The use of wood as a renewable source of energy in Ireland – developments and knowledge gaps in the control of wood fuel quality

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Abstract
In Ireland, on the basis of recent consumption and a favourable policy environment, the use of wood for energy is increasing. However, there are issues to address in order to realise policy targets for increasing wood energy consumption. Among these issues is a need for information on the impact of wood properties on the fuel quality of wood. Comprehensive knowledge of wood fuel properties assists in the optimisation of operations concerned with the harvesting, seasoning, processing and conversion of wood into energy. In Ireland, wood fuel property databases of forest biomass fuel sources are absent. This paper documents an overview to the developments that have necessitated a need for such databases, and current research that is being conducted to address knowledge gaps on the wood properties that have an impact on fuel quality.

Keywords: *Wood, energy, research, quality, trade.*

Introduction

In Ireland, consumption of wood for energy has increased in recent years for a number of concerns. The heavy dependence on finite resources of imported fossil fuels, declining indigenous energy production, and the adverse effects of climate change have been the key factors driving this increase. In response to these issues, a series of policies have been ratified, initially out of concerns for global climate change. The Kyoto Protocol set out aims to reduce greenhouse gas emissions (GHG) by 5.2% globally. Ireland, as a signatory of the Kyoto Protocol, has agreed to limit the growth in GHGs to 13% above 1990 levels by a target period of 2008–2012 (North and Healion 2003, Government of Ireland 2007). The Kyoto protocol commitments thus instigated a number of initiatives by the Irish Government to formally develop strategies in the effort to mitigate climate change. Among these strategies included increasing the use of renewable energy resources. The Energy Policy White Paper, in particular the Sustainable Energy Sub Programme, committed to an investment of €276 million for the development of a renewable energy sector in Ireland over the course of the National Development Plan (NDP) 2007–2013 (Department of Communications, Marine and Natural Resources 2007a). The Irish Bioenergy Action Plan outlined where this Government

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investment should be implemented for the development of a renewable energy sector in Ireland, including recommendations for increasing wood energy consumption (Department of Communications, Marine and Natural Resources 2007b). The EU Renewable Energy Directive (RED, 2009/28/EC) set out a commitment that 20% of total energy use is to be derived from renewable energy resources by 2020. In accordance with this directive, Ireland has committed to a 16% target for renewable energy resources by 2020 under the National Renewable Energy Action Plan (NREAP 2010). Targets under this plan relevant to wood consisted of the following (NREAP 2010).

- 12% renewable heat energy generation by 2020;
- 30% co-firing with biomass at the 3 peat-fuelled power plants by 2015;
- 800 MW of Combined Heat and Power by 2020.

The realisation of these targets poses significant challenges. Despite a favourable policy environment, the consumption of wood for energy in Ireland is underdeveloped. This paper documents the incentives in place to assist in the development of a wood energy sector in Ireland, and the challenges in maintaining and increasing consumption to fulfil policy targets. Research to support the development of a wood energy sector will also be documented. In particular, this paper will focus on research into wood fuel trade standardisation and quality control, as these have an influence on instilling consumer confidence into using wood for energy.

Emergence of wood energy consumption

In Ireland, there is an unsustainable reliance upon imported fossil fuels, as 95% of total primary energy requirement (TPER) is derived from fossil fuels and 88% of TPER is imported (Dennehy et al. 2012). This leaves Ireland in a precarious position in attempting to maintain security of fuel supplies. As a result the consumption of renewable energy resources should be increased (wind, solar, geothermal, biomass, tidal, wave and hydro), because they are underutilised, indigenous and do not pollute the atmosphere (O'Rourke et al. 2009). In 2011, the contribution of renewable energy to TPER was 6.5% and fell under three sub-categories; electricity (RES-E), heat (RES-H) and transport (RES-T) (Dennehy et al. 2011). Wood contributes mostly to RES-H consumption. Moreover, wood can also contribute to RES-E generation by means of co-firing and combined heat and power (CHP). Co-firing refers to electrical energy generation through the mixture of biomass and non-biomass sources, whereas CHP is a single process where thermal and electrical energy is generated together (REFIT III 2012). RES-H accounted for 5% of all thermal energy produced in Ireland during 2011, with 77.5% derived from biomass fuels in general (Dennehy et al. 2011). Since 2008 to the present, a series of documents have provided specific year-by-year estimates of wood energy consumption in addition to those incentives already in place to increase its use (Knaggs and O'Driscoll 2008, Knaggs and O'Driscoll 2012b). In 2011, 33% of the total round-wood harvest in Ireland was used for energy purposes and has made an overall contribution of 0.81% to TPER (Knaggs and O'Driscoll 2010, Knaggs and

Table 1: *Consumption of domestic, commercial and industrial wood fuel products (per 000m³) during the period of 2008-10 (O'Driscoll 2011).*

Product	End user	2008	2009	2010
Firewood	Domestic heating	171	184	199
Roundwood chipped in forest	Commercial heating	63	53	39
Short rotation coppice	Commercial heating	1	4	1
Wood pellets & briquettes	Domestic heating/commercial heating	82	110	121
Charcoal	Domestic use	2	2	2
Energy and forest products industry consumption	Process drying/heating/combined heat and power	384	418	554
	Total	**703**	**791**	**916**

O'Driscoll 2012b). Table 1 provides a breakdown of the consumption of wood for energy in Ireland.

Table 1 indicates that the forest products industry is the largest consumer of wood energy at 55–60% of the total. Markets for densified fuels such as wood briquettes and pellets have also been increasing in recent years in Ireland, as they are a cost competitive heating alternative to oil and gas for domestic and commercial heating (Knaggs and O'Driscoll 2008). Firewood for domestic use has also increased in recent years, particularly due to the increased availability of wood from private sector first thinnings (Knaggs and O'Driscoll 2012b).

The emergence of this increased use of wood for energy also coincides with the development of incentives and other policy mechanisms to promote an increase in its use. A carbon tax on fossil fuel sources was introduced by the Irish Government through the Budget and Finances Act 2010, with exemptions made for renewable energy resources and participants in Emission Trading Schemes (ETS) (Department of Finance 2010). This tax included a charge of €15 tonne^{-1} of CO_2 emitted, since increased to €20 tonne^{-1} (Department of Finance 2010, Department of Finance 2012). Coinciding with the introduction of this tax, fossil fuel consumption has reduced, but this is mainly due to the economic downturn Ireland has experienced (Gargan 2012). These carbon tax regimes initially covered fossil fuels such as mineral oil and gas, whereas solid fuels such as coal were not included. This was due to a need for the development of trade specifications for the sulphur content levels allowable for residential consumption of coal in Ireland (Department of Finance 2010, Gargan 2012). However, solid fossil fuels such as coal and peat have now been ratified for inclusion under carbon tax regimes as of the 1st May 2013 (Revenue Commissioners 2013).

Contractually binding fixed price tariff mechanisms for renewable energy producers over the course of fifteen years under the Renewable Energy Feed-In-Tariff scheme is another example of an incentive to stimulate wood energy consumption (REFIT III 2012). A variety of grant schemes with funds totalling €89 million have been made available under the direction of the Sustainable Energy

Authority of Ireland (SEAI) (Knaggs and O'Driscoll 2010). Domestically and commercially, the Greener Home and ReHeat schemes provided grants for the installation of renewable energy technologies. Among the technologies approved for grant aid are wood chip and wood pellet stoves and boilers (Knaggs and O'Driscoll 2010). Other grants available include the CHP scheme, which provides grants for the installation of biomass powered CHP facilities (Knaggs and O'Driscoll 2010).

According to Phillips (2011) there are three wood pellet manufacturing facilities and three CHP plants operating in Ireland using wood fuel. As of 2009, products such as wood chip, sawdust and pellets contributed to 66,000 tonnes to co-firing of peat with biomass at Edenderry Power (Reilly 2010). This biomass consumption for co-firing has since increased to 156,000 tonnes as of March 2012, with the majority of this biomass sourced from the sawmilling and forestry sectors (Bord na Móna 2012). An increase in 500,000 tonnes of biomass fuel is anticipated to be required for co-firing by the year 2020 in accordance with NREAP (2010) co-firing targets of biomass with peat. However, in order to meet such demand, not all fuels will be derived from wood biomass (Reilly 2010, Knaggs and O'Driscoll 2012a). The availability of incentives, demands for co-firing and the installation of wood pellet manufacturing and co-generation plants has created a supply and demand situation for wood fuel products. Ultimately, an appraisal of the different policies in place to incentivise wood energy consumption can only be measured over time in terms of their effectiveness, as most of this increase in wood biomass consumption in Ireland has occurred over course of five-six years. In addition to the incentives, there are issues to address if further growth in the use of wood for energy in Ireland is to be encouraged. Forecasting the supply and demand of raw material harvested from forest resources is essential to facilitate further developments and investment to increase the use of wood for energy.

Forecasting round wood supply and demand

Phillips (2011) compiled an all-Ireland round wood supply forecast for the 2011–2028 period. In conjunction, the COFORD Round Wood Demand Group (CRDG 2011) compiled demand scenarios for round-wood over the 2011–2020 period. Both reports concerned the wood processing and energy sectors. A key output from Phillip's (2011) forecast was that a large contribution of round-wood will be available from private sector thinnings, mostly from forests established in the last 20–30 years. The thinning area in Irish forests has been forecasted to double from 22,800 ha in 2011 to 49,400 ha in 2028 (Phillips 2011). The availability of round-wood volume from private and state forests in Ireland has been forecasted to increase from 3.79 million m^3 in 2011 to 6.95 million m^3 in 2028 (Phillips 2011). The majority of this round-wood contribution will come from coniferous species, that include spruce species (84%), lodgepole pine (*Pinus contorta* Dougl.) (9%) and other conifers (7%).

Phillips (2011) forecast also included information about resource availability for energy production, and estimated an increase from 1.07 million m^3 in 2011 to 1.75 million m^3 in 2028. The CRDG (2011) forecasted round-wood demand for conventional uses and energy generation. Wood energy demand forecasts were based on scenario models formulated by the SEAI for the period 2011–2020. The CRDG estimated that demand for wood energy will nearly double from 1.6 million m^3 to 3.1 million m^3 during the forecast period of 2011–2020. Wood for energy supply in 2020 is estimated at 1.5 million m^3 by Phillips (2011), indicating a considerable shortfall compared to the 3.1 million m^3 2020 demand scenario. In addition to this shortfall there are other issues regarding the mobilisation of material from thinnings to meet such supply and demand.

Issues with the mobilisation of wood for energy supply and demand

In the private forest sector, despite the forecasted increase of round-wood availability from first thinnings, there are constraints to mobilising this resource. Insufficient economies of scale result from small average plantation sizes of 8 ha and individual plantations that can range from 1–2 ha in size (Fennessy 2005, Byrne and Legge 2008). Moreover, there are a number of factors that will further affect the mobilisation of thinnings from the private forest sector. These factors include a landowner's management objectives, site access difficulties, poor ground conditions, the risk of windthrow, excessive infrastructure requirements, lack of knowledge on how to conduct thinning operations, marketing issues, perceived unfavourable prices for round-wood, and high harvesting costs (Maguire et al. 2010, Casey and Ryan 2012). Another facet to the mobilisation problem is that the competition for round-wood between the sawmilling and wood energy sectors will further affect supply and demand forecast scenarios (Phillips 2011). Nonetheless, a number of initiatives have been developed in recent years that may affect the allocation of first thinnings for energy use.

Initiatives for thinning mobilisation and supply chain development

To resolve mobilisation issues and initiate first thinning in privately owned plantations, farm forest owner groups supported by Teagasc have developed in recent years. The objectives of such groups are to collectively thinn plantations and develop markets for wood processing and/or energy generation in the private forest sector. There are currently 26 farm forest owner groups in total around Ireland (Teagasc 2012). The efficacy of these groups in delivering upon their objectives may possibly be reflected in the record number of felling license applications made to the Forest Service during 2012 from private forest owners (Magner 2012), coupled with favourable round wood prices for first thinnings in recent years (Casey and Ryan 2012). In 2011, 386,000 m^3 of thinnings were harvested from privately owned forests, representing 14% of the total round wood harvest, the remainder attributable to Coillte (84%) and imports (2%) respectively (Knaggs and O'Driscoll 2012b). This emergence of private forest sector first thinning coincides with an increase of domestic firewood consumption. The firewood market has experienced a 35% increase from 2006 to 2011 (O'Driscoll 2011). Total firewood consumption derived from indigenous sources in 2011 was 214,000 m^3, although this may be an underestimate as markets typically operate on a local basis, thus making it difficult to derive accurate estimates (Knaggs and O'Driscoll 2012b, Magner 2012). Despite this increase in thinning and fire wood consumption, the harvesting of thinnings for energy is only one operation contained within a broader supply chain from producer to consumer.

Wood fuel supply chains

Until recent times in Ireland, there was a lack of research into all the aspects of the use of wood for energy. The limited number of articles included guidelines for the construction of portable firewood mills (Donovan 1946), in addition to notes on firewood extraction (Deasy 1947). A considerable body of research into the use of wood for energy was instigated in Ireland as a response to the oil crisis of the 1970s. This research included trials examining forests established at tighter spacings than normal to maximise dry matter production for energy consumption (McCarthy 1979), seasoning trials of small sized round-wood (Savill 1979), biomass sampling from the point of view of nutrient removals as a result of total tree harvesting (Carey and O'Brien 1979, Carey 1980), and an appraisal of wood biomass availability within State-owned forests for energy purposes (McCarthy and Keogh 1983). There has been little research into the use of wood for energy from the 1980s and onward. The only significant bodies of work during this intervening period were an evaluation of the processing of above-ground logging residues from clearfell areas for the production of wood briquettes, an evaluation of above ground logging residue harvesting supply chains, and a feasibility study into the development of a wood energy sector in Ireland (Coggins 1996, Hoyne and Thomas 2001, North and Healion 2003). More recently, the Forest Energy Programmes of 2006–2008 were the first comprehensive published works concerning the development of cost-competitive wood fuel supply chains appropriate to Irish conditions (Kofman and Kent 2007, Kent et al. 2011). The programmes provided for support measures that stimulated owners to carry out to first thinning operations in private plantations.

The programmes involved an examination of the feasibility of using Scandinavian wood fuel harvesting and processing technologies that had not been previously trialled in Ireland. These included the production of wood chip material for industrial and domestic purposes, in addition to small-scale firewood supply chains from privately-owned forest plantations. Trials were mostly conducted on first thinning sites of both conifer and broadleaf tree species in different locations throughout Ireland. Other trials examined the storage and seasoning of wood fuel assortments in a forest environment and at dedicated terminals. Another feature of the programme was the testing and evaluation of the physical and chemical properties of wood chip and firewood. The physical and chemical properties of wood have an obvious influence on the quality of wood energy products, and therefore affect supply chain optimisation and efficiency.

Quality control for wood fuel products that are emerging and already established

In Ireland, the increased use of wood for energy generation in recent year's means, there is a compelling need to analyse wood properties that influence energy conversion and ensure transparency in the indigenous and international trade of wood fuel. The reasons for this are twofold. First, to ensure that wood enters the energy market on a cost-competitive basis with well-established fossil fuels. Due to comparatively higher oxygen content, wood is of a lower fuel density in comparison to fossil fuels such as coal, gas and oil (Dembris 2004, Swithenbank et al. 2011). Second, international trade of wood fuel products will be a likely scenario for countries that lack the indigenous resources to fulfil policy predictions for increasing wood fuel consumption (Hillring 2006). This is especially the case in Ireland, given the constraints in the supply of thinnings from the private forest sector, competition with the sawmilling sector and overall predicted shortage of raw material to meet demands for wood energy into the future. There is also a need to establish wood quality parameters for the testing of emerging and established wood fuel products. A key highlight of previous trials on the Forest Energy Programme was the benefits of utilising all the partitions of a tree, rather than the production of wood fuel products derived from round-wood only.

Irish studies into Sitka spruce (*Picea sitchensis* (Bong.) Carr.) have found that the majority of the total biomass accumulated in trees is in stem wood sections (Carey and O'Brien 1979, Carey 1980, Green et al. 2007). The remaining biomass, known as logging residues, is material left behind on site after the harvesting of round-wood from stem wood sections. This material includes branches, foliage, unmerchantable stem sections and stumps that could be harvested for energy from clearfell areas (Hakkila 2004, Alakangas, 2005). The quantification and characterisation of logging residues for conversion into energy in Ireland has been identified as a knowledge gap (Kent et al. 2011). In addition, the harvesting and processing of logging residues has the potential to reduce the predicted shortages in wood fuel supply from now until 2020 (Kent 2012). Although logging residues are typically harvested from clearfell areas, trials in Ireland have found that harvesting whole trees from first thinning sites proved to be a lower cost operation. This is due to a twofold increase in the biomass that can be harvested from whole trees in contrast to standard round-wood harvesting for energy only (Kent et al. 2011). Residue material was partially included in Phillips (2011) energy supply forecast in the form of unmerchantable <7 cm diameter stem sections, but neither the potential contribution of harvesting whole trees from first thinnings, nor logging residues from clearfell areas was estimated. Against the background of potential wood fuel products derived from logging residues, in tandem with wood fuel products that are already established, a number of initiatives concerning quality control in the regulation of trade between wood fuel producers and consumers have developed in recent years in Ireland.

Standardisation and initiatives to regulate wood fuel trade

In wood energy terms, quality is defined by the influence of fuel properties on optimal energy output (expressed as megajoules) or kilowatt hours, expressed as megajoules (MJ kg^{-1}) or kilowatt hours (kWh m^{-3}) (Alakangas et al. 2006, Kofman and Kent 2007). Over the last decade the European Commission (EC) mandated the development of standards for the harmonisation of wood fuel trade within and outside the EU (Alakangas et al. 2006). Standards are a set of rules to ensure quality which are described in unambiguous documents designed for repeatable and reproducible use (Loibneggar 2011, Solid Standards 2011). With this mandate for trade standardisation, the solid biofuels Technical Committee (TC) 335 was formed to develop standards in biomass trade (Kofman 2010). Ireland is represented on TC 335 through the National Standards Authority of Ireland (NSAI) (Kofman 2012). Other developments included the BioNorm project which evaluated the standardised testing procedures for both physical and chemical properties of wood, its suitability for energy conversion technologies, and the optimum utilisation of machinery operating in the field for the production of wood fuel (Alakangas et al. 2006, Obernberger et al. 2006).

Standards typically begin as Technical Specification (TS) drafts. After a period of use for five years, TS drafts are evaluated as to whether or not they should be upgraded to a European Standard (EN) (Kofman 2010, Solid Standards 2011). After 10 years of development, 28 EN standards have been adopted by participants and are now serving a role in the preliminary development of international trade standards for solid biofuels (Kofman 2012). Standards specify suitable terminology common to participants (e.g. EN: 14588: 2010), specify quality parameters for wood fuel products EN: 14961-1 2010 and to define quality assurance specifications for use between wood fuel producers and consumers EN: 15234-1 2011. The latter quality assurance standard is based upon an internal agreement of fuel specifications between producers and consumers (Loibneggar 2011). In Ireland, independent audits of internal trade agreements between wood fuel producers and consumers has been initiated in recent years through the wood fuel quality assurance scheme (WFQA), instigated by preliminary testing of European Standards on the Forest Energy Programme (Kent 2009). The WFQA is an industry-led initiative to certify wood fuels produced in Ireland in accordance with the National Working Agreement 4: 2009: Woodfuel Quality Assurance-Requirements (NSAI 2009). The resulting WFQA label is a quality mark awarded to wood fuel producers who meet the standards of external audits (Kofman 2010). Standards also exist for the scientific lab testing of the physical and chemical properties of wood fuels. For practical purposes, the implementation of such standards are required for quality assurance audits of wood fuel producers, and in the settlement of product quality disputes between producers and consumers (Kofman, 2010).

In relation to trading wood fuel there are a number of normative parameters that have to be specified under standardised trade procedures. The origin of the wood fuel product, moisture and ash content are among the most important parameters to specify when trading wood fuel EN: 14961-1 2010. Other parameters that are necessary to specify depend upon the type of wood fuel being traded, for example the particle size of wood chip EN: 14961-1 2010. Other properties are typically informative (voluntarily specified) when trading wood fuel such as heating values, presence of volatile matter and chemical properties as some examples. However all wood fuel properties have a role to play in the optimisation of energy conversion processes.

Physical and chemical properties of wood

The primary energy conversion process of wood is by means of combustion

(Obernberger et al. 2006). A thermochemical process, combustion essentially converts the solid organic components of wood into water (H_2O) and carbon dioxide (CO_2), releasing heat energy (Obernberger et al. 2006). Optimum combustion ensures that maximum energy output has been achieved; wood has fully volatilised, minimal emissions of GHGs and low amounts of wood ash have been produced, all depending upon the boiler capacity and fuel type (Savoleinen and Berggren 2000, Obernberger et al. 2006). To ensure optimum combustion, detailed analysis of physical and chemical wood properties are a necessary prerequisite (Ragland et al. 1990). There are a variety of properties that affect combustion efficiency. These properties include the calorific value of wood, moisture content, basic density, bulk density, particle size, the proportion of volatiles, chemical composition, ash forming elements and the quantity of impurities such as fungi, soil and stones (Savoleinen and Berggren 2000, Loibneggar 2011).

In its freshly felled state, wood typically contains 40–60% water and the remainder is dry matter biomass. The organic constituents of wood biomass consist of the long chain polymers cellulose (40–45% of total weight), hemicellulose (25–40%) and lignin (24–33% for conifers and 16–25% for broadleaves) (Alakangas 2005, Bowyer et al. 2007). The elemental composition of these organic constituents directly relates to the quantity of volatile chemicals released during combustion. Analysis of volatiles in wood is termed either as ultimate or proximate analysis. Proximate analysis of wood biomass consists of 80–90% volatiles, meaning it will give up this proportion of its weight to forming gases in the pyrolysis phase of combustion, the remainder being solid carbon (Savoleinen and Berggren 2000, Alakangas 2005). Ultimate analysis refers to the elemental composition of wood. The elemental composition of wood consists of 45–55% carbon (C), 4.5–6% hydrogen (H), 40–45% oxygen (O), 0.1% nitrogen (N), 0.1% sulphur (S) and 0.3–0.5% ash (Baker 1983). This composition is relatively uniform between different tree species (Bowyer et al. 2007). Wood also contains solid incombustible major and minor mineral trace elements that constitute wood ash (EN: 14588: 2010, Obernberger et al. 2006). Ash has a large diversity of major and minor constituent elements including aluminium (Al), antimony (Sb), arsenic (As), barium (Ba), cadmium (Cd), calcium (Ca), chlorine (Cl), chromium (Cr), cobalt (Co), copper (Cu), iron (Fe), lead (Pb), magnesium (Mg), manganese (Mn), mercury (Hg), molybdenum (Mo), nickel (Ni), phosphorus (P), potassium (K), silicon (Si), sodium (Na), sulphur (S), thallium (Tl), titanium (Ti), vanadium (V) and zinc (Z) (Obernberger et al. 2006). The concentration of these major and minor elements are relevant to and can affect the optimisation of energy conversion processes, including ash melting behaviour, fly-ash formation in chimney flues, aerosol emissions, particulate emissions, air purity and toxic elements. The elements specifically involved in the latter issues and the level of concentrations in different solid biofuels, including wood biomass, are reviewed extensively by Obernberger et al. (2006). The mineral elements of primary concern from a negative viewpoint are the quantities of Cl, N and S. Cl has the capability to react with K and Na to cause corrosion on heat transfer surfaces and chimney flues in boilers, whilst N and S possess the capability to convert into GHGs such as nitrous oxide (NO_X) and sulphur oxide (SO_X) (Hakkila 2004, Alakangas 2005, Obernberger et al. 2006). However wood generally has low levels of Cl, N and S. Cl is an issue with wood fuels that contain a high proportion of foliage (Alakangas, 2005). In addition wood emits low levels of NO_X and SO_X provided combustion is optimised (Obernberger et al. 2006).

The physical and chemical properties of wood may vary for a variety of reasons. Physical properties such as moisture content can vary according to species, tree partitions, age, seasons, location, proportions of sapwood to heartwood and the time of year wood fuel products are in storage (Savoleinen and Beggren 2000, Bowyer et al. 2007). Basic density is another source of physical variation in wood fuel and can vary according to species, climatic effects on radial growth, presence of reaction wood, proportions of juvenile and adult wood, between tree partitions, within stems, silvicultural practices and genetic sources (Repola 2006, Bowyer et al. 2007, Jyske et al. 2008).

Calorific values and ash-forming elements are typically classified by the inherent differences between tree parts such as stems, branches and foliage (Nurmi 1993, Werkelin et al. 2005). Investigations have shown that calorific values and chemical element concentrations are greater in the more biologically active parts of trees such as foliage, secondly in branch wood due to greater proportions of bark, descending in order to stem bark and concentrations being lowest in stem wood (Nurmi 1993, Alakangas 2005, Werkelin et al. 2005). As branches and foliage are constituents of logging residue material that can be harvested for wood fuel products, the implications of its harvesting would consequently have an effect on forest ecosystem nutrition dynamics. This is due to the exportation of essential nutrients for tree growth coinciding with intensified harvesting of wood for energy (Karltun et al. 2008). To rectify excessive nutrient exportation, one possible action that can be undertaken is the recycling of nutrients by means of fertilising forests with wood ash (Stupak et al. 2008). Wood ash fertilisation has a twofold benefit. These benefits include the capability of wood ash to neutralise soil pH on soils that tend to be acidic in nature and also reduce the costs of wood ash disposal in landfills resulting from increasing wood fuel consumption (Pitman 2006, Stupak et al. 2008). A synthesis of research into the utilisation of wood ash as a fertiliser in Nordic countries was reviewed by Rauland-Rasmussen et al. (2008). Nordic research has found that application of wood ash does not increase forest productivity on mineral soils, but has proven to be beneficial on less fertile peat type soils. Despite this observation, Rauland-Rasmussen et al. (2008) commented that there was a lack of research into the long term effects (>10 years) of nutrient removals and wood ash application. However this has been since remedied due to recent results accumulated from a 30 year old wood ash fertilisation trial in Finland. Saarsalmi et al. 2012 found that tree productivity was greater in plots where wood ash supplemented with artificial N was applied in comparison to control plots where no fertiliser was applied. N, a key nutrient for healthy tree growth, must be supplemented into wood ash fertilisers, as the naturally occurring N in wood is converted to NO_X during combustion (Obernberger et al. 2006, Saarsalmi et al. 2012). The higher productivity in the fertilised plots was observed by Saarsalmi et al. (2012) to be due to greater soil microbial processes in the circulation of N and C, in addition to higher concentrations of exchangeable Ca, K, Mg and extractable P found within the chemical composition of the soil organic layers. Despite the apparent benefits of utilising wood ash as a fertiliser, there is a complexity of factors to consider. The point at which wood ash is collected during the combustion process, the wood burning temperature, the type of wood fuel product combusted, presence of contaminants, the application method with regard to solubility, the amount applied in the field/ha^{-1}, the timing of application in a forest rotation, soil types, the types of soil organic layers, soil microbial sensitivities and soil water status all influence the suitability of ash as a fertiliser. (Pitman 2006, Karltun et al. 2008, Rauland-Rasmussen et al. 2008, Stupak et al. 2008). In Ireland, research into all the different aspects of wood ash recycling is currently underway (O'Halloran 2010).

Research efforts to address knowledge gaps on wood fuel properties in Ireland

In Ireland, wood fuel property databases of forest biomass fuel sources that have an impact upon fuel quality are absent. One aim of the research being carried out currently as part of the Forest Energy Programme in Waterford Institute of Technology is the development of a wood fuel property database covering the main commercial forest tree species in Ireland. The age-class for the characterisation of wood fuel properties is focussed upon stands ready for first thinning. The six species being investigated include alder (*Alnus glutinosa*), ash (*Fraxinus excelsior* L.), birch (*Betula* spp.), lodgepole pine, Norway spruce (*Picea abies* (L.) Karst) and Sitka spruce. The main fuel properties to be investigated are moisture content and basic density. These are physical properties of wood that have an impact upon energy conversion efficiency. Moisture content is one of the most important wood fuel quality parameters. High moisture content has an adverse effect on the energy generated from wood, can compromise the storage capabilities of wood fuel, and can increase the fuel consumption of trucks transporting wood intended for energy consumption (Hakkila 2004, Serup and Kofman 2005). These factors highlight the importance of developing strategies for harvesting and seasoning wood fuels with a view to reducing moisture content to a point suitable for end-user needs. Current research seeks to investigate the spatiotemporal variation in the moisture content of stem and branch wood partitions. This will aim to identify the most suitable times of year for harvesting and seasoning wood for energy production. The sampling methodology implemented for the measurement of moisture content in stem sections will also allow for an opportunity to investigate the basic density of the same six tree species. Basic density is an important wood fuel quality parameter that describes the potential energy content that may be yielded per unit volume (m^3) from wood fuel products. However, only basic density data for Sitka spruce have been reported for Irish conditions, at least within the public domain (Ward and Gardiner 1976, Gardiner and O'Sullivan 1979, Javadi et al. 1983, Treacy et al. 2000, Ní Dhubháin et al. 2006, Green et al. 2007, Tobin and Nieuwenhuis 2007).

Samples used for the analysis of physical wood fuel properties will be used to create a repository for the analysis of chemical wood fuel properties. This will provide an opportunity to measure calorific values and quantify the major and minor chemical elements associated with wood ash formation. This work will also attempt to collate wood fuel property data generated from the previous Forest Energy Programme, data from private firms, and accredited wood fuel testing centres across Ireland.

Conclusion

In Ireland, on the basis of recent consumption figures and a favourable policy environment, the use of wood for energy is increasing. However, there are issues to address in order to instil confidence into the use of wood for energy. Demands for wood fuel have been predicted to exceed supply in the future, especially if the harvesting and processing of round-wood only for wood fuel is solely relied upon. This in turn will inevitably lead to interest into the harvesting of logging residues that have not been utilised in the past to meet the shortfall in wood fuel supply in Ireland. As a result, research will be required to assess the feasibility of harvesting operations and the characterisation of the physical and chemical fuel properties of whole trees from first thinnings and logging residues from clearfell areas. Furthermore, mobilisation of key forest biomass fuel sources, especially from private forest sector first thinning, is often dictated by individual circumstances. Nonetheless, although private forest sector first thinning is increasing, in addition to firewood consumption, there is a need to address the ramifications of the influence of fuel properties on achieving optimum energy output and the long-term sustainability of ecosystem productivity.

In spite of the policies and incentives in place to promote an increase in the use of wood for energy, without knowledge of the variety of properties that dictate wood fuel quality, consumers will not be able to optimise output from wood fuel. This may affect public and industry confidence into the use of wood fuel products, especially in an energy market where wood fuels have to compete with well-established fossil fuels. Indeed, adoption of European trade standards and initiatives such as the WFQA scheme will help to address the issues associated with wood fuel quality. However, the fuel quality specifications required by individual end users may not necessarily conform to the WFQA requirements and European trade standard specifications. Nevertheless, flexibility is allowed in terms of trade audits between wood fuel producers and consumers EN: 15234-1 2011, and the very purpose of European standards is that they are evaluated every five years by the countries participating in their testing (Alakangas et al. 2006). A good aid in the evaluation of wood fuel product quality and trade standards is a comprehensive knowledge of the fuel properties of forest biomass fuel sources before processing (e.g. round-wood, above and below-ground logging residues).

The development of a database on the fuel properties of wood will serve as a template for the characterisation of wood fuel products derived from different forest biomass fuel sources in Ireland. In addition, this database will also provide a template to evaluate the suitability of European standards for testing different wood fuels under Irish conditions. The resultant data from this project will be made available to wood fuel producers and consumers through dissemination outputs.

These outputs will be in the form of project reports, peer reviewed papers and an online database with a user query interface. Ultimately, it is envisioned that the dissemination of such information will confer an increased degree of confidence to the use of wood for energy in Ireland.

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