MINISTRY OF BUSINESS, INNOVATION & EMPLOYMENT
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ENERGY AND BUILDING TRENDS

Industrial Bioenergy Use

Updated methodology to estimate demand

New Zealand Government

Contents

Overview

Estimated industrial bioenergy demand in New Zealand has been updated for 2016 using a new methodology. Total bioenergy demand including cogeneration from wood and black liquor has been estimated as 50.16 Gross PJ in 2016, showing a small decrease to the from 2015 at 50.78 PJ. However the methodology update, resulted in the total bioenergy demand being composed of 7.4 percent less black liquor and 6.5 percent more wood fuel consumption in 2016 compared to previous years.

Industrial bioenergy demand is split in to demand for process heat use and cogeneration and is published by MBIE in the annual energy balance tables. In 2016 the amount of bioenergy used for cogeneration is slightly lower at 4.66 PJ than in 2015 at 4.84.

This document sets out details of the updated methodology used to estimate industrial bioenergy demand. More details about the wood processing sector's fuel use can be found in the Energy Use data sheet published on the MBIE Industrial Process Heat Action Plan webpage.

There are two main changes to the bioenergy demand methodology:

- The bioenergy demand data from 2016 onwards is estimated based on the updated methodology set out in section 1.
- We have updated the conversion factors we use to convert the black liquor proportion of the bioenergy demand from Net PJ to Gross PJ. Revised bioenergy demand data in Gross PJ has been published from 1990-2015, based on updated conversion factors. The historic Net PJ demand is unchanged. Details of these changes are provided in section 2.

The term *site* is used to refer to a particular factory. The term *plant* is used to refer to a particular unit used to create process heat on the site, such as a boiler or an air heater.

1. Updated methodology to determine bioenergy demand

MBIE commissioned Scion in February 2017 to provide estimates of bioenergy (and other fuels) consumed in each wood processing and pulp and paper operation in New Zealand. Scion produced a database with details for 173 wood processing operations.

Two methods are used to estimate fuel use, one based on how each heat plant (and cogeneration plant) is operated and the implied fuel inputs, the other based on the 2016 production levels and implied energy requirement to produce each product.[1] The bioenergy demand from the heat plant based method is used to define the reported bioenergy demand and the production based method is used for comparison to check the validity of the assumptions made around heat plant operation. The methods estimate bioenergy consumption in 2016 within 2% at 40.3 (net PJ) from the heat plant based method and 39.8 (net PJ) from the production based method.

The bioenergy database will be updated annually by Scion, to provide annual bioenergy demand estimates that will be reported by MBIE.

[1] See table 1 for list of products produced in the Wood processing and pulp and paper sector that are captured in the database.

1.1. Boiler Operation Based Fuel Demand Estimate

Energy consumption by fuel type based on heat plant operation is estimate for each boiler, based on the following calculation:

$$\frac{\textit{Nameplate capacity} \times \textit{Hours in a year} \times \textit{Loading}}{\textit{Efficiency}} \times \textit{Capacity factor}$$

The database compiled by Scion includes the following values for 124 heat plants, including two cogeneration (heat and electricity) plants:

Nameplate capacity in megawatts (MW) is the maximum power output (or rate of heat energy transfer) of the boiler when it is run at full capacity. Also termed the rated capacity.

Loading is the proportion of time each year that the boiler is used. Loading varies with the type of process and values in the database vary from as little as 0.35 to 0.95. Pulp mill boilers tend to have very high loadings (0.9 or 90% of the time) and sawmill boiler loadings vary, but as many mills do not operate 24/7 the loadings are much lower (around 0.6 or 60% of the time).

Capacity factor is the ratio between the typical heat demand and the boiler's nameplate capacity to supply heat. Most boilers are rated slightly larger than the demand they are serving. The typical capacity factor is estimated to be around 0.8 in the data base, which indicates that, on average, the boiler is only operated to produce 80% of the heat output that it could provide at the rated (or full) capacity.[2]

Efficiency is assumed to be 0.85 for all boilers, this means that 85% of the energy in the fuel is converted to useful heat. This is based on a net (LHV) energy basis for the input fuel.

In some cases direct information from discussion with firms has been used instead of estimates, for example where multiple fuels are used in a boiler and bioenergy consumption cannot be estimated.

1.2. Production Based Fuel Demand Estimate

Energy consumption for all fuel types excluding black liquor estimated based on production level for each product type, based on the following calculation:

$$\frac{\textit{Product output per annum} \times \textit{Heat energy per unit of product}}{\textit{Heat system efficiency}}$$

Product output per annum is recorded in the database in either tonnes (t) or cubic metres (m^3) of product produced per year.

Heat energy per unit of product is an estimate of the energy required to make a unit of product, as set out in Table 1 below.

[2] Source: University of Waikato - Industrial Symbiosis project - heat plant database update

Table 1 – Heat energy consumed per unit of production

Product	Heat demand (GJ) per unit of product	Unit of product
Particle Board	1.95 to 3.50*	m^3
Hardboard	2.1	m^3
MDF	3.5	m^3
Plywood	10.1	m^3
LVL	10.1	m^3
Veneers	10.1	m^3
Kraft pulp	12.75	adt****
Carton board	12.75	adt
TMP	10	adt
CTMP	10	adt
Tissue paper	10	adt
Sawn lumber	1.52 to 2.10**	m^3
Remanufactured wood	0 to 2.10	m^3
CLT	0.to 2.10***	m^3
Glulam	0 to 2.10	m^3
Wood Pellets	2.1	t

*varies with product and feedstock, ** varies with kiln type, ***depends on sawn lumber purchased being dried or undried, **** adt is the acronym for air dried tonnes.

Heat system efficiency is the total aggregate efficiency of the boiler and the kiln/drying/curing unit. It is assumed to be 0.75 (75%) for all product types.

1.3. Production based black liquor energy production

Black Liquor is the lignin rich by-product from the chemical pulping process used in the production of Kraft pulp. Black liquor is burnt through recovery boilers to produce process heat and recover chemicals that can be reused in chemical pulp production. Black liquor energy consumption is calculated based on the tonnes of Kraft pulp produced using the following formula:

Kraft pulp production per annum × *Energy content of black liquor dry solids* × *Black liquor dry solids per tonne of Kraft pulp production*

Kraft pulp production per annum is recorded in the database in tonnes (t) of product produced per year.[3]

Energy content of black liquor dry solids is approximately 11 GJ/tonne.

Tonnes of black liquor dry solids produced per tonne of kraft pulp production is approximately 1.8 (dry tonnes black liquor/ tonne kraft pulp). Wood, which is used to make Kraft pulp, is composed of cellulose, hemicellulose and lignin. Most of the cellulose and small

[3] Kraft pulp production (also called chemical pulp) is published by the Ministry for Primary Industries on an annual basis here: http://www.mpi.govt.nz/news-and-resources/open-data-and-forecasting/forestry/

amount of hemicellulose is used to make pulp. Some of the hemicellulose and the lignin go into the black liquor.

1.4. Database structure and data sources

Details of 173 processing operations are included in the database - these are described in terms of location (region, city and geo-reference), ownership, process type, volume of log in, volume of product out, presence of a heat plant, size of the heat plant and the estimated fuel demand of the heat plant; based on its size & loading, and also by volume of product produced and estimated heat demand per unit of product.

The data provided to MBIE is derived from the Scion Wood Processing database. This database is updated on an irregular basis (3 to 4 times a year) as information becomes available on developments in the wood processing industry.

The main sources of information on processing sites used to create the original wood processing database (location, products and volumes) were the New Zealand Forest Products Industry Review 2014 & 2016 (Vaney and Nielson 2014, Nielsen 2016).

Supplementary information on conversion factors and heat demand by product has been derived from a range of publications and industry sources. The data on black liquor consumption is derived from information provided by OJI Fibre Solutions. The WoodScape project (Jack, Hall, Goodison and Barry, 2013) was a significant source of information on the heat demand of the various processes from direct contact with a wide range of wood processors.

Further information was derived from the Ecological Footprint of the wood processing industry study (Andrew, Forgie and Lennox, 2008) and Scion studies on wood processing and wood residues (Nicholas et al, 2004).

The EECA Heat Plant database was the key source of information on boiler presence, size and fuel type within the wood processing industry. Additionally, Scion staff regularly access a range of industry magazines and newsletters (NZ Logger, Wood Week, Friday Offcuts, etc.) which are a source of information on developments in the forestry and wood processing industry in Australasia. The wood processing database covers the majority of the large scale wood processors in New Zealand, and all those with heat plants captured in the EECA heat plant database. It has not necessarily captured all the smaller wood processors, especially those that do not have a heat plant.

There are expected to be gaps in the information on post and pole yards and from remanufacturing operations. However it is expected that the majority of operations that have been missed are unlikely to be using process heat.

2. Updates to gross to net PJ energy conversion factors

MBIE Web tables provide information about the annual energy production and consumption in New Zealand. These are published in gross PJ units as well as net PJ.[4] The bioenergy demand

[4] The energy content of fuel is the total energy released as heat when a substance undergoes complete combustion with oxygen under standard conditions. Gross PJ is a measure of the energy content of fuel based on a higher heating value. The higher heating value includes the heat energy produced by bringing all the products of combustion back to the original pre-combustion temperature, and in particular condensing any vapour produced.

estimated using the Scion database is in net PJ. The net PJ value is converted to gross PJ using a conversion factor.

In the past a single gross to net conversion factor has been use in the MBIE data system for both black liquor and wood, as follows:

Wood & Black liquor (Gross PJ) = Wood & Black liquor (Net PJ) / 0.78

However the gross to net conversion factor for black liquor is different from that for wood fuel. Two gross to net conversion factors are used in the revised data as follows:

Wood (Gross PJ) = Wood (Net PJ) / 0.78

Black liquor (Gross PJ) = Black liquor (Net PJ) / 0.85[5]

By using the conversion factor specific to Black liquor of 0.85 the gross PJ of black liquor demand is lower than it would have been with the previous value of 0.78.

2.1. Calculating net to gross conversion factors

The method used to calculate the net to gross conversion factor for wood fuel is set out below. The conversion factor for wood is based on the assumption that the wood fuel that is burnt has a moisture content of 56%.[6]

The net calorific value at 56% moisture content is calculated to be 6.9GJ/t. This is calculated based on the following formula:

$$NCV = GCV \left(1 - \frac{w}{100}\right) - 2.447 \frac{w}{100} - 2.447 \frac{h}{100} 9.01 \left(1 - \frac{w}{100}\right)$$

NCV: net calorific value in MJ/kg fuel (wet basis)
GCV: gross calorific value in MJ/kg fuel (dry basis)
w: water content of fuel as percentage of weight
h: concentration of hydrogen as a percentage of weight, h=6%

The water content of green, fresh radiata pine is around 56% on average. Immediately after harvest it can be higher (around 58%) but dries somewhat during movement through the supply chain.

The first term in the equation converts the gross calorific value to the wet basis. The second term is due to the latent heat of vaporisation of the water contained in the wood. The specific latent heat of vaporisation of water at 25°C and constant pressure is 2.447MJ/kg. The third term is due to the vaporisation of the water produced when the hydrogen in the wood is combusted. The concentration of hydrogen in woody biomass is typically about 6% (dry basis).

Net PJ is the energy content of fuel based on a lower heating value. The lower heating value is determined by subtracting the heat of vaporization of the water vapour from the higher heating value. The energy required to vaporize the water therefore is not released as heat. LHV calculations assume that the water component of a combustion process is in vapour state at the end of combustion.

[5] The gross to net conversion factor of 0.85 is based on Net calorific value 11 MJ/kg divided by Gross calorific value 12.98 MJ/kg for Black liquor. Calorific values sourced by Scion from OJI in New Zealand and the New Zealand Energy Information Handbook, 2008. Eng G., Bywater I. and Hendtlass C.

[6] Source for estimating moisture content: NZ Institute of Forestry Handbook, 2005. Section 9 – Utilisation of Forest Products, p206, Table 1 - Classification of wood properties

The average gross calorific value of oven dried Pinus radiata with a moisture content of 0% is assumed to be 20.2 GJ/t. Gross calorific value at 56% moisture content is 8.9 Gross GJ/t (which is 45% of what it is at 0% moisture content), based on the following formula:

$$\text{Gross Calorific Value at } w \text{ \% moisture content} = GCV(0\% \text{ moisture}) \times (1 - w)$$

w: water content of fuel as percentage of weight

To get the net to gross conversion factor of 0.78 at 56% moisture content, the net calorific value at 56% moisture content (6.9 GJ/t) is divided by the gross calorific value at 56% moisture content (8.9 GJ/t).

3. Methodology rational and future improvements

A methodology based on estimating demand was employed instead of surveying all users of wood energy for a number of reasons. Based on Scion's experience wood energy use and heat output is not directly measured in the majority of cases where wood residues are created and burnt onsite, therefore the data is not available to collect. Although in many cases measurements of wood fuel demand were not available, discussions with the larger wood energy consumers resulted in refined and improved inputs to estimate wood energy use based on heat plants operation.

Using two alternative methods to estimate the wood energy demand provides a check allowing us to compare the estimated wood and black liquor fuel demand for each site. Where large differences in the estimates occurred further investigation was carried out and where possible collection of information on boiler operation or fuel use from firms was incorporated. Overall the two methods of estimating bioenergy demand agree closely and are within 2% of each other.

3.1. Future improvements

The majority (80%) of the fuel demand is concentrated in the top 20 highest fuel consuming boilers. Data collection in the next annual update will focus on the sites with these larger boilers, with a survey of a sample of the smaller fuel consumers. Data collection will be carried out via conversations with firms to ascertain what information is a currently measured and available to be collected including:

- name plate capacity of boilers
- operating hours per year and loading on boilers
- capacity at which boilers operate
- metered boiler heat outputs where available
- measured bioenergy use where available

We proposed a targeted approach where data is collected via discussion with firms instead of sending out a survey that is completed and returned. A targeted approach provides oversight of the nature of the information provided, whether it is measured or estimated and therefore help to understand the quality of the data the is being collected. It also allows a two way discussion that can help identify additional information that maybe available that could improve our dataset.

We will update the list of boilers and bioenergy users in the database as part of an annual update carried out by Scion. MBIE will use the Council and seek information from other organisations that may have useful information to support this including other government agencies and associations.

MBIE plans to improve the current methodology used to determine the bioenergy use for co-generation to be allocated to electricity generation and process heat production. Currently the fuel used in cogeneration plants reported is the total fuel use for electricity and heat generation.

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George Estcourt (Scion) also provided input; on boiler loadings and efficiencies.

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