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Brash bale production on a clear-felled farm forest and comminution of bales to a biomass energy fuel

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ABSTRACT

Utilising logging residues (termed brash in the UK) for energy production has become a focus for energy providers since the development of specialist baling machinery to improve the logistical and financial potential of this material. To explore a farm-scale operations scenario, brash from a mixed conifer, temperate zone forest was baled and chipped with commercial machinery to produce fuel-grade woodchip. Clear-fell logging procedures presented a range of brash configurations to facilitate baling machinery to produce compacted, tied, regular sized bales. Average hourly bale production and fresh weight tonnage output was 28 ± 2 bales/h and 12.4 t/h respectively. Extraction of bales and stacking along access road verges achieved an average 24 ± 2 bales/h. Woodchipping output averaged 11.8, 13.7 and 13.0 green t/h respectively for whole bale, log only and bale-log composite woodchip. Chipping production efficiency was affected by bale condition, handling and machinery performance but chiefly by site transport accessibility and logistical planning. The average total cost of in-farm delivered fuel quality woodchip product from brash bales was £25.22 (€29.67) per green tonne. Brash bale chips contained more than double the percentage of fines <6.3 mm compared to round log woodchips and also had significantly higher gross energy and nutrients content. Brash bale moisture content was observed to fluctuate widely and nutrients and energy content reduced during the 3-yr monitoring period. In conclusion, the combination of equipment and the confined production scenario was a viable process that provided fuel-grade woodchip at relatively low cost.

1. Introduction

The pressure on European governments to reduce dependence on the use of imported fossil fuels and to reduce emissions of greenhouse gases (GHG) has increased greatly in recent years. The European Directive ‘Energy Policy for Europe (2007)’ [1] aims to force all member states to comply with respective legislation, requiring a minimum 20% of total energy use from sustainable renewable energy sources. Of this some 20% must come from biomass energy, encompassing energy crops, farm and food waste, and forest produce. Also incumbent on Member States is the 1998 Fuels Quality Directive (DIR 98/70) requiring fuel suppliers to furnish life cycle GHG emissions from production to end use. Formalised by the Commission in 2007 this is currently under review [1]. In

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response to these challenges the United Kingdom (UK) Government has produced a UK Biomass Strategy [2] which comprehensively covers the many existing and potential biomass energy supply and utilisation schemes. Due consideration is also given to environmental issues arising from these proposals, not least in land use change and forest production methodology. Landscape alteration, terrain conditions and soil nutrient status are all recognised areas of concern [3].

Forestry logging residues (LR) referred to as *brash* in the UK, have the potential to contribute up to 1 million tonnes (t) of biomass for energy in the UK [4]. These residues consist of the various fractions of the trees left after logging, log tops, tree crowns, branches, off-cuts, small trees and needles or foliage. Generally, this product has little or no commercial value and historically in Northern Ireland (NI) these materials were utilised for vehicle support and ground protection as a brash mat and then mechanically re-distributed over the clearfell site to assist re-stocking. Loose brash collection and transport has very high costs due to its low bulk density but compaction can alter this significantly [5]. Also critical are the harvesting techniques applied during clearfell operations as brash formed in specific, rather than random layouts during felling, aids baling [6]. Lately, the development of new forestry machinery specifically designed to gather, compact and produce bound brash bales, has created the possibility of using this material as a biomass energy source giving it an economic value over and above loose brash comminution [7]. Adoption of this type of technology could enhance the energy and financial performance of small scale biomass energy and realise the potential of large brash resources in the UK [4] for similar schemes.

At Hillsborough, in Northern Ireland, the Agri-Food and Biosciences Institute [AFBI] have developed an Environmental and Renewable Energy Centre (EREC) on its 300 ha research farm. This generates both thermal and electrical output from biomass and other renewable resources, supplying space heating and hot water via a district heating loop to offices, laboratories and farm buildings. Two biomass fired boilers; *a*) a Froling 320 kW(T) woodchip boiler and *b*) a 110 kW(T) Bio-Kompakt multi-fuel boiler provide the majority of hot water for office and space heating. The former (*a*) was designated to run continuously on three different chipped wood fuels; (1) locally sourced Short Rotation Coppice (SRC) willow, (2) on-farm harvested round log (RL) and (3) brash. To provision the latter, a 10 ha forest of mixed conifer and a small poplar stand within the farm boundary ~1.7 km distance of the EREC was selected for clear-felling. The confined locality and short travel distances of the operation potentially reduced many of the logistical problems normally associated with LR recovery [6,7]. During this work Forestry Commission (UK) Brash Management best practice guidelines [8] were closely observed and all aspects of the operation were conducted with due diligence to environmental and habitat protection while maximising efficiency of production.

The lack of homogeneity of chipped wood fuels, whether derived from round wood or brash, presents a range of important but not insurmountable problems for combustion equipment [9]. Moisture content (MC), normally ~50% for most fresh wood, must be reduced to at least 25% and preferably <20% for efficient functioning of most wood fired boilers [9]. Particle size range is important in that the proportion of fine particles (<1.2 mm) can cause problems in forced air drying systems [10,11] and during combustion can increase particle emissions in flue gases [12]. The use of a single screen gauge to produce regular size chips from different source materials is desirable to ensure a degree of homogeneity in fuel chips through the proportion of fines. This is especially important for automated auger and feed mechanisms in biomass boilers, to reduce the likelihood of blockages and resultant downtime [9]. Health and safety issues relative to microscopic particle ingestion and infectious air-borne spores from fungal and bacterial colonisers of stored woodchip are also important factors in woodchip production and handling [13].

Fuel quality is affected by chip size, particle distribution, storage and drying [14,15]. Long term storage methods of brash as bundles or as chips can have significant effects on wood mass, nutrient content and energy value [16,17]. Climatic conditions affect MC, with moisture absorption by wood (which is a hydroscopic material) possible in wet, high humidic conditions and over the longer term DM and energy value can also decrease in stored brash [15,16]. Nutrient content, nitrogen (N), phosphorus (P), potassium (K) and energy (MJ/kg) of wood fuel and boiler ash residues are also considered important factors in LR utilisation. This affords the possibility of recycling the by-products of combustion to the clear-fell site as a means of returning known amounts of nutrients removed during bale production [3].

In view of this background an experiment was conducted at AFBI Hillsborough to monitor, record, analyse and assess the feasibility of harvesting and utilisation of LR as brash bales and the production of woodchip from brash bales, by using a combination of farm machinery and heavy duty forestry equipment, to provide biomass energy in an on-farm energy unit.

2. Materials and methods

2.1. *Site description*

The clear-fell area (Global grid reference: 54.451691, −6.072543) contained mature mono-stands of 4.2 ha Sitka spruce (*Picea sitchensis*. L. sp) and 5.2 ha Lodgepole pine (*Pinus contorta*. L. sp), both species planted in 1978. The site, elevation 160–170 m AMSL, had gentle gradients 1:15 to 1:20 but a rough topography in places, mostly within Lodgepole pine stands, with rocky exposures of the Greywackes and Siluran shale solid geology emergent in the poor quality red/brown glacial till topsoil on boulder clay, which also composes the parent bedrock. Forest access roads were single lane (~4 m wide) unsurfaced compacted stone.

2.2. *Harvesting and brash preparation*

Harvesting with a Valmet 901 single grip harvester, began during January 2007, continuing for 6 weeks, with log extraction to roadside by a Valmet 860 forwarder. The trials were conducted in Sitka spruce (Ss) and Lodgepole pine (Lp) stands, both species planted in 1978. The Ss was relatively uniform in growth (yield class 16) within stands, whereas a high proportion of Lp stems