



Coed Cymru Product Development  
Glasu Project GEO20  
Pelleting alternative Materials



**An Investigation of the Feasibility of Preparing Fuel Pellets from a Range of Agricultural and Other Materials**

**Final Report**

**Aim of the project**

The aim of the project was to determine whether satisfactory fuel pellets could be made from non-wood biomass with a view to expanding the range of raw materials that could be utilised as fuel. Evaluations of the availability of resource and the economic viability of converting into pellets were also carried out.

**Background**

The conversion of timber and timber co-products into fuel pellets and the installation of suitable heating appliances has become a major business, particularly in Europe, during the last 10 or more years. In the UK, however, the industry has been slow to take off due in part to uncertainties over pellet supply. Balcas, in Northern Ireland, has a plant capable of manufacturing 50,000 tonnes of pellets annually and Welsh Biofuels, in Bridgend, is able to supply a number of pellet installations.

However, Balcas and many of the European pellet producers are sawmills or linked to sawmills so are in control of the supply of consistent raw material that does not appear to have competing markets. In Wales most sawmill co-product is used for particle board manufacture. Material that might be available from smaller sawmills and from wood using businesses tends to be of variable moisture content and quality (including mixed species) and even some of this may be in high demand by the relatively lucrative animal bedding and cat litter markets. Consequently, the development of pellet production in Wales (as well as in England) has not been rapid.

One solution might be to utilise other raw materials such as agricultural straws and other co-products, depending on their availability and cost. It was not known if it would be possible to convert these materials into pellets or how they might perform on combustion. At Coed Cymru we have a small scale Farm Feed Systems pellet mill that has been used for experimental and demonstration purposes, so it was decided to perform trials on a range of materials. One important aspect is the economic viability of producing pellets from materials that may already have a market value, and being able to match the production cost to the market price.

**Methodology**

**Materials to be Pelleted:** These were selected partly on availability and partly on their low value and/or that they are considered as waste

**Straws and grasses:** Wheat straw, oat straw, oilseed rape straw, hemcore (from hemp) miscanthus (actually grown as an energy crop), lavender (from France)  
**Oilseed cakes:** rape, camelina (the seed contains high levels of omega 3 oil, obtained from Mentera)

**Unwanted farm 'crops':** Bracken, rushes (juncus), garden prunings (largely roses)

**Timber wastes:** Miscellaneous landfill timber (solid wood only), plywood. These were included as their inconsistency makes them harder to pellet and it had been suggested that combinations with other materials such as oilseed cake may be of benefit.

**Silage wrap:** This was shredded and mixed 10% with wood sawdust. It lubricated the mill and made excellent pellets. In theory, as the plastic is composed solely of carbon and hydrogen it would be an ideal way of using the waste except that it is classified as waste that cannot be burnt without special licence.

**Shredding:** Generally all material had to be taken down to a moisture content around 15% by weight (10 – 20 % was the general range, although some bracken was nearly 30%). Some was already below this whilst some was very wet and needed to be dried in an oven. To reduce the size to that suitable for the pellet mill, all material was put through a Dragon Machinery shredder with a 4mm screen (Pencader, Carmarthenshire, 01559 384303). The straws and grasses usually needed to be passed through twice to reduce the percentage of long lengths that had managed to pass through the screen.

**Pelleting:** The pellet mill is a Farm Feed Systems (Cinderford, 01594 825106) 10 HP small scale mill, originally used for on-farm preparation of pelleted feed, but with a reduction in the gearing to cope with timber. The extrusion holes in the ring die had been tuned to be suitable for hardwood and softwood. The mill has controlled feed speed, and vegetable oil and water can be added at variable rates as desired. The oil lubricates and reduces friction to reduce compression in the die whilst the water increases friction and compression. Both can act to a certain extent as binders. The ability to add variable amounts of oil and water means that the mill can produce good pellets from a range of different types of timber so should be ideal for other materials. It will produce 20 to 80kg pellets per hour, depending on the feedstock.

A minimum of 20kg of each of the test materials was shredded and at least 5kg (generally more) put through the mill. Mixtures were prepared from the pre-shredded components just prior to pelleting. The mill was operated to achieve hard pellets of up to 20mm in length.

**Analysis of Pellets:** The density (weight per litre, with a target of about 650g/litre) and moisture content were determined. Hardness was determined subjectively. Samples were not formally tested for this as there would inevitably be refinements to the process if they were to be manufactured in bulk.

**Combustion properties:** 1kg pellets was burnt in the Coed Cymru room heating stove (Envirofire EF III). The ease of ignition and quality of burn were noted and the ash in the burning pot collected, weighed and the presence of clinker noted – fly ash was not considered, although comparing our ash estimations with those of Cardiff University this did not appear to be significant.

The pellets were sent to The Department of Engineering, University of Wales where Richard Marsh carried out quantitative measurements of the pellets (moisture content, sulphur content) followed by complete combustion and determination of calorific value, weight and analysis of the ash (weight, fusion temperature, 18 element analysis). Some of this information will be useful in identifying the type of boiler that the pellets could be compatible with.

**Market factors:** The likely profitability of producing these pellets was also estimated. Current market values or collection (harvesting) costs of the raw materials, strength of competing markets, pelleting costs, current cost of wood pellets were used to evaluate the market potential of the different pellets.

## **Results**

### **Ease of Pelleting (Tables 1 and 2)**

It was possible to produce pellets from most materials, though they varied widely in their ability to be pelleted successfully. Some of the straws and grasses tended to be more difficult. This is similar to what has been observed with timber, with some types being particularly difficult to pellet or which produce very short pellets. As with timber, it is probable that success with the alternative materials will depend on the material, its moisture content, its form and consistency and the type of die in the mill. The addition of small amounts of vegetable oil and/or water sometimes made a big difference. These parameters can all be varied, although it might be a slow process to hit upon the right formula for some materials.

What was clear was that the addition of oilseed cake (the residue from the extraction of the oil) tended to facilitate the production of the pellets and to produce a better quality (ie longer and firmer) pellet. Although this was the case with the agricultural materials (straws and miscanthus) it was particularly striking with waste wood products like plywood and landfill timber. The latter can be hard to pellet because it is very inconsistent – random mixtures of softwood and hardwood of different species. Inclusion of a percentage of whole wheat (grain) had the same effect, even though the wheat alone produced a pellet that burned poorly.

### **Combustion properties, ash.**

Most of the wood and straw based pellets lit easily and burnt well. Other agricultural/food co-products were harder to ignite and burnt with greater difficulty, but mixtures of a proportion of, say oilseed cake with wood or other material, burnt well.

**Ash quantity:** Some of the alternative materials produced large amounts of ash. For example, wheat straw pellets gave about 30 times more ash than softwood pellets (Table 4). This is a significant issue when considering the potential market for these pellets. Coed Cymru's own room heater pellet stove does not have automated ash removal so with some pellets the burn pot could fill up in an hour. The stove would have to be switched off, cooled and the ash removed – this is not acceptable. Boilers and stoves would need a good system of automated ash remove. (This is discussed later) High ash levels will also be a problem if a proportion becomes fly ash that can foul flues and heat exchangers.

**Ash quality:** Some ashes have a relatively low fusion temperature (Table 4) and melt to form a sinter or a hard slag on cooling. Miscanthus was particularly bad for this and is recognised as a potential problem with miscanthus. A stove or boiler run on this type of pellet would need to be able to cope with this. Some boilers with underfed burners might manage, but I would suggest a moving grate or horizontal feed, such that the ash and any sinter or slag will be pushed off the edge rather than pour back into the up-feeding pellets. This would help solve the problems caused by high ash volume and the accumulation of sinter or slag.

Another option may be to raise the fusion temperature of the ash. Table 4 shows that where silicon (Si) is present in appreciable amounts in the ash, the higher the ratio of calcium plus magnesium (Ca + Mg) relative to potassium plus sodium (K + Na), the higher the fusion temperature. Sintering and slagging can be reduced either by selecting raw materials to be pelleted to give a suitable ratio or by including a calcium source such as lime. (See 'The Quality of Pellets Made from Alternative Biomass', Klaus Hjuler, World Sustainable Energy Days 2007, O.O. Energiesparverband.) The downside is that this will increase quantity of ash.

**Combustion products:** Some materials (especially from brassicas) produced pellets that contained significantly higher levels of sulphur than wood pellets (Table 3). (Unfortunately we were unable to assay for chlorine) The level of sulphur in oilseed rape straw pellets was higher than the top value given in wood fuel standards CEN/TC335, although this is only normative where sulphur containing pressing additives are used (one would argue that oilseed rape cake and wood are 'blends').

Probably the main issue is the potential for serious corrosion of the combustion equipment and flue by sulphates and chlorides either in the ash or given off during combustion, and this has been recognised for some time (see the Klaus Hjuler paper above). It was beyond the scope of this work to pursue this, but anyone wishing to produce pellets from alternative materials should ensure that combustion equipment is suitable for the type of pellets they are considering making. It is possible that equipment that was originally designed for burning coal may be less susceptible to such problems.

The flue gasses may contain higher levels sulphur, chlorine or nitrogen compounds originating from pellets made with materials other than wood. I am uncertain whether this could be a problem under current emissions/clean air act legislation but I would hope that no-one is currently formulating stringent legislation that would inadvertently prevent the combustion of alternative materials merely based on a hypothetical precautionary principle.

### **Economics of producing pellets, market issues**

We are unable and reluctant to provide costings for the actual manufacturing process of producing pellets containing alternative materials. It would be highly dependent on the scale of the operation, capital cost of new/refurbished equipment and its running time and labour requirement. One could get a rough idea of total business costs by looking at the animal feed industry where the cheapest lower grade feed pellets (that might contain similar agricultural raw materials) could be delivered for under

£135/tonne (4 tonne minimum) at the start of this project. This was less than the price of wood pellets and less than the price of heating oil.

To-day the market for agricultural products and costs are changing rapidly, with expanding demand for food in China, drought affecting wheat in Australia and, particularly, the target-driven demand for biomass energy and biofuels all driving up costs and prices. Selecting and even finding raw materials that can be pelleted into a fuel that is comparable in price to oil is becoming increasingly difficult. Even timber co-products suitable for pelleting are expensive and hard to find (most going animal bedding and cat litter). Power stations are mopping up large quantities of food and farm co-products (138,000 tonnes of palm kernel last year) and paying good prices, as well as taking in timber waste. On top of this, the cost of investing in and operating a pellet line can be significant, particularly if it is small scale, so a reliable supply of low cost raw material will be needed to keep costs down. On the other hand the market price for pellets is fairly high and can be well in excess of the current oil price for domestic users (possibly £140 up to way over £200 per tonne with the oil equivalent price at £145). There is a market willingness to move to a sustainable fuel and a fear of increased fossil fuel prices.

### **Prospect for pelleting alternative materials**

The summary table below lists the materials that were tested and summarises their potential for use in pellets. Some materials may be too expensive resulting in an unaffordable pellet, others may pose problems in terms of ash quantity and quality. Bracken (and possibly rushes) are interesting in that they usually have no other commercial value so the material cost is only that of mowing and baling. Miscanthus is being grown as a dedicated energy crop, so pelleting is an obvious option as long as the ash can be accommodated.

This work has shown that it is technically possible to produce pellets from a range of alternative materials. It has also shown that there may be issues associated with the ash and combustion gasses and that one must ensure that the boiler or stove is compatible. The economics of manufacturing pellets will depend very much on the cost of the raw material, so for anyone considering establishing a business this should be the first consideration. Having one's own material, especially if it has low value, would be a big advantage. Given that there is a limited amount of wood-based raw material for making pellets, further development of the use of pelleted fuel may depend on a move to alternative materials.

For further information or to discuss details of pelleting alternative materials please contact Andy Stewart, Coed Cymru 01686 650777 or [andys@coedcymru.org.uk](mailto:andys@coedcymru.org.uk)

**Whilst every effort is made to ensure that the enclosed information is accurate, anyone considering making financial commitment should obtain independent advice.**

## Summary of the Potential for Producing Pellets from Alternative Materials

Material	Cost <i>Ease of pelleting</i>	Ash	Sulphur	Pellet Potential
Landfill timber	Could be low or negative cost <i>Hard to moderate</i>	Low	V.low	Very cheap but may need rape cake to improve pellet quality. Risk of contamination?
Bracken	Low cost, mowing and baling probably cost up to £15/tonne <i>Moderate to easy</i>	Med/high	Low	Low cost, may be reasonable amount available, low sulphur. Ash (high potash) OK for organic crops.
'Garden waste'	Low <i>Easy</i>	Med/high	Low but may vary	May be too mixed and unpredictable but low cost, suitable for power stations?
Hemcore	High – good markets in animal bedding <i>Moderate</i>	Med	Low	Probably too expensive due to competing uses (animal bedding, insulation)
Lavender	Cutting and baling costs only – may already be done <i>Easy</i>	Med/high	ND	France only – low cost, large quantities, good potential
Miscanthus	£45/odt but may need to be higher to attract growers <i>Moderate</i>	Low/med	Low	May need to be expensive to encourage production potential for high production. Ash and slagging may be a problem
Oilseed rape cake	£90/tonne	(Med/high?)	High	Expensive, competing markets forcing price up, but may be good as a blend to facilitate use of other materials
Oilseed rape straw	Baling cost only? <i>Hard to moderate</i>	High	High	Tends to be ploughed in? Could be a good material, low cost, but ash and sulphur high
Rushes	Mowing and baling cost only, up to £15/tonne <i>Easy</i>	Med/high	Med	Low cost but may not be large quantities. A niche market?
Wheat straw	Locally about £45/tonne delivered but can be much higher <i>Hard to moderate</i>	Very high	Med	High ash, high price variability, may be other demands when needed.
Wheat grain	£95 per tonne + delivery <i>Easy</i>	Med	ND	Expensive but best used as a binder
Willow	£45/odt but probably nearer £90/odt to attract growers <i>Hard to moderate</i>	Low/med	ND	Need to dry (drying costs?). May be expensive as need high price to encourage production. However, potential for high production.



**Appendices: Table 1 Non-wood materials**

Material	Ease of pelleting	Pellet quality			Combustion		Ash	
		Length	Density	MC%	Lighting	Burning	%	Quality
Apple pulp (dried)	Easy	20mm	0.75	6	Bit slow	Fairly good	1.45	Light grey 15% sinter
Bracken	Moderate to easy	5 – 15mm	0.61 Hard	14	Easy	Good	3.38	Dark, 25% sinter
Camelina cake	Easy	20mm	0.58 Soft, crumbly		Very hard	Moderately well	4.8	Large volume 5% sintering
Garden clippings (roses)	Easy	20mm	0.69 Fairly hard	16	Bit slow	Good	3	Pale wormy Little sinter
Hemcore	Moderate	3 - 12mm	0.67 Hard	8.4	Easy	Very good	2.7	Pale grey/buff powdery 20% sinter
Hemcore + 20% rape cake	Moderate/easy	8 – 20mm	0.67 Hard	8	Easy	Very good	3.33	Pale grey/buff powdery 5-10% sinter
Lavender (France)	Easy	20mm	0.75 V. hard	4.8	Slow	Bit slow	3.54	Beige/grey 10% sinter
Miscanthus	Moderate	2 – 12mm	0.62 Hard	8	Easy	Good	1.07	Mid/dark grey 35% sinter – (very hard)
Miscanthus + 20% camelina cake	Moderate/easy	8 – 20mm	0.7 Fairly hard	8.8	Easy	Good	1.83	Mid grey 35% sinter (soft)
Mixed agriculture/ etc residues	Easy	20mm	0.7 Hard		Hard	Slow	5.1	Wormy, no sinter
Oat straw	Not easy	5 – 15mm	0.54 Soft, crumbly	10.4	Easy	Very good	3.7	Dark grey, wormy 40% sinter
Rape straw	Not easy	8 – 15mm	0.67				5.21	
Rushes (juncus)	Fairly easy	8 – 18mm	0.67 Hard	13.2	Easy	Fairly good	3.46	Dark, bulky 5% sinter
Wheat straw	Hard to Moderate	10 – 20mm	0.64 F. hard	12.2	Easy	Very good	6.1	Black 15-20% sinter
Wheat straw + 20% camelina		12 – 20mm	0.7 F. hard		Easy	Very good	5.4	Black, 15% sinter
Wheat grain	Fairly Easy	15 – 20mm	0.76 Hard	11.2	Very hard	Moderate to poor	2.46	Black, 40% soft sinter
Willow	Moderate needed oil	Up to 20mm	0.66		Easy	Good	1.0	

**Table 2 Wood waste plus oilseed cakes**

Material	Ease of pelleting	Pellet quality			Combustion		Ash	
		Length	Density	MC	Lighting	Burning	%	Quality
Landfill timber (solid wood )	Not easy	4 – 10mm Short	0.7 Fairly hard		Easy	Very good	0.46	Very dark no sinter
Landfill timber + 6–10% oil	Moderate	10 – 20mm	Bit soft					
Landfill timber plus 20% oilseed rape cake	Fairly easy	10 – 20mm	6.4				1.23	Grey 15% sinter
Plywood scrap	Very difficult	1 – 4mm			Not enough			
Plywood + 10% camelina cake	Moderate	Inconsistent	0.6		Easy	Good	1.08	
Plywood + 50% camelina cake	Easy	20mm	0.67 Hard		Easy	Good	2.11	Very pale grey, bulky <2% sinter
Plywood + 25% wheat grain		10 - 20mm	0.71	7.6	Easy	Fairly good	1.83	Light/mid grey 5% soft sinter

**Table 3 Formal analysis**

Pellet	Calorific value MJ/kg		MC%	Sulphur %	Ash %	Ash fusion temperature (°C)
	As rec.	Dry				
Softwood	18.94	20.5	7.4	0.016	0.2	1400
Oak	18.08	20.16	9.7	0.02	0.6	1450
Bracken	18.37	21.54	11.4	0.09	3.4	1050
Rushes	17.14	20.24	3.9	0.15	3.9	1050
Garden clippings	16.9	20.34	13.53	0.07	3.4	1250
Wheat straw	17.51	21.7	11.1	0.14	6.2	1100
Rape straw	17.33	20.34	11.1	0.3	5.2	1550
Hemcore	18.93		7.67	0.055	2.5	
Hemcore + 20% oilseed rape cake	19.62		8.52	0.119	3.3	
Miscanthus	19.22		7.14	0.043	1.0	
Miscanthus +20% camelina cake	19.59		7.36	0.152	1.6	
Landfill timber	18.55	20.59	9.4	0.038	0.5	1350
Landfill timber +20% oilseed rape cake	20.88	23.0	7.9	0.104	1.3	1250

**Table 4 Elemental analysis and fusion properties**

Pellet	Ash % (Table 3)	Ash % (Table 1 & 2)	Sinter %	Ash fusion temp (°C)	Elements in ash: % by wt				
					Si	K	Na	Ca	Mg
Softwood	0.2	0.24		1400	9.2	5.6	1.1	26.2	3.9
Oak	0.6			1450	6.6	5.9	0.6	26.4	4.0
Bracken	3.4	3.38	25	1050	17.4	13.6	1.4	11.1	3.1
Rushes	3.9	3.46	5	1050	8.7	12.5	10.4	7.36	6.1
Garden clippings	3.4	3.0	Very little	1250	11.6	11.3	1.2	18.2	3.2
Wheat straw	6.2	6.1	20	1100	24.4	8.6	0.3	6.1	1.5
Rape straw	5.2	5.21		1550	2	23.5	1.1	17	2.4
Hemcore	2.5	2.7	20						
Hemcore + 20% oilseed rape cake	3.3	3.33	5 – 10						
Miscanthus	1.0	1.07	35						
Miscanthus +20% camelina cake	1.6	1.83	35						
Landfill timber	0.5	0.46		1350	7.4	6.5	3.2	17.8	2.8
Landfill timber +20% oilseed rape cake	1.3	1.23		1250	3.6	12.5	1.1	13.0	5.7

