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Research Paper

Evaluating potential policies for the UK perennial energy crop market to achieve carbon abatement and deliver a source of low carbon electricity

Peter Alexander [a,b,*], *Dominic Moran* [a], *Mark D.A. Rounsevell* [b]

[a] *Land Economy and Environment Research Group, SRUC, West Mains Road, Edinburgh EH9 3JG, UK*
[b] *Centre for the Study of Environmental Change and Sustainability, School of Geosciences, University of Edinburgh, Drummond Street, Edinburgh EH8 9XP, UK*

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ABSTRACT

The electricity infrastructure in many developed countries requires significant investment to meet ambitious carbon emissions reduction targets, and to bridge the gap between future supply and demand. Perennial energy crops have the potential to deliver electricity generation capacity while reducing carbon emissions, leading to polices supporting the adoption of these crops. In the UK, for example, support has been in place over the past decade, although uptake and the market development have so far been relatively modest. This paper combines biophysical and socio-economic process representations within an agent-based model (ABM), to offer insights into the dynamics of the development of the perennial energy crop market. Against a changing policy landscape, several potential policy scenarios are developed to evaluate the cost-effectiveness of the market in providing a source of low carbon renewable electricity, and to achieve carbon emissions abatement. The results demonstrate the key role of both energy and agricultural policies in stimulating the rate and level of uptake; consequently influencing the cost-effectiveness of these measures. The UK example shows that energy crops have the potential to deliver significant emissions abatement (up to 24 Mt carbon dioxide equivalent year^{-1}, 4% of 2013 UK total emissions), and renewable electricity (up to 29 TWh year^{-1}, 8% of UK electricity or 3% of primary energy demand), but a holistic assessment of related policies is needed to ensure that support is cost-effective. However, recent policy developments suggest that domestically grown perennial energy crops will only play a niche role (<0.2%) of the UK energy balance.

* *Corresponding author*. Land Economy and Environment Research Group, SRUC, West Mains Road, Edinburgh EH9 3JG, UK. Tel.: +44 131 535 4128.
E-mail address: peter.alexander@sruc.ac.uk (P. Alexander).
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1. Introduction

The world faces the challenge of meeting increasing energy demands while achieving economic, social and environmental sustainability [1]. In the UK, the energy challenge manifests itself through increasing political and public concern about the national energy mix and rising prices [2,3]. The UK's electricity generation sector is based on existing coal and nuclear plants that are reaching the end of their lives, reducing generation capacity [4], while electricity demand is projected to rise gradually [5]. As a result, spare capacity in the UK electricity market is due to reduce in the next few years [6]. New infrastructure to fill the potential gap between future electricity supply and demand, is estimated to require £110 billion of investment over the next 10 years [7]. The UK Government sets the overall framework for investment in energy infrastructure, but the private sector determines where and when this investment will occur.

Biomass is a source of renewable energy that could help to meet these challenges. Globally, it is already the largest source of renewable energy, and is expected to expand to 80–160 EJ $year^{-1}$ in 2050 from 50 EJ $year^{-1}$ today [8,9]. In the UK by 2020, it could provide 8–11% of the UK's total primary energy demand, a substantial increase from 3% in 2012 [10], and contribute to meeting the legally binding target of generating 15% of energy consumption from renewable sources [11]. Agricultural residues and energy crops are expected to have the greatest growth in UK domestic biomass supply [10]. Previous research suggests that the potential energy crop area in the UK will be around 1000–2000 kha in 2020 and 2030 [12–17]. It has been suggested that between 930 and 3630 kha of land in England and Wales could be used to grow dedicated perennial energy crops, without impinging on food production [10]. But UK Government policy plays a crucial role in determining the level and rate of adoption of these technologies.

Perennial energy crops, Miscanthus and willow or poplar grown as short-rotation coppice (SRC), have been grown in the UK since around 1996 [18]. Uptake has, however, been limited, with a total area of only 11 kha in 2011, with the planting rate dropping to only 0.5 kha $year^{-1}$ in the period 2008–11 [19]. There is currently no target for areas of these crops, although 350 kha by 2020 was suggested in the Biomass Strategy [13]; it is now expected that the actual figure will be much lower [18]. This low uptake occurs in spite of policies to support the production of energy crops, targeted at both farmers and energy generators. Since 2003, farmers in England have had access to grants to cover a proportion of the establishment costs for Miscanthus or SRC. The support rate was 50% for the last 5 years of the scheme, which closed to new applicants in autumn 2013 [20]. Since 2002 renewable electricity generators have been able to receive support under the Renewable Obligation mechanism [21]; renewable heat technologies have more recently been supported by the Renewable Heat Incentives (RHI) scheme [22]. The RHI scheme when launched in 2011 was initially available only to the industrial sector, but in 2014 expanded to cover domestic usage of renewable heat.

Economic and behavioural factors are implicated in farmers' decisions to adopt energy crops, and therefore potentially to explain the low uptake. Several studies have looked at the economic aspects of energy crops, estimating the annual land rental charge to account for the foregone opportunity to make greater returns from other activities, or opportunity costs [15,16,23]. A similar approach has compared annual gross margins of conventional crops with an equivalent annualised value for perennial energy crops [24–28]. A further method is to use a farm-scale economic model, maximising gross margin, to investigate the potential uptake of perennial energy crops [29]. These studies show that based on the economic case, energy crops should have been adopted more widely, leading to a focus on possible behavioural barriers to adoption. These might include cultural factors, awareness and educational barriers, long-term commitment of land, and perceived risks [18,30–35]. There is heterogeneity in the level of economic and behavioural factors, between farmers and over time, for example in investment return thresholds and risk perceptions [36]. A ‘chicken and egg’ problem is also an apparent barrier; farmers are unwilling to grow the crops without a more mature market, while potential investors are unwilling to develop the plants and technologies that are required to create the demand and so establish the market [30,37]. The cyclic contingent behaviour between farmers and plant investors increases the complexity of the overall system, complicating analysis of the market.

Energy crops compete with other potential land uses, and so have the potential to have positive and negative impacts on a range of environmental factors, e.g. greenhouse gas (GHG) emissions, soil organic carbon (SOC), biodiversity and water resources [38–41]. Increased uptake of these crops is therefore relevant to other policy objectives for the provision of ecosystem services, including food production [42]. Biomass energy has on occasions been assumed or stated as having zero net emissions of carbon dioxide [43,44], or given a zero emissions factor [45]. Although the carbon released during the energy production has been captured during plant growth, biomass use in energy generation potentially generates direct and indirect sources of emissions [39,46–50]. Direct emissions can occur in the production, transport, handling and processing, while indirect emissions are associated with land use change potentially causing SOC changes. These crops could, therefore, potentially provide an important source of low carbon energy, and so help to reduce the carbon intensity of energy production, as well as filling the gap between future electricity supply and demand. But the relevant economic, social and environmental trade-offs need to be understood to ensure sustainability.

The energy crop market is a complex system involving human decision-making by many individuals, working within an evolving policy context. Moreover, economic, ecological and social aspects of the system are strongly coupled, complicating understanding of any single aspect. The potential benefits and drawbacks of the adoption of these crops at scale requires the coupling to be more fully understood, and to suggest ways that net societal benefits can be maximised. Furthermore, related policies are currently in flux [7], increasing the need for greater scientific understanding of the trade-offs and analysis of which measures are appropriate and cost-effective. The reasons for the lower than anticipated uptake of these crops to date [18] also needs to be understood, and potential measures identified that could help to stimulate the market.