



An Australian Government Initiative



Biofuel Database

**A database of energy-related
characteristics for Australian
biomass**

**A report for the RIRDC/Land & Water
Australia/FWPRDC/MDBC
Joint Venture Agroforestry Program**

by Wesley Stein and Lasse Tobiasen

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Foreword

Responding to climate change is leading a drive toward technologies with a lower carbon dioxide footprint. Bioenergy is a widely accepted renewable technology, and enhances the possibility of multiple benefits from tree-farming operations.

This publication reports on the development of an online database of important fuel characteristics of a range of Australian biomass types, including a number of low rainfall species. The report includes the rationale for the project, and the methods used for chemical, combustion and gasification analysis of the 118 biomass type samples analysed. The database gives the results from analysis of different biomass samples from across Australia. In collecting samples, particular importance was placed upon sampling from harvesting operations as close as possible to the processes that biomass for energy may be subjected to. We recommend that bioenergy characterisation is considered during selection processes for tree-farming ventures.

The database and this report provide the methods, and fuel and related properties of a range of biomass resources, to inform planning for bioenergy and biofuel production in Australia.

This project was funded by the Joint Venture Agroforestry Program (JVAP), which is supported by three R&D Corporations — Rural Industries Research and Development Corporation (RIRDC), Land & Water Australia (L&WA), and Forest and Wood Products Research and Development Corporation (FWPRDC), together with the Murray-Darling Basin Commission (MDBC). The R&D Corporations are funded principally by the Australian Government. State and Australian Governments contribute funds to the MDBC.

This report is an addition to RIRDC's diverse range of over 1600 research publications. It forms part of our Agroforestry and Farm Forestry R&D program, which aims to integrate sustainable and productive agroforestry within Australian farming systems. The JVAP, under this program, is managed by RIRDC.

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Peter O'Brien

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Rural Industries Research and Development Corporation

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Executive Summary

What this report is about

This project has delivered an on-line database of important fuel characteristics of a range of Australian biomass types. The database presently contains entries for 118 biomass types, and can be accessed at <http://www.det.csiro.au/science/energyresources/biomass.htm>.

Who is the report targeted at?

The report is intended for use by industry participants and government agencies who are considering investment in biomass feedstock production or its conversion to biofuel.

Background

There is an increasing interest in renewable energy supplies with a lower carbon footprint, to address global warming and new industry development. Information on fuel characteristics for different biomass material is required. An earlier JVAP project, CSI-8A, helped develop the basic methodology. It suggested that there was benefit in expanding the database to a greater number of samples and making it available as a web-based database.

Aims/Objectives

The main outcome sought from this project was a database of fuel and energy characteristics for a range of Australian biomass fuels to provide a sound basis for biomass feedstock selection by private industry for bioenergy projects and for government agencies in facilitation programs.

Methods used

Representative samples of biomass were collected and analysed in terms of their ultimate, proximate, ash, combustion (fouling and corrosion) and gasification characteristics.

Results/Key findings

The implications of this project for the biomass industry relate to the use of biomass as a feedstock in bioenergy plants. All carbonaceous fuels have varying levels of moisture, ash, carbon, hydrogen and other elements. The process of thermal degradation of the fuel to release heat needs to be designed according to the properties of the fuel.

Even small levels of elements such as potassium and sodium can have a marked effect on properties such as melting point of ash, and thus boiler tube or refractory life. However such effects have proven very difficult to model from first principles, and also tend to be non-linear. This database has thus used experimental analysis on representative samples of material to provide predictions of likely fuel characteristics. By analysing a large number of samples for the database, it is possible to compare different biomass types, and assess likely relative performance.

The database contains relatively simple-to-use information such as calorific value to enable project proponents to draw conclusions as to likely plant capacity and annual output. Such information also provides a guide to growers of energy crops as to the particular characteristics to be enhanced, or avoided, under growing conditions. However it also contains much more detailed information pertinent to engineers and designers as to possible fouling, slagging and corrosion propensity, and devolatilisation and char burn-off characteristics under gasification conditions. Prior knowledge of such issues is essential. In some cases it is best to avoid the fuel, and in other cases engineers and designers may be able to make necessary alterations to minimise the unwanted effect. The solution may be as simple as blending two or more fuel types, and a facility is available in the database to determine the effect of such blending.

It is however noted that prior to any plant proceeding, project developers must carry out additional testing on the proposed fuel, as fuel properties do tend to vary from season to season, region to region, and due to sampling irregularities.

Outcomes and implications for relevant stakeholders:

A publicly available web-based database of biomass fuel characteristics is now available. At the time of project completion there were 118 entries, with all of them containing proximate, ultimate and ash analysis. Combustion and/or gasification analysis performance predictions are available for 59 of the list. The level of details contained in this database is believed to be unique in the world.

The database has already led to requests by industry for additional analysis work to be carried out.

This project has developed a useful database that is already in use by industry. The information contained in the database will allow project proponents to confirm the availability of biomass suitable for energy conversion at an earlier stage of the project, and will provide information on suitable energy crop characteristics.

Recommendations

The report recommends that the database is expanded as future clients allow, and that opportunities are explored to integrate this analytical method with tree selection studies to ensure multiple biomass benefits can be realised.

1. Introduction

Perhaps the single major determinant in the viability of a bioenergy project is the feedstock, not only in terms of its location, extent and ability to be collected, but also in relation to its energy characteristics.

This project has developed an extensive database of the combustion and gasification characteristics of biomass feedstocks available for energy generation purposes in Australia. In particular it has assessed specific woody biomass species where energy may be an end product in farm forestry situations and more particularly low rainfall species. Feedstocks have been sourced from all over Australia and characterised at CSIRO's Division of Energy Technology laboratories.

The database will assist the development of the Australian bioenergy industry by providing an understanding about the wide range of biomass fuels, and the specific technical knowledge that industry requires before projects can be undertaken. It will benefit the work of organisations such as the JVAP partners, by helping identify those species that have good potential for energy products, and those that would most likely create processing difficulties if used for energy. It will have, and has already demonstrated, application as a "filtering" mechanism in choosing prospective species for large-scale commercial development, as in the Search and Florasearch projects. As well as providing basic, low cost data such as specific energy, moisture and ash, this database details each fuel's combustion and gasification characteristics. It is the only known public database in the world to provide such detailed combustion and gasification characteristics, and complements various European databases.

Any solid carbonaceous material when subjected to high temperatures will thermally degrade. The process by which this degradation takes place and the resulting end products depend on many factors. The elements that constitute the biomass provide a first indication of likely issues that may arise under thermal degradation. However the combustion or gasification process contains many chemical interactions whereby the end-effects may be more easily and accurately predicted by subjecting a sample to a controlled combustion or gasification process under laboratory conditions. This project has developed the controlled environment and methodology for such analysis.

The database includes biomass sourced from agriculture (wheat straw, cotton trash, bagasse, poultry litter, etc), municipal (municipal solid waste in various forms including some involving sewage, refuse-derived fuel, green waste, wood waste), woody (from different forestry operations including some irrigated by effluent), and industrial sources (timber mills etc).

The database provides links with the National Biomass Atlas project by Bureau of Rural Sciences, which was also funded by JVAP and the AGO.

This project is an extension of the JVAP project CSI-8A that developed the necessary methodology for the database.

2. Objectives

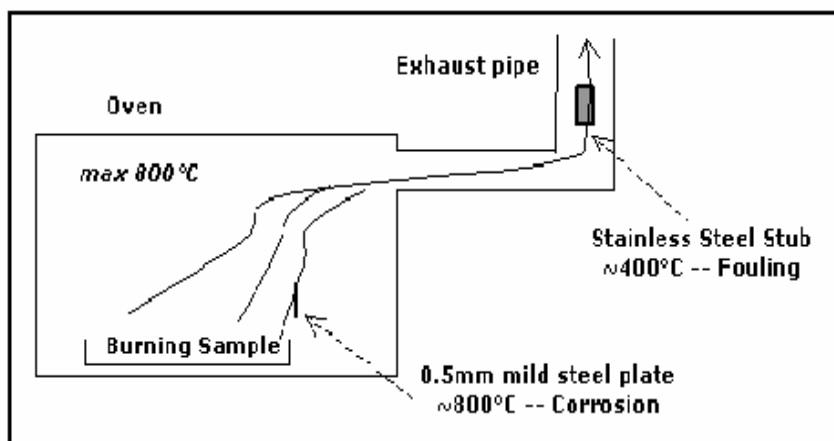
The main outcome sought from this project is a sound basis for biomass feedstock selection by private industry for bioenergy projects and for government agencies in facilitation programs.

The main deliverable is an expanded database of technical and analytical data relating to energy characteristics of selected types of woody biomass established in conjunction with the JVAP/AGO suite of projects (biomass fuel characteristics, biomass atlas and biomass technology review).

3. Methodology

1. Identification and selection of samples by consultation with industry and discussion as to the most likely species (and parts of the tree) that would be available for energy purposes. In most cases where there are multiple benefits from tree harvesting, energy is the one of the lowest value products in terms of \$/tonne of biomass, and thus availability is determined by other factors.
2. Request for a sample of anywhere from a few to 10 kg of material that would be representative of what might be available for energy purposes. In some cases, specific parts of a tree were collected as individual samples. For example, blue gum bark, leaves, branches, stemwood, logs and whole tree chips represent six different entries in the database. The database has facility to mix samples in desired proportions to determine properties of a customised mix. The low level of ash in most woody biomass meant a large sample was required to yield enough ash for ash analysis.
3. A portion of the sample was prepared and analysed for ultimate and proximate properties. This analysis was carried out in accordance with Australian Standards AS1038.1, AS1038.3, AS1038.5 and AS1038.7 (draft) to ensure compatibility with power station boiler practice.
4. A portion of the sample was ashed and ash analysis conducted to determine ash constituents. This will aid in the determination of ash disposal and/or crop application suitability.
5. Combustion fouling and corrosion properties were analysed according to the following table and schematic:

Purpose	To quantitatively estimate the fouling and corrosion propensity under simple combustion conditions
Method	Biomass is slowly burnt at temperatures up to 800°C with convective air passing over the sample. A mild steel plate is positioned close to the burning fuel, so that corrosion can occur on both surfaces at 800°C. A polished stainless steel stub, suitable for scanning electron microscopy (SEM), is positioned in the outlet air, where the temperature is 400°C. Volatile components from the fuel and vapours formed during combustion are able to corrode / foul the mild steel plate and stainless steel stub, respectively. In a simple way, this test can simulate the initiation of fouling or corrosion on variable surfaces at different temperatures in a conventional boiler.



6. Gasification analysis was carried out using thermogravimetric analysis (TGA) equipment. The biomass sample is reacted in a reducing atmosphere and the mass loss plotted over time and against temperature to determine pyrolysis characteristics. Char reactivity is also ranked. Gasification properties were analysed according to the following procedure:

Purpose	To measure the fuel's devolatilisation (pyrolysis) characteristics and char reactivity in a reducing atmosphere (gasification)
Method	About 35mg of pre-milled biomass sample is subjected to thermogravimetric analysis (TGA) at atmospheric pressure. The devolatilisation occurs at a constant heating rate of approx. 10°C/min to a final temperature of 750°C. The atmosphere is CO₂. The slow heating rate and small sample size ensure the sample is in thermal equilibrium, and does not experience any internal temperature gradients. After devolatilisation, the sample is kept isothermally at 750°C, allowing the sample (now char) to react with CO₂. Important notes: - o Both volatile yields and char reactivity are dependent on pressure, temperature and heating rate / temperature history. For this reason the results presented should not be used for design purposes (especially since actual reactors will have differing pressure and temperature profiles). Results are intended for comparison between different biomass materials. - o The reactivity of CO₂ is only indicative of gasification reactivities. The reactivity of H₂O, another commonly used gasification agent, is usually higher than CO₂ (by perhaps a factor of 3). One should note that, in real processes, heat transfer limitations could be an important factor which is not considered in this experiment. - o The chemical constituents & other properties of biomass samples can vary widely, even within a particular biomass type, due to growing location, weather conditions, available nutrients, etc, and thus care should be taken in using this information

4. Results

4.1 Samples analysed for database

The complete analysis of all samples and the full database facilities are provided in the database at the website <http://www.det.csiro.au/science/energyresources/biomass.htm>. It is impractical to provide the complete database in written form – the list of available samples and an overview of the analysis for one selected sample (*Eucalyptus globulus*) is provided below.

ID#	Description	Origin and Date	State
1	Radiata pine chips	Hunter Valley Sawmills. April 1999	NSW
2	Eraring bituminous coal	Eraring Power Station Feed, Hunter Valley. Pacific Power. April 2000	NSW
3	Dynamic lifter pellets	Bought in May 2000 (commercial product)	NSW
4	Biosolids	Quakers Hill. March 1999	NSW
5	Paper sludge	AMCOR. March 1999	NSW
6	Cotton seed hulls	Narrabri. March 1999	NSW
7	Rice hulls	Yanko Research Station plot. May 1999	NSW
8	Green waste	Whytes Gully, July 1999	NSW
9	Bagasse	Harwood	NSW
10	Sugar cane trash	Harwood	NSW
11	Pine sawmill waste	From Oberon Timbermill	NSW
12	Liddell bituminous coal	Liddell Power Station	NSW
13	Mt Piper bituminous coal	Mount Piper power station	NSW
14	Green waste	NSW waste station. Sample taken during the summer of 2000.	NSW
15	Hardwood chips	March 1999	NSW
16	Rice hulls / Chicken compost	Sourced in March 1999	NSW
17	Rice straw	Yanko	NSW
18	Rice grain	Yanko	NSW
19	Wheat grain	n/a	NSW
20	Pine chips	From Oberon Timbermill	NSW
21	Mimosa pigra	Adelaide River Floodplain. Harvested Sep 1998	NT
22	Blue gum bark	Short rotation crops (SRC) trial in Shepparton. Harvested Sep 2002	VIC

ID#	Description	Origin and Date	State
23	Blue gum leaves	Short rotation crops (SRC) trial in Shepparton. Harvested Sep 2002	VIC
24	Blue gum branches	Short rotation crop (SRC) trial in Shepparton. Harvested Sep 2002	VIC
25	Blue gum whole tree chips	Short rotation crop (SRC) trial in Shepparton. Harvested Oct 2002	VIC
26	Flooded gum chips	Short rotation crop (SRC) trial in Shepparton. Harvested Oct 2002	VIC
27	Blue gum logs	Short rotation crop (SRC) trial in Shepparton. Harvested Oct 2002	VIC
28	Blue Gum Logs	Short rotation crop (SRC) trial in Shepparton. Harvested Oct 2002	VIC
29	Blue Gum Stemwood	Short rotation crop (SRC) trial in Shepparton, Victoria. Harvested Oct 2002	VIC
30	Camphor Laurel Chips	NSW North coast (Wardell area). Harvested spring 2001	NSW
31	Orange Wattle, sticks/branches	Muchea. Harvested late 2002	WA
32	Orange Wattle, debarked wood	Muchea. Harvested late 2002	WA
33	Orange Wattle, bark	Muchea. Harvested late 2002	WA
34	Orange Wattle, leaves/twigs	Muchea. Harvested late 2002	WA
35	Callide coal	Callide deposit	QLD
36	Bagasse	North East NSW. Harvest date unknown	NSW
37	Sugar cane trash	North East NSW. Harvesting date unknown	NSW
38	Green waste	Sourcing date and specific origin not known	NSW
39	Camphor laurel chips	North East NSW. Harvest date not known	NSW
40	Radiata pine sawdust	Central west NSW. Harvesting date not known	NSW
41	Eucalyptus sawdust	North East NSW. Harvest date not known.	NSW
42	Curragh coal	Curragh deposit	QLD
43	Gippsland brown coal	Gippsland basin	VIC
44	Cotton gin trash	Narrabri. Oct/Nov 2001	NSW
45	Cotton gin trash	Moree. Late 1996 - early 1997.	NSW
46	Cotton stalks	Moree. Jan 1996	NSW
47	Minosa pigra (mature)	Adelaide River Floodplain. Feb 1998	NT
48	Minosa pigra (immature)	Adelaide River Floodplain. Feb 1998	NT
49	Green waste	Sample from Whytes Gully. Late 1998	NSW

ID#	Description	Origin and Date	State
50	Chicken manure	Central coast region. Analysed in 1997.	NSW
51	Municipal solid waste	Origin not known. Analysed in late 1998.	NSW
52	Rice hulls	Deniliquin. Analysed in late 2000	NSW
53	Wood waste	Kurnell. March 2000	NSW
55	Oil mallee residues	Farm at Woodanilling. Harvested Dec 2002	WA
56	Sugar gum residues	Farm at Dinninup. Harvested Dec 2002	WA
57	Blue mallee residues	Farm at Woodanilling. Harvested Dec 2002	WA
58	River red gum residues	Farm at Dinninup. Harvested Dec 2002	WA
59	Spotted gum residues	Farm at Dinninup. Harvested Dec 2002	WA
60	Saltbush	Farm at Woodanilling. Harvested Dec 2002	WA
61	Swamp (flat topped) yate residues	Farm at Dinninup. Harvested Dec 2002	WA
62	Blue gum residues	Farm at Dinninup. Harvested Dec 2002	WA
63	Stringy bark residues	Farm at Bridgetown. Harvested Dec 2002	WA
64	Red ironbark residues	Farm at Dinninup. Harvested Dec 2002	WA
65	Maritime pine residues	Farm at Woodanilling. Harvested Dec 2002	WA
66	Brutian pine residues	Harvested in Jarrahsend State Forest Dec 2002.	WA
67	Flooded gum residues	Farm at Bridgetown. Harvested Dec 2002	WA
68	Lucerne stems	Farm at Woodanilling. Harvested Dec 2002	WA
69	Wheat straw	Farm at Woodanilling. Harvested Dec 2002	WA
70	Pine chips	Gympie. Material collected Feb 2003	QLD
71	Eucalyptus sawdust	Gympie. Material collected Feb 2003	QLD
72	Softwood chips	Benalla	VIC
73	Softwood chips	Benalla	VIC
74	Particle board waste	Benalla	VIC
75	Sawdust wood waste	Benalla	VIC
76	Oil mallee leaf/twig	Farm at Woodanilling. Harvested Dec 2002	WA
77	Oil mallee bark	Farm at Woodanilling. Harvested Dec 2002	WA

ID#	Description	Origin and Date	State
78	Oil mallee wood	Farm at Woodanilling. Harvested Dec 2002	WA
79	Sugar gum leaf/twig	Farm at Dinninup. Harvested Dec 2002	WA
80	Sugar gum bark	Farm at Dinninup. Harvested Dec 2002	WA
81	Sugar gum, wood	Farm at Dinninup. Harvested Dec 2002	WA
82	Blue gum leaf/twig	Farm at Dinninup. Harvested Dec 2002	WA
83	Blue gum bark	Farm at Dinninup. Harvested Dec 2002	WA
84	Blue gum wood	Farm at Dinninup. Harvested Dec 2002	WA
85	Maritime pine leaf/twig	Farm at Woodanilling. Harvested Dec 2002	WA
86	Maritime pine bark	Farm at Woodanilling. Harvested Dec 2002	WA
87	Maritime pine wood	Farm at Woodanilling. Harvested Dec 2002	WA
88	Brutian pine leaf/twig	Harvested in Jarrahsend State Forest Dec 2002.	WA
89	Brutian pine bark	Harvested in Jarrahsend State Forest Dec 2002.	WA
90	Brutian pine wood	Harvested in Jarrahsend State Forest Dec 2002.	WA
91	Sugar gum wood	Yarralumla	ACT
92	Sugar gum bark	Yarralumla	ACT
93	Dogwood forest residue	Harvested ~30km West of Huonville (Warra Long Term Ecological Research site), Feb 2003	TAS
94	Tea-tree forest residue	Harvested ~30km West of Huonville (Warra Long Term Ecological Research site), Feb 2003	TAS
95	Stringybark - processing residue	Harvested ~30km West of Huonville (Warra Long Term Ecological Research site), Feb 2003	TAS
96	Stringybark, limbwood	Harvested ~30km West of Huonville (Warra Long Term Ecological Research site), Feb 2003	TAS
97	Radiata pine stemwood	Mt Gambier	SA
98	Radiata pine stemwood	Colac	VIC
99	Cypress pine stemwood	Roma	QLD
100	Cypress pine stemwood	Narrabri	NSW
101	Caribbean pine stemwood	Ravenshoe	QLD
102	Slash pine stemwood	Tuan	QLD
103	Hoop pine stemwood	Imbil	QLD

ID#	Description	Origin and Date	State
104	Hoop pine stemwood	Ravenshoe	QLD
105	Cypress pine bark	Baradine	NSW
106	Alpine ash stemwood	Heyfield	VIC
107	Alpine ash stemwood	Alexandra	VIC
108	Mountain ash stemwood	Powelltown	VIC
109	Messmate / stringybark stemwood	Powelltown	VIC
110	Spotted gum stemwood	Prosperine	QLD
111	Spotted gum stemwood	South Grafton	NSW
112	Flooded/rose gum stemwood	South Grafton	NSW
113	Blue gum stemwood	South Grafton	NSW
114	Flooded/rose gum stemwood	Prosperine	QLD
115	Blackbutt stemwood	North coast	NSW
116	Kangaroo Island narrow leaf mallee	Murray Bridge Revegetation Centre, Kangaroo Island	SA
117	Broombush	Murray Bridge Revegetation Centre, Kangaroo Island	SA
118	Macadamia nut shells	Gympie. Nut shells obtained in Apr 2003.	QLD

4.2 Database extract showing *Eucalyptus globulus* (Sample 25) analysis results

4.2.1 Database sample description



Australian Greenhouse Office

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[Coal & Biomass Mixtures](#)

[Analysis Results - Guidelines](#)

Database Sample Details

Sample ID 25

Details of sample

ID	25
Short Description	Blue gum whole tree chips
Full Description	Eucalyptus Globulus (blue gum) whole tree wood chips, includes wood, branches, leaves and sticks. Sample was a 3 yr growth in a short rotation crop (SRC) effluent irrigated trial in Shepparton
Type	Wood or tree derived
Common Name or Category	Hardwood
Species or Plant Type	Eucalypt
Sample Form or Treatment	Whole tree
Origin and Date	Short rotation crop (SRC) trial in Shepparton. Harvested Oct 2002
State	VIC
Country	Australia
Date Entered	2003-01-29



[Click to enlarge image](#)

Biomass Resources in Australia : [Forest biomass, current plantation extent and plantation potential](#)
(External link to Bioenergy Atlas)



On this page

[Details of sample](#)

[Sample Analysis](#)

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[Ash Fusion](#)

[Fouling / Corrosion](#)

[Gasification](#)

Sample Analysis

		[guiding values for unproblematic conversion]			
		(ar)	(ad)	(db)	(daf)
Analysis Basis					
Proximate Analysis					
Moisture	(wt.%)	57.5	9.2		
Ash	(wt.%)	0.6	1.2	1.3	
Volatile Matter	(wt.%)	34.9	74.6	82.2	83.3
Fixed Carbon	(wt.%)	7.0	15.0	16.5	16.7
Gross Calorific Value	(MJ/kg)	8.25	17.63	19.41	19.67
	(kcal/kg)	1970	4208	4636	4698
Ultimate Analysis					
Carbon	(wt.%)	21.1	45.0	49.6	50.2
Hydrogen	(wt.%)	2.51	5.36	5.90	5.98
Nitrogen	(wt.%)	0.22	0.47	0.52	0.52
Total Sulfur	(wt.%)	0.09	0.20	0.22	
Oxygen (by difference)	(wt.%)	18.1	38.8	42.7	
Chlorine	(mg/kg)	173	370	407	

Analysed in accordance with Australian Standard Methods AS1038.1, AS1038.3, AS1038.5, AS1038.6.3.3, AS1038.7(draft)

Total sulfur and chlorine in biomass were determined by ICP-AES. Biomass was combusted in the presence of Eschka's mixture and the residue dissolved in acid to obtain solutions suitable for analysis. The CSIRO procedures are NATA certified

(ar) = "as received" basis, (ad) = "air dried" basis, (db) = "dry basis", (daf) = "dry, ash free" basis

Note: The chemical constituents of biomass samples can vary widely, even within a particular biomass type, due to growing location, weather conditions, available nutrients, etc, and thus care should be taken in using this information.

4.2.2 Ash analysis results for sample 25

Ash Analysis

[guiding values for unproblematic conversion]

wt.% of ash (Calculated from elements)		wt.% of ash (Measured)	
Oxides		Elements	
Na ₂ O	15.9	Na	11.8
MgO	9.30	Mg	5.60
Al ₂ O ₃	0.39	Al	0.21
SiO ₂	1.42	Si	0.66
P ₂ O ₅	4.30	P	1.89
K ₂ O	12.6	K	10.5
CaO	16.4	Ca	11.7
TiO ₂	0.08	Ti	0.05
Mn ₂ O ₃	0.25	Mn	0.18
Fe ₂ O ₃	1.49	Fe	1.04

The major elements of the ash were determined by CSIRO Energy Technology using a NATA certified method based on a borate fusion/ICP-AES procedure

Ash (1.55%) obtained at 500°C from air-dried material

Sum of all oxides do not add up to 100% mainly due to carbonate matter not being removed during oxidation at 500°C

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Ash Fusion

Ash Fusion Temperatures (Oxidising Atm)

Deformation	(°C)	1500
Sphere	(°C)	1560
Hemisphere	(°C)	1560
Flow	(°C)	1560

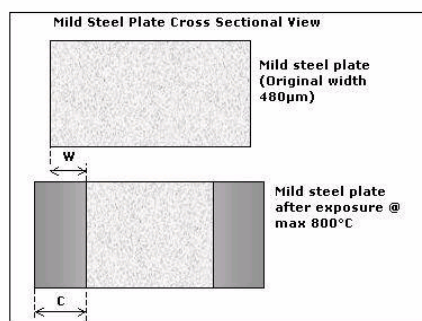
4.2.3 Combustion corrosion, fouling and deposition analysis results for sample 25

Corrosion of mild steel plate - Details

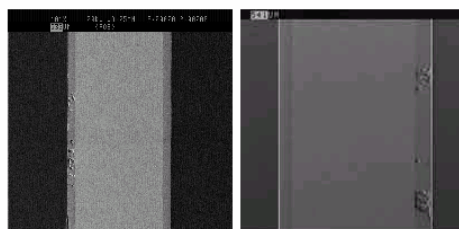
	mild steel reference (no fuel)	mild steel biomass corroded	
Atmosphere	excess air	variable*	
Max Temperature	800	800	°C
Material Wastage (W)	17	24	µm
Wastage (W) SEM image	Figure 1		
Corroded Layer (C)	43	54	µm
Wastage (W) SEM image	Figure 2		
Apparent Corrosion	Minor	Moderate	
Relative W increase: $W_{\text{biomass}}/W_{\text{reference}}$	N/A	1.42	-
Relative C increase: $C_{\text{biomass}}/C_{\text{reference}}$	N/A	1.26	-
Corrosion scale (visual): Negligible - Minor - Moderate - Major			

* Mainly N₂, O₂, CO₂ and H₂O

Notes:



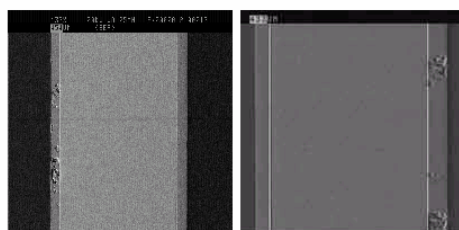
Corrosion SEM cross sectional images



Reference plate, no fuel Biomass corroded plate
[Click to enlarge image](#)

Figure 1: Wastage (W) cross sectional view
SEM images of mild steel plate, $T_{\text{max}} \sim 800^\circ\text{C}$

Please refer to measuring cursors. Note: Original width = 480µm



Reference plate Biomass corroded plate
[Click to enlarge image](#)

Figure 2: Corroded (C) cross sectional view
SEM images of mild steel plate, $T_{\text{max}} \sim 800^\circ\text{C}$

Please refer to measuring cursors. Note: Original width = 480µm

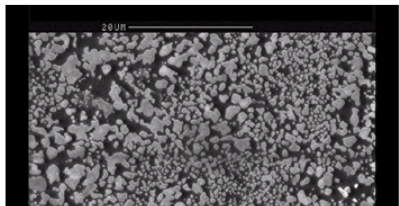
Fouling of stainless steel stub - Details

	stainless steel stub	
Atmosphere	variable*	
Max Temperature	800	°C
Apparent Fouling	Minor	(visual)
Surface image (SEM) of stub	Figure 3	
Elemental analysis of a typical deposit	Figure 4	
Corrosion scale (visual): Negligible - Minor - Moderate - Major		

* Mainly N2, O2, CO2 and H2O

Notes:

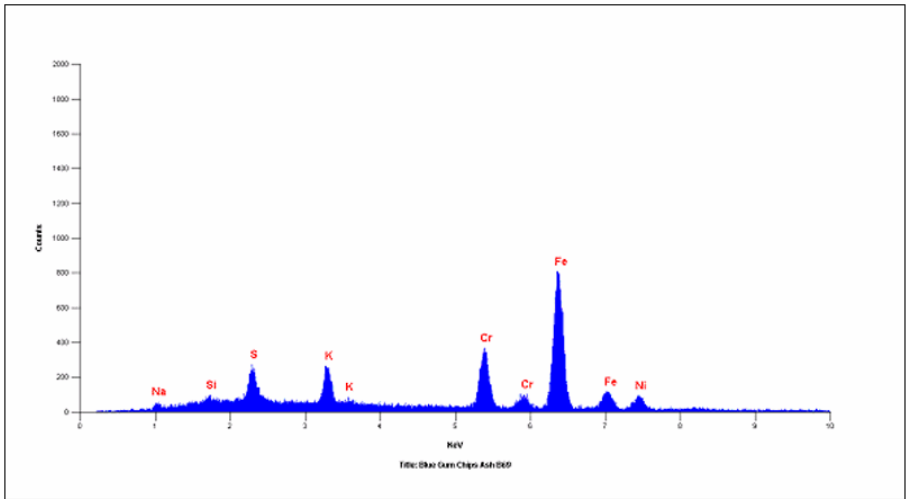
Fouling SEM Images



Click to enlarge image
Figure 3: SEM image of stainless steel stub deposit
(Fouled with biomass vapours @ $T_{max} \sim 400^{\circ}\text{C}$)

Image Details (Deposit Elements - Stainless Steel)

ID 25
Material Blue gum whole tree chips



4.2.4 Gasification analysis results

Pyrolysis and char reactivity in CO₂ - Details

Overview of whole experiment	Figure 1	
T max weight change	348	°C
Solid yield 300°C	80.9	wt.% dry basis.
Solid yield 400°C	36.2	wt.% dry basis.
Solid yield 600°C	27.0	wt.% dry basis.
Pyrolysis (devolatilisation) characteristics	Figure 2	
Char reactivity @ 10% conversion in CO ₂ T=750°C (comparative result only)	31.7	mg _{converted} / mg _{remaining} / s × 10 ⁵
10% burnout time (comparative result only)	5.1	Minutes
Graph of char conversion in CO ₂	Figure 3	
Overall Estimate of char reactivity	Very Fast	

Reactivity scale:

Very Slow	Slow	Moderate	Fast	Very Fast	
<1	1-3	3-10	10-25	>25	mg / mg / s × 10 ⁵

Notes:

Image Details (TGA Experiment curve)

ID 25

Material Blue gum whole tree chips

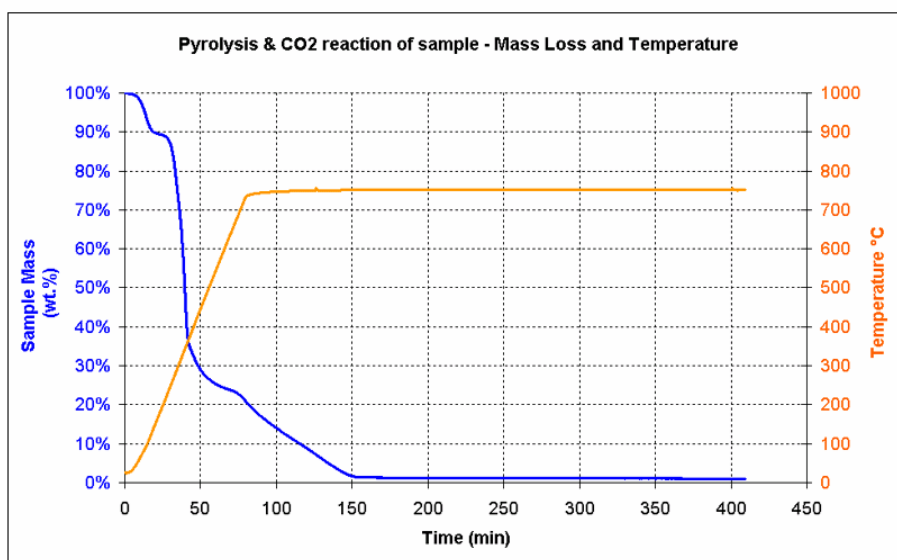


Image Details (Pyrolysis characteristics)

ID 25
Material Blue gum whole tree chips

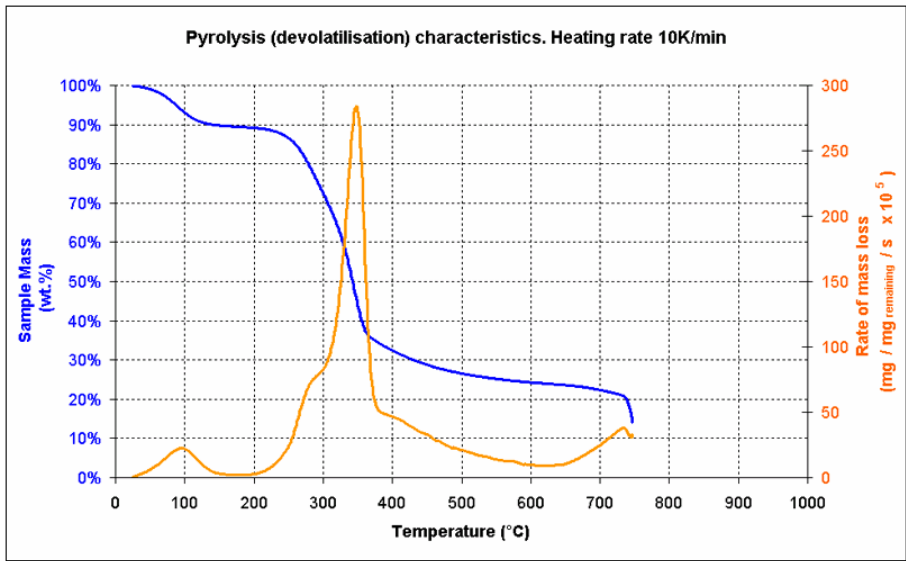
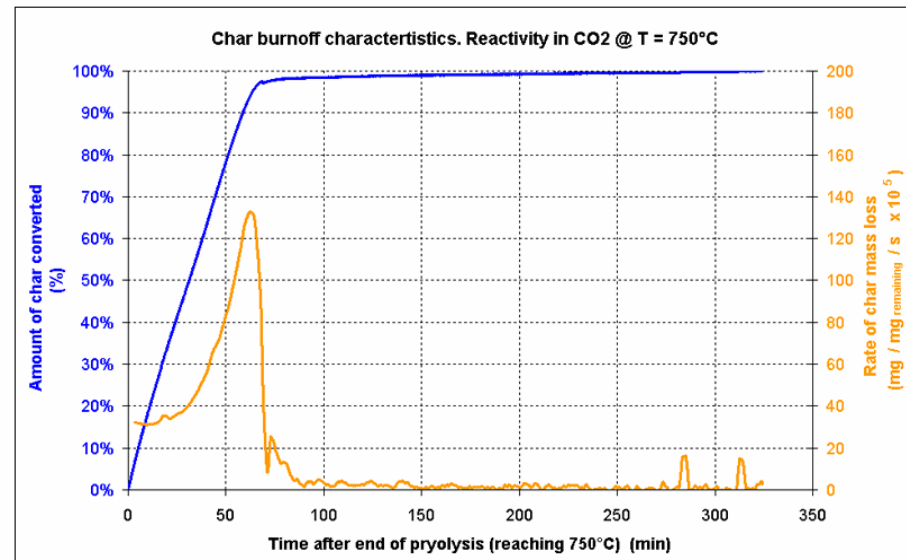


Image Details (CO2 char burn off)

ID 25
Material Blue gum whole tree chips



5. Implications

The implications of this project for the biomass industry relate to the use of biomass as a feedstock in bioenergy plants. All carbonaceous fuels have varying levels of moisture, ash, carbon, hydrogen and other elements. The process of thermal degradation of the fuel to release heat needs to be designed according to the properties of the fuel. Many years of experience have shown that even small levels of elements such as potassium and sodium can have a marked effect on properties such as melting point of ash, and thus boiler tube or refractory life. However such effects have proven very difficult to model from first principles, and also tend to be non-linear. This database has thus used experimental analysis on representative samples of material to provide predictions of likely fuel characteristics. By analysing a large number of samples for the database, it is possible to compare different biomass types, and assess likely relative performance.

The database contains both relatively simple-to-use information such as calorific value to enable project proponents to draw conclusions as to likely plant capacity and annual output. Such information also provides a guide to growers of energy crops as to the particular characteristics to be enhanced, or avoided, under growing conditions. However it also contains much more detailed information pertinent to engineers and designers as to whether combustion or gasification is likely to be a preferred path, and whether or not issues such as slagging or fouling are likely to occur. Prior knowledge of such issues are essential. In some cases it is best to avoid the fuel, and in other cases engineers and designers may be able to make necessary alterations to minimise the unwanted effect. The solution may be as simple as blending two or more fuel types, and a facility is available in the database to determine the effect of such blending.

It is however noted that prior to any plant proceeding project developers must carry out additional testing on the proposed fuel, as fuel properties do tend to vary from season to season, region to region, and due to sampling irregularities.

The database has already led to requests by industry for additional analysis work.

6. Recommendations

There are two main recommendations for further work.

1. Continuation and expansion of the database entries. This could be undertaken as new analysis is carried out for clients, and where the client allows the data to be included in the database.
2. Explore opportunities to work with biomass growers or species screening studies such as the Florasearch project to yield beneficial fuel characteristics. In some cases it may be possible to combine energy properties with other biomass benefits to provide overall net positive synergies.

