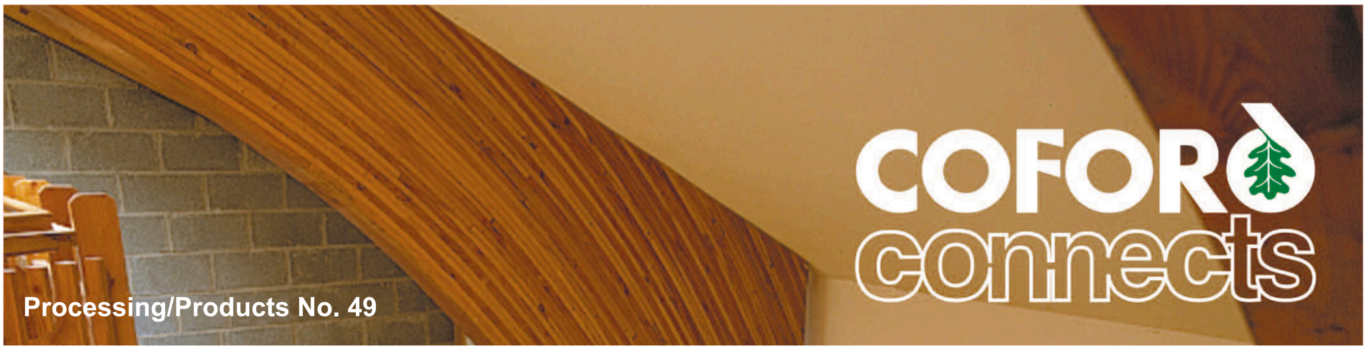

- *Embedded fossil energy is the amount of fossil fuel used to produce a product*
- *The embedded energy in a range of common wood fuels used in Ireland are calculated in this note*
- *All wood fuels show a positive balance between embedded energy and the amount of energy that can be produced from the fuel*
- *In order of benefit, it would be best to use domestically produced whole-tree (best dry otherwise wet) wood chips, rather than wood chips made from roundwood, firewood or domestically produced wood pellets. Imported wood pellets have the highest amount of embedded energy in relation to the produced energy but still show a positive balance.*

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Embedded energy in wood fuels

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Introduction

Embedded fossil energy is the amount of fossil fuel that has been used during the production process of a product.

It has been suggested that the amount of greenhouse gas emissions produced from using wood biomass can be more than those produced from fossil fuels, as a result of the carbon lost at harvesting and the processing and transportation of the fuels. This would suggest that the use of wood fuels is not beneficial to reducing overall greenhouse gas emissions and in the mitigation of climate change. Wood fuels, like any fuel, require processing before they can be used. Fossil fuels are typically used to harvest, process and transport wood fuel. Measuring the embedded fossil energy in wood biomass is key to understanding the extent of their potential to reduce greenhouse gas emissions.

Emissions from wood fuels can be understood as part of the circular relationship between the biosphere and the atmosphere. The carbon in the wood would be released eventually through decomposition and the biosphere has the capacity to reabsorb that emitted carbon. For a productive forest, this could mean that it only takes some 50 years for carbon released through decomposition or used as a fuel to return as wood. Conversely emissions from fossil fuels only flow in one direction; from stores of carbon which would not be released without human intervention to the atmosphere. For carbon released from fossil fuels to return to a fossil fuel, millions of years and special circumstances are needed. However, for the emissions reducing benefit of wood fuels to be realised fully it is essential that the forest is sustainably managed and that their production does not result in permanent land-use change, such as deforestation.

This COFORD Connects Note aims to calculate the amount of fossil energy, used to harvest, process and transport the most common wood fuels in Ireland. The results are presented as the proportion of fossil energy in an energy unit of wood fuel.

A wide brush has been used to paint the picture, absolute numbers are not reported, rather the relationship between the different wood fuels and their application is reported.

Scope of the information note

There are a large number of wood fuel types, produced through a variety of processes. This article does not attempt to include each and every one but rather the most common types of wood fuels used in Ireland, including:

- Wood chips dry (<30% moisture content for domestic and other small-scale boilers from seasoned 3 meter roundwood from first thinning Sitka spruce
- Wood chips wet (>45% moisture content for large scale CHP and district heating systems), produced from partly seasoned whole trees in first thinning Sitka spruce
- Firewood, seasoned by natural means with a moisture content of around 20% for domestic boilers, produced from hardwood thinnings
- Firewood, kiln dried with a moisture content of around 20% for domestic boilers produced from hardwood thinnings
- Irish Wood pellets, produced and used in Ireland, produced from sawdust from the saw milling industry for domestic boilers
- Imported wood pellets from USA, produced from plantation roundwood harvested for the purpose, for industrial boilers.

Methodology

Data for the analysis were assembled from a number of sources; many of them located on the www.woodenergy.ie website as COFORD Connect Notes (CCN). Energy output data for each fuel-type were based on CCN-10-HT21 and assumed moisture contents. Energy input data for the felling, delimbing, forwarding, processing, and seasoning activities of the wood chip and firewood fuel types were based on CCN-09-HT11, CCN-09-HT13, CCN-10-HT24, and CCN-13-PP31; kW ratings for the machines used to carry out each activity were used to calculate liquid fuel consumption rates, and therefore energy consumption, for the stated machine productivities. Energy input data for the road transport and delivery activities for the wood chip and firewood fuel types were based on typical transport distances, travel speeds, truck payloads, and liquid fuel consumption rates for Irish conditions based on expert opinion. The basic density of softwood (e.g. Sitka spruce) and hardwood (e.g. ash) is assumed to be 400 kg/m^3 and 550 kg/m^3 respectively.

Energy input data for activities related to the production of wood pellets were derived from five sources. These included two studies carried out in the US (Anon, 2011; Katers & Snippen, 2011) two studies carried out in Europe (Chen, 2009; Magelli et al., 2009) and the BEAC model developed for the UK Department of Energy and Climate Change. Where multiple products were produced from an activity (e.g. sawdust and sawn timber), energy consumption was allocated on a mass basis.

For the Irish wood pellets and firewood several methods of delivery and packaging are included: delivery in bulk, in big bags (1000 kg) or in plastic bags (15 kg each). It was assumed that the big bags would be used 3 times and that the plastic bags were discarded after use. In relation to kiln dried wood, the use of fossil fuels in the kiln is assumed. An overview of the main fuels included in the study and their characteristics is presented in Table 1.

What is included and what is not?

This CCN does not present a Life Cycle Analysis (LCA), but only what is normally seen as direct fossil energy use for the harvesting, processing and transportation of the fuels.

The fossil energy that was used during the preparation and planting of the site, and the tending of the trees until the first harvest has not been included. This energy cannot be allocated to the present harvest alone, many more harvests and rotations on the same area will follow which share in this initial energy investment. Likewise, the energy input in the construction of forest roads has not been included. This investment will also be spread over many generations of forests to come.

In Table 2 it is schematically shown which actions have been included in the production of the different fuels. In the case of Irish wood pellets, a small amount of the harvesting and transport energy has been included in the amount of embedded energy, hence the small single x. Sawdust usually amounts to about 10% in mass of the wood entering the sawmill. The rest of the consumed energy is allocated to the sawn timber and pulpwood chips.

Table 1 Overview of included wood fuels

Fuel	Country of Origin	Moisture content, %	Tree species type	Base material	Boiler type
Dry wood chips	Ireland	30 or 45	Softwood	3 m roundwood	Domestic
Wet wood chips	Ireland	30 or 45	Softwood	Whole tree	Industrial
Seasoned firewood	Ireland	20	Hardwood	3 m roundwood	Domestic
Kiln dried firewood	Ireland	20	Hardwood	3 m roundwood	Domestic
Irish wood pellets	Ireland	8	Softwood	Sawdust	Domestic
Imported wood pellets	USA	8	Softwood	3 m roundwood	Industrial

Table 2 Actions in the production of wood fuels in this information note

Fuel	Base material	felling	delimbing	forwarding	Road transport	Pro-cessing splitting	seasoning	Kiln drying	grinding	pressing	Long distance transport	delivery
Wood chips, wet 45% and dry 30%*	Whole tree	XX		XX	XX	XX	X					XX
Wood chips, wet 45% and dry 30%*	Pulpwood	XX	XX	XX	XX	XX	XX					XX
Firewood sea-soned, 20%*	Pulpwood	XX	XX	XX	XX	XX	XX					XX
Firewood kiln dried, 20%*	Pulpwood	XX	XX	XX	XX	XX	XX	XX				XX
Wood pellets Irish, 8%*	Sawdust from sawmill	X	X	X	X			XX	XX	XX		XX
Wood pellets imported, 8%*	Pulpwood	XX	XX	XX	XX			XX	XX	XX	XX	XX

*% moisture content

Table 3 The amount of embedded fossil energy in selected wood fuels

Energy Source	Moisture content of the fuel %	Embedded Energy MJ/GJ	Percentage of energy output %
Dry Wood Chip, Whole Tree, Softwood, 1st thin	30	28	2.8
Wet Wood Chip, Whole Tree, Softwood, 1st thin	45	33	3.3
Dry Wood Chip, Pulpwood, Softwood, 1st thin	30	103	10.3
Wet Wood Chip, Pulpwood, Softwood, 1st thin	45	112	11.2
Seasoned Firewood, Hardwood, Bulk	20	106	10.6
Seasoned Firewood, Hardwood, Big Bags	20	121	12.1
Seasoned Firewood, Hardwood, 15 kg Bags	20	152	15.2
Kiln Dried Firewood, Hardwood, Bulk	20	201	20.1
Kiln Dried Firewood, Hardwood, Big Bags	20	216	21.6
Kiln Dried Firewood, Hardwood, 15 kg Bags	20	247	24.7
Irish Wood Pellets, Bulk	8	274	27.4
Irish Wood Pellets, Big Bags	8	282	28.2
Irish Wood Pellets, 15 kg Bags	8	360	36.0
Imported Wood Pellets, USA, Bulk	8	523	52.3

Results

The amounts of embedded energy

In Table 3 the amount of embedded fossil energy is expressed in MJ per GJ contained in the fuel. The energy content of the fuel is based on the moisture content of that fuel. In the second column, the amount of embedded energy is expressed as a percentage of the total energy contained in the fuel. Since the moisture content of the fuel has a decided influence on the energy output, the moisture content of the fuel is indicated in the first column.

Table 3 shows that the amount of embedded fossil fuel is much less than the amount of energy that can be produced by the fuels, so using wood fuels instead of fossil fuels has a clear benefit to the alleviation of CO_2 emissions from energy production in this regard. As expected, the amount of embedded fossil energy increases with the amount of handling and packaging, thus wood chips from whole trees have the lowest amount of embedded energy, while the imported pellets from USA have the highest amount of embedded energy.

Also, as expected, the kiln drying of firewood adds considerably to the amount of embedded energy, so it is better to season the wood naturally before or after processing. This is based on reaching a moisture content of 20%, a level that requires careful storage to achieve through air drying in Ireland's climate (see CCN-HT-19). The packaging of firewood and pellets also contributes considerably to the amount of embedded energy, since the packaging material is made from fossil fuels and is discarded after use.

The fact that the imported pellets have such a high amount of embedded energy is caused by several factors: the raw material for these pellets is roundwood (which must be chipped, dried and ground before the pellets can be pressed) and because the transportation of these pellets is much more cumbersome and over a long distance.

Conclusions

This COFORD Connects Note presents an overview of the amount of embedded energy in the most common wood fuels in Ireland. The numbers are not absolute, but have been painted with a wide brush and do not include emissions from silviculture or possible land use change. However, the comparison of the fuels between each other shows remarkable differences.

From the perspective of minimising embedded energy in wood fuels it is better to use domestically produced wood chips than firewood and certainly better than using imported wood pellets. However other circumstances may exist that makes the preference for fuels, other than wood chips, valid. Not everyone has enough space to store copious amounts of wood chips, which take at least double or more of the amount of space required by wood pellets. Especially in the small-scale appliances, the internal handling of wood chips is cumbersome and handling wood pellets can be much easier. For domestic space heaters, employing properly dried, high quality wood fuels is important for more efficient and cleaner heat production.

In conclusion, all wood fuels have a much greater energy output than the amount of embedded fossil energy. The amount of processing of wood chips, is lower than that of firewood or wood pellets, resulting in a lower amount of embedded energy. If one packages the fuel in big bags or even worse in net bags or plastic bags, the amount of embedded energy increases rapidly. Pellets made from roundwood and imported from far away have the highest amount of embedded energy. However, even for imported, processed wood fuels the percentage of embedded energy is much less than 100%.

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