

Assessment of the use of landscape management arisings as a feedstock for commercial pellet production.

Feasibility report



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29th July, 2010

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Executive Summary

In March 2010 wood pellet producer Harvest Wood Fuels investigated, on behalf of the Forestry Commission, the use of landscape management arisings as a feedstock for commercial pellet production. Samples of heather, gorse and rhododendron were harvested using traditional landscape management techniques and delivered to the pellet production facility. The samples were dried, pelleted and sent to an independent UKAS accredited laboratory for testing against European quality standards for wood pellets.

While the pellets did not achieve the highest standards expected of wood pellets supplied for domestic pellet boilers, they did perform well enough to justify their use in larger scale commercial and industrial boilers.

With regard to certain key characteristics such as ash content and calorific value it is likely that the quality of the heather and gorse pellets was significantly reduced due to soil contamination during harvesting. The problem could be eliminated by the use of more appropriate, cleaner harvesting methods, resulting in a higher quality pellet, though it is still unlikely that these herbaceous raw materials could result in a 'Grade A' pellet standard.

Heather and gorse pellets are therefore best suited to the commercial and industrial markets for larger pellet boilers, district heating systems, CHP plants and steam turbines for power stations. For the latter the market for lower grades of pellets, such as miscanthus, straw and reed canary grass is well established. In the test results the heather and gorse pellets performed at least as well as these established energy crops.

The rhododendron sample (stem wood, no leaves), a woody rather than herbaceous biomass, formed pellets that came close to achieving the European 'Grade A' standard; the main area for concern was a relatively low ash softening temperature. This could indicate a propensity for the pellets to form clinker in the boiler burn chamber, though further testing would be required to verify this.

Advances in boiler technology will enable the use of lower grades of pellet in the future. There are already boilers available - moving grate and gasification boilers - which can overcome clinker and potential emissions (such as Nitrous Oxide) issues. Localised Combined Heat and Power plants can run on lower grade pellets and are best placed close to where the biomass is harvested to minimise transport and maximise efficiency. In the same way pellet boilers installed close to the pellet production plant provide a ready market for locally produced good value pellets. Raw materials can also be mixed with wood so as to ensure that the pellets produced are of a Grade A standard.

The implication of this research is that heather, gorse and rhododendron arisings are a viable feedstock for commercial pellet production. Bearing in mind the prevalence of these species of plant in the UK and the need to manage them, (especially rhododendron with concerns over the spread of *Phytophthora ramorum* or 'Sudden Oak Death'), the potential for biomass pellet production is huge. Many significant land owning organisations such as the Forestry Commission, National Trust, MOD, National Parks, councils and the Highways Agency will have an incentive to establish or support the establishment of localised pellet making facilities. Managed appropriately opportunities such as this should mean that the cost of managing the land is covered, income generated and renewable energy produced locally.

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1. Introduction

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 as either a domestic or commercial wood fuel product. Specifically the study aims to:

- **Assess the suitability of heather, gorse and rhododendron arisings for producing fuel pellets using existing wood pellet production equipment and processes.**
- **Obtain a clear Fuel Quality Declaration for the pellets produced from heather, gorse and rhododendron.**

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 October 2009 to explore the possibility of them undertaking the work; an initial meeting was held.

A visit to the New Forest was organised in January 2010 in order to view heathland management activities, such as gorse swiping and heather baling in order to assess the harvesting methods and options for the production of the pellets using the trial feedstock.

It was agreed that Harvest Wood Fuels would undertake pellet production trials of gorse, rhododendron and heather on behalf of the Forestry Commission. A brief was prepared by the Forestry Commission as per below.

2. Project Brief

Assessment of suitability of heather, gorse and rhododendron arisings as material for wood fuel 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:

- Dry and prepare the arisings as necessary for use in their wood pellet mill.
- Attempt to produce wood fuel pellets from heather, rhododendron and gorse arisings.
- Report on the performance of the pelleting machinery in using these materials.
- Submit a sample of the wood pellets derived from these products for official laboratory testing according to CEN 14961 standards.

- Report on the outcome of the tests with respect to the implications of the subsequent use and saleability of the pellets as either a domestic or commercial wood fuel product.

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

CEN/TS 14961:2005(E), 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.

The Forestry Commission will undertake to:

- Harvest heather, gorse and rhododendron in a fashion suitable for use in this project.
- Provide 1 tonne of arisings each of heather bales, chopped gorse arisings and chipped rhododendron arisings (lesser amounts may be agreed between FC and Harvest woodfuels).
- Arrange delivery of the arisings to the premises of Harvest Wood Fuels in Farnham, Surrey.

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

3. Research Objectives

3.1 Primary Aim

- Provide information on the qualitative nature of the wood fuel pellets derived from heather, gorse and rhododendron.
- 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, gorse and rhododendron arisings in order to promote their use as a source of biomass energy.

3.2 Secondary Aims

- To explore harvesting and transport costs of utilising these materials (as undertaken by FC in this contract).

4. Method

4.1 Raw material Harvesting and Preparation

The raw materials were harvested using basic brash harvesting methods for the New Forest, where the gorse and heather originated, and basic tree surgery/ chipper methods for the rhododendron. It was originally proposed that the rhododendron samples would also come from the New Forest. However with recent concerns over the spread of disease (particularly *Phytophthora ramorum* or 'Sudden Oak Death') there has been a ban on transporting rhododendron from one area to another, so the sample was sourced locally to the pellet plant in Tilford, Farnham. In the New Forest areas of heathland to be managed were selected as part of the Heathland Management Programme, and the material harvested from sites that were originally proposed to be managed by controlled burning.

The particular methods used to harvest the gorse and heather are outlined below. In future more appropriate harvesting methods will clearly be needed. By adopting more bespoke methods it will be possible to prevent the uptake, during harvesting, of non-combustible material such as soil. **This is detrimental to the quality of the pellets produced, causing higher ash content and lower calorific value.** Similarly, more suitable methods of drying the raw materials prior to pelletising will also be required. The methods used for each material are outlined below.

Rhododendron

The rhododendron chip was cut locally to the pellet plant using traditional tree surgery methods (i.e. with a chainsaw) on 19th March 2010. The stem wood was chipped (including bark) into a tipper truck (approx 8m³) and delivered to site on the same day.

The chip, delivered wet, was stored outside in a storage bay to start the drying process. The measured (by oven drying) moisture content on 7th April 2010 was 55%; this was found to be too wet to make pellets. Also the high moisture content would mean that left in a pile in the open air the chip would start to compost.

For this reason a portion of the wood chip was hammer milled and spread out to air dry in a 20 foot shipping container, where it dried to an average moisture level of 25% over a period of 7 weeks (see Figure 1). This is quite rapid for the reason that the container became very warm inside on sunny days, thus evaporating the moisture in the rhododendron fibres more rapidly. The material was regularly raked to ensure consistency of drying.

Figure 1 – 20 foot shipping container used to dry rhododendron fibres



Gorse

The gorse was harvested in the New Forest using two implements. Firstly a front tractor mounted mower was used to cut the gorse and chop the vegetation (see Figure 2). Secondly a single chop forage harvester (see Figure 3) which collected the cut gorse and blew it into an in line trailer.

Figure 2 – Front mounted tractor mower



This method of collection does not provide the medium best suited for pelleting as a significant quantity of earth and material other than gorse is also collected; this is likely to detrimentally affect pellet quality. However, it was decided to use the material harvested and to assess quality and make recommendations for future alternative harvesting methods according to the results.

Figure 3 – Single chop forage harvester and trailer



Approximately 10m³ of chopped gorse was delivered to site on Friday 26th March in a tipper truck. The material was tipped into the pellet factory in order to keep it undercover for drying purposes. The measured moisture content of the recently harvested gorse on 7th April, 2010 was 35%. As with the rhododendron a portion of the chopped gorse was hammer milled and spread out to air dry in a 20 foot shipping container, where it dried to a moisture level of 15% over a period of 4 weeks.

Heather

Heather baling enables the Forestry Commission to deliver its heathland management programme targets and is a practical alternative to the usual practice of the controlled burning of heather stands.

The ideal baling site selection is driven by several factors, primarily the age and canopy structure of the heather stand. The terrain must also be considered - flat, free-draining sites that are free of ditches, banks and other obstructions are essential to make the operation viable. Baling however is not a pre-requisite for pellet production and other harvesting methods may be suitable providing they do not contaminate the material with soil.

Once the sites were selected they were dropped from the burning programme to be harvested between November and March. Currently, all baling is carried out using the skills of a local agricultural contractor with specialised machinery to offer a unique service suited to meet the Forestry Commission's requirements for heather bales.

The baling process is, in principal the same as conventional hay baling. The heather is mown beforehand and left for a couple of days. Then it is baled using a 'beefed up' agricultural baler to produce bales measuring 50cm X 50cm X 75cm. As the bales are produced, they are dropped into a 12-bale sled that is towed in-line behind the tractor/baler unit (see Figure 4).

Figure 4 – Agricultural baler and bale sled



Once the baling is completed the bales are collected using a 12-bale grab that is attached to the tractor's loader (see Figure 4). Once loaded, the bales are either transported to a work site where they will be used for mire or river restoration, or taken to a storage area for later use. As with the gorse this method of harvesting and collection does not provide the medium best suited for pelleting as there is likely to be significant contamination of earth and material other than heather, which will detrimentally affect pellet quality. Other, potentially more suitable harvesting methods should be considered.

Figure 5 – Bale grab and loading



Approximately 50 bales of heather were delivered to the pellet production plant on the same day as the gorse (26th March, 2010) in a tipper truck. As with the gorse these were stored inside the pellet factory to ensure the material was kept dry (see Figure 6). The measured moisture content of the heather on 7th April, 2010 was 20%.

Figure 6 – Heather bales, chopped gorse and chipped rhododendron in factory



4.2 Pelleting Process

The pelleting trials for gorse and heather took place on 7th and 8th and 29th and 30th April 2010. The trials for rhododendron took place on Friday 28th May following the air drying of the material. The pellet press used was a 22kW Chinese press (Figure 7).

Figure 7 – 22kW Flat plate die pellet press



The first stage of the pellet production, once the material was sufficiently dry, was to reduce the particle size of the raw material in order for it to be pelleted. This was done using a hammer mill (the red and blue machine in Figure 7). The hammer mill

uses hammer blades to reduce the particle size of the raw material in order for it to pass through a 5mm screen.

The smaller particles are then sucked into the raw materials bin from where it is fed - by means of a screw auger - into the pelleting chamber. The pelleting chamber consists of a flat plate 'die' - a round block of steel with hundreds of holes - through which rollers push the raw material under pressure (see Figure 8).

Figure 8 – Flat plate die and rollers



The pressure and heat generated cause the lignin in the biomass particles to melt and bind the fibres together, forming a pellet which exits the underside of the die. The pellets then enter a rotary sieve/ cooling chamber where fine material and heat are removed using an air extraction system.

The process and experience during the current trials with gorse, heather and rhododendron is described below.

4.3 Pelleting experience with rhododendron, gorse and heather

All three raw materials produced good quality, robust pellets. In order to pelletise wood successfully it typically needs to be at a very low moisture content of 15% or less. The raw materials being tested were at varying moisture levels of between 15% and 35% when the pellet trials took place. It was therefore necessary to pass the wetter material through the press two or three times in order for it to further dry sufficiently to pellet successfully. In normal circumstances the material would have been dried sufficiently so as to require only one pass through the pellet press. The experience with each material is expanded on below.

Rhododendron

Following 7 weeks of air drying in a 20 foot shipping container used to collect sawdust (see Figure 1) the average moisture content of the rhododendron was 25%, deemed dry enough to attempt pelleting trials.

However due to excess moisture levels the pellets produced on the first pass were not acceptable. When fed through the pellet press a second time the pellets produced were of a good consistency and high durability. A sample of these pellets was selected for laboratory testing against the European Quality Standards.

Figure 9 – Rhododendron pellets



Gorse

The chopped gorse was measured at 35% moisture on 7th April. This was fed by hand into the hammer mill and was reduced to 5mm particles.

The nature of the chopped gorse was such that it was difficult to feed into the hammer mill and needed to be pushed in by hand and shovel. If the gorse were chopped or chipped more finely then it would flow better and be more suitable for automated feed pelletising systems. This could be readily achieved at the harvesting stage using appropriate methods – one such method could be the use of a *billeter*, typically used for harvesting willow.

The pellets produced on the first press were of low durability and crumbled relatively easily. As with the rhododendron, this was due to the high moisture content of the raw material. However when fed through the pellet press a second or third time the gorse formed pellets of good consistency and high durability (see Figure 10). This supports the received wisdom that the maximum moisture level required for successful pelletisation of biomass material is 15%.

To see whether pellet quality was improved by further air drying the gorse was hammer milled and spread out to air dry in a 20 foot shipping container, where it dried to an average moisture level of 20% over a period of 4 weeks. This dryer material was pelleted on 29th April but also required a second (not third) pass through the pellet press. This again supports the 15% rule.

A sample of the gorse pellets produced was sent for laboratory testing with the rhododendron pellets in May 2010.

Figure 10 – gorse pellets



Heather

The heather measured an average moisture content of 20% when the pelleting trials were undertaken. Pellets were formed on the first pass through the pellet press were generally poor quality with low durability (see Figure 11).

Figure 11 – Heather pellets formed at high moisture level of raw material



There was a significant improvement in the quality of pellets formed on the second press – i.e. when the moisture content of the raw material was lower (see Figure 12). A sample of these pellets was sent for testing in June 2010.

Due to its stringy nature, (as with the gorse), it was difficult to feed the heather into the hammer mill and for ease of handling should be chopped more finely in order to facilitate flow/ auger feeding.

Figure 12 - Heather pellets formed at low moisture level of raw material



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

5. Laboratory test results

The samples of gorse, heather and rhododendron pellets 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 CEN/TS 14961:2005 (see 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. It should be noted that the standards are based on clean wood pellets without bark and it is very unlikely that the materials being tested in this research will reach the highest grade of pellet quality.

The CEN/TS 14961:2005 standard has recently been updated to EN 14961 (2009) and is awaiting publication at the time of writing. The updated standards propose 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 respective standards for each of these pellet classes are listed for comparison in Table 1 and the performance of each of the raw materials in relation to each parameter is discussed below. The pellets are also compared against typical values for miscanthus pellets and Grade 'A1' pine wood pellets.

Table 1 – Laboratory Pellet Test Results

Parameter	Test Pellet Samples		Typical Pellet Values				European Specification		Notes		
	Heather	Gorse	Rhodo.*	Pine	Misc.**	Straw	Canary grass	ENplus-A1		ENplus-A2	EN-B
Pellet Durability (%)	99.3 ✓✓✓	97.9 ✓✓✓	96.6 ✓	99 ✓✓✓	99 ✓✓✓	99 ✓✓✓	99 ✓✓✓	≥ 97.5	≥ 97.5	≥ 96.5	<p>Samples good - possible to increase durability by using a die with higher compression holes Further drying will bring samples within specification Soil contamination in heather/ gorse? Use alternative harvesting methods Herbaceous biomass/ needles/ green content? Acceptable but heather and gorse could be increased by reducing soil contamination Gorse too high - linked to soil contamination? Rhododendron too low - may cause clinker problems, so use in burners with moving grate</p>
Total Moisture %	10.9 x	10.1 x	6.2 ✓✓✓	8 ✓✓✓	8 ✓✓✓	8 ✓✓✓	8 ✓✓✓	≤ 10			
Ash %	1.7 ✓	6.6 x	0.7 ✓✓✓	0.2 ✓✓✓	4 ✓	5 x	6.4 x	≤ 0.7	≤ 1.5	≤ 3.0	
Sulphur %	0.07 x	0.08 x	0.02 ✓✓✓	0.03 ✓✓✓	0.1 ✓✓✓	0.1 x	0.2 x	≤ 0.05			
Net Calorific Value MJ/kg	17.35 ✓✓✓	16.67 ✓✓✓	17.32 ✓✓✓	17.5 ✓✓✓	17 ✓✓✓	18.5 ✓✓✓	19.1 ✓✓✓	≥ 16.5	≥ 16.3	≥ 16.0	
Nitrogen %	0.7 ✓	1.28 x	0.39 ✓✓	0.3 ✓✓✓	0.7 ✓	0.5 ✓✓	1.4 x	≤ 0.3	≤ 0.5	≤ 1.0	
Ash softening temp (°C)	1130 ✓✓	1270 ✓✓✓	1010 ✓	1270 ✓✓✓	1150 ✓✓	1050 x	unknown	≥ 1200	≥ 1100		

Key:

- * Rhododendron
- ** 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

5.1 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.

The durability of both the heather and the gorse samples were acceptable within the standard required for all grades of pellet under EN Plus.

The durability of the rhododendron pellet sample was below the standard required for a 'grade A' pellet but within the minimum requirement for a 'grade B' pellet.

By using a pellet die with higher compression holes (achieved by altering the hole geometry) the durability of all the pellets would be improved and the rhododendron pellets brought within the specification of 97.5% required for grade A1 and A2 pellets.

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 the heather and gorse pellets were both slightly above the maximum allowed moisture level of 10%. This can be prevented by ensuring that the raw material has been more thoroughly dried prior to pelletisation.

The moisture level of the rhododendron pellets, at 6.2%, was well within the 10% upper limit, due to the fact that the raw material was more thoroughly dried than the heather and gorse.

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 rhododendron pellets the ash level was 0.7%, equal to the maximum allowed level for grade A1 pellets. This is despite the fact that the rhododendron was pelleted with the bark on, which increases ash levels

The ash level of the heather pellet sample was 1.7%. 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.

The ash level for the gorse pellets was a relatively high 6.6%, higher than any of the specified levels under the EN standard.

It is likely that the harvesting methods employed for both the heather and gorse contributed to higher ash levels, as both were mown using a front mounted tractor mower and then collected by a forage harvester (gorse) and a baler (heather). These methods are likely to have collected a significant amount of soil and any other vegetation growing amongst the harvest.

A cleaner method of harvesting is likely to reduce ash levels significantly. However it is questionable, given the herbaceous nature of both heather and gorse with both stem and green matter, whether ash levels would be within the 0.7% required for grade A1 pellets – more likely within the A2 or grade B limits.

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 levels for the heather pellets (0.07%) and gorse (0.08%) are higher than maximum recommended level of 0.05% under the EN standard. The sulphur content of the rhododendron pellets was well within this level at 0.02%.

It is likely that the relatively high sulphur content of gorse and heather is due to the high proportion of green matter as opposed to just stem wood in the case of the rhododendron.

It worth noting that these sulphur levels are lower than typical levels for energy crops such as miscanthus or virgin straw or grass materials with typical sulphur levels of 0.1 - 0.2%. These types of biomass tend to be used in much larger burners in power stations or industrial situations, which are more robust and able to cope with a lower grade of pellet.

5.5 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 16.5 MJ/kg for an A1 grade pellet. The heather pellets measured 17.35 MJ/kg, the gorse 16.67 MJ/kg and the rhododendron 17.32 MJ/kg.

The relatively low calorific value of the gorse was surprising as previous research had indicated that gorse has a high calorific value of in excess of 20 MJ/kg. The fierce burning characteristics of gorse and the fact that gorse was often used in bread ovens for this reason are commonly reported. This is attributed to the high concentration of volatile oils in its foliage and branches.

The low recorded value therefore indicates that soil contamination may be responsible for significantly reducing the calorific value and increasing the ash content of the tested sample pellets. This could be improved upon by adopting 'cleaner' harvesting methods.

5.6 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 0.7%. 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 was higher than this level at 1.28% and in the rhododendron was 0.39%, below the maximum 0.5% level specified for grade A2 pellets.

It is not known whether soil contamination may be partially responsible for the relatively high nitrogen levels in the heather and gorse samples, (and once again a cleaner method of harvesting would test this), or whether the high levels are due more to the significant proportion of green matter in the pellets.

When considering the nitrogen emissions from burning biomass fuels it should be recognised that these are generally lower than those from burning fossil fuels and comparable to emissions from natural wildfires. If the material would have been burnt as part of a landscape management programme the net emissions would be the same but the heat energy produced is not being utilised. Finally as biomass boilers become more sophisticated it will be possible to use ceramic filters to reduce/eliminate harmful emissions such as nitrogen oxide.

5.7 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.

Of the pellet samples the gorse pellets had the highest ash softening temperature at 1,270 °C; this is higher than the minimum specified level for an A1 pellet of 1,200 °C. The ash from the heather pellets began to soften at 1,130°C, below the A1 standard but above the A2 and B-grade standard of 1,100°C. Ash from the rhododendron pellets softened at 1,010 °C, below this specified level.

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 chain grate which keeps the fuel moving and prevents it from forming a solid clinker mass; or through gasification boilers which achieve more efficient combustion and have appropriate ash handling systems.

5.8 Other Issues

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 45 mm. All the

pellets produced for the current trials were 6mm in diameter and complied with the length criteria.

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 – pellets were 100% gorse, rhododendron or heather, notwithstanding any additional substances which might have entered the raw material during the harvesting process.

In terms of bulk 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.

6. Conclusions

Although all of the pellets produced had sufficient calorific value to qualify as a 'Grade A' pellet under the EN standard, none were of a sufficient standard on all measured criteria to qualify as under this class. This is to be expected considering the fact that the European pellet standards are based on virgin wood material without bark (see Table 2).

Despite this the pellets produced did generally perform well and were of grade suitable for industrial and commercial applications. The rhododendron came closest to the highest pellet grade, and with cleaner harvesting methods the gorse and heather are likely to qualify as an 'EN-B' or possibly a 'ENplus-A2' pellet.

Below is a summary of compliance within the three EN classes compared with typical values for virgin pine and miscanthus pellets.

Table 2 - Pellet quality summary

Material	DU (%)	M (%)	A (%)	S (%)	CV MJ/kg	N (%)	A soft. temp (°C)	Summary
Heather	99.3	10.9	1.7	0.07	17.35	0.7	1170	M, A, S too high
Gorse	97.9	10.1	6.6	0.08	16.67	1.28	1470	M, A, S, N too
Rhodo.	96.6	6.2	0.7	0.02	17.32	0.39	1010	A melt too low
Miscanthus	99	8	4	0.1	17	0.7	1150	
Virgin pine	99	8	0.2	0.03	17.5	0.2	1270	
Straw	99	8	5	0.1	18.5	0.5	1050	
Canary grass	99	8	6.4	0.2	19.1	1.4	n/a	

Key:

ENPlus A1
 ENPlus A2
 EN B
 Non-EN

6.1 Rhododendron

The rhododendron pellets comply with the requirements for an A1 class of pellet on all characteristics except the Nitrogen content (0.39% compared to a minimum

requirement of 0.3%) and the ash melt temperature (1010 °C compared to a required 1,200 °C). The ash level is 0.7% which is the highest allowed level for an A1 grade pellet. While the Nitrogen level complies with the requirement for class A2 the ash melt temperature is below the requirement for an A2 or B class of pellet.

This is significant as if pellets deform and melt in the pellet burner clinker (ash melt) is formed causing boiler failure. A solution may be the use of a special type of boiler with a moving or 'chain' grate which acts to prevent the pellets from reaching such high temperatures and forming clinker.

6.2 Gorse and heather

The moisture levels of the gorse and heather pellets were slightly too high, though this could be improved by further drying of the raw materials 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.

Soil contamination increases both ash and nitrogen levels and as sulphur uptake is primarily through the soil it is likely that a reduction in soil contamination would also reduce the sulphur level in the pellets. A possible alternative harvesting method is 'billeting', as used for harvesting willow coppice, whereby a tracked harvester gathers the crop which is cut into short lengths; this can then be dried and chipped or hammer milled prior to pelletisation; this method is much cleaner than mowing, baling and forage harvesting.

While the high ash content (6.6%) and Nitrogen content (1.28%) of the gorse pellets is likely to be reflective of high soil levels, it is probably also due in part to the herbaceous nature and high needle content of the raw material. Alternative harvesting methods would be likely to reduce these levels, though not to the 0.7% ash level required for an A1 pellet, or 1.5% for an A2 pellet, though perhaps the 3% or lower specified for a Grade B pellet. Similarly, eliminating soil contamination may not reduce Nitrogen levels to the required 0.3% (A1) or 0.5% (A2) levels but may do so enough to achieve a Grade B pellet level (1%).

The level of ash in the heather pellets was 1.7% and it seems likely that with more careful harvesting this level could be reduced to below 1.5%, which is the requirement to achieve a grade 'A2' standard. The ash melt temperature of the heather pellets is also within the required level for A2 pellets.

Based on the results then it is possible that heather pellets, if harvested using alternative cleaner methods, may fall within the standard necessary for a Grade A2 pellet, suited to larger commercial and industrial boilers, rather than most currently available domestic boilers.

However it is unlikely that either gorse or rhododendron would make pellets that fall within any of the three EN classes of pellet, due to their high ash levels and low ash melt temperatures, respectively. Despite this both gorse and rhododendron will produce a pellet suited to commercial or industrial grade boilers which are able to cope with lower grades of pellet. Miscanthus for example is an accepted energy crop, often used for the co-firing of power stations, but does not fall within any of the three stipulated pellet grades under the EN Standard. Specifically miscanthus pellets do

not typically achieve the minimum standard required for ash or sulphur levels and only achieve a Grade B level for nitrogen, yet as a crop it still has a wide part to play in the UK biomass energy market.

Technical innovations with pellet boilers should also mean that landscape management arisings such as such as gorse, rhododendron and heather will have more of a part to play as a feedstock for commercial pellet production in the future.

7. Recommendations

The implications of this research are that, if the rhododendron pellets do not cause clinker problems, they may be suited to domestic boilers requiring an 'A1' pellet; heather pellets could be used to fire boilers whose manufacturers recommend a minimum requirement of an 'A2' class of pellet; while gorse pellets would be unsuitable for most commercially available domestic pellet boilers.

Should either the rhododendron or heather pellets not prove suited to the Grade A market, they as well as the gorse pellets still have an application in the commercial pellet market. Larger industrial boilers and burners tend to be more robust and are able to run effectively using a lower grade of pellet. This is the case for instance with biomass power stations or co-fired power stations using coal and biomass. There is a big incentive for power stations to use more renewable energy such as biomass, as they are now penalised for burning fossil fuels such as coal. Energy crops like miscanthus, canary grass and short rotation coppice (e.g. willow) are commonly used to produce pellets for power stations.

The disadvantage of producing a lower grade of pellet is that the selling price is significantly lower than for high grade pellets produced for the domestic or smaller scale heating market. Low grade pellets for power stations are typically worth £100/tonne compared to £200/tonne for the heating market. The scales of economy and investment required to produce low grade pellets at a sufficient quantity to make a profit are considerable.

In a localised situation such as the New Forest where quantities of raw material are unlikely to be sufficient for a large scale pellet production, another approach may be appropriate.

There are smaller scale pellet boilers available which can burn lower grade pellets; these are typically less sophisticated and are most commonly used in district heating situations, so tend to be relatively large boilers within the heating market. One country where this is common is Finland where large, low tech boilers which can take low grade pellets are typically used.

Several manufacturers supply boilers with a moving grate, which prevents the formation of clinker and the build up of harmful substances. Ceramic filters are also available to reduce harmful emissions, such as Nitrogen Oxide, to acceptable levels. While this increases the cost of the boiler hardware this is minimal compared to the advantages to be gained from the use of locally abundant raw material for pellets. Most of the cost of a boiler, which typically lasts for 20 years, is the fuel cost. By utilising low grade pellets significant savings could be made on the cost of purchasing A-grade pellets (perhaps 20-40%).

Another option for the use of lower grades of pellet at a local level is their possible use in a small scale CHP plant to provide both heat and power. CHP plants tend to

be more robust than pellet boilers and able to cope with lower pellet grades. Perhaps the most sensible approach here would be to use industrial grade pellets produced at a pellet factory to produce the electricity used in the factory and the heat needed to dry appropriate raw material to produce high value 'Grade A' pellets. It may also be desirable to mix landscape management arisings with wood in order to produce Grade A pellets.

By identifying a local raw material supply and a local need for heat it is possible to match up local supply and demand. The land owner, such as the Forestry Commission, usually has a need for heat in office buildings. When a boiler replacement is due, if an appropriate boiler can be specified, there is an ideal opportunity for establishing a local supply of pellets made from raw material sourced from the user's own land.

This may be true of the Forestry Commission, the local council, estates, schools, hospitals and so on. By assessing local heating requirements and working with end users the landowner has the opportunity to become a fuel or even heat supplier (perhaps under an ESCO approach). In this way the cost of managing the land is covered, income generated and renewable energy produced locally.

James Little
Harvest wood Fuels
28th July, 2010

APPENDIX A – QUALITY STANDARDS FOR PELLETS IN EUROPEAN COUNTRIES

Specification	Austria ÖNORM M7135		Sweden SS 18 71 20			Germany DIN 51731 / DIN plus			CEN 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 x Diameter	
						HP1	>30	>10	D08 ≤ 8 mm ± 0,5 mm and L ≤ 4 x 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				
EDX, 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 : 10/MAY/COA/7849
 Customer : Harvest Wood Fuels
 Grange Road
 Tilford
 Farnham
 Surrey
 GU10 2DQ
 Date Received : 28th May 2009
 Sample Date :
 Date Analysed : 28th May to 9th June 2010
 Report Date : 9th June 2010
 Customer Reference :

Test Method	Sample Reference	Heather 7/4/10	Gorse 28/4/10
SP 21	Mechanical Durability (%)	99.3	97.9
SP 20	Total Moisture %	10.9	10.1
CA 3	Ash %	1.7	6.6
CA 6	Volatile Matter %	71.4	66.6
CA 31	Sulphur %	0.07	0.08
CA 11	Gross Calorific Value kJ/kg	18739	17971
*	Calorific Value kJ/kg (DAF)	21440	21570
*	Net Calorific Value kJ/kg	17351	16663
CA 9	Carbon %	46.52	42.25
CA 9	Hydrogen % **	3.07	4.50
CA 9	Nitrogen %	0.70	1.28
Test results calculated to "As received" Moisture Basis*			

TES Bretby does not accept responsibility for the sampling relating to the above results.
 * Calculated using determined value, ** Hydrogen corrected for moisture.

Report Authorised By 
 Jonathan Clay
 (Energy Services Reporting)



1253

Report Number : 10/MAY/COA/7849
 Customer : Harvest Wood Fuels
 Grange Road
 Tilford
 Farnham
 Surrey
 GU10 2DQ
 Date Received : 28th May 2009
 Sample Date :
 Date Analysed : 28th May to 9th June 2010
 Report Date : 9th June 2010
 Customer Reference :

Sample Reference	Ash Fusion Temperatures (°C) **			
	Initial Deformation	Softening	Hemisphere	Flow
Heather 7/4/10	1030	1130	1150	1170
Gorse 28/4/10	1040	1270	1380	1470
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)



Report Number : 10/JUN/COA/8013
 Customer : Harvest Wood Fuels
 Grange Road
 Tilford
 Farnham
 Surrey
 GU10 2DQ
 Date Received : 7th June 2009
 Sample Date :
 Date Analysed : 7th to 16th June 2010
 Report Date : 16th June 2010
 Customer Reference :

Test Method	Sample Reference	Rhododendron
SP 21	Pellet Durability (%)	96.6
SP 20	Total Moisture %	6.2
CA 3	Ash %	0.7
CA 6	Volatile Matter %	78.1
CA 31	Sulphur %	0.02
CA 11	Gross Calorific Value kJ/kg	18643
*	Calorific Value kJ/kg (DAF)	20020
*	Net Calorific Value kJ/kg	17317
CA 9	Carbon %	47.19
CA 9	Hydrogen % **	5.24
CA 9	Nitrogen %	0.39
Test results calculated to "As received" Moisture Basis*		

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

* Calculated using determined value. ** Hydrogen corrected for moisture.

Report Authorised By
 Jonathan Clay
 (Energy Services Reporting)





1253

Report Number : 10/JUN/COA/8013
 Customer : **Harvest Wood Fuels**
 Grange Road
 Tilford
 Farnham
 Surrey
 GU10 2DQ
 Date Received : 7th June 2009
 Sample Date :
 Date Analysed : 7th to 16th June 2010
 Report Date : 16th June 2010
 Customer Reference :

Sample Reference	Ash Fusion Temperatures (°C) **			
	Initial Deformation	Softening	Hemisphere	Flow
Rhododendron	920	1010	1060	1100
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)