Southern Tasmanian forests residue recovery trial

Department of State Growth

Tasmanian Government

Contents

Abstract

The Tasmanian Government is committed to enabling industry to achieve the highest possible value for wood harvesting and processing residues. And the use of forest harvest residues for energy generation is already well established in Europe and is attracting growing interest in Australia (Rothe et al, 2015 and Ghaffariyan, 2012). In recognition of this, the Department of State Growth (DSG) and Sustainable Timbers Tasmania (STT) undertook an operational trial to further understand how to maximise the recovery of timber and fibre products from forestry operations in Tasmania's southern forests. The trial was also undertaken in conjunction with Ta Ann, Midway Plantations Pty Ltd, Neville Smith Forest Products, Private Forests Tasmania (PFT) and Reliance Forest Fibre, from February – April 2020. The trial was been co-funded by DSG, STT and PFT and had a governance framework comprising the three organisations.

The aim of this trial was to determine the indicative volumes and cost of residue recovery from harvested native forest coupes. Whereby recoverable residues (separated into stemwood (suitable for pellet production) and fuelwood (suitable for boiler fuel)) were collected from three sites and transported to Southwood where they were weighed, chipped and sampled for moisture content. These sites were representative of the productive native forest estate in the Southwood catchment. In brief:

- Site 1: 14.1 km from Southwood, where residues were collected 3 months post-harvest, produced:
    - 47 tonnes per hectare of stemwood at a Southwood chipped and delivered cost of $112.44/t.
    - 53 t/ha of fuelwood at a Southwood chipped and delivered cost of $105.44/t.
- Site 2: 55 km from Southwood, where residues were collected 3 months post-harvest produced:
    - 13 t/ha of stemwood at a Southwood chipped and delivered cost of $183.9/t.
    - 87.6 t/ha of fuelwood at a Southwood chipped and delivered cost of $176.9/t
- Site 3: 59 km from Southwood, where residues were collected concurrent with harvesting operations produced:
    - 85.3 t/ha of stemwood at a Southwood chipped and delivered cost of $72.21/t.
    - 102.3 t/ha of fuelwood at a Southwood chipped and delivered cost of $65.21/t.

The results showed that the preferred time of residue recovery would be while harvesting is taking place. And in this situation the cost of recovery, chipping and delivery is similar to what has been found in other studies (at between $60-80/t), while the volumes of residues recovered (at between 100-150 t/ha) are lower than what has been found in previous studies. Average wood chip moisture content was 40.2%. This is in line with previous studies.

Introduction

Tasmania has a long history of forest utilisation for timber production. Historically timber production has relied on supply from native forests and it remains an important part of the Tasmanian forest sector. The sawmilling industry in Tasmania has specialised in processing hardwood logs for appearance and structural timber markets.

The harvesting and processing of native forests generates a significant volume of material that has not been suitable for appearance and structural grade timber production. Historically this residue material has been chipped and exported for the production of a range of pulp and paper products. More recently, investment in processing technology has allowed some of this material to be peeled and converted into plywood (URS, 2015). Pulpwood is produced from timber recovered during harvesting operations, and exported unsubsidised out of Burnie and Bell

Bay to Asia. The remaining components are stemwood and other residues. Stemwood is the non-merchantable wood, including the stump that is usually left in the forest but excludes, foliage and roots. Residues is a generic term for material generated through the harvesting and processing of forests. This includes: harvested wood not taken for sawlog, veneer or peeler billets (including pulp logs, crowns, roots, leaves, bark and offcuts from harvested logs and thinnings); and processing residues (including woodchips, shavings, sawdust and dockings).

Stemwood and some residues are not currently recovered from native harvesting operations. The difficulty associated with handling this material and its low bulk density have been key barriers to further utilisation. Therefore the viability of collecting it will depend on a combination of the site, species, forest age, economics of recovery, its suitability for and value to end markets and the environmental impacts associated with its removal from the forest.

As such this is a currently unutilised resource in Tasmania, some of which could be used for renewable bioenergy purposes such as feed stock to make wood pellet and fuel wood for wood fired boilers. Wood pellets are generally produced from eucalypt sawdust, shavings, chips that are first dried then ground to small particles. This feedstock must be of a low moisture content and contain no bark.

Therefore the component of the residues that is suitable for pellet production are those pieces of eucalypt that already have or can have the bark removed (stemwood). All pieces of eucalypt with bark remaining and other species remain suitable as fuelwood for bioenergy burners.

The cost of recovery of residues and the volumes available from hardwood and softwood plantations around Australia which would be suitable for pellet production has been quantified in various published studies (Ghaffariyan, 2013 and 2014). However not for native forest. And the dynamics and subsequently cost variables between plantation and native forests are quite different. For example, native forests have non-linear stands, understory species, more difficult terrain, more regulatory restrictions, etc. Native forests are said to however produce a greater amount of harvest residue than plantations (URS, 2015). Forestry Tasmania (now STT) has undertaken three operational trials that each assessed various elements of residue recovery:

1. In 2000 Forestry Tasmania undertook an internal operational study harvesting two biomass plots. The aim was to test the difference between assessed and actual biomass yields. This study quantified volume per hectare of biomass available, but it did not quantify the costs associated with harvesting, it did not separate fuelwood from stemwood suitable for pellets and it collected a broader range of biomass than the current trial did, i.e. bark, leaves, twigs and downers (existing fallen decaying timber).
2. Andrewartha (2003) undertook an operational native forest Integrated Fuelwood Harvesting Trial in predominantly mature *E. regnans* forest with large dead standing trees and downers, that reported fuelwood production rates and costs and processing options. However transportation costs were not quantified and fuelwood was not separated from potential pellet material. They also picked up downers and dead standing wood.
3. Raspin et. al. (2009) undertook an operational native forest Fuelwood Harvesting Trial on the East Coast of Tasmania for bioenergy in Japan. This trial provided information on machinery and methodology for collecting biomass and the amount of biomass recoverable and production rates. It didn't calculate the cost of collection and separate fuelwood from potential pellet material.

Knowledge of the sustainable supply of feedstock is an essential part of understanding the potential of biomass for energy production (Rothe et al, 2015). Therefore this study aims to fill this knowledge gap by examining the viability of collecting stemwood from predominantly regrowth native forest coupes post-harvest and during harvest, as well as measuring the economics of its recovery (volume and cost) and separating biomass which is suitable as pellet material (stemwood) from which is only suitable as fuelwood.

Materials and methods

Site details

Site 1 - Denison 19R (DN019R)

- 28.2 ha clear fell harvested in late 2019.
- 80% of the coupe was *Eucalyptus obliqua* with the remaining *E. regnans.*
- Stemwood was harvested from 5.62 ha.
- The coupe has a history of harvesting and regeneration in the 1930s through to the 1950s and burnt in the 1967 bushfire, as such there are multiple age classes on site, with the least being 52 years old.
- Distance via road to Southwood was 14.1km.
- Harvesting period: 3-15 February 2020.

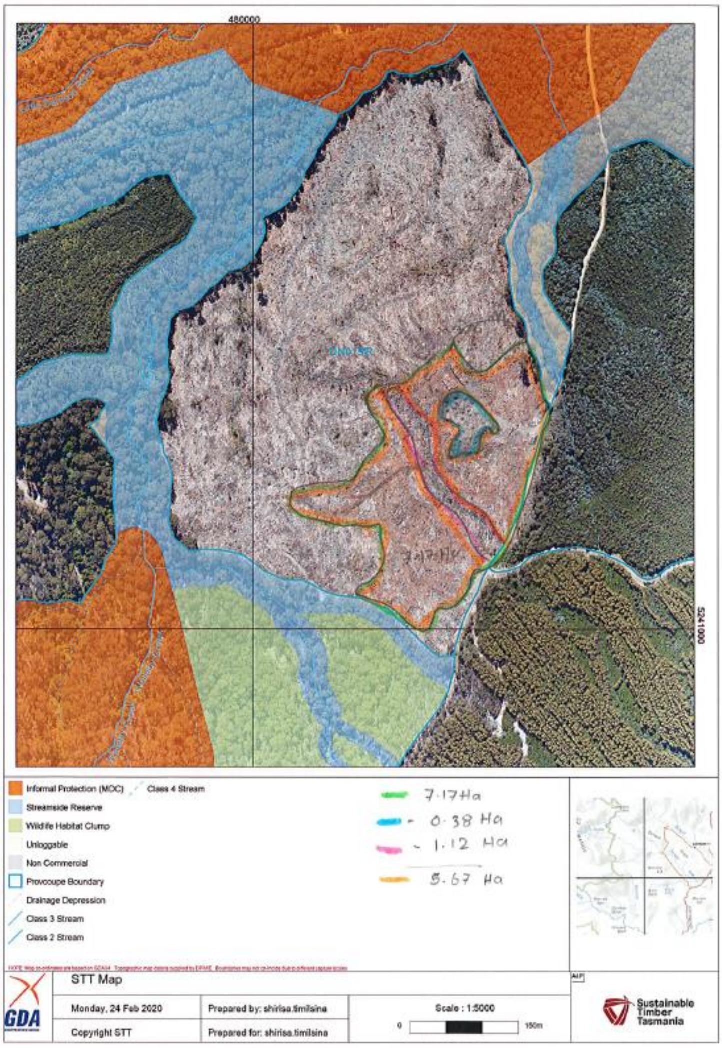

Figure 1: actual trial recovery area for Site 1 of 5.76 ha (orange boarder)

Figure 2: Denison 19R landing

Site 2: TN069C

- Harvesting completed December 2019.
- 57.7 ha clear fell harvested in late 2019.
- Stemwood was harvested from 3.14 ha.
- 49% *E. regnans*, 26% *E. obliqua*, and 25% *E. delegatensis*. Between 50-60 years old.
- Distance to Southwood was approximately 55 km.
- Harvest period was 16-27 March.

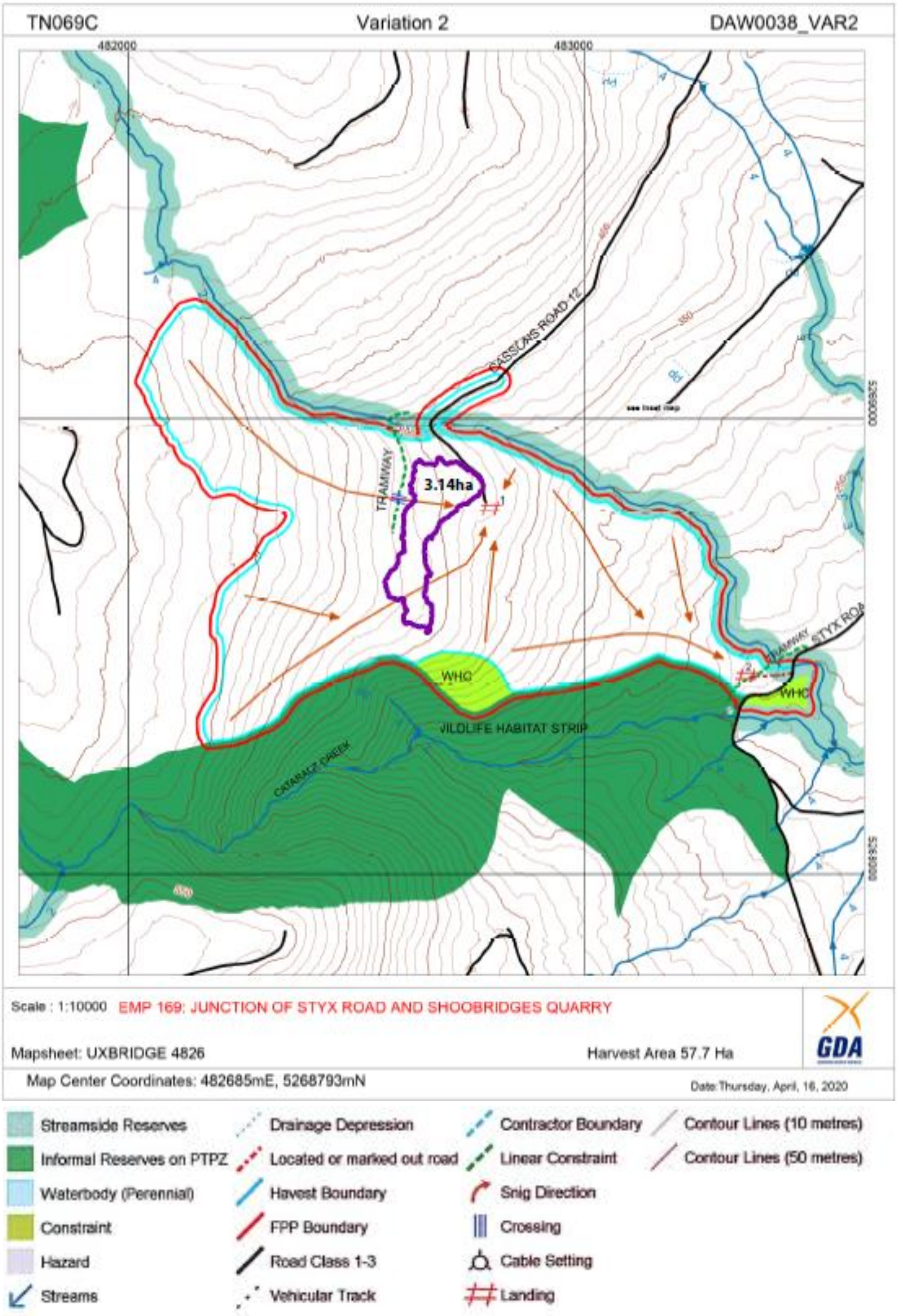

Figure 3: TN069C coupe map including actual recovery area 3.14 ha.


Figure 4: TN069C

Site 3: SO005D

- Active harvesting coupe – integrated operation.
- Net coupe area is 45.06 ha.
- Stemwood was harvested from two separate areas in the coupe. Area 1 = 0.88 ha and Area 2 = 2.93 ha.
- 72% *E. regnans* and 28% *E. obliqua.* Between 50-60 years old.
- The distance via road to Southwood was 59 km.
- Harvest period was 6 March – 20 March.

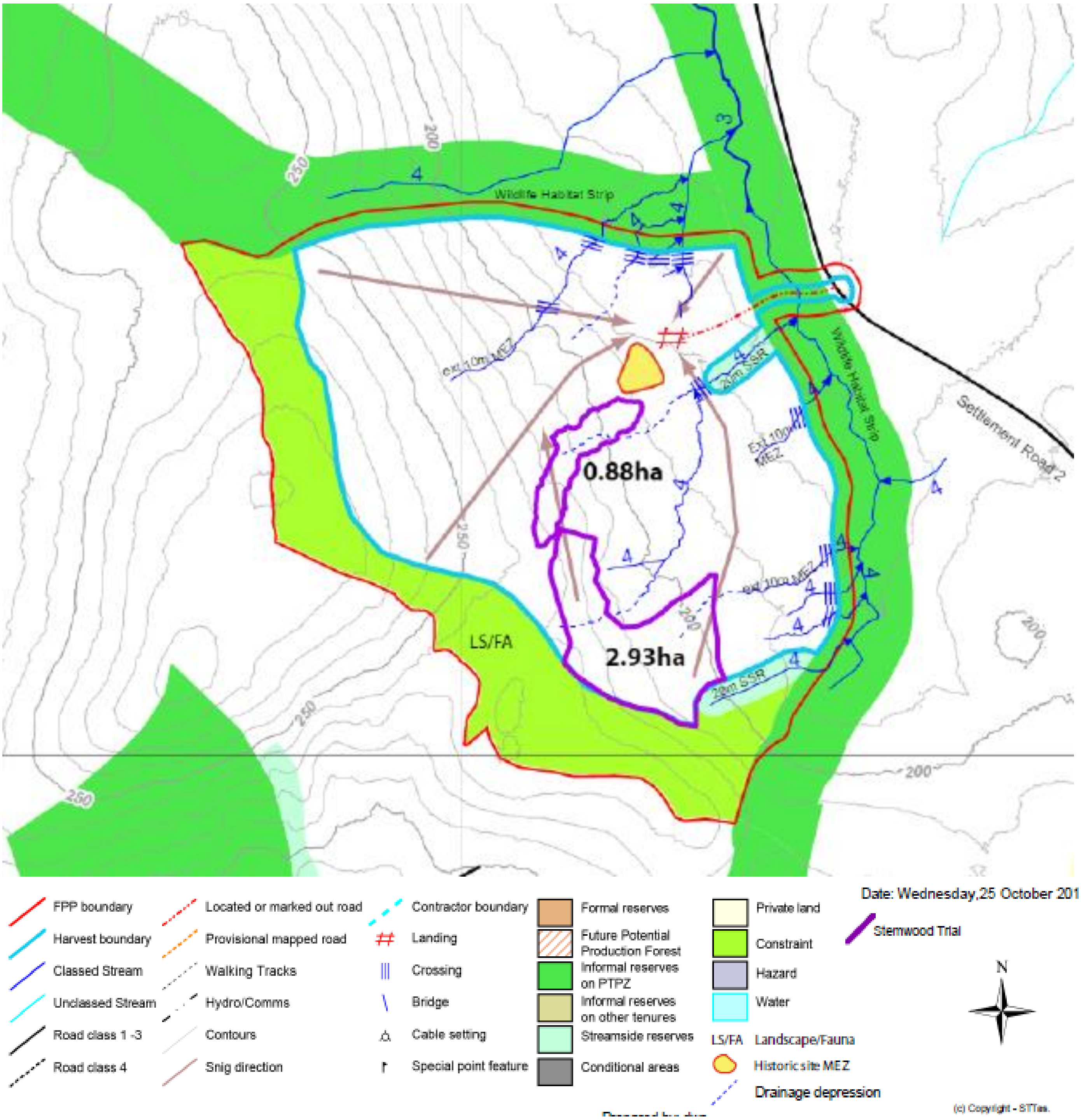

Figure 5: SO005D coupe map

Figure 6: SO005D (photo: Mitch Raspin)

Product specification

Material deemed suitable for pellet production was:

- Eucalypt pieces that had ~>95% of the bark removed.

Fuel wood material was:

- Eucalypt pieces that could not have ~>95% of the bark removed.
- Pieces of non-eucalypt species, that were of a retrievable size.

Downers, remaining standing timber were not taken.

Harvesting method

Sites 1 and 2:

Les Walkden Harvesting Pty Ltd conducted the operations on sites 1 and 2, whereby:

- Eucalypt stemwood was bunched up across the coupe with an excavator.
- This material was then collected by a grapple skidder and taken back to the landing.
- At the landing the materials were processed by an excavator whereby:
    - pieces of eucalypt biomass which bark could be removed were placed in a "stemwood" pile
    - everything else was placed in a "fuelwood" pile.
- The material in the stemwood pile was transported to Southwood where it was chipped and screened.

- Bark and other remaining debris that had built up on the landing were re-distributed back out into the coupe. Coupes were regenerated as per normal.

Figure 7: residue harvesting (Mitch Raspin)

Site 3:

Operations on Site 3 were undertaken by CP & SM Cowen and Sons. They undertook an integrated operation, whereby:

- Sawlogs, peeler logs and pulp logs were harvested in the coupe and returned to the landing by a skidder where each was segregated into piles.
- Stemwood and fuelwood were bunched up in the coupe. Stemwood was brought to the landing concurrently with other products and fuelwood was bunched at trackside.
- The material in the stemwood pile was trucked to Southwood where it was chipped and screened.
- Bark and other remaining debris that had built up on the landing were re-distributed back out into the coupe.

Coarse woody debris and environmental management

STT developed and implemented an additional set of management prescriptions so that the collection of stemwood and fuelwood activities are planned and conducted in such a way as to facilitate the maintenance of an adequate and representative complement of coarse woody debris within each harvested coupe. So that such coupes can continue to contribute to the maintenance of viable populations of the coarse woody debris dependent species occurring there at the time of harvest.

Wood chip moisture measurement

Wood chip moisture was measured in accordance with AS/NZS 1301.010s:2007(2017). Whereby:

- Two representative samples (at least 200 grams) were taken from the input to the wood chip container, once a week for the length of the trial.
- Samples were placed in double snap lock plastic bags and labelled.
- Specimen containers were weighed (W_e)
- Samples that were not subject to drying conditions were emptied into a container (W_I).
- Samples were placed into a drying oven at 105˚C for 16 hours.
- Samples were removed from oven and weighed.
- Samples were placed back in the oven and re-weigh after an hour. If the weight was the same, then constant dry weight had been achieved (W_2). If the weight was different, then it was repeated until constant dry weight was achieved.
- Percent moisture content of the chips was then calculated: $((W_I - W_2) / W_I – W_e)) \times 100$
- Percent dry matter content was calculated from $((W_2 – W_e) / W_I – W_e)) \times 100$
- Mean of the replicate results was calculated.

Cost calculations

Contractors provided harvest and transport costs aggregated to the coupe level.

Chipping and screening costs were estimated to be $14.5/t.

STT stumpage estimate was $10/t for stemwood and $3/t for fuelwood.

Road tolls are nominal Huon road tolls at $9.7/t.

The ALPACA (Australian logging productivity and cost appraisal) model, developed by the CRC for Forestry, was used to estimate the cost of transport for the "other studies" component of this report (Table 1).

Table 1: trucking costs (AFORA trucking costing sheet)

	B-double	Semi	Train
Chips (BDT)	23.88	13.2	27.9
50km Trip cost Per BDT ($)	17.07	23.88	14.88
Per tonne-km	0.342	0.477	0.298

Based on average 50km trip. Chip density = 425 kg/m^3 and 40% moisture content. Fuel = $1.5/l

Figure 8: proximity of sites to Southwood

Results

Residue recovery

Table 2: residue recovered for each site

	Site 1	Site 2	Site 3
Area harvested (ha)	5.67	3.14	3.81
Stemwood produced (t)	267	40.8	325.1
Fuelwood produced (t)	300	275	90*
Site productivity for stemwood (t/ha)	47	13	85.3
Site productivity for fuelwood (t/ha)	53	87.6	102.3
Site productivity for residue (stemwood + fuelwood) (t/ha)	100	100.6	187.6

Note: As there was no market for the fuelwood, it was piled on the coupe landing and a visual estimate was made by experienced foresters.

** Fuelwood was only collected from 0.88 ha at Site 3.*

Table 3: distance of sites to Southwood and tonnes delivered.

Site	Distance (km)	Tonnes delivered to Southwood
Site1	14.1	267
Site 2	55	40.8
Site 3	59	325.1

Note: no fuelwood was delivered to Southwood.

Results from other studies

The Burch (2000) biomass trial recovered 624m^3/ha of biomass (or roughly 936t/ha). Noting that this included stemwood, fuelwood and included also downers and bark.

The Andrewartha (2003) Integrated Fuelwood Harvesting Trial collected from two plots of different age classes: 170t/ha and 450t/ha. Noting that this material included stemwood, fuelwood, downers, and dead standing timber.

The Raspin (2009) Fuelwood Harvesting Trial estimated that 276m^3/ha (or roughly 414t/ha) of fuelwood was produced. Noting that this material included material suitable for pellet material, fuelwood and included downers and dead standing timber.

Costs

Total costs

Table 4: Total costs by component

	Site 1 ($/t)		**Site 2** ($/t)		**Site 3** ($/t)	
Activity	Stemwood ($/t)	Fuelwood ($/t)	Stemwood ($/t)	Fuelwood ($/t)	Stemwood	Fuelwood
Harvest and transport	78.24	78.24	149.7	149.7	38.01	38.01
Road tolls	9.7	9.7	9.7	9.7	9.7	9.7
Chipping	14.5	14.5	14.5	14.5	14.5	14.5
Stumpage	10	3	10	3	10	3
Total	***112.44***	***105.44***	***183.9***	***176.9***	***72.21***	***65.21***

Note:

- *Fuelwood was not transported to Southwood. It was assumed that the costs of transport of fuelwood would be the same as those for stemwood.*
- *Due to the commercial in confidence nature of harvesting and transport costs only the aggregated costs are provided in this report.*

Results from other studies

Modelled transport costs using the AFORA trucking costing sheet were $23.88/t for a 50 km round trip or $0.477/t/km.

Andrewartha 2003 who undertook a trial in mature *E. regnans* forest estimated the production costs of chipped fuelwood at $13.65/t or ~$20.4/t (in 2020 terms, although this is likely to be an underestimate, as according to industry sources the cost of harvest and transport has increased at a greater rate than CPI) for chipped residue. Note that this did not separate stemwood from fuelwood and did not include transport costs. If you were to include a modelled delivery round trip of 50 km, nominal road tolls ($9.7/t) and stumpage ($10/t) the cost would be $63.98/t.

Indufor (2016) quoted "industry sources" and provided an indicative delivered residue cost of ($57-$108/t) for processed other stemwood based on a 25 km to 75 km haulage distance. Although this report does not specify if these are figures from native forest or plantation, an integrated operation or separate residue recovery operation and what the categories of residue were.

Wood chip moisture

Average moisture content (MC) was 40.2%.

Sample and description	MC (%)	Estimated time since harvest (days)
DNO19R	42.1	162
TNO69C	39.0	160
SO005D. High proportion of acacia spp. in this sample.	39.5	15
Merchandising trial Site 1	39.6	123
Merchandising trial Site 2	40.7	100

Results from other studies

In 2013 Ghaffariyan undertook a study analysing the drying process of logs and harvesting residues from *E. globulus* plantations in Western Australia. It was found that in the residue piles, initial moisture content was 45%, after one month in the field it was 23%, after three months it was 14% then after 6 months it was 10%.

Rothe et al (2015) suggest that the water mass fraction of green wood is 45%.

In a study of the drying of *E.globulus* plantation whole logs stacked into bunches after harvest Strandgard and Mitchell (2019) found that MC started at 46.7%, was 37% after one month and after 6 weeks is was 35.5%.

Andrewartha (2003) found moisture content ranges from 30-56% depending on species and structure (Table 6).

Table 6: Fuel moisture analysis (for combined biomass material classes) (Andrewartha, 2003)

Sample No.	Plot No	Description	Date processed	Total MC%
1	2	Mature eucalypt / mixed species	8/04/2003	46.1
2	2	Split over-mature eucalypt	8/04/2003	43.9
3	2	Euc / over-mature myrtle	9/04/2003	43.6
4	2	Euc / over-mature myrtle	9/04/2003	44.2
5	2	Mature / over-mature eucalypt	10/04/2003	45.8
6	2	Mixed species	11/04/2003	41.9
7	2	Understorey spp	11/04/2003	30.7
8	2	Understorey species < 30 cm diameter	11/04/2003	30.3
9	2	Understorey species	14/04/2003	36.4
10	1	Understorey species <30 cm diameter	15/04/2003	32.7
11	1	Mature / over-mature eucalypt	15/04/2003	55.7
12	1	Understorey <30 cm diameter	15/04/2003	39.7
			AVERAGE MC %	**40.9**

Plantation residues

Plantation residues were not assessed as a part of this trial. However there are several studies that have, detailed below.

Residue recovered

In a study by Ghafarian (2012) *Assessment of harvest residues from different harvesting operation sites in Australia*, it was found that there was an average of 105 t/ha of residues left on *Eucalyptus nitens* and *E. globulus* coupes. The same study found that at an *E. globulus* coupe ~ 5% of the residue is stemwood and ~25% is branches (potentially suitable for pellets). Meaning that a maximum of 30 t/ha of residue would available for collection for pellet production. The remainder (bark, leaves and twigs) would not be suitable for pellet production.

Cost of production

Modelled transport costs using the AFORA trucking costing sheet were $23.88/t for a 50 km round trip or $0.477/t/km.

A Ghaffariyan et al. (2014) study analysed costs to collect residues from *E globulus* plantations post-harvest in Western Australia – *Analysing the effect of fire operational factors on the operating costs of a biomass supply chain: A case study in Western Australia.* This study found that:

- The cost of chip production from residues was approximately $17.4/t ($5.2 for forwarding and $12.2 for chipping) or $19.8/t in 2020 terms. For chips with a chips of MC>35%.
- The costs of chipping increased with a decrease in moisture content, because the wood became harder. However were offset by the changes in transport costs due to the drier product being lighter.

If you were to include a modelled delivery round trip of 50 km, nominal road tolls ($9.7/t) and stumpage ($10/t) the cost would be $63.38/t.

Discussion

Residue recovery

The amount of residue collected at Site 1 is estimated to be at a per hectare rate of 100 t. The split between stemwood/ fuelwood was approximately 50/50. At Site 2 the amount of residue collected at was 100.6 t/ha. However the split between stemwood and fuelwood was further geared towards fuelwood. This is likely a function of the higher portion of Dogwood species in the residue, as bark is harder to remove from these species than eucalypts. At Site 3 187.6 t/ha of residue was collected and the split between stemwood/ fuel wood was approximately 40/60.

For sites 1 and 2 combined the ratio of stemwood to fuelwood was lower than Site 3. This is because at these sites, stemwood was collected approximately 2-3 months post-harvest operation, and the process of de-barking the drier materials was difficult. If residues from sites 1 and 2 were green wood from an integrated trial it would be expected that a higher proportion of stemwood would have been recovered. However, it must be noted that the ratio of stemwood to fuelwood in the residue collected and reported should only be considered as a guide. This is because the actual ratio in an *in vivo* situation would depend on a number of factors that were not investigated in this trial.

These include customer tolerance for bark in the product; tolerance of non-eucalypt species; time of year of harvest (in Winter bark is harder to remove); experience of the harvest contractors; and bark removal technology employed at the point of production.

In terms of previous studies, the Burch (2000) Andrewartha (2003) and Raspin (2009) operational trials had residue recovery rates that ranged from 170 t/ha to 930 t/ha. Reasons for the large variations in residue recovered include but are not limited to: forest type; forest age (older forests produce more harvest residues); contractor experience and competency; regulatory and certification restrictions (i.e there are a greater level of coarse woody debris environmental management requirements now, then there were 10-20 years ago).

Therefore it would be expected that the level of recovery from a typical coupe in the southern forests (60-90 year old re-growth *E. obliqua* and *E. regnans* mix, with the potential of some *E. delegatensis* and *E. globulus*) in an integrated operation with current harvesting, processing and de-barking techniques and management prescriptions would be between 100-150 t/ha of residues, and the amount of stemwood within in this, slightly lower.

Cost of production

The total cost of production for stemwood harvest that included, chipping, stumpage, road tolls and delivery to Southwood from Site 1 was $112.44/t; at Site 2 it was $183.9/t; and at Site 3 it was $72.21/t. The cost of production was significantly less as Site 3 because it was an integrated operation.

In sites 1 and 2 extra production costs would have been incurred by: machines having to be re-floated back to the coupe and essentially passing over the coupe twice; operational efficiencies by not concurrently harvesting post, poles, sawlogs, peelers, pulp and stemwood residues were not realised; and cording and matting had to be re-established.

In a somewhat comparable study Andrewartha (2003) found that the cost of production (harvest and chipping) of residues would be $20.4/t (in 2020 terms, although this is likely to be an underestimate, as according to industry sources the cost of harvest and transport has increased at a greater rate than CPI), and $63.98/t including 50 km round trip transport, tolls and stumpage costs.

Indufor (2016) quoted “industry sources” and provided an indicative 50 km delivered cost of $82/t. They also note that it may be possible to collect some other Stemwood volume for a lower cost than this especially if it is concentrated around a central processing area.

There is a wide variation in the costs of production found in this study and others. This most likely due to the variables that contribute to the cost. These includes but are not limited to; age; forest type; regulatory constraints; tolerance of bark in the material; having an integrated harvesting operation; and having contractors with specialised equipment experienced in residue recovery. Managing these variables, where possible, to find efficiencies, or “supply chain optimisation” should bring the costs down.

Wood chip moisture

Wood chip moisture was similar to that found in previous studies. The sample from coupe SO005D was processed only several weeks post-harvest but had a comparable MC to the samples that were processed over 100 days post-harvest. This is likely a function of the SO00D sample containing a higher proportion of acacia spp. than the other samples. As acacia spp. have been shown to have a lower MC than eucalypt spp (Andrewartha, 2003).

Moisture of wood chips from others studies of chipped stemwood of a similar age since harvest has been 40-45%.

The moisture content of logs, stemwood pieces and other harvesting residues can significantly impact the energy content (or calorific value) of the forest biomass product. Moisture content may also affect the economics of chipping and transportation (Ghaffariyan, 2013). Acuna *et al.* (2012) notes that the single most important quality attribute is the moisture content of chips or raw material delivered to energy plants. It affects heating value, storage properties, chipping and transport costs of the fuel. An excessive moisture content results in a price reduction, while a low moisture content brings a bonus (Acuna et al, 2012).

Strandgard et. al. (2020) stated that "transport costs of logs and forest biofuel can make up 50% of their delivered costs". Natural drying of forest biomass infield has been identified as an effective means to reduce its costs by increasing its net calorific value and reducing its weight (Strandgard and Mitchell, 2019). However, infield drying can also increase delivered forest biomass costs because forest biomass owners incur harvest and transport costs but are not paid until delivery, incur additional costs to return equipment to the site to collect and load the biomass and storage may delay site re-establishment storage (Strandgard and Mitchell, 2019).

Therefore it is suggested that any further residue processing facility commercially study investigate the costs and benefits of immediate processing of residues post-harvest vs delayed processing. In terms of the trade-off between lower moisture content vs costs of returning machinery to site and additional chipping costs due to the material being harder. BIOPLAN, a linear programming model used to determine total operating costs of the supply chain and the best storage period for natural drying of residues prior to chipping and transportation to meet quality criteria for moisture content of bioenergy. This tool is available online could be used to explore these trade-offs.

Residue available from plantation sites

Ghafarian's (2014) study of Eucalyptus plantation residue availability found that ~30t/h was recoverable. He also estimated the costs of production at $19.8/t (in 2020 terms). Including a 50 km round trip and nominal road tolls and royalties, the cost of production would be an estimated $63.38/t.

Plantation volume recovery results are much less than those from native forests, while their residue production costs remain comparable. This is most likely because plantation harvesting operations are efficient in terms of their product recovery, i.e not a lot of residues gets left on coupe and the coupes are very uniform, therefore is easy to collect the materials, therefore keeping costs down.

Plantation residues would be available in the Southwood catchment. Therefore this warrants further investigation.

Residue available across the estate

Rothe et al (2015) modelled that 900,000 t/a of bone dry residues would be available for energy production across Tasmania this included 450 000 from native forests, 350 000 from hardwood plantation and 100 000 from softwood. Indufor (2016) have since stated that other Stemwood accounts for 950-980,000 tonnes/year over the first 15 years and around 630,000 tonnes/year from 2027 across Tasmania.

However, operational constraints, such as those discussed throughout this paper, would mean that these figures would be lower in reality.

Therefore it is suggested that any further residue processing facility commercial study use the information identified in this study and others, combined with STT and private sector harvest projections only to establish a rough estimate of total residue available.

Conclusion

Conclusions that can be drawn from this trial include:

- It is cost prohibitive to collect residues post-harvest.

- The production cost for stemwood material in this trial at Site 3, the integrated harvest operation, was similar to those found in previous forest residue recovery studies.
- It would be expected that the level of recovery from a typical coupe in the southern forests in an integrated operation with current harvesting, processing and de-barking techniques and management prescriptions would be between 100-150 t/ha of residues, and the amount of stemwood within in this, slightly lower.
- The ratio of stemwood to fuelwood in this operation was variable across the three sites. In an industrial scale operation the ratio would be relative to the: tolerance to bark; tolerance of non-eucalypt species; proficiency of the harvest contractors; and bark removal technology employed at the point of processing.
- Wood chip moisture is likely to be slightly over 40%.

To build on these findings, it is recommended that further work be put into:

- Supply chain optimisation modelling to identify where costs can be saved to reduce the processing and delivery costs of residues. Particularly in relation to mobile chipping vs fixed mill chipping; the value of including specialist residue recovery machinery at the harvest operation; and transport costs.
- Detailed wood basket analysis, including private forestry companies intention to harvest, to determine the potential available resource available to a Southwood operation.
- Cost and benefit analysis of immediate processing of residues post-harvest vs delayed processing. In terms of the trade-off between lower moisture content vs costs of returning machinery to site and additional chipping costs due to the material being harder.

Acknowledgements

This project would not have been possible without the funding provided by Private Forests Tasmania, STT and the Department of State Growth, and the assistance, often in-kind, of the following:

Greg Hickey and Mitchell Raspin, Richard Lindley from STT – operational management of the project

Craig Patmore (Consultant) from FCS – merchandiser yard operations manager.

Les Walkden Pty Ltd – Harvesting and chipping contractor.

CP & SM Cowen & Sons Pty Ltd – Harvesting contractor.

P L & N R Voss Pty Ltd. – Harvesting contractor.

Anthony O'Grady – CSIRO – wood chip moisture measurement assistance.

Troy Geeves – Ta Ann Tasmania – use of the Ta Ann weighbridge and office facilities.

Josh Turnbull – Neville Smith Forest Products - provision of merchandising site.

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