

Assessment of the use of gorse and heather arisings as a feedstock for commercial pellet production.

Feasibility report – Part 2



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Executive Summary

This report follows a feasibility report completed in July 2010 – Assessment of landscape management arisings as a feedstock for commercial pellet production. It is a follow up investigation, on behalf of the Forestry Commission, into the potential use of gorse and heather for fuel pellet production. The focus was on discovering whether it would be possible to produce a gorse or heather pellet which achieved the highest 'Grade A' European quality standard for use in domestic pellet boilers.

The findings of the 2010 research suggested that the method of harvesting the raw material (a tractor mounted mower) was likely to have contributed to soil contamination, detrimentally affecting pellet quality. The gorse was therefore hand cut and to maximise pellet quality only the woody stem, (and not the smaller branch and needles), was used in the pellet trials. Hand cutting was chosen because only a relatively small amount of test material was needed for this trial but more efficient mechanised methods would be required in a commercial application. It was not possible to harvest the heather effectively in any other way than mowing and baling during this investigation. Other more commercial, clean methods of harvesting are briefly examined. For both types of raw material different proportions of wood (oak) sawdust was mixed in to ascertain to what extent this would improve pellet quality.

The samples were chipped, hammer milled, dried and pelleted, and then sent to an independent UKAS accredited laboratory for testing against European quality standards for wood pellets. The pellets produced were also tested in a 'pellet basket' in a wood burning stove and a domestic wood pellet boiler to gauge their performance as a domestic heating fuel.

The test results were very encouraging for the gorse pellets, which largely achieved the highest standards expected of wood pellets supplied for domestic pellet boilers. The Heather pellets, being a 'non-woody' biomass, did not achieve the 'Grade A' standard for wood pellets, but the research suggests that with more careful harvesting methods and/ or mixed 50:50 with wood, they could achieve this. Both gorse and heather pellets performed well in a wood burner and pellet boiler. The heather pellets in particular, lasted considerably longer than the gorse or other wood pellets in the wood burner and generated a significant amount of heat.

The implications of this research are that gorse and heather both have a commercial application in the production of high value fuel pellets for the domestic heating market. As the 2010 research concluded gorse and heather would also be suitable for the commercial and industrial markets for larger pellet boilers, district heating systems, CHP plants and steam turbines for power stations. However the domestic heating market is preferable as the unit price is higher and production is likely to be on a small, local scale, more suited to the local, domestic market.

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1. Introduction

As with the work completed in July 2010 this study is intended to assess the use of arisings from habitat restoration and management operations as a feedstock for wood pellet mills producing pellets for heating fuel. Specifically the study aims to:

- **Build upon the findings of the 2010 study and further investigate the suitability of heather and gorse for producing high quality fuel pellets for domestic boilers.**
- **Obtain a clear Fuel Quality Declaration for the pellets produced from heather and gorse and different percentage mixes with wood.**

Studies of the amounts of available material and the practicalities of harvesting are not included in this work.

The potential use of these materials in the production of wood fuel is considered important as they could:

1. Make a significant contribution to a future low carbon economy based on the use of biomass fuels.
2. Make a significant contribution to offsetting the costs of habitat management and restoration.
3. Further rural employment in the energy sector.

The Forestry Commission approached Harvest Wood Fuels, an established wood pellet producer based in Tilford, Surrey in December 2010 to request a follow up study to the work completed in July 2010; an initial meeting was held and the work programme agreed.

2. Project Brief

Assessment of suitability of heather and gorse arisings as material for high quality pellet production and submission of pellets for assay and laboratory testing.

Description of the services to be undertaken and the outputs to be provided

The Contractor will:

- Collect, dry and prepare the arisings as necessary for use in their wood pellet mill.
- Produce four samples of each heather and gorse pellets mixed with 10%, 20% and 40% by weight of wood sawdust.
- Submit a sample of the wood pellets derived from these products for official laboratory testing according to EN 14961 standards.
- Where appropriate test the pellets in domestic applications – a wood pellet boiler and in a pellet basket in a wood burning stove.
- Report on the outcome of the tests with respect to the implications of the subsequent use and saleability of the pellets as a domestic heating fuel.

The supplier is responsible for providing correct information in terms of a Fuel Quality Declaration, in this instance derived from physical and chemical analysis.

EN 14961, outlines the Technical Specification which determines Fuel Quality Classes and Specifications for Solid Biofuels. In this instance derived from Agricultural & Forestry Sources.

The following criteria need to be tested and a minimum standard reached in order to determine whether the pellets produced are of a High Quality Class for Household Usage ('Grade A') or of a 'Grade B' class for more industrial applications:

Origin: *In this case* Landscape Management Herbaceous Biomass

Moisture content

Mechanical Durability

Amount of Fines

Dimensions

Ash content

Sulphur content

Additives

Energy density

See *Test Results* and Appendix A for the main European quality standards.

This contract is intended to assess the qualities of these materials for use as a feedstock for milling into wood fuel pellets for domestic use.

3. Research Objectives

- Provide information on the qualitative nature of the wood fuel pellets derived from heather and gorse and different mix ratios with wood.
- Provide information on the practical aspects of wood pellet mill performance using these materials as a feedstock.
- Provide a Fuel Quality Declaration for wood fuel pellets derived from heather and gorse arisings, and different mix ratios with wood, in order to promote their use as a source of biomass energy.

4. Method

4.1 Harvesting and Preparation

The findings of the 2010 research suggested that the method of harvesting the gorse and heather (using a tractor mounted mower) was likely to have contributed significantly to soil contamination, thus detrimentally affecting pellet quality. The gorse was therefore hand cut (in the New Forest) using a chainsaw and to maximise pellet quality only the woody stem, and not the smaller branch and needles, was used in the pellet trials.

Figure 1 – gorse felling



For practical reasons it was not possible, during this investigation, to harvest the heather effectively in any other way than mowing and baling. This method of harvesting leads to contamination of earth and material other than heather, which is likely to detrimentally affect pellet quality. However no other 'cleaner' harvesting method was available during the current investigation. Also as heather is a herbaceous biomass it is likely that certain characteristics, such as the ash content of the pellets, would be higher than with a woody biomass such as gorse.

Figure 2 – Baling heather



Approximately 2m³ of the felled gorse stem and 8 bales of heather were collected from the New Forest in February 2011 and delivered to the Harvest wood Fuels site.

Figure 3 – Collecting the raw material



The gorse and heather was chipped into separate bulk bags, hammer milled and fed through a dryer to reduce the moisture content to approximately 12% in preparation for pelleting.

Figure 4 – Drying the raw material



4.2 Pelleting Process

The pelleting trials took place in March 2011. The pellet press used was a P-systems Italian bespoke wood pellet press (Figure 7).

Figure 5 – Wood pellet press



Four different mixes of material for each of the gorse and heather pellets were trialled, as follows:

- 100% gorse/ heather
- 90% gorse/ heather: 10% oak sawdust
- 80% gorse/ heather: 20% oak sawdust
- 60% gorse/ heather: 40% oak sawdust

The hammer milled gorse and heather was weighed and mixed in a drum by the appropriate weight of sawdust (see below) before being fed into the pellet press.

Figure 6 – Mixing drum and scales



All four mixes of gorse produced good, hard, robust pellets with little dust. The heather pellets were shorter and less durable with a significant amount of dust. This was because the pellet die used in the trials was not of sufficient compression. Where the material is pushed by a roller through the 6mm holes in the pellet die if the parallel length of the holes is longer (i.e. a thicker die ring) the material is more highly compressed. This results in a higher temperature, which in turn melts the lignin in the raw material which binds the particles together to form a robust pellet.

In the 2010 pellet trials a different pellet press was used with a higher compression die and the heather pellets produced were of a good resilient quality (see below). For the commercial production of heather pellets it would be necessary to use a high compression die.

Figure 7 – gorse and heather pellets



High quality gorse pellets



Low durability heather pellets



Highly compressed heather pellets, 2010

Each different mix of gorse and heather pellets was collected and left to cool, before being sent for laboratory and domestic testing.

Figure 8 – pellets cooling



The experience of pelleting the gorse and heather during the current trials confirms that handled correctly each of these raw materials can be successfully pelleted using a conventional wood pellet production plant. The laboratory and domestic burner test results will show to what extent the pellets produced may be regarded as a suitable fuel for domestic heating.

5. Laboratory test results

The pellet samples were sent to TES Bretby, a UKAS accredited testing laboratory with a proven, reliable track record in biomass fuel testing. TES Bretby were asked to perform standard pellet tests according to the technical specifications in the proposed European standards for biomass fuel as outlined in Appendix A. These standards are being implemented in order to ensure the supply for end users of standardised high-quality wood pellets that can be fired trouble-free in commercially available wood pellet boilers. The CEN/TS 14961:2005 standard has recently been updated to EN 14961.

A European certification system for wood pellets based on the specifications in EN 14961 - 'ENplus' - has been developed by the German Pellet Institute (DEPI). The DEPI currently grants licenses for the usage of the ENplus seal but it is intended that this right will be transferred to a European Association of Wood Pellet Industries, (yet to be established), which will in turn transfer this right to national wood pellet associations. In the UK HETAS is the organisation responsible for establishing an accreditation scheme for wood fuel and this has taken the form of the Solid Biomass Assurance Scheme. HETAS is currently talking to the DEPI about introducing ENplus for wood pellets and it is likely to become the de facto certification scheme in the UK.

ENplus proposes three classifications of wood pellet, Grades 'ENplus-A1', 'ENplus-A2' and 'EN-B'. Grade A1 pellets tend to be required for smaller domestic pellet boilers and are the most valuable, worth approximately £200 per tonne. Grades A2 and B pellets are more appropriate for burning in larger commercial and industrial boilers (including power stations) and are worth approximately £150 and £100 per tonne respectively.

The test results for the gorse pellets are listed in Table 1 and for the heather pellets in Table 2 below. The respective standards for each of the ENplus pellet classes are listed for comparison in each table and the performance of each of the raw materials in relation to each parameter is discussed below. The pellets are also compared against values for typical energy crop pellets and Grade 'A1' pine wood pellets.

5.1 Durability

Durability is important as if the pellets are likely to fall apart the resulting 'dust' will ultimately cause pellet store/boiler screw augers to jam and the boiler to fail. A high dust content also reduces the density of the pellets and can starve the boiler of fuel.

The durability of the gorse samples were acceptable within the standard required for all grades of pellet under EN Plus, except for the 100% gorse sample which achieved 97.4% durability (97.5% is acceptable). This would be improved by screening the pellets when exiting the pellet press, meaning that the smaller less durable pellets would be filtered out, improving the overall durability of the main bulk of pellets.

The heather pellets were shorter and less durable with a significant amount of dust, achieving a durability of between 90-95% (the higher the proportion of oak within the pellet, the higher was the durability). This was because the pellet die used in the trials was not of a sufficiently high compression for heather. By using a pellet die with higher compression holes (achieved by altering the hole geometry) the durability of the pellets would be improved and the heather pellets brought within the specification of 97.5% required. This was demonstrated in the 2010 research where a high

compression die (a different pellet press to the current trials) was used and the heather pellets produced achieved 99.3% durability.

5.2 Moisture levels

A low moisture level in pellets for biomass boilers is important as the higher the moisture level the lower the calorific value. This is because a higher proportion of the energy in the pellets is used to evaporate the moisture and therefore not used for heat for the end user. The moisture content of all the gorse pellet samples was well within the maximum allowed moisture level of 10%. The moisture level of the heather pellets was slightly above the 10% upper limit. This can be prevented by ensuring that the raw material has been more thoroughly dried prior to pelletisation.

5.3 Ash levels

High ash levels in biomass pellets both reduces calorific value and can cause a build-up of clinker, a result of ash melting, in the boiler. This results in boiler failure.

For the gorse pellets all four samples were within the maximum acceptable limit of 0.7%, for a grade A1 pellets. There was a slight reduction in the ash content (from 0.7% to 0.6%) for the gorse pellets mixed with oak sawdust.

It seems that using just the gorse stem, cut with a chainsaw and not gorse harvested using a tractor mower as in the 2010 study, has dramatically reduced the ash content, which measured 6.6% in the last study. This is most likely to be due to the elimination of soil contamination which is non-combustible, but may also be related to the fact that just the woody stem and not the needles and foliage were used in the pellet trials. It remains to be seen as to whether there could be an alternative economically viable alternative to harvesting gorse with a mower.

The ash level of the pure heather pellet sample was 1.6%, similar to the 1.7% measured in the last study. This is above the 0.7% maximum level required for grade A1 pellets and the 1.5% required for Grade A2, but within the upper 3% limit specified for Grade B pellets. It is interesting to note that as the quantity of wood mixed with heather increased the ash level of the pellets reduced, down to 0.9% for the 60% heather 40% oak mix. All heather mixes with wood were within the 1.5% ash limit required of a Grade A2 pellet and it is likely that a 50:50 mix of heather and wood sawdust would come within the 0.7% limit for a Grade A1 fuel pellet.

It is also likely, as with the gorse in the 2010 study, that the harvesting method employed for the heather contributed to higher ash levels, as it was mown using a front mounted tractor mower and then collected by a baler. This method also collects a significant amount of soil and any other vegetation growing amongst the harvest. However it is questionable, given the herbaceous nature of heather, whether if a cleaner method of harvesting were employed, ash levels would be within the 0.7% required for grade A1 pellets. Also it is difficult to envisage another economically viable way of harvesting heather other than mowing.

Table 1 – Laboratory Pellet Test Results for Gorse

Parameter	Gorse Pellet Samples				Typical Pellet Values				European Specification		Notes on Gorse	
	Gorse (100%)	Gorse/Oak (9:1)	Gorse/Oak (8:2)	Gorse/Oak (6:4)	Pine	Misc. *	Straw	Canary grass	ENplus-A1	ENplus-A2		EN-B
Pellet Durability (%)	97.4 x	98.3 ✓✓✓	98.4 ✓✓✓	98.8 ✓✓✓	99 ✓✓✓	99 ✓✓✓	99 ✓✓✓	99 ✓✓✓	≥ 97.5			100% gorse just under – poss to increase durability by screening
Total Moisture w-% as received	6.8 ✓✓✓	6.3 ✓✓✓	7.3 ✓✓✓	7.4 ✓✓✓	8 ✓✓✓	8 ✓✓✓	8 ✓✓✓	8 ✓✓✓	≤ 10			All samples within Grade A specification
Ash w-% dry	0.7 ✓✓✓	0.6 ✓✓✓	0.6 ✓✓✓	0.6 ✓✓✓	0.2 ✓✓✓	4 ✓	5 x	6.4 x	≤ 0.7	≤ 1.5	≤ 3.0	All samples within Grade A specification
Sulphur w-% dry	0.03 ✓✓✓	0.02 ✓✓✓	0.02 ✓✓✓	0.02 ✓✓✓	0.03 ✓✓✓	0.1 ✓✓✓	0.1 x	0.2 x	≤ 0.03	≤ 0.03	≤ 0.04	All samples within Grade A specification
Chlorine, Cl w-% dry	0.04 x	0.04 x	0.04 x	0.04 x	0.01 ✓✓✓	0.2 ✓✓✓	0.4 x	0.5 x	≤ 0.02	≤ 0.03		Too high for ENplus
Net Calorific Value kWh/kg	4.81 ✓✓✓	4.83 ✓✓✓	4.68 ✓✓✓	4.69 ✓✓✓	4.86 ✓✓✓	4.72 ✓✓✓	5.14 ✓✓✓	5.31 ✓✓✓	≥ 4.6	≥ 4.5	≥ 4.4	All samples within Grade A specification
Nitrogen %	0.56 ✓	0.52 ✓	0.45 ✓✓	0.52 ✓	0.3 ✓✓✓	0.7 ✓	0.5 ✓✓	1.4 x	≤ 0.3	≤ 0.5	≤ 1.0	Marginally too high for A1 – 8:2 mix within Grade A2 specification
Ash softening temp (°C)	1160 ✓✓	1190 ✓✓	1180 ✓✓	1140 ✓✓	1270 ✓✓✓	1150 ✓✓	1050 x	unknown □	≥ 1200	≥ 1100		Marginally too low for A1 – within Grade A2 specification

Key:

- * Miscanthus
- ✓✓✓ Equal to or exceeding European specification for Grade 'A1' pellet
- ✓✓ Equal to or exceeding European specification for Grade 'A2' pellet
- ✓ Equal to or exceeding European specification for Grade 'B' pellet
- x Does not achieve minimum European pellet standard

Table 2 – Laboratory Pellet Test Results for Heather

Parameter	Gorse Pellet Samples				Typical Pellet Values				European Specification		Notes on Heather	
	Heather (100%)	Heather / Oak (9:1)	Heather / Oak (8:2)	Heather / Oak (6:4)	Pine	Misc. *	Straw	Canary grass	ENplus-A1	ENplus-A2		EN-B
Pellet Durability (%)	89.7 x	87.8 x	92.4 x	95.3 x	99 ✓✓✓	99 ✓✓✓	99 ✓✓✓	99 ✓✓✓	≥ 97.5			Too fragile – needs high compression die
Total Moisture w-% as received	11.6 x	10.8 x	11.1 x	11.3 x	8 ✓✓✓	8 ✓✓✓	8 ✓✓✓	8 ✓✓✓	≤ 10			Moisture too high – needs further drying
Ash w-% dry	1.6 ✓	1.4 ✓✓	1.2 ✓✓	0.9 ✓✓	0.2 ✓✓✓	4 ✓	5 x	6.4 x	≤ 0.7	≤ 1.5	≤ 3.0	All samples within Grade B specification, 6:4 mix Grade A2
Sulphur w-% dry	0.05 x	0.06 x	0.05 x	0.04 ✓	0.03 ✓✓✓	0.1 ✓✓✓	0.1 x	0.2 x	≤ 0.03	≤ 0.03	≤ 0.04	Sulphur level too high
Chlorine, Cl w-% dry	0.03 ✓✓	0.02 ✓✓✓	0.02 ✓✓✓	0.02 ✓✓✓	0.01 ✓✓✓	0.2 ✓✓✓	0.4 x	0.5 x	≤ 0.02	≤ 0.03		All except 100% sample within Grade A specification
Net Calorific Value kWh/kg	4.72 ✓✓✓	4.77 ✓✓✓	4.69 ✓✓✓	4.64 ✓✓✓	4.86 ✓✓✓	4.72 ✓✓✓	5.14 ✓✓✓	5.31 ✓✓✓	≥ 4.6	≥ 4.5	≥ 4.4	All samples within Grade A specification
Nitrogen %	0.67 ✓	0.63 ✓	0.60 ✓	0.55 ✓	0.3 ✓✓✓	0.7 ✓	0.5 ✓✓	1.4 x	≤ 0.3	≤ 0.5	≤ 1.0	All samples within Grade B specification
Ash softening temp (°C)	1090 x	1100 ✓✓	1090 x	1090 x	1270 ✓✓✓	1150 ✓✓	1050 x	unknown □	≥ 1200	≥ 1100		Too low for Grade A specification

Key:

- * Miscanthus
- ✓✓✓ Equal to or exceeding European specification for Grade 'A1' pellet
- ✓✓ Equal to or exceeding European specification for Grade 'A2' pellet
- ✓ Equal to or exceeding European specification for Grade 'B' pellet
- x Does not achieve minimum European pellet standard

5.4 Sulphur levels

High sulphur levels result in the formation of sulphuric acid which is harmful to internal parts of the boiler. The burn chamber/ crucible in particular, is rapidly corroded as a result of contact with sulphuric acid. Sulphur dioxide is also thought to be one of the main compounds involved in acid rain and the acidification of soils and waterways.

For the gorse pellets all four samples were within the maximum acceptable limit of 0.03%, for a grade A1 pellets. There was a slight reduction in the sulphur (from 0.03% to 0.02%) for all the pellets produced with gorse mixed with oak sawdust. This compares to a relatively high level of sulphur (0.8%) in the gorse pellets produced in the 2010 study.

Sulphur levels for all the heather pellet samples except the 60:40 oak mix were higher than maximum recommended level of 0.04% under the EN standard. The 60:40 oak mix achieved 0.04%, and therefore a Grade B pellet standard. As with the ash level for the heather pellets is likely that a higher proportion of wood sawdust (possibly a 50:50 mix) would reduce the sulphur level to an acceptable maximum level of 0.03% required for a Grade A1 or A2 pellet standard.

Sulphur occurs naturally in the soil and it stands to reason that the higher the soil content the higher the sulphur level in the pellet samples produced. This is demonstrated by the fact that the sulphur content of the gorse pellets produced in this study was significantly less than the content of the 2010 samples, which had a high level of soil contamination, due to the harvesting method employed.

5.5 Chlorine

The EN standard requires that for a Grade A1 or A2 wood pellet the chlorine content should be no more than 0.02% by dry weight and for a Grade B pellet 0.03%. This is because high levels of Chlorine in the flue gas emissions can give rise to corrosion on a boiler's surfaces and the formation of dioxins.

The laboratory tests showed that the Chlorine level for all of the gorse pellet samples was 0.04%, above the EN maximum allowed quantity. The Chlorine level of the heather pellets was 0.02%, except the 100% heather pellets in which a Chlorine level of 0.03% was measured. This is within the maximum allowed level for a Grade A2/B pellet but not the 0.02% level for a Grade A1 pellet, which all the samples with an oak mix did conform to.

Possible reasons for the high Chlorine level in the gorse pellets are: a high bark content and/ or the origin of the wood is from a coastal location and it has been exposed to sea salt through rain and wind.

The gorse stem used did have bark attached and as gorse stem has a small diameter the relative bark content is likely to be higher than most types of wood. However the typical Chlorine level in both soft wood and hard wood **bark only** is 0.02%, so it seems unlikely that high bark content would explain the 0.04% level measured in the gorse pellets. More likely is the fact that the gorse harvested for the current research was taken from a site in the New Forest within 10 miles of the coast.

Other possible reasons generally for high chlorine levels are: contamination during storage/transportation by road salting and the presence of preservation chemicals,

but neither of these are plausible explanations for the samples tested in the current research.

5.6 Calorific Value

The greater the calorific value of the pellet the better, as the more heat value will be generated for the end user. This means that less space is required to transport and store the fuel. (As a yardstick kerosene or heating oil has an energy density of approximately 10 kWh per litre, compared to a typical value for wood pellets of 4.8 kWh per kilogram.)

The calorific values for all pellet samples were above the minimum specified level of 4.6 kWh/kg for an A1 grade pellet. The heather pellets measured 4.6-4.8 kWh/kg (with a tendency to reduce slightly in value as the proportion of oak increased), and the gorse pellets measured 4.7-4.8 kWh/kg, again with a tendency to reduce slightly as more oak was added.

This is indicative of hardwood being slightly lower (approximately 5%) in calorific value by weight (not volume) than softwood, as evidenced from laboratory tests for Harvest Wood Fuels. However, anecdotal evidence from Harvest wood Fuels' customers is that it burns more slowly and therefore lasts longer.

5.7 Nitrogen level

Burning biomass as a fuel does result in the release of some nitrogen oxides, which are greenhouse gases. For this reason the EN standard specifies maximum nitrogen quantities permitted for the different standards of pellet.

The level of nitrogen in the heather pellets was measured at between 0.55 to 0.67% (with a tendency to reduce as the proportion of oak increased). This is higher than the minimum level of 0.3% for grade A1 and 0.5% for A2 pellets but below the 1% maximum level for grade B pellets.

The nitrogen level in the gorse pellets was between 0.45% and 0.56%. The level in the 2010 samples was 1.28% which again demonstrates the high soil content, as nitrogen occurs in the soil. The lowest level of 0.45% for the 80:20 gorse/ oak mix is below the maximum allowed level of 0.5% for Grade A2 pellets, but higher than the A1 limit of 0.3%. The other three pellet samples were all above this level and conformed only to the standard required of a Grade B pellet.

Inexplicably, (as in pure oak pellets nitrogen levels are typically 0.05%), the level of nitrogen in the 60:40 oak mix was higher (0.52%) than the 80:20 mix. This is thought to be due to the gorse and oak not being thoroughly mixed in this sample and it is likely that a higher proportion of wood thoroughly mixed in would reduce the nitrogen level further.

When considering the nitrogen emissions from burning biomass fuels it should be recognised that these are generally comparable to those from burning fossil fuels. Also many biomass boilers have become more sophisticated and, although more expensive, it is possible to use ceramic filters to reduce harmful emissions such as nitrogen oxide.

5.8 Ash softening temperature

Pellets with a low ash softening and melt temperature cause clinker build up in the biomass boiler; this happens when high concentrations of potassium and chlorine melt and fuse with silica. This hard ash and clinker leads to blockages and causes the boiler to fail by blocking the burn chamber and preventing ignition.

The ash softening temperature for the gorse pellet samples varied between 1,140 and 1,190 °C; this is lower than the minimum specified temperature for an A1 pellet of 1,200 °C but above the A2 and B-grade level of 1,100°C. The ash from all the heather pellet samples began to soften at just below 1,100°C - below the required temperature for Grade A2 and Grade B pellets.

While the ash softening point for the gorse pellets measured below the temperature required for the highest pellet grade it is only just below (the 9:1 mix with oak was 1,190°C) and is unlikely to cause significant clinker problems in pellet boilers. Pure oak pellets for instance tend to soften at just over the minimum temperature of 1,200 °C (the last oak pellets tested by Harvest Wood Fuels had a softening temperature of 1,210°C). This theory was tested in the pellet boiler used at Harvest Wood Fuels and is discussed in Section 6 below.

One way to overcome potential clinker problems would be by using boilers which are capable of using biomass fuel with lower ash melt temperatures. This can be achieved by for instance, the use of a moving grate which keeps the fuel moving and prevents it from forming a solid clinker mass; or through the use of boilers which have appropriate ash handling systems such as regular air cleaning.

5.9 Other Issues

Size

To comply with the EN Plus specification pellets should be either 6mm or 8mm in diameter with a maximum allowed variance of 1mm either way. Pellets should be no less than 3.15mm long – otherwise they are regarded as ‘fines’, of which there must be no more than 2.5% (the criteria of 97.5% durability). No more than 1% of the pellets should be longer than 40 mm and there is a maximum allowed length of 45 mm. All the pellets produced for the current trials were 6mm in diameter and complied with the length criteria.

Additives

Pressing agents or additives to improve fuel quality, to decrease emissions or to boost burning efficiency are allowed to make up a maximum 2% of the total mass. For the current pellet trials no additives were used.

Density

The EN standard stipulates a minimum density of 600 kg/m³; all pellets measured were between 650-700 kg/m³ and well within the specification.

Trace Metals

Although unlikely to occur in significant quantities in the gorse or heather pellets being tested the EN pellet standard stipulates a maximum level of mg/kg for each of the following trace metals: Arsenic, Cadmium, Chromium, Copper, Lead, Mercury, Nickel, Zinc. In order to pass pellets for commercial supply as an A or B-grade pellet it is necessary to ensure that for each of the above trace metals the content is within the maximum allowed limit. These tests were beyond the scope of the current research.

6. Domestic burner test results

Samples of both gorse and heather pellets were tested in a 'pellet basket' designed to burn wood pellets in a wood burning stove and in a 20kW pellet boiler in order to assess the performance of the pellets in a domestic situation.

6.1 Pellet Basket

The pellet basket used for testing the pellets in a 5kW domestic wood burner has a capacity of 5kg of pellets. Two full baskets of each of the 100% heather and gorse pellets were burnt in March 2011 in the researcher's wood burning stove at home. Once the pellets had been sufficiently ignited (using a lighting gel) the wood burner door/ vent was closed and the pellets left to burn. They burned, (as with wood pellets), with a flame for the first half of the burn and hot glowing embers for the second half.

The 5kg of gorse pellets lasted for approximately 7 hours and gave off a significant amount of heat, similar in both respects to softwood pellets. (Hardwood pellets tend to burn more slowly, giving off less heat but typically lasting for over 10 hours.) As the gorse tested at 4.81 kWh/ kg this means that the 5kg basket of gorse pellets contained 24.05kW of heat energy, emitting an average of 3.44kW/ hour over the 7 hours. It was possible to control the intensity of the burn and therefore the amount of heat generated by increasing the airflow in the wood burner by opening the door slightly or moving the air vent to the open position.

Figure 9 – pellet basket with heather pellets



The heather pellets lasted for a surprising 14 hours – a total of 23.6kW of heat energy, released on average at a rate of 1.69kW/ hour. To the domestic user the heat generated felt significant, effectively warming the c. 100m³ kitchen in which the

wood burner is located; it did not seem as though the heather pellets were emitting less than half the amount of heat as the gorse or other wood pellets. The wood burner felt as warm to the touch as with the gorse pellets and the smell of the heather pellets was pleasing.

While these are personal observations, lacking in scientific validity, for the purposes of the current investigation it is really the potential of the pellets as a domestic fuel and therefore the benefit experienced by the end user which is important. This will decide whether the pellets may be sold for a premium price or not.

6.1 20kW Pellet Boiler

A 20kW Woodpecker pellet boiler located at the Harvest Wood Fuels office was used to test the basic performance of both the gorse and the heather pellets in a pellet boiler in late March/ early April 2011.

Figure 10 – 20kW Woodpecker boiler



The quantity/ weight of pellets used was not measured and it is not known at what rate the pellets burned. This was difficult to measure and control over the period of the tests as the atmospheric temperature varied considerably from day to day and the boiler is thermostatically controlled. The main purpose of the test was to see if the pellets functioned in a wood pellet boiler.

Both gorse and heather pellets were loaded into the boiler hopper at the beginning of consecutive weeks at the end of March/ early April 2011. The boiler ran successfully with no ignition failures for one week for both types of pellet.

Figure 11 – Boiler pellet hopper



For both the gorse and more so for the heather pellets there was a build-up of hard ash and clinker in the burn chamber of the boiler (see below). While this didn't cause a problem during the week of testing, if left without being cleared it would have blocked the air holes and eventually caused a boiler ignition failure.

Figure 12 – Boiler burn chamber and clinker



One week's clinker from gorse pellets



One week's Clinker from heather pellets

It should be noted that the type of boiler in which the tests took place is a 'top fed' boiler, where the pellets are pulled from the hopper by a screw auger and dropped down a pipe into the burn chamber. This tends to result in 'mounding' of the fuel which burns very hot in the centre of the mound but does not spread easily to the periphery. This can cause the material in the centre to reach the ash melt temperature, causing a build-up of clinker when the boiler cools down.

This is a particular problem with oak pellets in the same type of boiler, (the manufacturer only recommends the use of softwood pellets), but has been easily managed by a weekly two minute clean out. However, the same problem has not yet been experienced in other boilers supplied by Harvest Wood Fuels with oak pellets. The explanation for this may lie in the fact that many of these boilers are 'under fed'

rather than top fed, or if top fed they have appropriate ash handling systems such as regular air cleaning. In such boilers it is very possible that the same clinker issues as experienced in the Woodpecker boiler would not occur with the gorse/ heather pellets.

7. Conclusions

The quality of the gorse pellets produced for this study was significantly better than in the 2010 study (see Table 3), achieving a Grade A pellet standard on most measured criteria and performing well in the pellet boiler and wood stove trials. The improvement is attributed to the cleaner harvesting method used, eliminating soil contamination, and the use of only the woody stem, not the smaller branch and needles. The heather pellets were similar in quality to those produced for the 2010 study, with the exception of the pellet durability, which was poor. This was due to the fact that a low compression pellet die was used, whereas the die used in 2010 was of a high compression and produced good durable pellets. The heather pellets also performed well in boiler and wood stove trials. The laboratory test results suggest that the higher the proportion of wood mixed with heather, the better the quality of the pellets and that a 50:50 mix of heather and wood may be sufficient to achieve a Grade A pellet standard.

Table 3 - Pellet quality summary

Material	DU (%)	M (%)	A (%)	S (%)	CL (%)	CV kWh/kg	N (%)	A soft. temp (°C)	Summary
Gorse (2010)	97.9	10.1	6.6	0.08	- *	4.61	1.28	1470	M, A, S, N too high
100% Gorse	97.4	6.8	0.7	0.03	0.04	4.81	0.56	1160	DU too low, CL too high
Gorse 9:1 Oak	98.3	6.3	0.6	0.02	0.04	4.83	0.52	1190	CL too high
Gorse 8:2 Oak	98.4	7.3	0.6	0.02	0.04	4.68	0.45	1180	CL too high
Gorse 6:4 Oak	98.8	7.4	0.6	0.02	0.04	4.69	0.52	1140	CL too high
Heather (2010)	99.3	10.9	1.7	0.07	- *	4.80	0.7	1170	M, A, S too high
100% Heather	89.7	11.6	1.6	0.05	0.03	4.72	0.67	1090	DU, °C ↓, M, S ↑
Heather 9:1 Oak	87.8	10.8	1.4	0.06	0.02	4.77	0.63	1100	DU ↓, M, S ↑
Heather 8:2 Oak	92.4	11.1	1.2	0.05	0.02	4.69	0.60	1090	DU, °C ↓, M, S ↑
Heather 6:4 Oak	95.3	11.3	0.9	0.04	0.02	4.64	0.55	1090	DU, °C ↓, M ↑

*Not measured in 2010

Key:

ENPlus A1
 ENPlus A2
 EN B
 Non-EN

6.2 Gorse

The four gorse pellet samples produced were of a Grade A standard on six out of eight of the measured criteria. The exception was on the durability of the 100% gorse pellets which were at 97.4%, just 0.1% below the required 97.5% for Grade A status, and likely due to the fact that the pellets were not screened for fine/ crumbling material as they would be in normal production.

Two areas of concern for the gorse pellets were the relatively high nitrogen level and the slightly low ash softening temperature. However both were still within the acceptable limit for a Grade B pellet and for all pellet samples the ash softening temperature was above the 1,100°C minimum softening temperature required for Grade A2 pellets. The performance of the gorse pellets in the Harvest Wood Fuels' boiler was satisfactory, with no ignition failures for the duration of the seven day test. Although there was a slight build-up of clinker (see figure 12 above), it is likely that this would not occur in more modern pellet boilers with adequate ash handling systems such as regular air cleaning. The release of nitrogen oxides can be reduced to acceptable levels or even eliminated through the use of ceramic filters in boilers.

The main area of concern for the gorse pellets was the chlorine level; even at relatively low concentrations chlorine can result in both corrosion of a boiler's surfaces and in the formation of dioxins. The 0.04% of chlorine by weight measured for all the gorse pellet samples was above the maximum stipulated concentration for a Grade A1 (0.02%) or Grade A2/B (0.03%) wood pellet. It is thought that the reason for this may be a higher than average level of chlorine in the soil of the New Forest, where the gorse samples originate from, due to the region's proximity to the coast and the tendency for sea salt to infiltrate some distance inland through precipitation. This theory needs to be tested by sampling gorse grown further inland and potential reasons investigated for the heather samples, (which also grew in the New Forest), not being affected in the same way.

The effect of adding higher concentrations of oak sawdust to the gorse appeared to have little significance. There was a slight reduction in the ash and sulphur content of the gorse pellets mixed with oak as opposed to the 100% gorse pellets. However as the pure gorse pellets already achieved a Grade A1 standard for these criteria this did not have the effect of 'upgrading' the pellets.

There was a reduction in the calorific value of the pellets as the concentration of oak increased. This is because while oak is a very dense wood and by volume tends to have a high calorific value, when measured by weight it actually has a slightly lower calorific value than soft wood. This may be seen by the fact that dense oak logs burn much more slowly than pine and other less dense wood. This is an advantage for biomass boilers which work more efficiently burning for longer to reach thermostat temperature, rather than quickly reaching temperature and then modulating.

There was a possible lessening of the nitrogen level as more oak was added, but the lowest level of nitrogen at 0.45% by weight, (within the maximum limit of 0.5% stipulated for a Grade A2 pellet), was measured in the 8:2 gorse/oak mix, not the 6:4 mix, (which increased to a 0.52% nitrogen level). This may be explained by an inconsistent material mix, as oak typically has a very low nitrogen level and should reduce the overall level measured; this indeed appears to be the case in the reduction from 0.56% in the pure gorse pellets to 0.52% in the 9:1 mix and then 0.45% in the 8:2 mix. If an inconsistent mix is to blame then it may be expected that a 50:50 mix of gorse with oak would still further reduce the nitrogen level, though unlikely to the 0.3% level required of a Grade A1 pellet.

6.2 Heather

As well as a low durability, which would be rectified by using a higher compression pellet die in the pelletising process, the moisture levels of the heather pellets were slightly too high. This is also easily rectified by further drying the raw material prior to pelletising. It is also likely that the relatively high levels of ash, sulphur and nitrogen would be significantly reduced by more careful harvesting methods, thus preventing the contamination of the raw material with soil.

While the current study used a cleaner method of harvesting for the gorse samples (a chainsaw was used to prepare gorse stem only) no viable alternative to mowing and baling the heather was available. As with first mowing the gorse and then collecting it using a single chop forest harvester in the 2010 study, the mowing of the heather, leaving it on the ground for several days and collecting it with a baler is likely to have collected a significant quantity of earth and material other than heather. The effect of this on pellet quality can be seen in the dramatic improvement in the gorse pellet quality from the 2010 study to the current study, especially on ash levels and sulphur and nitrogen content (see Table 3). Of course it must be remembered that gorse is a woody biomass and heather is a herbaceous biomass, so such a dramatic improvement should not be expected. For a discussion on improved harvesting techniques see 'Recommendations' below.

Another possibility for improving the quality of the heather pellets produced would be to further increase the concentration of wood mixed in. It can be seen that as the oak concentration increases so the ash, sulphur and nitrogen content of the pellets reduces. In the 6:4 heather/oak mix the pellets are of a Grade A2 standard for ash and a Grade B standard for sulphur and nitrogen. The reduction in the levels of these criteria is such that the research suggests a 50:50 mix of heather and oak would achieve a Grade A standard of pellet for these criteria.

The ash softening temperature for the heather pellets remained constant in all the pellet samples at just below (by 10 °C) the threshold for a Grade A2 or B pellet. This is typically 50-100°C lower than the ash softening temperature for the gorse pellet samples and the effect of this lower softening temperature has can be seen in the difference and quantity of the clinker in Figure 12. There is much more heather than gorse clinker after the same amount burning (7 days) and the heather clinker has been thoroughly melted and fused together. The gorse clinker by contrast is more like hard ash loosely held together. This is likely to cause a problem in a standard pellet boiler, unless it incorporated a specially designed ash handling system.

6.3 Commercial harvesting

As with any harvesting operation for biomass fuel production, the harvesting of heathland management arisings needs to be efficient and cost effective. It is unlikely that a man with a chainsaw and the collection of gorse stem by tractor and trailer would be a cost effective method for harvesting raw material. So while it can be seen from this study that the careful harvesting and handling of gorse results in a considerably improved pellet quality, another more viable method of collecting the raw material needs to be found.

A recent innovation is the Ahwi H-600 Bio harvester (see figure 13), a German harvester of which at the time of writing there is only one in the UK. The manager of the Surrey Heathland Project described the harvest as 'The machine we have been waiting for, for 20 years!'

Figure 13 – Ahwi H-600 Bio harvester



The Ahwi can 'mow' heathland, including any tree growth up to six inches in diameter. It has different blades for different types of work, which 'float' above the contours of the ground, so that it does not come into contact with the soil. It collects the vegetation which it mulches and blows into a container towed by a tractor. This is the sort of machine which will allow the cost effective management of heathland and harvesting of arisings in the years to come.

Figure 14 – Ahwi in action



It is unlikely that a machine such as this would be able to be used to selectively harvest different types of heathland vegetation. It is much more likely that all growth – heather, gorse, birch, pine and bracken for example, would be harvested together. The question remains as to what sort of pellet could be created from the mixed material but the current research suggests that a mix may be the best approach. Gorse and heather are the most prevalent heathland plant species and appear to complement one another in several ways. For example, where the sulphur content of the heather pellets was high, for gorse it was low; the chlorine level of gorse was high and for heather it was low; and the ash content of gorse is low while for it is high for heather.

There are likely to be improvements in the quality of heather pellets if soil contamination is reduced and possibly for gorse pellets if harvested from inland soil with low chlorine content. Other species commonly found on heathland such as birch and scots pine, being woody biomass, are likely to improve pellet quality rather than detract. It is possible therefore that a heathland management operation could also become a commercially viable process with machines such as the Ahwi.

6.4 Summary

The tests showed that the gorse pellets meet all the criteria required to achieve an ENPlus Grade A pellet, suitable for use in domestic wood pellet boilers, except for –

- a) Chlorine levels at 0.04% by weight for all samples compared to the required 0.02% or less for a Grade A1 pellet and 0.03% for a Grade A2 or B pellet.
- b) Nitrogen levels of between 0.45% and 0.56% by weight compared to a required 0.3% or less for Grade A1, 0.5% or less for Grade A2 and 1% or less for Grade B.

The level of chlorine would need to be reduced accordingly before gorse pellets could be sold either as a grade A or B pellet. This might be achieved by sourcing gorse grown further inland as it is likely that the origin of the wood, from a coastal location, has contributed to the high chlorine level. This is due to exposure to sea salt through rain and wind. Further research would be needed to verify this.

The nitrogen levels for all four gorse pellet samples were within the limits required for a Grade B pellet but only one sample was within the limit necessary to achieve a Grade A2 standard. Mixing gorse thoroughly with a higher concentration of virgin wood without bark is likely to reduce the nitrogen content to a consistent Grade A2 and potentially a Grade A1 standard, though this would require further testing.

The heather pellets were generally of a poorer quality than the gorse pellets, with each of the samples below the required standard for a Grade A or B pellet for half of the eight measured criteria. It is likely that with improved harvesting and production methods, including a higher concentration of virgin wood without bark, that the pellet quality would be significantly improved and could achieve a Grade A pellet standard for most criteria. However the low ash melting temperature would remain a problem and a likely cause of clinker and boiler failure in many domestic boilers.

The purpose of the current investigation was to investigate the suitability of heather and gorse for producing high quality fuel pellets for domestic boilers with a view to maximising the commercial value of heathland management arisings. If, as is likely in the future, heathland areas will be managed using modern harvesting machinery such as the Ahwi H-600 Bio harvester, discussed above, it may be most appropriate to produce a mixed species 'heathland pellet' in order to achieve maximum commercial gain.

Modern machinery can harvest large quantities of material cost effectively whilst minimising soil contamination but is unlikely to be able to selectively harvest unique species such as gorse or heather separately. A mixed species heathland pellet made from heather, gorse, birch, pine and bracken for example, may not achieve a Grade A pellet standard but mixed with wood it is likely that this standard could be achieved. Further investigation would be required to verify this. It is questionable however whether achieving the highest ENplus pellet standard for domestic boilers is even necessary or indeed desirable in order to achieve the maximum commercial benefit.

The use of heathland pellets in wood burning stoves, which are more robust than pellet boilers and have no minimum requirement for pellets, should also be considered. The quality of fuel likely from a heathland pellet will be significantly higher than logs which are usually burned in wood stoves, due to their low moisture content and high calorific value. Pellets are also a dense fuel taking up much less

space than logs and are more convenient, burning for a significantly longer time by weight.

The implications of this research are that gorse and heather both have a commercial application in the production of high value fuel pellets for the domestic heating market. Gorse and heather, or a mixed heathland pellet would also be suitable for the commercial and industrial markets for larger pellet boilers, district heating systems, CHP plants and steam turbines for power stations. However the domestic heating market is preferable as the unit price is higher and production is likely to be on a small, local scale, more suited to the local, domestic market. If pellets made from heathland management arisings fall short of the standard required for domestic pellet boiler then a preferable use for the pellets would be as a fuel for wood burning stoves. Used in a pellet basket they are an efficient, effective, convenient and cost effective fuel for wood burners.

James Little
Harvest wood Fuels
13th April, 2011

APPENDIX A – QUALITY STANDARDS FOR PELLETS IN EUROPEAN COUNTRIES

Specification	Austria ÖNORM M7135		Sweden SS 18 71 20			Germany DIN 51731 / DIN plus			CEH CEN/TS 14961:2005 Annex A	
	Wood pellets	Bark pellets	Group 1	Group 2	Group 3	5 size classes [cm]				
Origin										Chemically untreated wood without bark
Size	- Pellets : 4 - 20 mm Ø max.100 mm lg.	-Briketts: 20 -120 mm Ø max. 400 mm lg.	max. 4 Ø**)	max. 5 Ø	max. 6 Ø		Length	Ø	D06 ≤ 6 mm ± 0,5 mm and L ≤ 5 × Diameter	
						HP1	>30	>10	D08 ≤ 8 mm ± 0,5 mm and L ≤ 4 × Diameter	
						HP2	15-30	6-10		
						HP3	10-15	3-7		
						HP4	<10	1-4		
						HP5	<5	0,4-1		
Bulk density			≥ 600 kg/m ³ **)	≥ 500 kg/m ³	≥ 500 kg/m ³					Recommended to be stated if traded by volume basis
Fines in % <3mm			≤ 0,8	≤ 1,5	≤ 1,5					F1.0 ≤ 1,0 % F2.0 ≤ 2,0 %
Unit density	≥ 1,0 kg/dm ³	≥ 1,0 kg/dm ³						1-1,4 g/cm ³		
Moisture content	≤ 12 %	≤ 18 %	≤ 10 %	≤ 10 %	≤ 12 %			<12 %		M10 ≤ 10 %
Ash content	≤ 0,5 % *)	≤ 6,0%*)	≤ 0,7 %	≤ 1,5 %	>1,5 %			< 1,5 %		A0.7 ≤ 0,7 %
Calorific value	≥ 18,0 MJ/kg*)	≥ 18,0 MJ/kg*)	≥ 16,9MJ/kg ≥ 4,7 kWh/kg	≥ 16,9MJ/kg 4,7 kWh/kg	≥ 16,9MJ/kg 4,7 kWh/kg			17,5 - 19,5 MJ/kg ***)		16,9 MJ/kg 4,7 kWh/kg
Sulphur	≤ 0,04 %*)	≤ 0,08 %*)	≤ 0,08 %	≤ 0,08 %	anges			< 0,08		S0.05 ≤ 0,05 %
Nitrogen	≤ 0,3 %*)	≤ 0,6%*)						< 0,3		N0.3 ≤ 0,3 % N0.5 ≤ 0,5 % N1.0 ≤ 1,0 % N3.0 ≤ 3,0 % N3.0+ > 3,0 % (actual value to be stated)
Chlorine	≤ 0,02%*)	≤ 0,04%*)	≤ 0,03%	≤ 0,03%	anges			< 0,03		Recommended to be stated in category: CL 0.03 CL 0.07 CL 0.10 CL 0.10+ (if CL>0.10 % the actual value to be stated)
Arsenic								<0,8 mg/kg		
Cadmium								<0,5 mg/kg		
Chromium								<8 mg/kg		
Copper								<5 mg/kg		
Mercury								<0,05 mg/kg		
Lead								<10 mg/kg		
Zinc								<100 mg/kg		
EOX, extractabl.org. halogens								<3 mg/kg		
Fines. bevor delivery to costumer	max. 1 %							max. 1 %		
Additives	max. 2 % only natural		to be stated							< 2w-% of dry basis. Only products from the primarily agricultural and forest biomass that are not chemically modified are approved to be added as a pressing aids. Type and amount of additive has to be stated.
Ash melting point			temperatur to be stated							
Durability										DU97.5 ≥ 97,5

*) of dry basis **) at factory ***) without ash and water

APPENDIX B – PELLET TEST RESULTS

Report Number : 11/MAR/COA/4386

Customer : **Harvest Wood Fuels**
Grange Road
Tilford
Farnham
Surrey
GU10 2DQ

Date Received : 22nd March 2011

Sample Date :

Date Analysed : 23rd to 31st March 2011

Report Date : 31st March 2011

Customer Reference :

Test Method	Sample Reference	100% Gorse	100% Heather	90% Gorse 10% Oak	80% Gorse 20% Oak
SP 21	Pellet Durability (%)	97.4	89.7	98.3	98.4
SP 20	Total Moisture %	6.8	11.6	6.3	7.3
CA 3	Ash %	0.7	1.6	0.6	0.6
CA 6	Volatile Matter %	76.0	69.9	76.6	75.8
CA 31	Sulphur %	0.03	0.05	0.02	0.02
*	Chlorine %	0.04	0.03	0.04	0.04
CA 11	Gross Calorific Value kJ/kg	18679	18294	18720	18259
**	Calorific Value kJ/kg (DAF)	20188	21072	20106	19821
**	Net Calorific Value kJ/kg	17333	16879	17378	16865
CA 9	Carbon %	46.52	45.59	46.62	46.12
CA 9	Hydrogen % ***	5.40	5.20	5.45	5.57
CA 9	Nitrogen %	0.56	0.67	0.52	0.45
Test results calculated to "As received" Moisture Basis*					

TES Bretby does not accept responsibility for the sampling relating to the above results.

*Non accredited method for this matrix ** Calculated using determined value. *** Hydrogen corrected for moisture.

Report Authorised By .
Jonathan Clay

Report Number : 11/MAR/COA/4386

Customer : **Harvest Wood Fuels**
Grange Road
Tilford
Farnham
Surrey
GU10 2DQ

Date Received : 22nd March 2011

Sample Date :

Date Analysed : 23rd to 31st March 2011

Report Date : 31st March 2011

Customer Reference :

Test Method	Sample Reference	60% Gorse 40% Oak	90% Heather 10% Oak	80% Heather 20% Oak	60% Heather 40% Oak
SP 21	Pellet Durability (%)	98.8	87.8	92.4	95.3
SP 20	Total Moisture %	7.4	10.8	11.1	11.3
CA 3	Ash %	0.6	1.4	1.2	0.9
CA 6	Volatile Matter %	75.7	70.8	71.0	71.4
CA 31	Sulphur %	0.02	0.06	0.05	0.04
*	Chlorine %	0.04	0.02	0.02	0.02
CA 11	Gross Calorific Value	18250	18559	18279	18090
**	Calorific Value kJ/kg	19832	21142	20849	20614
**	Net Calorific Value	16898	17160	16882	16694
CA 9	Carbon %	46.64	45.63	45.53	45.33
CA 9	Hydrogen % ***	5.37	5.21	5.16	5.13
CA 9	Nitrogen %	0.52	0.63	0.60	0.55
Test results calculated to "As received" Moisture Basis*					

TES Bretby does not accept responsibility for the sampling relating to the above results.

*Non accredited method for this matrix ** Calculated using determined value. *** Hydrogen corrected for moisture.

Report Authorised By .
Jonathan Clay
(Energy Services Reporting)

Report Number : 11/MAR/COA/4386

Customer : **Harvest Wood Fuels**
Grange Road
Tilford
Farnham
Surrey
GU10 2DQ

Date Received : 22nd March 2011

Sample Date :

Date Analysed : 23rd to 31st March 2011

Report Date : 31st March 2011

Customer Reference :

Sample Reference	Ash Fusion Temperatures (°C) **			
	Initial Deformation	Softening	Hemisphere	Flow
100 % Gorse	1120	1160	1190	1250
100% Heather	1010	1090	1100	1140
90% Gorse : 10%	1140	1190	1210	1260
80% Gorse : 20%	1090	1180	1190	1230
60% Gorse : 40%	1080	1140	1150	1220
90% Heather : 10%	1020	1100	1110	1140
80% Heather : 20%	1030	1090	1110	1170
60% Heather : 40%	1040	1090	1100	1140
Analysis Conditions : Reducing Atmosphere				

TES Bretby does not accept responsibility for the sampling relating to the above results.

** Non accredited test for this matrix

Report Authorised By .
Jonathan Clay
(Energy Services Reporting)