Forestry Tasmania; May 2013. 23pp. FT Technical Report 01/2013 (unpublished).
[24] Friedrich S, Schumann C, Zormaier F, Schulmeyer F, Dietz E, Burger F, et al. Energieholzmarkt Bayern 2010. Freising: Bayerische Landesanstalt für Wald und Forstwirtschaft. LWF Wissen 70. December 2012. Available from:, http://www.lwf.bayern.de/service/publikationen/index.php.
[25] Ghaffariyan M, Acuna M. Evaluating a cut-to-length harvesting system in Tasmania. Hobart: CRC for Forestry. CRC Bulletin 23/2012.
[26] Ghaffariyan M. Assessment of harvesting residues from different harvesting operation sites in Australia. Hobart: CRC for Forestry. CRC Bulletin 31/2012.
[27] Grove S, Meggs J. Coarse woody debris, biodiversity and management: a review with particular reference to Tasmanian wet eucalypt forests. Aust For 2003;66:258–72.
[28] Grove SJ, Stamm L, Barry C. Log decomposition rates in Tasmanian Eucalyptus obliqua determined using an indirect chronosequence approach. For Ecol Manag 2009;258(4):389–97.
[29] Härtl F, Knoke T. The influence of the oil price on timber supply. For Pol Econ 2014;39:32–42. http://dx.doi.org/10.1016/j.forpol.2013.11.001.
[30] Hofer P, Altwegg S. Holz-Nutzungspotenziale im Schweizer Wald auf Basis LFI3. Zürich: Bundesamt für Umwelt (BAFU); 21.01.2008. p. 38.
[31] Macintosh A. Chipping away at Tasmania's future. Alternatives to subsidising the forestry industry. Canberra: The Australia Institute; December 2013. Institute Paper No.15, ISSN 1836–8948.
[32] Mantau U. Holzrohstoffbilanz Deutschland. Entwicklungen und Szenarien des Holzaufkommens und der Holzverwendung 1987 bis 2015. Hamburg: Universität Hamburg; October 2012. p. 65.
[33] Mantau U, Saal U, Prins K, Steierer F, Lindner M, Verkerk H, et al. EUwood - real potential for changes in growth and use of EU forests. Final report. Hamburg. June 2010. p. 160.
[34] Moroni M. The role of forest management in greenhouse gas mitigation: a contextual framework for Australia. Melbourne: Forest&Wood Products Australia; May 2011, ISBN 978-1-921763-21-2. Available from: www.fwpa.com.au.
[35] Moroni MT, Musk RA. Domestic timber harvesting affects dead wood quantities in Tasmanian dry eucalypt forests. Aust For 2014;77(2):86–91. http://dx.doi.org/10.1080/00049158.2014.901884.
[36] Moroni MT, Kelley TH, McLarin ML. Carbon in trees in tasmanian state Forest. J For Res 2010;2010:13. http://dx.doi.org/10.1155/2010/690462. Article ID 690462.
[37] Niemelä J, Young J, Alard D, Askasibar M, Henle K, Johnson R, et al. Identifying, managing and monitoring conflicts between forest biodiversity conservation and other human interests in Europe. For Pol Econ 2005;7:877–90.
[38] Pérez S, Renedo CJ, Ortiz A, Mañana M, Silió D. Energy evaluation of the Eucalyptus globulus and the Eucalyptus nitens in the north of Spain (Cantabria). Thermochim Acta 2006;451:57–64.
[39] Private Forests Tasmania. Annual report 2011-12. Hobart: Private Forest Tasmania; Nov 2012. http://www.pft.tas.gov.au [accessed 13.05.14].
[40] Raison RJ, Kirschbaum MU, McCormack RJ, Attiwill PM, Richardson AM. Review of the science relevant to the sustainable use of native and plantation forest-harvesting residues for energy production in Tasmania. Canberra: CSIRO Forestry and Forest Products; 2002.
[41] Raspin M. Fuelwood harvesting trial TO010C. Hobart: Forestry Tasmania; 2009 [Internal Research Report].
[42] Raunikar R, Buongiorno J, Turner JA, Zhu S. Global outlook for wood and forests with the bioenergy demand implied by scenarios of the intergovernmental panel on climate Change: forest sectormodels and their application. For Pol Econ 2010;12:48–56.
[43] Röder H, editor. Cluster Forst und Holz in Bayern: Ergebnisse der Cluster Studie 2008. Freising: Pöyry Forest Industry Consulting GmbH; August 2008. Available from: http://www.lwf.bayern.de/mam/cms04/forsttechnik/dateien/abschlussbericht-cluster-2008.pdf [accessed 25.01.15].
[44] Rothe A. Forest biomass for energy: current and potential use in Tasmania and a comparison with European experience.

Hobart. July 2013. Available from: http://www.forestrytas.com.au/topics/2013/07/prof-dr-andreas-rothe-wood-fired-renewable-future-for-tasmania [accessed 13.05.14].
[45] Routley R, Plumwood V. The "Fight for the Forests" affair. In: Martin B, Baker CMA, Manwell C, Pugh C, editors. Intellectual suppression: australian case histories, analysis and responses. Sydney: Angus & Robertson; 1986. p. 70–3.
[46] Sandström C, Eckerberg K, Raitio K. Studying conflicts, proposing solutions — Towards multi-level approaches to the analyses of forest conflicts. For Pol Econ 2013;33:123–7.
[47] Schelhaas MJ, Nabuurs GJ, Schuck A. Natural disturbances in the European forests in the 19th and 20th centuries. Glob Change Biol 2003;9:1620–33.
[48] Schirmer J, Dunn C, Loxton E. Socio-economic impacts of forest industry change Tasmanian forest industry employment and production 2012-13. Phase 1 report. Hobart: Tasmanian Government Department of State Growth; October 2014. Available from:, http://www.stategrowth.tas.gov.au/__data/assets/pdf_file/0004/98149/Socio-economic_impacts_of_forest_industry_change_-_November_2013.pdf.
[49] Shorohova E, Kuuluvainen T, Kangur A, Jogiste K. Natural stand structures, disturbance regimes and successional dynamics in the Eurasian boreal forests: a review with special reference to Russian studies. Ann For Sci 2009;66(2):1–20.
[50] Statista. Hoehe der EEG-Umlage für Haushaltsstromkunden in Deutschland in den Jahren 2003 bis 2014 Hamburg: Statista GmbH. Available from: http://de.statista.com/statistik/daten/studie/152973/umfrage/eeg-umlage-entwicklung-der-strompreise-in-deutschland-seit-2000/[accessed 12.05.14].
[51] Statistisches Bundesamt (German Bureau of Statistics). Wald und Holz - Holzeinschlag nach Holzartengruppen bzw. Holzsorten und ausgewählten Besitzarten – Jahresabschluss. 2012. Available from: https://www.destatis.de/DE/ZahlenFakten/Wirtschaftsbereiche/LandForstwirtschaftFischerei/WaldundHolz/Tabellen/HolzeinschlagDeutschland.html [accessed 12.05.14].
[52] Stone MG. Forest-type mapping by photo-interpretation: a multi-purpose base for Tasmania's forest management. Tasforests 1998;10:15–32. Available from: http://www.forestrytas.com.au/publications [accessed 31.03.15].
[53] Suda M, Schaffner S. Das Phänomen meinungs- und mehrheitsbildender Bevölkerungsumfragen als Instrument zur Legitimierung von Interessen im politischen Raum-Sozialempirische Befragungstechnik zwischen Stimmungsmache und Erkenntnisgewinn. "Greenpeace" und "Aktionsbündnis zur Holzvermarktung in Bayern" – Zwei forsa-Umfragen mit unterschiedlichen Ergebnissen. Forstarchiv 2013;84:152–61.
[54] Teckenburg E, Rathmann M, Winkel T, Ragwitz M, Steinhilber S, Resch G, et al. Renewable energy policy country profiles. Report under contract Contract EIE/08/517/SI2.529243. Munich: Fraunhofer Institute for Systems and Innovation Research; March 2011. Available from:, http://www.reshaping-res-policy.eu/downloads/RE-SHAPING_Renewable-Energy-Policy-Country-profiles-2011_FINAL_1.pdf [accessed 14.05.14].
[55] TFZ (Technology and Support Centre of the Bavarian Ministry of Food, Agriculture and Forestry). Scheitholzpreise. Straubing: Technologie und Förderzentrum; TFZ Merkblatt 15Febr002, Version 01/2015. Available from: http://www.tfz.bayern.de/mam/cms08/festbrennstoffe/dateien/15ebr002_mb_brennholzpreisindex.pdf [accessed 23.01.15].
[56] Todd JJ. Residential firewood estimates for Tasmania. Hobart: Eco-Energy Options Pty Ltd. [unpublished].
[57] DU Toit B, Gush M, Pryke JS, Samways MJ, Dovey SB. Ecological impacts of biomass production at stand and landscape levels. In: Seifert T, editor. Bioenergy from Wood: sustainable production in the tropics. Springer; 2014. p. 211–36. Managing Forest Ecosystems 26.
[58] Ulrik K. Seeing the Forest for the Trees – Australian Forest Biomass for Energy: An Investigation of Understanding, Acceptance, Trust & Legitimacy [dissertation], University of Lund, SE. IIIEE Publications 25/2012.
[59] Walker T, editor. Massachusetts biomass sustainability and carbon policy study. Brunswick: Manomet Center for Conservation Sciences; 2010. Report to the Commonwealth of Massachusetts Department of Energy Resources. Natural Capital Initiative Report NCI-2010-03.
[60] Weich T. Konflikte zwischen Naturschutz und Energieholzerzeugung? AFZ-Der Wald 2015;5:17–9.
[61] West J, Arundel A, Adams D, Butchart DB, O'Brien K, Gatenby S, et al. Diversifying Tasmanias economy: analysis and Options—final report. Canberra: Australian Government, Department of Infrastructure and Regional development; October 2012. Available from: http://www.regional.gov.au/regional/tasmania/diversifying-tasmanias-economy/index.aspx [accessed 14.05.14].
[62] Wilnhammer M, Rothe A, Weis W, Wittkopf S. Estimating forest biomass supply from private forest owners: a case study from Southern Germany. Biomass Bioenergy 2012;47:177–87.
[63] Wilson J. Huon woody biomass pre-feasibility study 2013: A regional inventory of potential woody biomass resources surrounding Huonville. Hobart: Esk Mapping and GIS. Report to Private Forests Tasmania 68p. (unpublished).