Wood Energy Programme - Engineering Solutions Phase II

Woody biomass for boiler fuel

Guidelines for Payment by Energy Content

Wood residue can be measured and paid for by weight or volume but:

How much energy is in the fuel pile?

and

What did it cost per unit?

Contents

Introduction

Woody biomass is an excellent resource for low- or high-grade heat via combustion. It is a valid alternative to fossil fuels, with benefits of being carbon neutral and renewable and fitting within the New Zealand Energy Strategy.

The use of woody biomass has been limited, as it has lower energy content per unit of weight or volume than alternatives such as coal or gas. Woody biomass is also bulky and awkward when processed into hog fuel and thus requires specialised, and often expensive, handling equipment and storage facilities.

To increase and improve the use of woody biomass as a fuel its value needs to be better understood and improved where possible. The easiest method to increase the value of woody biomass as a fuel is to ensure it is clean and dry.

A dry fuel has lower moisture content and therefore higher energy content per unit of weight or volume.

A clean fuel is easier to handle and has lower operating costs than a fuel with contaminants such as dirt and stones. These contaminants cause machinery breakages, blockages, and reduced energy recovery. A clean fuel has higher energy content and lower ash content. Low ash content can result in better combustion characteristics and lower ash disposal costs.

A payment system based on energy content is one method of ensuring a high-value fuel – the higher the quality of the fuel, the higher the energy content, the higher the value to both seller and purchaser.

It is currently common practice in New Zealand to pay for woody biomass by weight, particularly at large-scale industrial sites. This is often a quick and convenient method of paying for the material, as it is transported by truck to facilities that have, or are near, weighbridges. The forestry and wood processing industries have a long history of using weight as a measure for paying for logs and log transport and the infrastructure for weighing trucks is well established. The wood processing industry is also the largest user of woody biomass as fuel

In some cases the biomass fuel material is paid for by volume, especially if there is a regular supply from a known source, which is transported by vehicles with a known load space volume. In this case there must be trust that the truck is actually full for each load. It is also convenient for occasional, or intermittent, deliveries.

The drawback of paying for biomass by weight is that biomass is different to many other common forms of energy (gas, diesel and, to some extent, coal) in that the energy content of a given volume or weight is not necessarily constant. This is particularly so for forest-derived residues, which have varying sources, supply chains and storage times. The weather is also a factor. The two main parameters which affect the energy content of woody biomass are:

- moisture content (Fig. 1)
- contamination with dirt, which ultimately affects ash content.

In paying for a material with variable energy content by weight or volume, the fuel buyer ends up not knowing exactly what the cost of energy is. It may also be in the interests of the fuel supplier to know at least what volume of material they have produced, as dry material weighs less (less revenue in a weight-payment system) but takes just as much effort to produce (volume of throughput).

The reality is that paying by weight for wood fuels actively discourages the fuel supplier from producing a clean, dry fuel, as it is not in his financial interests to do so.

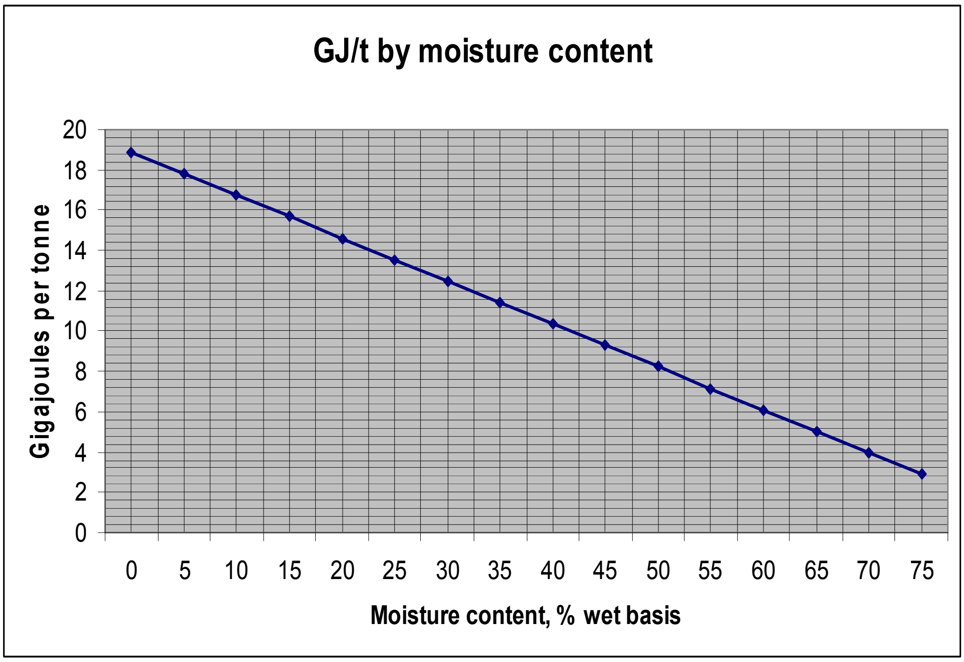

Figure 1: Specific energy content by weight (GJ / tonne) by moisture content (wet basis)

Current practice

In many cases the wood used as boiler fuel is brought in from off-site and it is paid for on a per tonne basis. The amount paid is affected by the cost of hogging, transport distance and loading costs. Costs may be as low as $14 or as high as $35 per tonne, depending on how much processing is required, and how far it is transported.

In some cases the material is paid for on a volume basis, but this is less common and is generally applied to material coming from a processing plant (shavings and/or sawdust) where the moisture content of the material is known to be within a narrow range, and the volume of the truck bringing the material is known. In this case the energy content of the load can be estimated, but the load density is still unknown.

A combination of known volume, weight and narrow moisture content range would allow for the energy content to be calculated with some accuracy, but this is rare.

For hog fuel from a sawmill, log-yard, or forest landing the moisture content will vary widely. Buying this material by the tonne means that both the buyer and supplier are at risk of not getting what they expect.

What can be done

It is possible for many sites, particularly larger wood-energy users to move from a weight-only based system to a simple weight-by-moisture content system. This ensures there is less likely to be major over- or under-payments for a given load.

The collecting and testing of samples for energy is relatively easy, and quite low cost, and should be able to be done for around $15 per sample. A recent case study found that testing for moisture content was available at $10 per sample.

Once the moisture content of the load is established (estimated based on sample), the energy content per tonne can be estimated and, then using the load weight, the energy content of the load can be calculated. The payment for the fuel can then be made based on the energy content and its energy value, as opposed to its weight which is driven by moisture content. Payment by weight can work against a fuel purchaser (i.e., more moisture, more weight, less energy per tonne) (see Fig. 2 and Table 1).

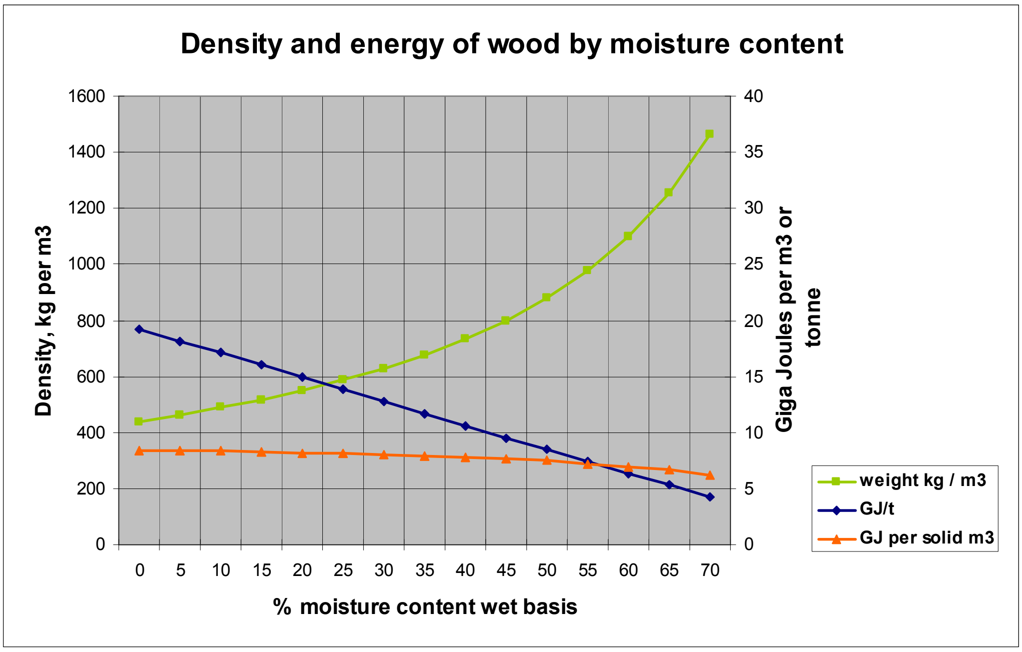

Figure 2: Energy by weight and volume, and density (weight per m^3) by moisture content

The density (weight/ m^3) of the wood increases or decreases, depending on the moisture content (Fig. 2, green line, left-hand scale). If a solid cubic metre of wood is assumed which has a basic density of 420 kg/m^3 oven dry, as the moisture content increases the weight increases, but there is not more wood, just more water. The inverse also applies, if you have a green cubic metre which weighs 1000 kg and is 56% moisture content, as it dries there is still a cubic metre, but it weighs less, has greater energy content per kg, but has less kgs than the original volume.

Table 1: Energy by weight and volume by moisture content, volume by weight and density by volume by moisture content

Moisture content (wet basis)	GJ / t	Solid m^3 / t	GJ / m^3	t / m^3 Solid
0	19.2	2.27	8.45	0.44
5	18.1	2.16	8.38	0.46
10	17.1	2.04	8.36	0.49
15	16.0	1.93	8.28	0.52
20	14.9	1.82	8.20	0.55
25	13.8	1.70	8.10	0.59
30	12.8	1.59	8.05	0.63
35	11.7	1.48	7.92	0.68
40	10.6	1.36	7.77	0.73
45	9.5	1.25	7.60	0.80
50	8.5	1.14	7.48	0.88
55	7.4	1.02	7.23	0.98
60	6.3	0.91	6.92	1.10
65	5.3	0.80	6.66	1.26
70	4.2	0.68	6.15	1.47
75	3.2	0.57	5.63	1.76

* Note 1 m^3 of solid wood = approximately 2.5 m^3 of chip or 2.7 m^3 of hogged wood

How Moisture Content affects energy

Gigajoules per tonne can be estimated from the following equation

GJ / tonne = -0.212 * Moisture content (% wet basis) + 18.842

(van Loo and Koppejan, 2008, www.bioenergy-gateway.org.nz (Biomass calorific value calculator))

This equation can be used in a spreadsheet to calculate energy from the sample and, subsequently, energy per tonne and per load.

How Moisture content affects Volume and Weight

Table 2: Shows the impact of varying moisture content on the energy value ($) for tonnes and cubic metres

Moisture content, wet basis	Value per tonne	Value per m^3
0	$48.00	$21.13
5	$45.25	$20.95
10	$42.75	$20.90
15	$40.00	$20.70
20	$37.25	$20.50
25	$34.50	$20.25
30	$32.00	$20.13
35	$29.25	$19.80
40	$26.50	$19.43
45	$23.75	$19.00
50	$21.25	$18.70
55	$18.50	$18.08
60	$15.75	$17.30
65	$13.25	$16.65
70	$10.50	$15.38
75	$ 8.00	$14.08

Dollar values are based on energy value of $2.50 per gigajoule.

Calculating Energy Content

The relationship between moisture content and energy content can be used with the weight to calculate the energy content of the biomass.

Moisture content is the key variable affecting energy content. At the weigh-station a sample can be taken and the sample then measured for moisture content. Using the equation below moisture content can be used to determine the energy content of the material and, together with the weight of the load, the total energy of the load is calculated.

The equation used to estimate the energy content based on moisture content is:

Energy (GJ/t) = -0.212 * Moisture content (% wet basis*) +18.842.

* See Appendix II

Setting up an energy-based payment system

In order to set up a payment system by energy content the following steps need to be taken:

Step 1: Determine a target value for woody biomass.
The target value is what the purchaser wants to pay for energy from woody biomass. This can be calculated from the current contracted price per tonne of hogged woody biomass based on a maximum average acceptable moisture content (typically maximum moisture content is around 55%). In order to calculate the target value of the woody biomass, the energy content of the fuel must first be estimated. This can be done using the formula above.

Once the energy content is known the target energy value can be set. For example, if the current price is set at $15 per tonne, and the energy content is 8.2 GJ per tonne (assuming 50% moisture content, wet basis) then the target energy value can be set as $1.83 per GJ.

Step 2: Obtain the weight of the load.

Step 3: Measure moisture content from a sample of each load of biomass.

Step 4: Calculate energy content in the load using the formula on page 7.

Step 5: Calculate total energy content in the load by multiplying energy content by weight of load.

Step 6: Calculate value of the load by multiplying total energy content by energy value (for example, as above $1.83 per GJ).

A further method to increase the accuracy of the energy content estimate is to measure ash content of the fuel. This is done by sampling and testing. The wood naturally contains <1% ash and bark about 2% to 3%. Anything over this is probably due to contamination, typically dirt. Many boilers will cope with ash content of up to 5%. However, anything much higher than this is likely to affect boiler performance, and will have a significant effect on ash disposal cost, due to the increased quantity.

It would be reasonable to have a specification which set a maximum ash content and periodically test for this. If the tests showed ash content over the agreed limit then the payment could be reduced by the same percentage that the ash has exceeded those limits, as the dirt that the ash came from has no fuel value. For example, if the ash limit is set at 4%, and samples indicate an ash content of 6%, the payment could be reduced by 2%, as that is approximately the amount of material delivered that was not fuel.

Sampling and Testing

Care should be taken when collecting samples as they must fairly represent the loads used to determine payment. It is good practice to collect the sample from several points within a load, rather than all from the one place.

Ideally each load would be sampled. However, if a fuel source is historically homogenous, samples could be used across loads (say 1 in 3). If this approach is used, the variability of the results of the testing must be monitored, and if the results become excessively variable (more than +/- 3%), then frequency of sampling and testing should be increased.

The samples should be kept in paper bags in a cool, dry place (chilly bin), and submitted for testing within 12 hours of collection, preferably less.

The size of the sample required may be a source of debate, but a volume of approximately 2 litres, if it constitutes material collected from several points within a load, should be sufficient.

Testing should be done by an independent third party. The procedure would be:

1. Weigh the sample as bagged (wet weight).
2. Dry the sample for 24- 48 hours at 100°C.
3. Weigh the dried sample as bagged (dry weight).
4. Weigh the bag and deduct this from the sample weights.
5. The difference between the wet and dry weights is the moisture content.
6. The moisture content is expressed as a percent of the wet weight (mc wet basis).

Data should be shared between seller and purchaser.

The sample used for ash content would typically be a small sub-sample of the moisture content sample, and care must be taken that the fines (which may contribute to the ash) are included, and not removed from the sample during drying and handling.

Payment calculation example

Target value for fuel = $2.50 per gigajoule

- Sample weight wet = 315 g
- Sample weight dry = 145 g
- Moisture content = 170 g
- MC wet basis = 54 %

Using the equation:

Energy (GJ/t) = -0.212* Moisture content (% wet basis) +18.842

gives the result of 7.36 GJ per tonne for energy content of the fuel.

Load weight = 15.73 tonnes

Energy content of load = 15.73 * 7.36 = 115.77 GJ

<u>Value or cost of load = 115.77 * $2.50 = $289.42</u>

Issues

1. Sampling and testing must follow proper procedure to obtain accurate results, and results should be available to both seller and purchaser.
2. Sample drying and moisture content testing is readily available at large wood processing sites (e.g., pulp mills) but may require a special set-up at smaller sites where wood fuel consumption is a recent development.
3. Ash content testing may be difficult to achieve at short notice for smaller sites.

Benefits

1. The fuel purchaser gets the true value of the fuel, and is not paying for weight that has no fuel value (moisture).
2. The seller gets paid for the true value of the volume he has produced, particularly relevant to situations where dry material (high volume, low weight) is being processed and transported.
3. There is an incentive for seller and processor to produce a better, more consistent fuel, avoiding unnecessary moisture content and dirt contamination.
4. Moves away from the current common system, paying by weight, which actively discourages producers from producing a dry fuel.

References

www.bioenergy-gateway.org.nz

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Hall P and Gifford J, Bioenergy Options for New Zealand. Scion 2008

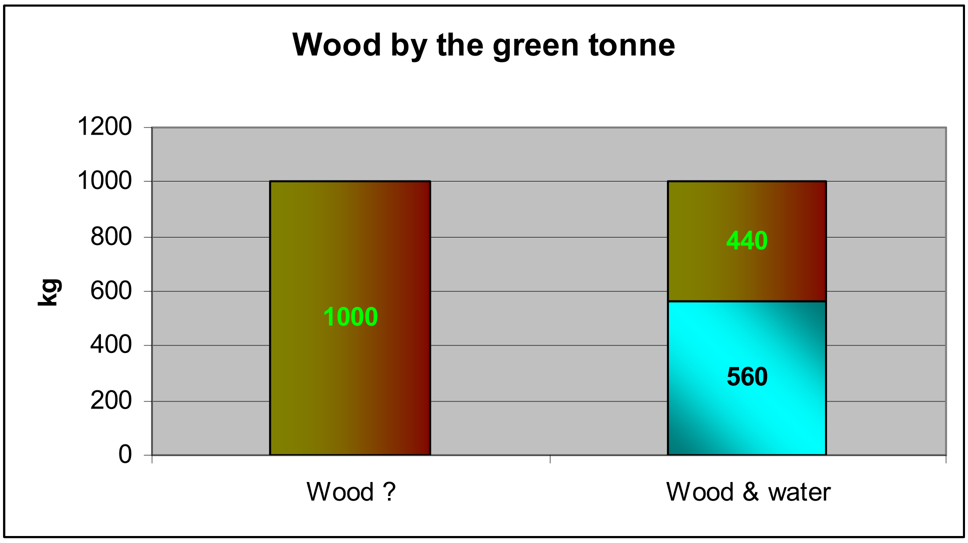
Van Loo S. and Koppejan J. (2008). The Handbook of biomass combustion and co-firing.

Glossary

C	= Celcius
GJ	= gigajoule ($1*10^9$ joules)
t	= tonne
m^3	= cubic metre
MC	= moisture content
ww	= wet weight
wb	= wet basis
kg	= kilogram

Appendix I

Any wood purchased by weight, when it is green has high water content. It looks like wood, and is heavy, but a significant proportion of its weight is water, which has no fuel value. The left column represents the appearance, the column on the right represents what the proportions of wood and water commonly are for fresh green wood.



Appendix II

Moisture content, Wet Basis

The amount of water in the wood is expressed as a percentage of the wet weight of the material; wet weight is 1000 kg, moisture is 560 kg, moisture content wet basis is 56%.

Moisture content, Dry Basis

The amount of water in the wood is expressed as a percentage of the dry weight of the material; original weight 1000 kg, dry weight 440kg, moisture 560 kg, moisture content dry basis is 127%.