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The potential uptake of domestic woodfuel heating systems and its contribution to tackling climate change: A case study from the North East Scotland

Diana Feliciano [a, *], Bill Slee [b], Pete Smith [a]

[a] Institute of Biological and Environmental Sciences, School of Biological Sciences, University of Aberdeen, 23 St Machar Drive, Aberdeen AB24 3UU, Scotland, UK
[b] The James Hutton Institute, Craigiebuckler, Aberdeen AB15 8QH, Scotland, UK

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ABSTRACT

This study explores the scope for increasing the contribution of woody biomass for private space and water heating in the North East Scotland, which corresponds to the administrative districts of Aberdeen, Aberdeenshire and Moray. It assesses the potential benefits in terms of carbon dioxide (CO_2) emissions reduction of a partial shift from non-renewable heat sources to wood energy. Woody biomass is an interesting case to study because it is a source of renewable energy that directly depends on the rural land use sector. At the same time woody biomass can play an important role in fuel poverty reduction. North East Scotland has good potential for woody biomass production but the trade-off between food security and energy production has to be taken into account if more woodland creation is sought. Forests occupy 19% of the land area, and a number of towns and villages are close to extensive forested areas. North East Scotland administrative districts have supported the development of wood energy through the development of woodfuel-based public service heating and institutional structure is broadly conducive. Fuel poverty and greenhouse gas emissions from space and water heating could be drastically reduced through the wide adoption of heating systems in the region. However, large up-front capital costs, delays in establishing support systems, and the nature of support offered to contribute to the likely failure to deliver policy targets such as for reduced fuel poverty and CO_2 emissions reduction.

1. Introduction

Burning fossil-fuel to produce energy is the main human activity contributing to greenhouse gas (GHG) emissions, specifically carbon dioxide (CO_2), into the atmosphere which consequently leads to climate change [20]. Replacing fossil fuels with energy produced from renewable sources, such as biomass, can significantly decrease the current levels of GHG emissions. Because of this, renewable energy has been regarded as highly important for the future of our society [5]. The need to make increasing use of renewable energy sources is reflected by policies in many parts of the world, including Scotland. In 2009, the Climate Change (Scotland) Act created a statutory framework for GHG emissions reduction, by setting an interim 42% reduction target for 2020 and an 80% reduction target for 2050 [43]. One option to deliver significant carbon savings is the production of heat from renewable energy [44]. Renewable heat can be produced with solar, geothermal, heat pumps or biomass technologies. According to Agostini et al. [1], forest biomass, or woodfuel, is one of the most promising renewable resources in terms of climate mitigation potential, and thus it is likely to be widely exploited in the transport and energy sector. In 2008, biomass as a renewable energy (RE) source provided about 10.2% (50.3 EJ) of global total primary energy supply (TPES) [7]. Examples of biomass sources are wood, energy crops such as short-rotation coppice and short-rotation forestry, waste and agricultural residues such as straw [48]. These sources are normally classified in three groups: primary residues; secondary and tertiary residues and biomass specifically produced for energy production. The mix will vary greatly depending on region, markets, processing capacity, etc., but forestry can provide wood raw material in all three categories. Nordic countries (with which comparison is frequently made in Scotland) use far more wood for heating than the United Kingdom and in such countries the greater use of wood energy has

* Corresponding author. Tel.: +44(0) 1224 273810; fax: +44 (0)1224 272703.
E-mail addresses: diana.feliciano@abdn.ac.uk, dianafeliciano80@gmail.com (D. Feliciano), bill.slee@hutton.ac.uk (B. Slee), pete.smith@abdn.ac.uk (P. Smith).

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been a defining feature of their attempts to decarbonise their heating systems [11]. Developments relating to the use of wood waste have a relatively high potential [22]. However, the high costs and complexity of the logistics and supply chain management are limiting factors for the successful utilisation of waste biomass [18].

The use of woody biomass as a source of renewable energy has repercussions on the rural land use sector where it contributes to above-ground and soil carbon sequestration during the plant's growth, and consequently mitigation of GHG emissions within the sector. It also contributes to GHG emissions mitigation in the energy sector since it displaces fossil fuels with high carbon content by a low-carbon emission fuel, the biomass. The Land Use Strategy for Scotland considers renewable energy a key resource in Scotland and proposes a new strategic approach where land use decisions (agriculture, forestry or renewable energy) are considered holistically and not in isolation [40].

The production of renewable heat from woodfuel has also been advocated as a strategy to confront the rise of energy prices, to support energy security and to address fuel poverty [24,47,48]. A household is said to be in fuel poverty if it needs to spend 10% or more of its income on fuel to meet its energy needs (Baker, 2011). High oil and gas prices have underlined Europe's increasing dependency on imported energy and this encouraged the European Union to respond with a range of measures to reduce energy imports, including support for the use of biomass [38]. Rising energy costs have pushed many consumers to fuel poverty, especially those not connected to the gas grid [17]. According to Baker [4], in Scotland, about 30% of the households are in fuel poverty, and 34% of these are not on the gas grid. Abundant resources of woodfuel at local level in some rural areas may provide a sustainable source of energy if the woodlands from which woodfuel is extracted will be replanted. In addition, the extensive use of woodfuel contributes to a decrease in the dependence on fossil fuels which price is regulated by the global market price. The increase in timber ready to harvest may contribute to future capacity of the forest sector to produce energy.

Scottish houses generally have relatively poor insulation and consequently relatively high heating costs and high GHG emissions due to oil consumption, and this contributes both to high levels of fuel poverty and climate change [19]. A cost-effective way of reducing emissions from heating is to improve energy efficiency of households through better insulation but retrofitting is often rather challenging because of house design. The acceleration of renewable heating distribution in the domestic sector was the objective of Renewable Heat Incentive (RHI) [9]. The RHI prioritises the support of biomass boilers for households off the gas grid since these areas are more prone to fuel poverty and higher GHG emissions due to the use of expensive heating fuels with high-carbon content such as heating oil [45]. According to Baker [4], households depending on other fuels than gas for heating have much lower energy efficiency standards than households heated on gas.

According to the Sustainable Development Commission [47], small to medium-scale woodfuel heating could make a significant contribution to climate change mitigation in Scotland, given the established forest culture, a supply of low grade wood, together with a high demand for heat and high fuel prices, especially in rural areas. The Forum for Renewable Energy Development in Scotland (FREDS) considers that market penetration of renewable heat must reach the private sector to deliver significant renewable heat capacity [45]. There has been substantial policy rhetoric for the use of renewable heat from woodfuel in Scotland, but several factors such as high upfront capital costs or the poorly developed supply chain have slowed down the uptake in the domestic sector and this may create a gap between political ambitions and the reality of expanded woodfuel use. In Scotland, about one third of primary energy consumption is for heating purposes [38], the majority of which is derived from non-renewable sources. Over 90% of the renewable heat is generated from woodfuel, although compared to many European countries, the overall level of woodfuel use is very low [41]. In Denmark, the total use of biomass resources for energy purposes (including heat, electricity and transportation) make up around 70% of the consumption of renewable energy with the use of firewood, woodpellets and chips steadily increasing during the past years. In Finland, in 2004, about 20% of the total consumption of primary energy was based on wood, and in Sweden, the bioenergy originated from the forestry sector accounted for approximately 90% of the bioenergy used [11].

North East Scotland, which includes the administrative districts of Aberdeenshire, Aberdeen City and Moray, was the study region chosen to explore the critical factors affecting domestic renewable heat uptake because forest resources to produce woodfuel are abundant, some of the coldest places in the UK are in this region, and around 60% of the households are in rural areas. In addition, Aberdeenshire aspires to become carbon neutral by 2030 [37]. Previous studies have given an overview of different governmental strategies to stimulate the use of renewable energy sources [1,13,16] and presented a framework for the understanding of barriers and supporting factors behind wood energy technology implementation and commercialisation [36]. This study focuses on the production of renewable heat from woody biomass. It considers woody biomass a land-based option for fuel poverty reduction and GHG emissions mitigation since it directly depends on rural land uses, primarily, but not exclusively, forestry. A method to estimate CO_2 emissions from domestic space and water heating in North East Scotland for different potential scenarios of woodfuel uptake is suggested. The study also estimates the availability of wood to produce woodfuel in the region and identifies the barriers (e.g. economic, education, planning) to the expansion of the woodfuel market for space and water heating purposes.

2. Data and methods

2.1. Generating scenarios for the uptake of renewable heat in the domestic sector by 2021

Three scenarios (business-as-usual, scenario A and scenario B) for renewable heat uptake in the domestic sector were generated using several sources of data:

a) The General Register Office for Scotland for data on household projections in North East Scotland;
b) The IPA Energy and Water Economics report on *Renewable Heat in Scotland: 2020 Vision to Scottish Renewables* [19] for the Scottish housing stock in 2011, and;
c) The report *Off-gas consumers* [4] for the main heating fuel by dwelling type in Scotland and the main heating fuel in North East Scotland.

In the business-as-usual scenario (BAU) it was considered that no existing or projected houses would adopt woodfuel systems. Scenario A considered that detached and semi-detached houses off the gas grid and 100% of the new houses built until 2021 would adopt woodfuel systems. Scenario B considered that detached and semi-detached houses off the gas grid and 15% of the new houses built until 2021 would adopt woodfuel systems. According to the Department of Energy & Climate Change [10], domestic energy consumption in the UK is, on average, 1.9 t of oil equivalent (toe) per year and per household [10]. About 85% of this value (1.6 toe $\approx$ 20 MW h) is used for space and water heating [4,10]. It is likely that domestic energy intensity for space and water heating is