

# Opportunity Costs of Woodland Creation in England

A review of data sources  
and evidence

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## Executive summary

Woodland creation on private land is an important component of the UK Government's strategy to achieve carbon net zero and other environmental targets. While the net income foregone – an indicator of the financial opportunity costs – is important in deciding whether to create new woodlands, previous studies on this topic are sparse.

This review presents estimates of the net income foregone when creating woodlands in England by comparing net returns for a range of alternative land uses with those for woodland creation. It also briefly explores whether a 'financial premium' may be required to overcome wider non-financial barriers to woodland creation.

Estimates of net income were computed using publicly available data. They cover nine agricultural categories (defined under the Farm Business Survey) for the period 2017/18–2021/22, four types of renewable energy generation technologies, as well as Biodiversity Net Gain (BNG). For woodland creation, a limited set of estimates were derived from Forestry Commission publications. They cover three broad woodland types: productive conifer, productive broadleaf, and native broadleaf. In each case, the estimates include government subsidies. They have also been annualised and are presented in 2022/23 financial year prices, with a discount rate of 3.5% applied, where possible, to account for the different timeframes in which income is received under the different land uses.

Figure 1 presents the annualised net return estimates per hectare for agriculture, renewable energy, BNG, and woodland creation. Table 1 provides corresponding minimum and maximum estimates (where available) to enable more nuanced comparisons.

Figure 1 Annualised net returns (inclusive of government grants) estimated for agriculture, renewable energy, BNG, and woodland creation (£/ha/year)

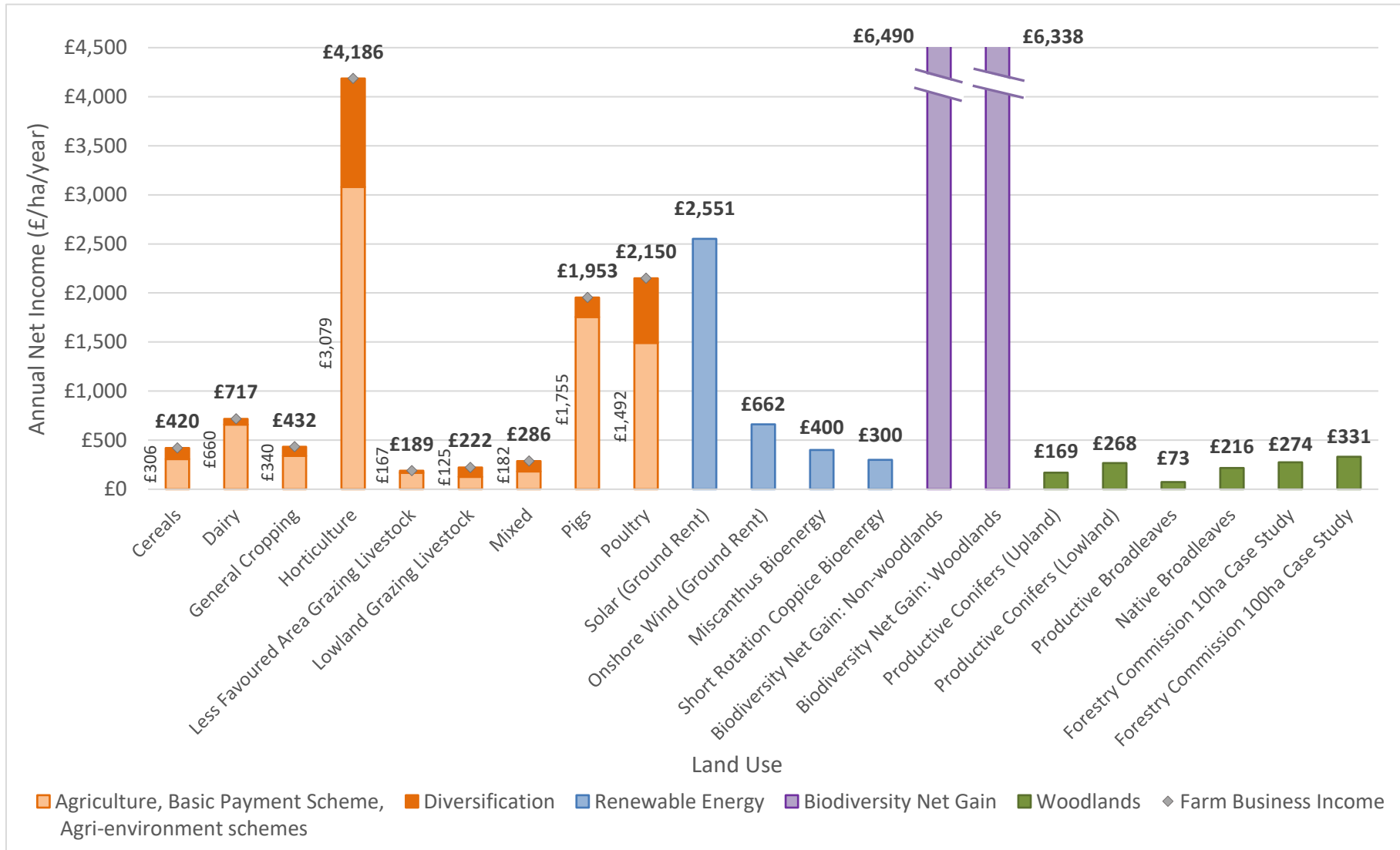


Table 1 Annualised net returns (inclusive of government grants) to all land uses (£/ha/year)

Land Use	Annualised Net Returns (£/ha/year)		
<b>Agriculture <sup>1, 6</sup></b>	<b>Average</b>	<b>Min</b>	<b>Max</b>
Cereals	£420	£306	£692
Dairy	£717	£198	£909
General Cropping	£432	£331	£594
LFA (Less Favoured Areas) Grazing	£189	£123	£247
Lowland Grazing	£222	£154	£273
Mixed production	£286	£148	£375
<b>Renewable Energy <sup>2</sup></b>	<b>Midpoint</b>	<b>Min</b>	<b>Max</b>
Solar Ground Rent	£2,551	£2,224	£2,878
Onshore Wind Ground Rent	£662	£470	£853
Miscanthus Bioenergy	£400	£300	£500
SRC (Short Rotation Coppice) Bioenergy	£300	£250	£350
<b>BNG <sup>2, 4, 5</sup></b>	<b>Midpoint</b>	<b>Min</b>	<b>Max</b>
Non-woodland habitats, medium distinctiveness	£5,573	£2,355	£9,483
Non-woodland habitats, high or very high distinctiveness	£7,778	£4,072	£11,930
Woodland habitats, medium distinctiveness	£4,787	£1,317	£9,099
Woodland habitats, high distinctiveness	£7,137	£2,230	£13,530
<b>Woodland creation <sup>3, 4</sup></b>			
Productive Conifers (Upland)	£169		
Productive Conifers (Lowland)	£268		
Productive Broadleaves	£73		
Native Broadleaves	£216		
Forestry Commission Case Study: 10-ha Productive Broadleaves	£274		
Forestry Commission Case Study: 100-ha Productive Conifers and Broadleaves	£331		

<sup>1</sup> The average estimates for agriculture represent the mean annual Farm Business Income (FBI) per hectare from 2017/18–2021/22, adjusted to 2022/23 prices. Min and max figures represent the minimum and maximum averages in particular regions of England.

<sup>2</sup> The midpoint estimates for renewable energy and BNG represent the average of min and max estimates rather than an arithmetic mean of a sample of estimates. The min and max estimates are based on ranges found in the literature, online sources, and/or reports.

<sup>3</sup> The estimates for woodland creation are not averages and do not have a min-max range. Instead, they correspond to a specific set of assumptions (see 'Section 4.4.3').

<sup>4</sup> Estimates for BNG and woodlands are in the form of Equivalent Annual Values (EAV). For more details, see 'Section 3.3' and 'Appendix A1.60'.

<sup>5</sup> The habitats assumed under BNG are: medium distinctiveness non-woodlands (heathland and scrub, other neutral grassland, individual trees); high or very high distinctiveness non-woodlands (traditional orchards, lowland meadows); medium distinctiveness woodlands (medium distinctiveness woodland and forest, wet woodland); high distinctiveness woodlands (high distinctiveness woodland and forest, mixed deciduous woodland).

<sup>6</sup> Estimates for horticulture, pigs, and poultry farms are omitted because they occupy relatively little land and are deemed less of an opportunity cost, with spatially disaggregated data unavailable for these.

The review of published evidence indicates that, compared with the returns from woodland creation, the opportunity costs tend to be relatively high.

Returns from woodland creation estimated using legacy woodland grants available prior to the England Woodland Creation Offer (EWCO) range from £73/ha (productive broadleaves) to £268/ha (lowland productive conifers). Estimated returns instead calculated using EWCO grants (rates applicable in February 2023), are higher, ranging from £274/ha for productive broadleaves to £331/ha for mixed woodlands (of productive broadleaves and conifers).

Only three of the nine farm types considered have net returns that are lower on average than the most profitable woodland creation estimates. These are mixed farms (£286/ha), lowland grazing livestock farms (£222/ha), and less favoured areas (LFA) grazing livestock farms (£189/ha). However, when the lower bound returns from agriculture in different regions of England are considered, they suggest that in specific locations woodland creation may also generate higher

returns than other farm types. This highlights the potential importance of spatial variations in opportunity costs.

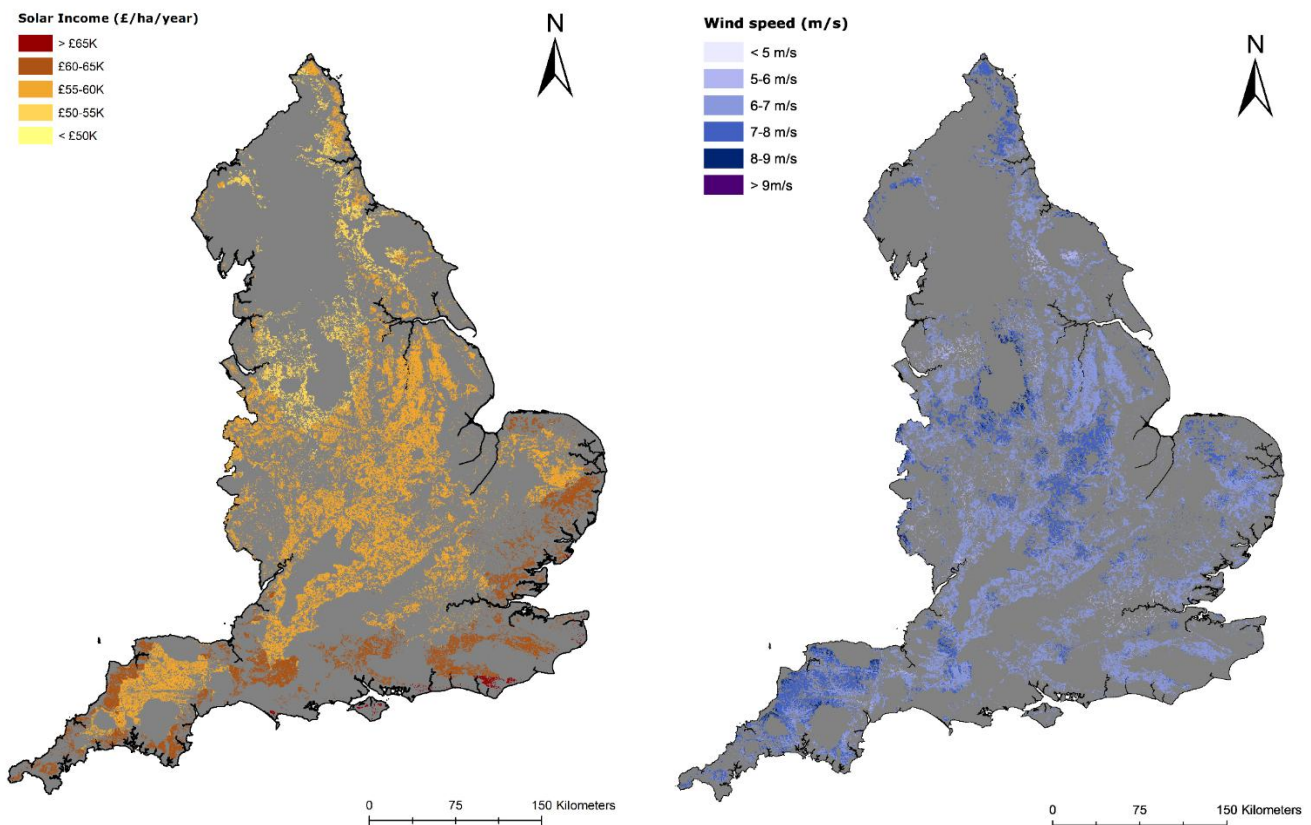
Agricultural opportunity costs also depend partly on how diversification income (e.g. from tourism and recreation) is treated. If it is excluded from calculations (i.e. this income is retained rather than lost when woodland is created), the returns from agriculture would be lower relative to woodland creation. For instance, the average returns from cereal farms would fall from £420/ha to £306/ha, while those from lowland grazing livestock farms from £222/ha to £125/ha. Seen from another angle, returns from forestry would be higher if income from diversification were retained in creating woodlands and if any significant wider sources of income from non-timber forest products were included in estimating returns.

Although subject to high uncertainty and variability, some of the emerging alternative land uses appear significantly more profitable than creating woodlands, especially BNG non-woodland habitats (£2,355–£11,930/ha/year), solar ground rents (£2,220–£2,880/ha/year), and onshore wind ground rents (£470–£853/ha/year). This is unlikely to change despite periodic increases in EWCO payment rates, especially in the case of BNG and solar ground rents where the returns are higher by an order of magnitude or more.

Alongside the more common case of accepting ground rents from energy developers, average estimates were computed for when landowners invest in solar and wind energy themselves. Figure 2 shows how potential solar income (based on photovoltaic output) and wind speeds vary spatially across England within areas of low sensitivity to woodland creation. Generally, solar power opportunity costs are higher the further south and east in the country, while wind power opportunity costs are higher at higher altitudes or in more exposed regions. It is estimated that 66.6% of land of low sensitivity to woodland creation could generate returns of £55,000–£60,000/ha/year, with a further 20.9% having potential to generate £60,000–£65,000/ha/year, compared to an estimated average of £57,100 for England as a whole. Wind speeds can proxy wind income generation potential, with

66.2% of low sensitivity areas registering average speeds of 6–7 m/s and a further 29.3% registering 7–8 m/s, within a full range for England of 5–9 m/s.

Figure 2 Maps of estimated potential solar income from landowners' own investment (£/ha/year) and wind speeds across England (m/s), intersected with areas of low sensitivity to woodland creation.



In considering the potential for combining woodlands with other land uses, there can be both benefits and drawbacks. While joint wind turbine and forestry operations may occur within a woodland site, few examples appear to currently exist in England. Agroforestry is more widespread, but the limited evidence available indicates that in the recent past it has often generated lower net returns than either agriculture or forestry. This may, however, no longer hold true as a consequence of new Environmental Land Management Scheme (ELMS) agroforestry grants announced in January 2024. For instance, rough adaptation of an existing

estimate from the literature suggests returns of around £410/ha/year could be anticipated from a 'medium density infield' poplar silvoarable system in the east of England under the new payments. Nonetheless, further analysis is required to accurately assess the impact of latest grant rates on financial returns.

The conclusions that can be drawn from this study are limited as only two published estimates incorporating EWCO grant payments were available for comparisons at the time of analysis (with no published estimates available for native broadleaved woodlands or purely productive conifer woodlands). Nevertheless, as EWCO payment rates have periodically increased and new payments have been introduced, financial returns from woodlands are likely to be higher than the published estimates reviewed, and hence also potentially more comparable with the average returns for the alternative agricultural land uses considered. This assumes that the contribution of agricultural grants to overall Farm Business Income (FBI) remains unchanged as the England ELMS gradually replaces previous grants – an assumption that is not tested in this study.

Apart from cash flows, wider issues that may be important for landowners considering the opportunity costs of woodland creation include the permanence of woodland creation, the length of time before generating returns, and risks and uncertainty. It is also well established that there can be non-economic, social-cultural barriers to woodland creation, such as the desire by farmers to self-identify as a farmer rather than a forester and hence to maintain agricultural land as 'productive' land. To incentivise woodland creation, a 'financial premium' may therefore be required above the net returns to the most profitable alternative land use.

However, evidence on the existence and level of such a premium in forestry appears sparse. No studies were identified for the UK, with only two examining forestry premiums in Ireland and one examining short rotation coppice (SRC) systems in Germany. Each of the latter studies identified a premium of some form. For example, the studies on Ireland estimated a financial premium for forestry (i.e.

margin of profit over agriculture) of roughly 97%, or 383% if the opportunity cost of family farm labour is accounted for.

Some landowners may be motivated to undertake woodland creation for reasons other than profitability – such as for amenity and recreational benefits, water quality improvement, and erosion control. This would tend to reduce the level of any 'financial premium' needed and, in some instances, may imply that a net return below the average opportunity cost estimates reported here is sought in creating woodlands.

Further research to improve the existing evidence on the opportunity costs of woodland creation is recommended to:

- 1) explore development of spatially explicit approaches to estimating the opportunity costs of woodland creation.
- 2) use a wider range of more precise, location-specific, woodland return estimates in comparisons with opportunity costs.
- 3) investigate the net returns associated with mixed land uses (e.g. agroforestry and combinations of renewable energy generation with agriculture or forestry) in exploring further opportunity costs of woodland creation.
- 4) conduct research on the existence and level of any 'financial premiums' that exist for woodland creation in England. This includes investigating the perceived cost to landowners of (i) loss of flexibility due to the irreversibility of woodland creation as a land use, (ii) impacts of planting trees on the value of underlying land, and (iii) exploring whether wider non-financial barriers can be expressed as a financial premium.

# 1 Background & context

Pledging to leave the environment in a better state than it was found, in May 2021 the UK Government published the England Trees Action Plan (ETAP) 2021–2024, and more recently the Environmental Improvement Plan 2023. These specified the Government’s long-term vision for trees, woodlands, and forests in England – including in achieving its net zero carbon and other environmental targets. A key aim is to raise woodland cover from 10% of total land area in 2018 to 12% by 2050. The ETAP outlines various actions needed for realising these targets. One of these is Action 5.12 to “build the economic evidence base to help land managers and businesses make informed decisions on land use change and woodland management” (Defra, 2021c, p. 36).

In support of Action 5.12, this report investigates the financial ‘opportunity costs’ of woodland creation in England – broadly defined as the income foregone from the best alternative use of resources (Hardaker and Healey, 2021; Bateman *et al.*, 2022) – by comparing the income that can be derived from planting woodlands with that from alternative land uses. The report is part of the Nature for Climate Fund (NCF) Economics of Woodland Creation Project (ETPP-29). Its findings help better understand the economic barriers to and wider financial implications of woodland creation.

The remaining sections are structured as follows: ‘Section 2’ provides more detail on the aims and objectives of the study. ‘Section 3’ explores the approaches to examining opportunity costs of woodland creation and justifies the methodology chosen for quantifying income foregone. ‘Section 4’ explores the financial returns that can be made from woodlands and alternative land uses and provides comparisons between them. ‘Section 5’ briefly discusses various other economic, social, and cultural barriers to woodland creation that need to be considered, in addition to financial opportunity costs. It also explores evidence on the existence of a financial premium for woodland creation associated with a loss of option value.

The concluding section, 'Section 6', highlights policy implications and existing evidence gaps, including recommendations for further research.

## 2 Aim & objectives

To gain a better understanding of opportunity costs associated with woodland creation in England, the specific objectives of this report are to:

1. explore and compare approaches used in the literature to express opportunity costs, focusing on measures of income foregone.
2. search and review data sources and evidence available on the income that can be gained from alternative land uses, focusing on agriculture, renewable energy generation, and Biodiversity Net Gain (BNG).
3. compare the income potential from the alternative land uses with that associated with woodland creation to provide indicative estimates of the opportunity costs.
4. explore the current evidence on the existence of a 'financial premium' needed to overcome wider economic, social, and cultural barriers to woodland creation in England.

## 3 Methodology

### 3.1 Scope of study

For woodland creation decisions in England, a key consideration is often the level of net income foregone due to the switch from the previous agricultural land use, but in some cases the best alternative option considered may be a completely different activity, such as installing solar panels or wind turbines. This study focuses on agriculture, renewable energy generation, and BNG as opportunity costs of woodland creation.

Planting trees solely for bioenergy (i.e. woodfuel production) is not considered separately in this report (although some of the woodland creation and agroforestry studies covered can in theory involve a small element of woodfuel production through harvests from thinning). In addition, even though in some instances housing or property development may also be considered an opportunity cost of woodland creation, consideration of associated returns is beyond the scope of this report (where permitted, house building might be expected to generate much higher returns than woodland creation).

### 3.2 Approaches to opportunity cost estimation

Woodland creation involves a variety of costs – including planning, planting, maintenance, and subsequent forest management costs. To gauge the full economic cost of woodland creation to landowners, it is important to also estimate the opportunity costs (Ronzon *et al.*, 2014). For example, in an agricultural context, there can be two distinct elements to consider: (i) the opportunity cost of the land (e.g. agricultural or land rental income foregone); and (ii) the opportunity cost of family labour (e.g. off-farm wages foregone) (Ronzon *et al.*, 2014). Emphasis in this report is placed on the opportunity cost of the land due to limited data on family labour (although labour requirements for alternative land uses are also briefly compared in 'Section 5.1').

To quantify the opportunity costs of using a resource, it is useful to first review the various approaches available (

Table 2). Several of these approaches to estimating opportunity costs are designed with particular tenure systems in mind. Some previous studies have used two or more approaches to obtain more robust estimates (Rendon, Dallimer and Paavola, 2016).

According to Ronzon *et al.* (2014, pp. 27–28), who reviewed approaches used globally to value farm-owned factors of production, the most common approach to estimating the opportunity costs of land is the ‘rent approach’ which assumes that the opportunity cost for each land parcel can be calculated from the rent paid to the landlord under different tenure agreements. This approach tends to be applied in agricultural contexts but can also be applied to other land uses subject to land tenure agreements, such as land for solar and wind energy projects. As land rents tend to lie slightly below long-term average net returns, land rents are sometimes adjusted upwards to represent the opportunity costs more accurately (Wünscher, Engel and Wunder, 2011).

A wide variety of contractual tenancy agreements exist, and this can complicate estimating opportunity costs. For example, under share rental agreements, where tenant farmers and landowners share risks and returns (benefitting from combined use of resources and expertise), all transactions must be converted to a cash equivalent value (Ronzon *et al.*, 2014). The rental approach to estimating opportunity costs works best when most land comes under tenancy agreements (Iowa, 2000). However, as of June 2023, 68% of agricultural holdings in England were managed by landowners rather than under tenancy agreements (Defra, 2024f). Additionally, high resolution (e.g. farm- or parcel-level) agricultural land rental data is not publicly available for England. Even if detailed data were available, the rental approach may not be a good reflection of future opportunity costs due to the ongoing agricultural policy transition. This is because past rental data would in part reflect the Basic Payment Scheme (BPS) and agri-environmental

scheme (AES) payments for which land managers were eligible up until 2024, while future data will depend on the new subsidy payments under the Environmental Land Management Scheme (ELMS).

A closely related approach is the 'market sales price approach', often used in contexts where most land is managed by the landowners. The approach entails adjusting market sales prices by the appropriate real interest rates and annual costs such as maintenance costs and property taxes (Ronzon *et al.*, 2014).

In cases of both the rent approach and the market sales price approach, spatially explicit data at the land parcel level can be used to incorporate the impact of site-specific factors into opportunity cost estimates. For example, land values or rental prices may rise where planning permission is granted to install renewable energy generation equipment (e.g. solar panels) (Farrer&Co, 2023a), or potentially may decline where new public access paths are established (Buckley *et al.*, 2008). However, market sales data containing such land attributes at land parcel scale does not appear to be readily available for England.

A third approach to estimating opportunity costs, which has been applied in the context of Payments for Ecosystems Services (PES), entails conducting, or simulating, procurement auctions for PES contracts. For example, landowners place bids for the level of compensation they would accept for creating woodlands on their land (e.g. in the form of woodland creation grants). The competitive nature of the auction and bidding rules could be expected to provide landowners with the incentive to place bids marginally higher than their opportunity costs, thus providing indicative estimates of opportunity costs (Ferraro, 2008). Various types of procurement auctions exist, such as open versus sealed bidding, where bidders can and cannot view other bids, respectively. In addition, rules may stipulate that contracts will be awarded equal to the bid, or at a uniform rate equal to the lowest non-winning bid (Ferraro, 2008). Repeat auctions can help reveal opportunity cost changes over time.

An example of a PES procurement auction is the US Conservation Reserve Program which offers contracts based on landowners' single sealed bids and the expected ecosystem services derived from retiring the land parcel from agricultural use, subject to a bid cap equal to the estimated agricultural rental rate (Hellerstein, 2017; Wallander *et al.*, 2023). However, in the absence of implementation of wide-scale auction-based PES schemes in Great Britain, procurement auctions are unlikely to be a practical means to estimate opportunity costs in the UK (no simulated, hypothetical auction examples were found). This is because they would require a large, representative sample of landowners to take part to ensure sufficient competition and reduce possibilities for collusion. This can be a challenging, time consuming, and an expensive process, not least if landowners believe that revealing their true opportunity costs to researchers could potentially disadvantage them in future (e.g. if it could lead to a reduction in future grant rates) and may also have ethical implications (Ferraro, 2008).

The 'model approach' estimates opportunity costs for the given land parcels by regressing per hectare returns on spatially explicit independent variables, e.g. topography, soil quality, climate, distance to markets, and input and output prices (Wünscher, Engel and Wunder, 2011). Landowner socioeconomic characteristics (e.g. education and age) and farm specific variables such as farm type, capital investment, and off-farm labour can also be incorporated. The usual econometric assumption tests are required (e.g. exogeneity, normality, and homoskedasticity) (Wünscher, Engel and Wunder, 2011). While this would be a robust method for estimating opportunity costs, and spatial data on agricultural land classification (summarising soil quality, climate, and topography) is available for England, sample data on per hectare returns would need to be collected. To incorporate socioeconomic and farm-specific variables into opportunity cost estimates, nationwide data would be needed at land parcel level, which is not currently available in the public domain. These high data and time requirements put it beyond the scope of this review, although it could be explored in future research.

Finally, the ‘income approach’, sometimes referred to as the ‘flow approach’, focuses on land managers’ cash flows when making use of land, and involves subtracting the sum of monetary outflows from the sum of monetary inflows (Wünscher, Engel and Wunder, 2011). This can be used either on a parcel-by-parcel basis, or in estimating average opportunity costs. It is worth noting that these average figures would be across all qualities of land for each land use or farm type and therefore potentially mask the availability of economically marginal land where woodland creation could be an attractive land use (Wünscher, Engel, and Wunder, 2011). Two methods for calculating opportunity costs using the income approach are (1) the ‘net income’ method, which considers both variable and fixed costs; and (2) the ‘gross margins’ method, which only considers variable costs (FBS, no date a). While gross margins may be useful for short-term agricultural land use decisions, net income is a more comprehensive measure of opportunity costs for land use decisions with long-term implications, such as woodland creation. Good agricultural income data for England is available via the Farm Business Survey (FBS) for both these methods.

Table 2 Overview of approaches to quantifying opportunity costs of land use

Approach	Method for Deriving Estimates	Advantages	Disadvantages
Rent approach	<p>Uses data on cash rental prices (£/ha/year).</p> <p>Where land rental data is missing (and spatially explicit estimates desired), can be estimated from land market sales prices (Wünscher, Engel and Wunder, 2011).</p> <p>For share tenancy agreements, converts all transactions to cash-equivalents (Iowa, 2000).</p>	<ul style="list-style-type: none"> <li>• Market based: relies on real-world rent price data.</li> <li>• Location-specific: Where spatially explicit data is available, accounts for factors such as land quality and climate.</li> <li>• Applicable to a variety of land uses, including solar and wind energy.</li> </ul>	<ul style="list-style-type: none"> <li>• Precise, spatially explicit, and regionally differentiated data not publicly available for England.</li> <li>• May not well reflect returns well under changing subsidy policy.</li> </ul>

<p>Market sales price approach</p>	<p>Equivalent to the rent approach but uses market land sales prices (£/ha). Requires standard capitalisation techniques: 'market sales price' × 'real interest rate' and adjusted for risk, plus annual associated costs (Iowa, 2000; Ronzon <i>et al.</i>, 2014)</p>	<ul style="list-style-type: none"> <li>• Market based: relies on real-world sales price data.</li> <li>• Location-specific: with spatially explicit data, accounts for factors such as land quality and climate.</li> <li>• Can also be used for renewables and BNG.</li> </ul>	<ul style="list-style-type: none"> <li>• Lack of publicly available market sales data at land parcel level (average <a href="#">agricultural land values</a> in each local authority available from HM Land Registry).</li> <li>• May not reflect returns well under changing subsidy policy.</li> </ul>
<p>Procurement auction approach</p>	<p>In procurement auctions for PES contracts, landowners place bids close to their opportunity costs due to market competition (Ferraro, 2008).</p>	<ul style="list-style-type: none"> <li>• Repeated auctions can reveal changes in opportunity costs over time.</li> </ul>	<ul style="list-style-type: none"> <li>• Requires a large, representative sample of bidders.</li> <li>• Potentially costly to simulate an auction for research purposes and landowners may not be willing to reveal true level of opportunity costs.</li> </ul>
<p>Model approach</p>	<p>Net returns to land are regressed against several independent variables (e.g. slope, precipitation, soil) based on the geographic position of sampled land (Wünscher, Engel and Wunder, 2011).</p>	<ul style="list-style-type: none"> <li>• Robust and spatially explicit: Impact of variables such as soil quality, topography, and climate on net returns accounted for in estimates.</li> <li>• High resolution at land parcel level.</li> </ul>	<ul style="list-style-type: none"> <li>• Greater data requirements (e.g. sample data on net returns at parcel level) and time requirements to implement analysis.</li> <li>• Difficult to account for socioeconomic and farm-specific characteristics at national level.</li> </ul>
<p>Income approach (or 'flow approach')</p>	<p>Net income method (£/ha/year): monetary inflows minus monetary outflows, including fixed costs (Wünscher, Engel and Wunder, 2011).</p>	<ul style="list-style-type: none"> <li>• Variable and fixed costs considered, hence useful for long-term land use decisions.</li> <li>• Good data sources for England (e.g.</li> </ul>	<ul style="list-style-type: none"> <li>• Data available is not spatially explicit at individual land parcel level and is made of average figures, masking income variation</li> </ul>

		<p>the FBS, which is longitudinal and granular).</p> <ul style="list-style-type: none"> <li>Regionally differentiated data: region specific data is available from the FBS.</li> </ul>	<p>over time and between farms.</p>
	<p>Gross margins: annual revenues minus annual variable costs (£/ha/year)</p>	<ul style="list-style-type: none"> <li>Regionally differentiated data: region specific data is available from the FBS.</li> </ul>	<ul style="list-style-type: none"> <li>Data available is not spatially explicit at individual land parcel level and are average figures.</li> <li>Overestimates long-term opportunity costs as fixed costs not accounted for.</li> </ul>

This study found limited evidence on the implications of using the different methodologies to estimate opportunity costs. Nevertheless, some inferences can be drawn on differences between the rent and income approach using data from the FBS. Table 3 presents and compares snapshot estimates of average farm rent, net income (FBI), and gross margins in 2022/23 prices. It shows that the gross margins method suggests the highest opportunity costs – which might be expected due to no account being taken of fixed costs. It also shows that use of farm rent estimates, particularly those for Farm Business Tenancy (FBT) agreements, would suggest opportunity costs approximately half those suggested by FBI net income estimates. The exact reasons for this are unclear, but it could potentially be explained in part by farm tenants needing to retain a portion of the profits they generate rather than passing all to the landowner in rent. Another potential explanation is the general finding that rent levels tend to lag behind farm returns by one to two years (Paulson *et al.*, 2023), but further analysis would be required to confirm whether this applies in England.

Table 3 Comparisons of different approaches to estimating opportunity costs (£/ha/year)

Approach to Estimating Opportunity Costs	Opportunity Cost Estimate (£/ha/year)
Rent approach (Farm Business Tenancy) <sup>1</sup>	£228
Income approach: net income method <sup>2</sup>	£564
Income approach: gross margin method <sup>2</sup>	£1,502
Sources: (Defra, 2024j; FBS, no date b)	
<p><sup>1</sup> The farm rent estimate is an average across England for 2022/23. Of all the tenancy agreement types under the FBS, the FBT arguably best represents the counterfactual scenario to use for the opportunity costs of woodland creation to tenant farmers. This is because such agreements can cover a longer period, unlike seasonal agreements (Defra, 2024j), and allow greater flexibility to undertake secondary non-agricultural activities, unlike Full Agricultural Tenancy agreements (Defra, 2024d).</p> <p><sup>2</sup> The estimates of FBI and gross margins are averages for all farm types in England. They correspond to estimates for 2021/22 (adjusted to 2022/23 prices), rather than a five-year average as adopted in the rest of this report.</p>	

In this report, the income approach, specifically the net income method, is chosen to estimate the opportunity costs of woodland creation. This is because, as well as the fact that data is readily available, it is arguably the most straightforward approach and is commonly adopted in the literature – e.g. see Stern (2007, p. 217) and CJC Consulting (2014). Furthermore, data is readily available. For agricultural opportunity costs, average net returns are calculated using FBI estimates from the FBS. For renewable energy generation and BNG, net returns are calculated based on evidence compiled from peer-reviewed studies, grey literature, and online sources. It is worth noting that where returns estimates are based on ranged data (often the case for renewable energy or BNG), the midpoint between the minimum and maximum values is given as the average, rather than based on the mean of a full sample of data (as with agricultural returns estimates).

### 3.3 Approach to comparing estimates

To enable comparisons between land uses with varying timeframes, the net income estimates for all land uses are expressed in annual terms – henceforth termed as ‘annualised net returns’. For agriculture and renewable energy, no discounting was applied as returns tend to accrue on an annual basis and no detailed information was collected on the timings of cashflows for these land uses. For BNG and woodlands, where returns are assumed to accrue upfront and at the end of long rotation periods respectively, discounting was applied at a rate of 3.5%, and estimates are presented in the form of Equivalent Annual Values (EAV), which are annualised versions of Net Present Values (NPV), to allow for more equal comparisons. Further details of calculations, along with assumptions and implications, are provided in the Appendix (A1.6).

All the monetary estimates presented in this report have been inflated to 2022/23 financial year prices using the Office for National Statistics’ (ONS) GDP Deflators (ONS, 2024). A minor discrepancy exists in the inflated FBI estimates as the original FBS data corresponds to a March to February fiscal year (Defra, 2024h), whereas the ONS GDP deflators correspond to a April to March fiscal year. However, this one-month discrepancy is deemed inconsequential for computing the estimates in this report as the average amount of inflation within the one-month period is less than 1%.

## 4 Comparing financial returns

This section estimates and reports annual financial returns per hectare for a range of different land uses in England. Various forms of agriculture, renewable energy, and BNG are considered. These are then compared with potential returns from woodland creation.

### 4.1 Agriculture

Agriculture is the economic activity with the largest land use in England and is the most commonly used comparator in estimating the opportunity cost of woodland creation. This section first outlines the changing policy landscape and the agricultural subsidies available to farmers. These represent a high proportion of FBI (51% on average over 2017/18–2021/22) and hence significantly influence estimates of the opportunity costs of woodland creation. The section then presents statistics on land cover dedicated to different agricultural uses. The final part and main focus of this section analyses potential returns to agriculture using data from the FBS for various farm types.

#### 4.1.1 Policy and financial incentives

Prior to January 2020, agricultural policy was primarily determined by the EU's Common Agricultural Policy (CAP) (further information on this and England's 2014–2020 agricultural policy can be found in the standalone Addendum). However, following the UK's departure from the EU, Defra announced its aim to provide 'public goods for public money' (HM Treasury, 2019), helping farms boost profitability while sustaining the environment and tackling issues related to climate change (Defra, 2019).

The Agriculture Act 2020 set out plans to replace direct payments with ELMS as the primary agricultural subsidy scheme in England (Coe *et al.*, 2020). The Act instituted a seven-year transition period from 2021–2027, with a gradual phasing out of BPS payments between 2021 and 2023. Between 2024 and 2027, 'delinked payments' will be paid to landowners based on their 'reference amounts' (the

average annual direct income support received 2020–2022) and will be subject to progressive reductions each year (Coe *et al.*, 2020; RPA, 2023; Defra, 2024e).

Meanwhile, ELMS will be gradually introduced over this transition period and consists of three components:

- The Sustainable Farming Incentive (SFI)
- Countryside Stewardship (CS) and CS Plus
- Landscape Recovery (LR)

The SFI provides ‘action-based payments’ to promote sustainable farming practices. It focuses on providing farmers with continued access to grant payments following the phasing out of BPS payments, supporting them in managing their land in an environmentally sustainable way (Defra, 2023b), rather than encouraging land use change (LUC) away from farming. This is achieved through support for actions such as livestock management and establishment of hedgerows (Scott, 2024). Table 4 shows some examples of grant payments available under the SFI in 2023.

The CS, with significant changes under ELMS, provides more targeted payments to help support nature recovery at a landscape scale, both within and beyond agricultural land (Defra, 2020). It consists of eight categories of grant agreements. The Higher Tier, Mid-Tier, and Wildlife Offers include environmental management payments made every five years and grants for one-off capital items. The remaining categories consist of grants for planning and feasibility studies, woodland management, and capital costs. Meanwhile, the CS Plus scheme offers support to farmers who collaborate to deliver CS outcomes (Defra, 2023d). The LR scheme provides grants for a more limited number of large-scale, long-term custom projects to significantly enhance natural ecosystems and habitats (Defra, 2023d). As a result, unlike the SFI, the CS and LR schemes extend beyond farming and aim to produce positive environmental outcomes through wider-scale LUC.

Table 4 Sustainable Farming Incentive (SFI) packages and payments

Packages	Example Actions	Payments (£/ha)
Actions for soils	Multi-species winter cover crops, herbal leys	£129–£382
Actions for integrated pest management	Flower-rich grass margins, blocks, or in-field strips; companion crop on arable and horticultural land; no use of insecticide	£45–£798
Actions for nutrient management	Legumes on improved grassland or legume fallow	£102–£593
Actions for farmland wildlife on arable and horticultural land	Pollen and nectar flower mix; winter bird food; grassy field corners and blocks.	£590–£853
Actions for farmland wildlife on improved grassland	Take grassland field corners or blocks out of management; winter bird food	£333–£515
Actions for buffer strips	Grass buffer strips	£235–£515
Actions for low input grassland	Manage grassland with very low nutrient inputs	£151
Source: SFI Handbook 2023 (Defra, 2024m)		

Table 5 below illustrates how CS payment rates have increased (in some cases substantially) since the integration of CS into ELMS in 2024, focusing on six examples.

Table 5 Examples of Countryside Stewardship options and changes in payment rates between 2020 and 2024.

Countryside Stewardship Options	Payment Rates (£/ha)					Percentage Change Between 2020 and 2024 (Real Terms)
	2020	2021	2022	2023	2024	
Nectar flower mix (AB1)	£511	£511	£579	£614	£739	21%
Flower rich margins and plots (AB8)	£539	£539	£628	£673	£798	24%
Creation of species-rich grassland (GS8)	£267	£267	£374	£428	£646	102%
Management of species-rich grassland (GS6)	£182	£182	£182	£182	£646	197%
Creation of heathland from arable or improved grassland (LH3)	£517	£517	£577	£607	£711	15%
Flood mitigation on arable reversion to grassland (SW15)	£488	£488	£488	£493	£740	27%
Sources: (RPA, Defra and Natural England, 2021, 2022; RPA and Defra, 2023; RPA, 2024b)						
Note: The percentage change in payment rates from 2020 to 2024 were computed using a forecasted 2023/24 GDP deflator value.						

In addition to ELMS, Defra launched two schemes as part of the Farming Investment Fund to support farm performance during this transition phase (Coe and Uberoi, 2023). These are the Farming Equipment and Technology Fund, which provides grants for productivity-boosting equipment, and the Farming Transition Fund, which supports larger and more complex farm investments (Coe and Uberoi, 2023).

Beside public incentives, an increasing number of corporate schemes have emerged in recent years on the back of consumer interest in the environmental and animal welfare impacts of food production (Coyne *et al.*, 2021) and in supporting farmers. For example, Marks and Spencer has run the M&S Milk Pledge Plus payment scheme since 1999, charging a premium to consumers to pay dairy suppliers 'fair' prices, with the aim of improving income stability of farmers and rewarding good animal health and high farm production standards (M&S Food, 2023).

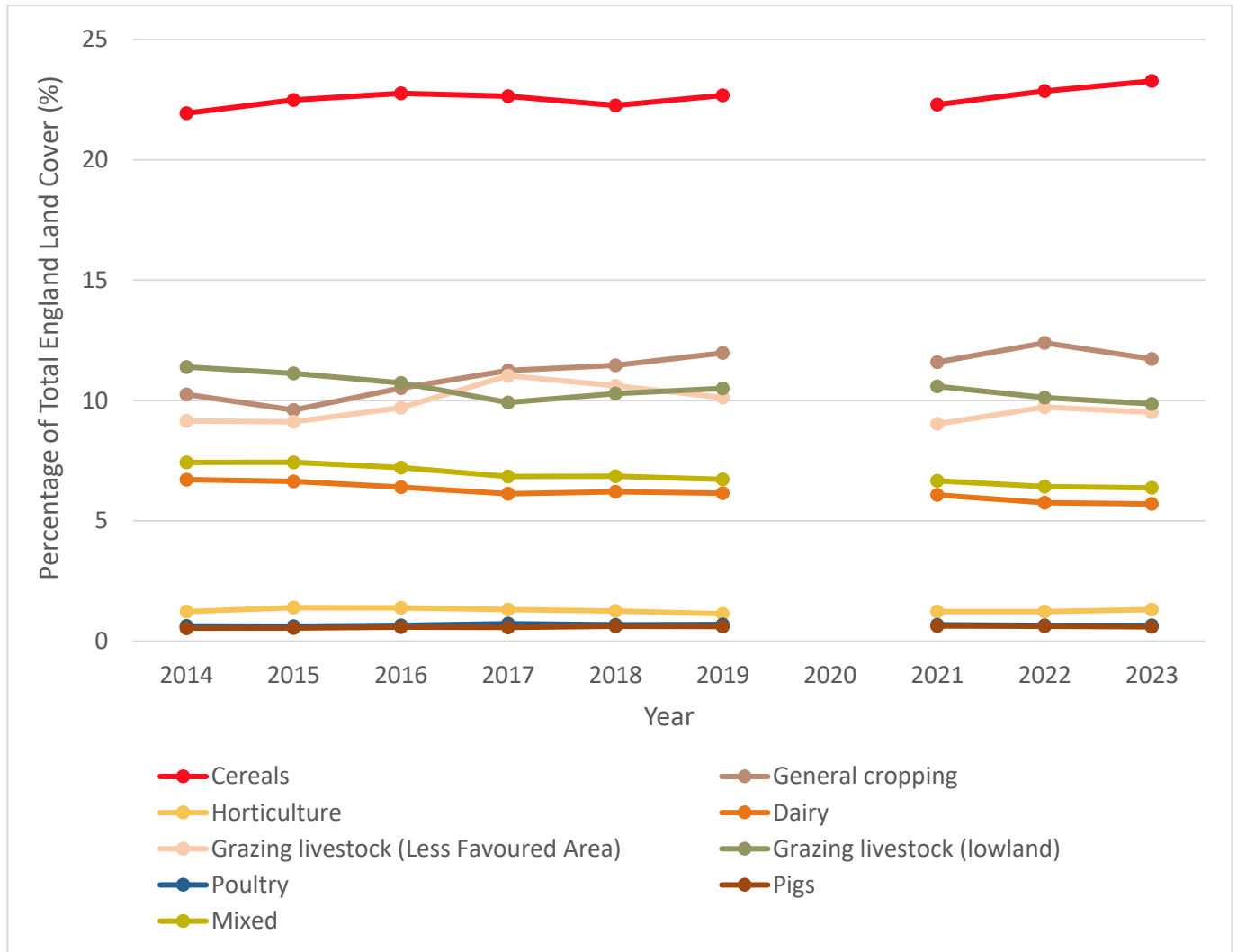
It is worth noting that, apart from subsidies and private incentives, volatile agricultural prices and input costs are also key drivers of agricultural net income. Farmers are typically price takers, and output values can rise or decline between planting and harvest. Many products are also perishable and not possible to store on-farm, meaning farmers cannot wait for better prices (Defra, 2024i). In recent times, the war in Ukraine and rising energy costs created considerable input price volatility during 2021–2023 in fertiliser, fuel, and feed (House of Lords, 2022). For example, UK-produced and imported ammonium nitrate fertilisers respectively experienced 158% and 155% price increases in the year to July 2022, followed by 58% and 57% decreases in the year to July 2023, stabilising thereafter (AHDB, 2024). Modelling from Savills of the effect of rising fertiliser and fuel prices on winter wheat income suggested that significant upfront costs in 2023 would lead to lower return on capital that year (43%) compared with 2021 (57%) (Buckingham, 2022). Some farmers may have adapted their business models to these higher production costs, including scaling back production, using fewer inputs, or shifting away from food production altogether (Buckingham, 2022; House of Lords, 2022). On the other hand, higher farmgate prices also drove higher farm incomes for several farm types in 2022/23 compared with the year before, including cereals, dairy, pigs, and horticulture (Reeve, 2023). Further detailed analysis on the impacts of markets on agricultural income is beyond the scope of this report and can be found in other publications such as that by the Agri-food & Bioscience Institute (Sherry *et al.*, 2023).

### 4.1.2 Land cover

Agriculture represents roughly 68% of England's total land area (Defra, 2024c). Figure 3 compares the current land cover of each farm type as a percentage of England's total land area (13,031,047 ha to high water, excluding inland water).

The distribution of agricultural land use in England remained relatively unchanged between 2014 and 2023. Of England's total land area, arable farms covered an average of 34% over this period, livestock farms 20%, and dairy farms 6.2%. Horticulture, poultry, and pig farms covered just 1.3%, 0.66%, and 0.59% respectively. Over the decade, the coverage of arable farms increased (32.1% to 34.9%), while the coverage of lowland grazing and dairy farms decreased (11.4% to 9.9%, and 6.7% to 5.7% respectively).

Figure 3 Proportion of land area in England (%) occupied by different agriculture types between 2014–2023



N.B. Data for land cover in 2020 was not available due to the Covid-19 pandemic. Estimates are derived from own calculations based on the Agricultural Industry Structure (Defra, 2024p).

### 4.1.3 Average returns

This section first presents average per hectare net returns to agriculture, estimated using data from the FBS for each farm type. This is followed by a brief section on agroforestry to account for land use options that combine agriculture and forestry ‘within the same plot of land’ (Perks *et al.*, 2018, p. 4), often creating synergies that generate a different set of returns.

#### 4.1.3.1 Farm Business Survey data

Figure 4 shows the per hectare FBI returns at 2022/23 prices for each farm type in England, averaged across the five years from 2017/18 to 2021/22 and disaggregated by income categories. FBS farm types include cereals, general cropping, horticulture, LFA grazing livestock, lowland grazing livestock, dairy, pigs, poultry, and mixed farms. A farm is categorised as belonging to a specific farm type when more than two-thirds of its output corresponds to that type, otherwise it is categorised as a 'mixed' farm (FBS, 2014). Under the FBS, total FBI equals the sum of the net income to the farmer from each of the following income categories (also referred to as 'cost centres'): agriculture, AES payments, BPS payments, and diversification.

The average FBI across all farms in England was £572/ha/year, with the agricultural income category accounting for 26% of net returns on average. The lowest opportunity costs of woodland creation were those for LFA and lowland livestock grazing farms, whose average FBIs were £189/ha/year and £222/ha/year respectively. These farm types had negative average income from agricultural production over the period, reportedly due to a decrease in prices and an increase in input costs (Franks *et al.*, 2020; Defra, 2024e). Unsurprisingly these farm types were also the most dependent on BPS payments, which comprised, on average, 101% and 102% of the total FBI earned by LFA and lowland grazing farms respectively. The profits associated with arable farming were roughly double the livestock farms at £420/ha/year for cereals and £432/ha/year for general cropping. Horticulture had the highest average FBI at £4,186/ha/year, followed by poultry and pig farming at £2,159/ha/year and £1,953/ha/year respectively, each earning much higher proportions of their FBI from agricultural production. However, it should be noted these latter figures were influenced by unusually high profits in 2020/21. Dairy farms also performed strongly, with an average FBI of £717/ha/year, of which agricultural income accounted for an average of 58% throughout the period. The average diversification income for this farm type was

£57/ha/year, making up an average of 8% of the total FBI, which was the lowest among all other farm types.

Figure 4 Farm Business Income (£/ha/year) by farm type and income categories based on a 5-year average (2017/18–2021/22)

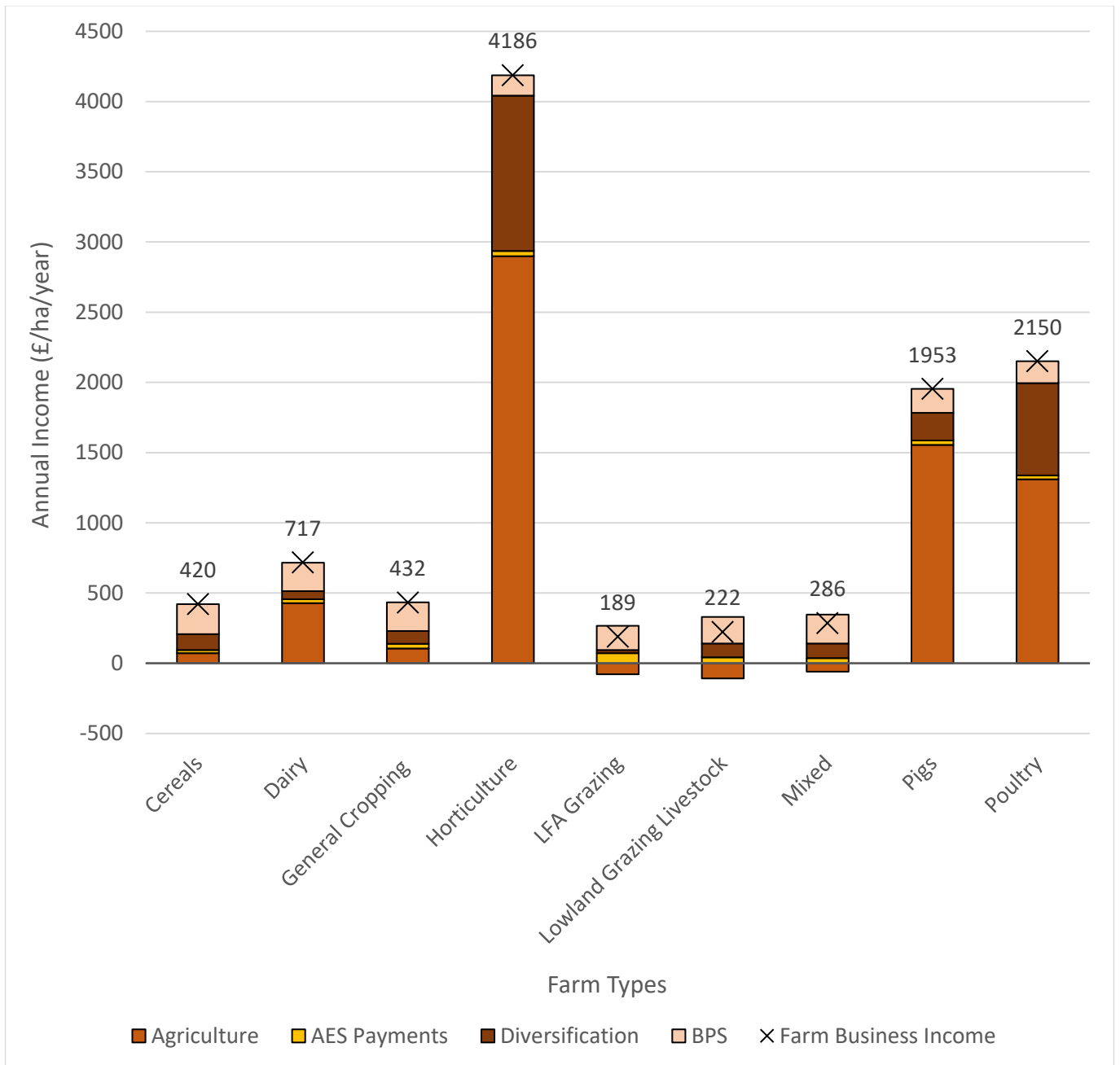


Table 6 Farm Business Income (£/ha/year) by farm type and income categories based on a 5-year average (2017/18–2021/22)

	Agriculture	AES	Diversification	BPS	FBI	FBI without diversification
<b>Cereals</b>	£71	£23	£114	£212	£420	£306
<b>Dairy</b>	£428	£28	£57	£203	£717	£659
<b>General Cropping</b>	£106	£32	£92	£203	£432	£341
<b>Horticulture</b>	£2,899	£36	£1,107	£144	£4,186	£3,079
<b>Grazing Livestock: LFA</b>	-£78	£72	£22	£172	£189	£166
<b>Grazing Livestock: Lowland</b>	-£109	£43	£97	£190	£222	£124
<b>Mixed</b>	-£60	£37	£104	£205	£286	£182
<b>Pigs</b>	£1,554	£32	£198	£169	£1,953	£1,755
<b>Poultry</b>	£1,310	£27	£658	£155	£2,150	£1,492

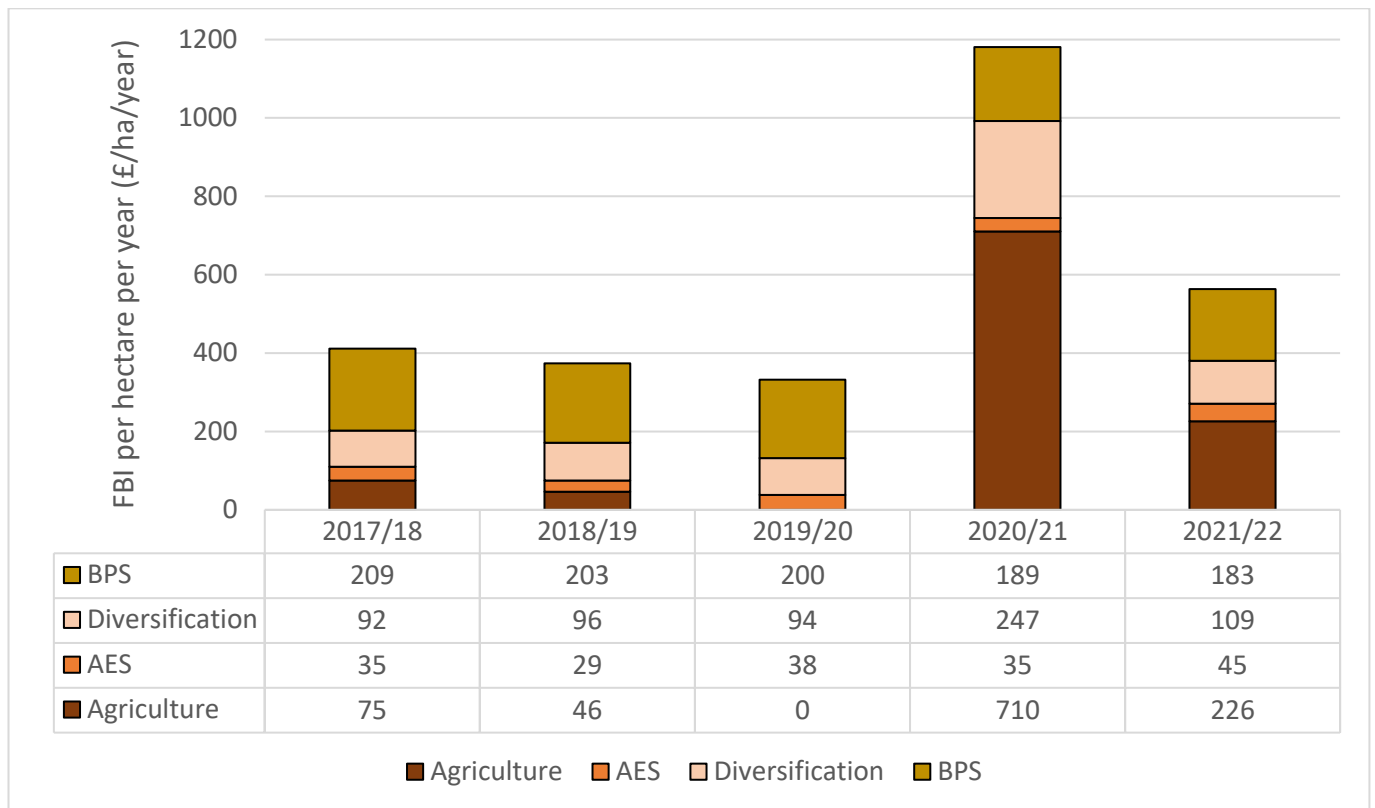
There are two reasons for caution when interpreting the returns to specific income categories as opportunity costs of woodland creation. Firstly, diversification activities may or may not continue under a transition to woodland creation, likely depending on (i) how closely tied these activities are to agricultural land use, (ii) how well these activities align with the new land use, and (iii) landowner preferences. For example, diversification activities related to recreation, property rental, and tourism may be more likely to complement woodland creation whereas activities that rely specifically on agricultural output, such as food processing and retailing, may be less feasible following woodland creation (although in many cases,

not all agricultural land on the farm will be converted to woodland) (Lang, 2020). Table 6 shows that the estimated net returns to all farm types are slightly lower if diversification income is omitted. Figure 18 in the Appendix shows the breakdown of the sources of diversification revenue for each farm type as a rough indication of the extent to which diversification income represents an opportunity cost of woodland creation (note that data on diversification costs and the exact amount of land occupied by these diversification activities is not available from the FBS).

Secondly, in this report BPS and AES payments received by landowners between 2017/18 and 2021/22 are generally considered as opportunity costs of woodland creation as once woodlands are classed as a 'permanent LUC', the land would no longer be eligible for BPS payments (with some notable exceptions – see Forestry Commission (2022a)). This is further complicated by the potential for future agricultural grant income from ELMS to vary considerably from past BPS and AES subsidies (see 'Section 4.1.1', particularly Table 4 and Table 5, on changes to financial incentives available). If ELMS payments are taken up by farmers and the increase in rates more than offsets the reduction in past BPS payments, then future income from agricultural grants may be expected to rise. However, whether this necessarily translates into higher FBI – and hence opportunity costs of woodland creation – depends on whether agricultural production costs increase in tandem.

In terms of interannual variations in FBI over the five-year period, Figure 5 shows how average agricultural returns fell in 2019/20, likely due to the negative impact of poor weather conditions in 2020 (Rivington *et al.*, 2021). However, agricultural income swiftly rebounded to above average levels in 2020/21, with diversification income also seeing a good year. COVID-19 related factors, the end of the EU transition period, and variable weather may have all contributed, with strong output prices offsetting high input costs and low yields for cereals and specialist pig farms, and high output on livestock grazing farms (Defra, 2023e).

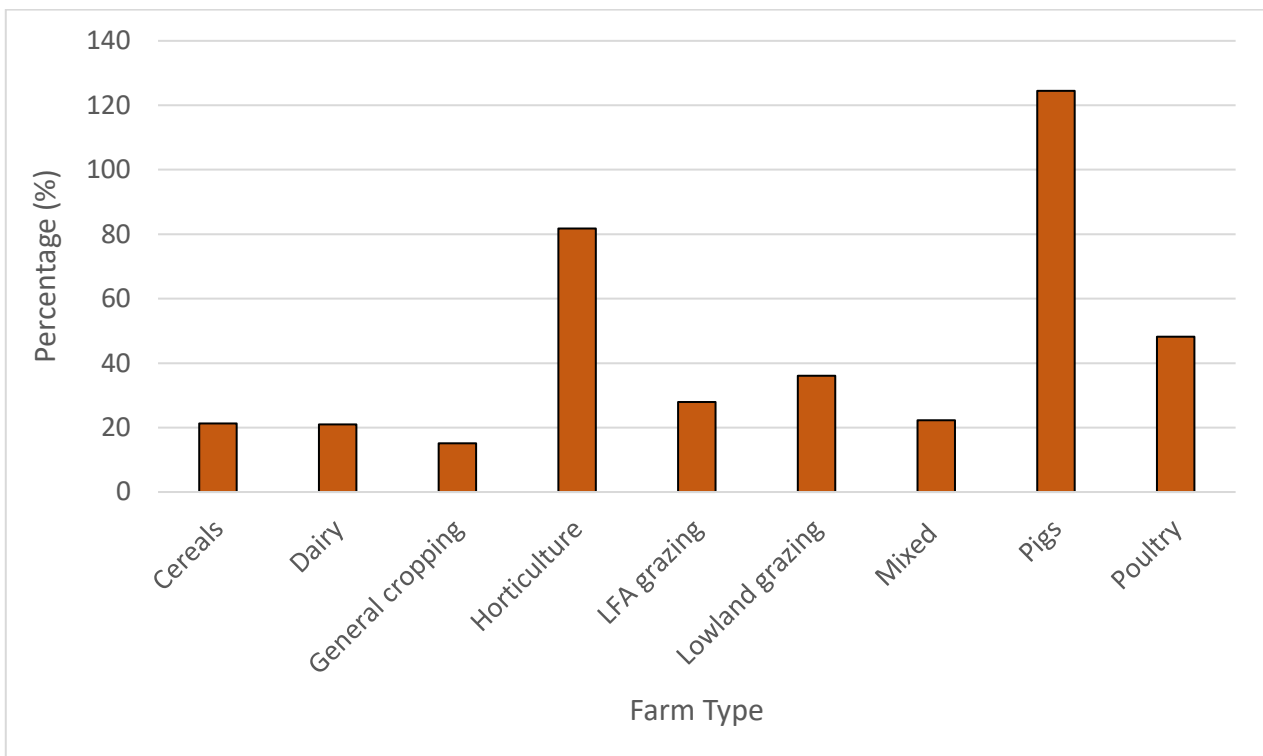
Figure 5 Average annual FBI per hectare for all farm types, 2017/18–2021/22 (£/ha/year)



It is worth noting that some farm types experienced higher annual variation in FBI than others over the five years. Figure 6 shows for each farm type the mean absolute deviation of FBI (the average deviation from the mean over the five years). It is expressed as a proportion of the mean in order to account for the fact that the individual farm types have varying levels of average income and hence have differing abilities to withstand variations in income. By this measure, arable and livestock farms experienced relatively low-income variation over the 2017/18–2021/22 period. In a typical year, general cropping farms could expect per hectare income to deviate 15% from the mean, with lowland grazing income deviating 36%. On the other hand, much higher variation was experienced by horticulture, pig, and poultry farms over the period, driven mostly by relatively high income in 2020/21 (£12,742/ha, £8,029/ha, and £4,744/ha respectively). This could potentially be attributed to recovery from poor weather and COVID-19 related

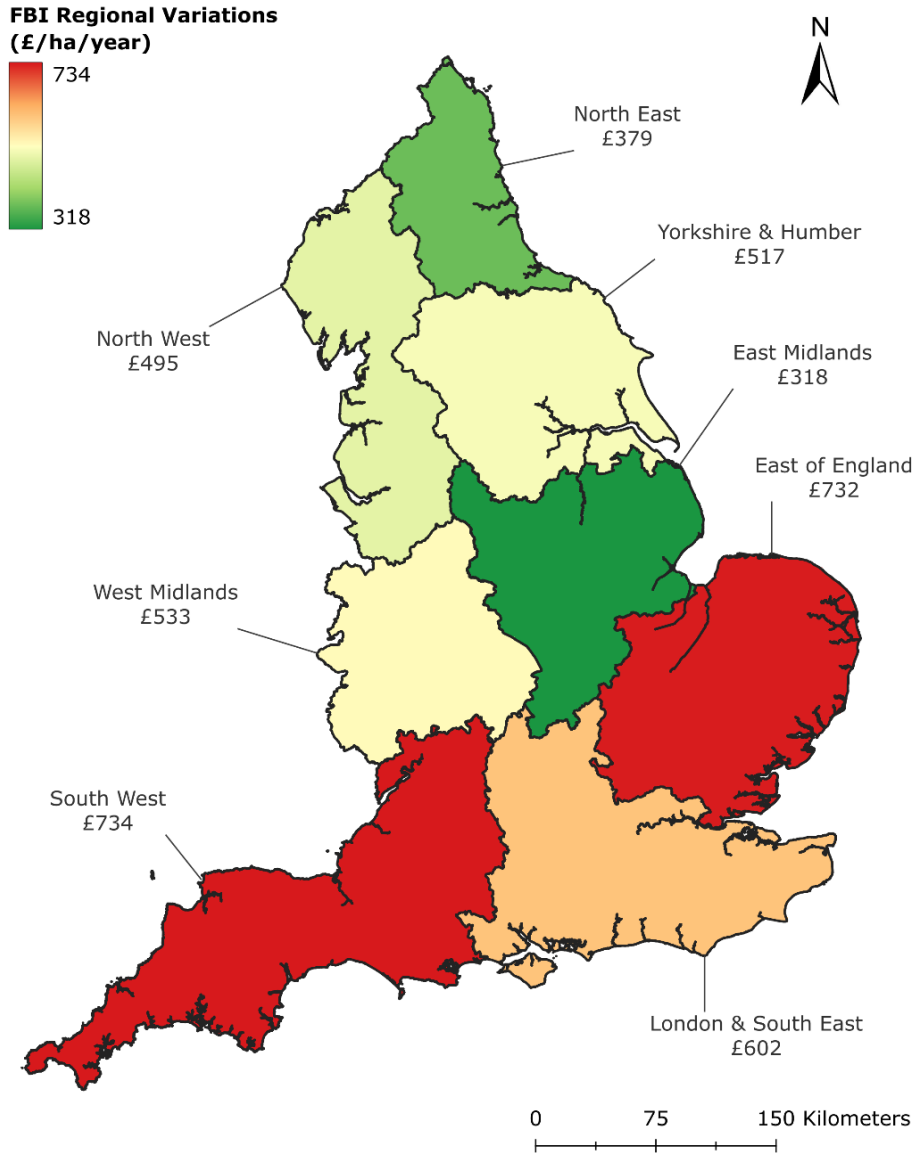
issues that affected 2019 and 2020. Nevertheless, the NFU reported that inflationary pressures have reduced profits in the horticultural sector since 2022 (NFU, 2024).

Figure 6 Mean absolute deviation of FBI (2017/18–2021/22), expressed as a proportion of mean FBI (%)



Significant income variation also occurs inter-regionally. Figure 7 illustrates the regional average FBI across all farm types in England across the years 2017/18–2021/22. The South West region recorded the highest average FBI (£734/ha/year), while the East Midlands recorded the lowest (£318/ha/year). This pattern of findings could be partly attributed to the high prevalence of dairy farms in the South West (Defra, 2024b), which tend to also generate higher incomes compared to other farm types; and the high prevalence of grazing livestock farms in the East Midlands, which generally yield lower returns (Defra, 2024a, 2024k).

Figure 7 Regional average FBI across all FBS farm types (£/ha/year) over the period 2017/18–2021/22



Sources: (i) ONS Geography (2024)<sup>1</sup>; (ii) FBS (no date b)<sup>2</sup>

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<sup>2</sup> Crown Copyright. Contains public sector information licensed under the Open Government Licence v3.0. See <http://www.nationalarchives.gov.uk/doc/open-government-licence/version/3>.

Table 7 Gridded heatmap of average FBI across England (£/ha/year) for a subset of farm FBS farm types, 2017/18–2021/22

Region	Farm Types					
	Cereals	Dairy	General Cropping	LFA Grazing	Lowland Grazing Livestock	Mixed
East Midlands	£416	£663	£331	£177	£201	£312
East of England	£382	NA	£415	NA	£196	£262
London & South East	£381	£198	£547	NA	£252	£187
North East	£692	NA	NA	£241	£243	£155
North West	£306	£756	NA	£184	£230	£148
South West	£425	£785	£453	£247	£235	£289
West Midlands	£449	£598	£594	£201	£154	£375
Yorkshire & Humber	£470	£909	£375	£123	£273	£357
<b>England</b>	<b>£420</b>	<b>£717</b>	<b>£432</b>	<b>£189</b>	<b>£222</b>	<b>£286</b>

Note: Values in the table are ranked on a red-yellow-green colour scale, with dark red indicating higher values and dark green indicating lower values.

Table 7 further illustrates how average FBI from 2017/18 to 2021/22 varies spatially by individual farm types. Note that horticulture, pigs, and poultry farms have been excluded because they have relatively low land cover and high net returns and are therefore less likely to pose an opportunity cost to woodland creation. Of the farm types presented, dairy farms in Yorkshire & Humber experienced by far the highest average FBI, whilst LFA Grazing Livestock farms in

the same region experience the lowest. These estimates should, however, be interpreted as more of a transitory indicator of regional variations in opportunity costs as there can be significant inter-annual variations in income across each farm type and region. Furthermore, while there is some evidence explaining factors driving variations in dairy farm performance (Jones, 2020), little evidence has been found to explain drivers of wider income variation across other farm types and regions.

### 4.1.3.2 Agroforestry

Agroforestry is a land use that broadly involves a 'combination of forestry and agricultural land uses within the same plot of land' such that 'significant ecological and economic interactions between the two components' are achieved (Perks *et al.*, 2018, p. 4). While it can be viewed as a standalone land use in its own right, within a farming context it is also viewed as a means of diversifying agricultural activity (Pagella and Healey, 2020; Staton *et al.*, 2022) and hence income sources for farmers. These benefits are underpinned by the synergies generated from interactions between the two components, which besides generating societal benefits through greater ecosystem services, can also benefit farmers through increased agricultural productivity as well as economic resilience to environmental change (Raskin and Osborn, 2019; Woodland Trust, 2022).

Information on the extent of agroforestry in England is sparse at the time of writing as the land use is not classified as a particular farm type within the national agricultural statistics. Nevertheless, evidence from the academic literature indicates that it occupies roughly 2.2% of the UK's land area, or 3.3% of Utilised Agriculture Area, as of 2017 (Den Herder *et al.*, 2017).

Published evidence on the financial returns from agroforestry have mostly been derived through modelling hypothetical scenarios rather than a survey of actual returns (e.g. using the FBS). A rapid evidence review conducted by Saraev *et al.* (2022) on the financial viability of agroforestry in the UK found that in the recent past, agroforestry systems tend to generate net positive returns, especially in the

long run – e.g. Kaske *et al.* (2021) found annualised net returns of roughly £420/ha/year (£99/ha/year without any grant income) for a poplar silvoarable system in Bedfordshire with a planting density of 156 trees/ha. However, in most cases the land use tended to be less profitable than conventional agriculture and in some cases also less profitable than woodland systems. This tended to hold true even where grant support was included in the estimations and did not change unless landowners were to be compensated for the ecosystem services generated, such as through sale of carbon or nutrient mitigation credits.

In terms of economic insights from qualitative studies investigating the perceptions of landowners towards agroforestry in the UK, Graves *et al.* (2017) found that a large proportion of farmers view silvoarable farms to be less profitable than the status quo of arable farming, citing poor timber markets and high production costs for crops as potential concerns. It is also a common perception that the land use involves long time lags in terms of the revenue generated from timber and tree-related products (Felton *et al.*, 2023). However, Newman *et al.* (2018) point out that agroforestry systems can be attractive for landowners because they generate short-term income through the arable or pasture component that helps compensate for the time lags in returns from the forestry component, with the latter often considered more akin to a capital asset that provides a different form of value to landowners.

Overall, the limited evidence from published literature suggests that agroforestry has tended to be a less profitable land use than conventional agriculture (with fewer comparisons with forestry available), but it could deliver greater financial returns for landowners if payments for ecosystem services are available. In addition to existing incentives for specific agroforestry practices (e.g. wood pasture) that have been available since the former CS scheme (Defra, 2023d), the introduction of new grants under the SFI and CS in 2024 likely helps to strengthen the financial case for agroforestry. For example, payments between £248–£849/ha/year can be received for maintaining agroforestry depending on the density of trees (Defra,

2024n), and supplementary capital item payments of £5.40/tree and £17.83/tree for planting regular, and fruit, trees, respectively, are also available (Rural Payments Agency, 2024). In the case of the poplar silvoarable example from Kaske *et al.* (2021) provided above, assuming the capital item payment of £5.40/tree and medium density maintenance grant of £595/ha (for 10 years) applies to the system (inferred from the definition of 'low density' being 51–130 trees/ha (Defra and Rural Payments Agency, 2024)), annualised net returns could be expected to be approximately £410/ha/year. This is, however, only a crude approximation and further analysis is required to obtain more robust estimates in assessing the impact of new grant payments.

Regardless of financial returns, agroforestry provides a useful means to increase England's tree cover given that it does not entail the loss of flexibility associated with permanent LUC resulting from woodland creation (see 'Section 5.1.4').

## 4.2 Renewable energy

While agriculture is the most common land use in England, renewable energy technologies are opening up new alternatives for land managers looking to diversify. Renewable energy therefore constitutes an increasingly important opportunity cost of woodland creation.

Following an introduction to renewable energy policy and current land cover, the main focus of this section lies on the potential per hectare returns from solar and onshore wind energy as the most widely adopted renewable energy technologies by private landowners. The average per hectare returns from more land-intensive renewables, such as dedicated bioenergy crops (miscanthus and SRC willow) and battery energy storage systems (BESS), are also analysed. Information relating to anaerobic digestion (policy, land cover, and a summary of studies indicating net returns) can be found in the standalone Addendum. Descriptions and general details of the individual technologies can be found in the Glossary (A1.1).

### 4.2.1 Policy and financial incentives

England currently operates separate policies to incentivise investment in small ( $\leq 5\text{MW}$ ) and large-scale ( $> 5\text{MW}$ ) renewable energy capacity. Although a few have now closed to new applicants, Table 8 shows current and past public support and subsidy schemes available for the various renewable technologies.

From January 2020 onwards, new small-scale renewable energy generators have been eligible to export electricity to the National Grid via the Smart Export Guarantee (SEG) scheme. This requires the UK's largest electricity suppliers to purchase low-carbon electricity from small-scale producers using wind, solar photovoltaic (PV), hydro, anaerobic digestion (AD), and micro combined heat and power (micro-CHP) (Ofgem, 2024b). Available rates vary substantially, but in May 2023, the best market rate for exporting electricity to the National Grid that did not also require the producer to be a customer of the electricity supplier was 12.0p/kWh (Heatable, 2023). In contrast, for producers using electricity directly on-

site (displacing the need to purchase electricity from the National Grid), it is the average electricity purchase price in the non-domestic sector that is relevant, standing at 21.97p/kWh over the 2022/23 financial year (N.B. renewable energy producers are exempt from the Climate Change Levy (CCL)) (BEIS, 2024).

Table 8 Support and subsidy schemes available for renewable energy generation (past and present)

Renewable technology	Current policies		Policies closed to new applicants
Solar	≤ 5 MW: SEG	> 5 MW: CfD	≤ 5 MW: FiT (2010–2019)
Onshore wind	≤ 5 MW: SEG	> 5 MW: CfD	≤ 5 MW: FiT (2010–2019)
Dedicated bioenergy crops	-		Energy Crops Scheme (ECS) (2007–2013)
BESS	-		-
Note: '-' indicates that no subsidy schemes were found to be available.			

The Contract for Difference (CfD) scheme is open to renewable electricity generators with capacity above 5MW and aims to increase investor confidence by offering a guaranteed 15-year flat rate contract (BEIS, 2019). Competitive bidding sets a strike price, sharing risk between electricity suppliers and generators: when the strike price lies above the variable market reference price, the difference is paid by suppliers, while when the market reference price lies above the strike price, the difference is paid by generators. The strike price for the fifth allocation round for projects delivered in 2027/28 has been agreed at £47.00/MWh for solar PV and at £52.59/MWh for onshore wind (BEIS, 2023a).

Several schemes have now closed to new applicants but continue to make payments to producers. Most notably for small-scale renewable energy generators

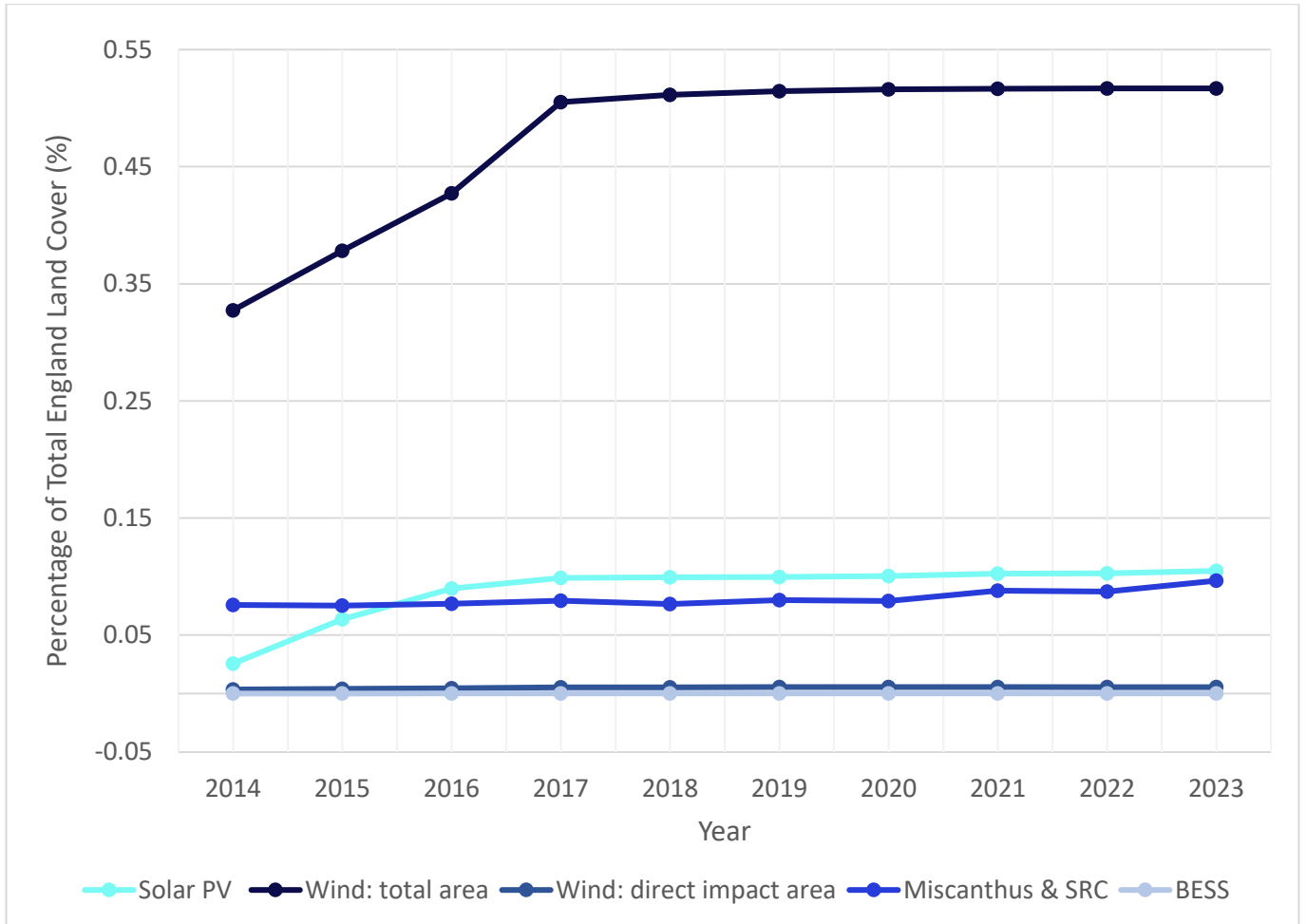
( $\leq 5\text{MW}$ ), the Feed-in Tariff (FiT) scheme ran from April 2010 to March 2019 offering (i) a 'generation tariff' and (ii) a FiT for contracts of typically 20 years' duration (DECC, 2012). Further detail on the FiT scheme and the other subsidy schemes now closed to new applicants can be found in the Appendix (A1.4).

The incoming party of Government has pledged to provide public investment for renewable energy 'where there is a clear case that public sector investment would accelerate private sector development' (Labour Party, 2024, p. 11). This investment will be channelled through Great British Energy (GBE), a new publicly owned clean energy company, endowed with £8.3 billion in capital investment. GBE will aim to de-risk leading technologies, support capital intensive projects, as well as boost municipal and community owned energy. By 2030, the Government aims for a 'net zero electricity system', including by doubling onshore wind capacity to 35 GW and trebling solar capacity to 50 GW (House of Lords, 2024).

### 4.2.2 Land cover

The total land area taken out of other uses for renewable energy is currently very low as a proportion of England's total land area (roughly 0.2%), with no rapid increases seen since 2017. The figure stands at around 0.7% when the total area for wind (including the area between wind turbines) is included. Figure 8 compares the changes in land cover for each technology from June 2014 to June 2023 as a percentage of England's total land area.

Figure 8 Percentage of England’s land area (%) used by renewable energy technologies between 2014–2023



Sources: (Defra, 2023a; DESNZ, 2024a)

Note: England’s land area is defined as the total land area to high water, excluding inland water area (13,031,047 ha) (ONS Geography, 2023b). Miscanthus and SRC land cover statistics have been taken from the June Agricultural Census (Defra, 2023a). Solar (ground-mounted), onshore wind, and BESS figures have been calculated based on data on electrical capacity in England from the Renewable Energy Planning Database (REPD), July 2023 quarterly extract (BEIS, 2023b) and estimates of the average number of hectares required per MW (1.6–2 ha/MW (NFU, 2015; Addland, 2023)). The REPD does not include energy installations ≤150 kW, or <1MW prior to 2021, and therefore could be a slight underestimation. ‘Wind: total area’ refers to the total area of land required for wind farms, including space between turbines, whereas ‘Wind: direct impact area’ refers to only the area of land taken out of other land uses by the wind turbines themselves.

#### 4.2.2.1 Solar

The land area devoted to solar (and overall capacity) is estimated to have increased by a factor of over 3.5 between 2014 and 2016, during which time high FiT payments were available, but subsequently plateaued between 2017 and 2023 (Figure 8) (DESNZ, 2024a).

As of July 2023, England had 7.6 GW of ground-mounted solar energy capacity plus 9.9 GW of projects in the planning pipeline (throughout the report, this refers to planning permission granted and not yet expired) (BEIS, 2023b). The large number of projects in the pipeline may reflect the current backlog of projects waiting for a grid connection (Renews.biz, 2023). Assuming that PV arrays require an average of 1.6–2 ha of land per megawatt depending on size, design, and condition of the site (NFU, 2015; Addland, 2023), the figures imply that in July 2023 around 0.09–0.12% of England's total land area was devoted to solar power generation (12,200–15,200 ha), with potential additional land cover of 0.12–0.15% required for pipeline projects (15,800–19,800 ha) (NFU, 2015; Addland, 2023).

The Government's target to triple UK solar capacity to 50 GW by 2030 would equate to 23.8 GW of ground-mounted capacity in England, assuming a baseline of 7.9 GW operational in July 2024 (DESNZ, 2024b), 1.6–2.0 ha of land per megawatt, and that the tripling of capacity occurs proportionately across all four nations of the UK and PV mount types. An estimated total of 0.29–0.37% of England's land area would be required (38,100–47,600 ha). This compares with a previous target set out in the 'British Energy Security Strategy' to increase total solar capacity five-fold by 2035 compared with 2022 levels (BEIS, 2022) (when 7.51 GW were operational (DESNZ, 2024a)), implying an estimated total requirement of 0.46–0.58% of England's land (60,100–75,100 ha) under the same assumptions. It should be noted that future gains in technological efficiency could reduce land use requirements.

#### 4.2.2.2 Wind

As with solar, there was high growth in England's onshore wind capacity and land cover up to 2017, with years of very low growth following. Between January 2016 and July 2023, only 29 planning applications greater than 150 kW in capacity were submitted, of which 21 were approved (BEIS, 2023b). The reduction in the rate of approvals resulted from the greater leverage granted under the National Planning Policy Framework to small numbers of people with objections locally, as well as requirements for local authorities to produce a local suitability plan, provisions which in effect halted almost all approvals (Windemer, 2022; CLA, 2023). The amendments to the National Planning Policy Framework in September 2023 aimed to reverse this decline in approval rates (DESNZ and DLUHC, 2023). After a period in which expansion of onshore wind generation had largely stalled, in July 2024 the UK Government rescinded two key restrictions on development in England and introduced a target to double onshore wind power generation capacity in Great Britain by 2030.

As of July 2023, England had 2.86 GW of operational onshore wind capacity and 53 MW in the planning pipeline (DESNZ, 2024a). It is estimated to cover around 0.41–0.63% of England's total land area (53,200–81,800 ha, with negligible land covered by pipeline projects), assuming turbines were optimally spaced in a grid pattern with 5 x 10 rotor diameters (D) between them to maximise efficiency (Our World of Energy, 2023). Table 9 below shows the relationship between the size of turbines and the estimated area required per megawatt of capacity assuming optimal spacing.

A study of 172 wind power plants in the USA found 49% of projects required 10–30 ha/MW; a further 30% required 30–50 ha/MW. Interestingly, total area requirements varied for different landscapes, with turbines requiring greater space in agricultural landscapes (24.5–47.6 ha/MW) than in forest landscapes (18.3 ha/MW) (NREL, 2009). The spacing between turbines may need to be wider in agricultural landscapes to accommodate larger agricultural machinery.

Table 9 Hectares of land required per megawatt of wind generation for turbines of varying capacity

Turbine capacity	Typical rotor diameter (D)	Capacity per hectare	Total area requirements
100 kW	24m	34.9 kW/ha	28.6 ha/MW
1 MW	61m	53.8 kW/ha	18.6 ha/MW
4.26 MW	138.25 m	44.7 kW/ha	22.4 ha/MW
Note: Own calculations based on turbine capacity and typical rotor diameters from Renewables First (2024b) and an optimal spacing grid of 5 x 10 rotor diameters.			

By contrast, the direct impact area of wind turbines nationally – the area taken out of alternative land uses – is considerably lower, estimated at a total of 715 ha for wind power operating in July 2023 and 13 ha for pipeline projects (in both cases almost negligible in relation to England’s total land area). This is because wind power requires only around 1–2% of the total area covered for the turbines and associated infrastructure (e.g. access roads and substations), so that the remaining land can continue to be used for agriculture or forestry (NREL, 2009). The latter estimates are based on National Farmers’ Union (NFU) expert judgement that 0.25 ha/MW is required on average (NFU expert judgement, 2023). A similar range for directly impacted land area was found for permanent wind farms in the USA of 0.24–0.31 ha/MW in agricultural settings and 0.36 ha/MW in forest landscapes (NREL, 2009). The latter study speculates that the direct impact area is likely to be slightly higher for forest landscapes due to the need to clear additional areas of forest for access and to maintain a buffer around each turbine.

A doubling of onshore wind capacity in England by 2030 compared with a July 2024 baseline (2.86 GW), in line with the Government’s UK-wide target, would lead to an estimated 0.82–1.26% of England’s land area being required. This would roughly double the current land take from onshore wind.

### 4.2.2.3 Dedicated bioenergy crops

According to the June Survey of Agriculture and Horticulture, 8,760 ha of miscanthus and 3,800 ha of SRC were planted across England in June 2023 (a total of 12,600 ha, or 0.1% of England's land area) (Defra, 2023a). This has increased slowly and steadily over the past decade: miscanthus has risen 23.7% and SRC 33.4% since 2014. It is worth noting that, while the majority of dedicated bioenergy crops is sent to UK power stations or used in CHP systems on- or off-site, there are additional uses, such as for horse and livestock bedding (miscanthus only) and domestic heat and power generation systems, including wood burners and open fires (Defra, 2021b).

### 4.2.2.4 Battery energy storage systems (BESS)

As of July 2023, England had 1.2 GW of installed BESS capacity (excluding batteries co-located with fossil fuel plants), which is undergoing rapid growth, more than doubling since 2020 and with a planned pipeline capacity of 9.1 GW. Around 92% of capacity is via standalone battery storage, the remainder co-located with renewable energy sources (BEIS, 2023b).

Nevertheless, BESS takes up little space: current land cover estimates stand at just 15–19 ha, with an estimated 119–146 ha required for pipeline battery storage, both of which are negligible in relation to the total land area of England. These estimates are based on the assumption that battery storage requires 0.013–0.016 ha/MW (Alder King and Conrad Energy, 2023)<sup>3</sup>.

## 4.2.3 Potential returns

Potential returns from each renewable energy technology have been collated from various sources and are expressed as an average net income per hectare per year (subtracting total costs from total revenues and then dividing by the area covered and annualised). Unless stated otherwise, the electricity prices used in the new calculations made for this study are based on those stated in 'Section 4.2.1'.

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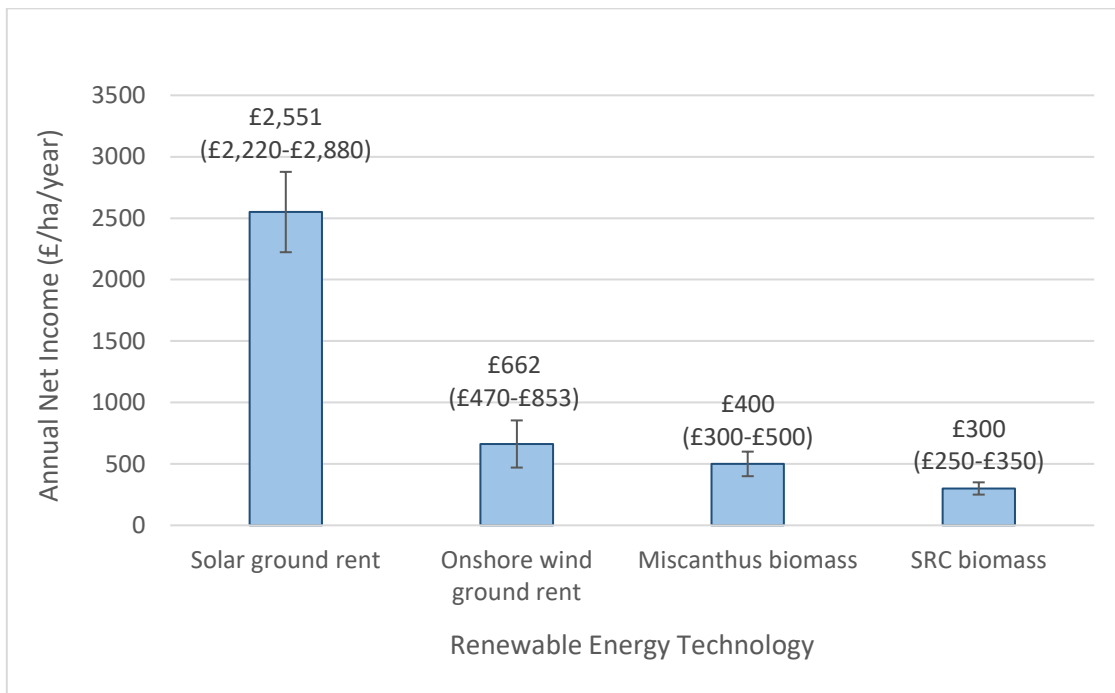
<sup>3</sup> 0.5–1 acre of land (0.2–0.4 ha) needed for a 15–30 MW scheme and 2–6 acres (0.8–2.4 ha) for larger 50–150 MW schemes.

However, these prices are only indicative for 2022/23 and are unlikely to be representative of future prices given the inherent volatility and uncertainty in electricity market prices.

Figure 9 summarises the indicative estimates derived for the different renewable energy technologies, focusing on business models that are both (i) commonly considered by land managers and (ii) land-intensive (hence more likely to be considered a potential opportunity cost of woodland creation). Bar heights and the summary figures represent the mid-points of the estimated range of potential net returns (shown underneath the summary figure, in brackets): the summary figures should not be interpreted as an arithmetic mean across a sample of estimates.

The figure shows the very high ground rents land managers can receive from energy developers for ground-mounted solar, around £2,220–£2,880/ha/year. Onshore wind ground rents can vary within an estimated range of £470–£853/ha/year. Larger capacity turbines on windier sites generally offer the most competitive per hectare rents. Turbines generally lead to very little land being taken out of production and, in most cases, can be considered a supplement to existing agricultural returns. By contrast, net returns per hectare from miscanthus and SRC are closer to those associated with woodlands or arable farming (see 'Section 4.5').

Figure 9 Average potential returns from renewable energy technologies in 2012



Note: The bars represent the mid-point of the range of possible returns rather than an arithmetic mean across a sample of estimates. Typical contract agreement timeframes are 30–50 years for solar energy, 20–25 years for wind energy, 25–35 years for BESS and 20 years for AD. Miscanthus and SRC bioenergy crops have estimated lifespans in the UK of 15–20 and 22–30 years respectively (Glithero, Wilson and Ramsden, 2013).

The sub-sections below describe these indicative estimates and methods of calculation in greater detail, alongside average net return estimates for BESS and land managers’ own investment in solar and wind. The potential to combine solar and wind with woodland creation is explored in their respective sub-sections as this would no longer represent an opportunity cost but rather an opportunity to diversify the returns from and raise the attractiveness of woodlands.

#### 4.2.3.1 Solar

Due to the high capital and installation costs of solar energy generation projects, the most common way for land managers to earn income from solar energy is to lease land to developers and receive ground rents. Solar ground rents provide guaranteed, index-linked income to land managers based on leasing agreements of 30–50 years with few costs involved (Stephens Scown, 2022). Stephens Scown

(2022), a law firm, provides an estimate of roughly £2,220–£2,880/ha/year, noting that land managers may also be eligible for a 'top-up' payment. Specifically, if 4–6% of the developer's revenue exceeds per hectare rent, the landowner receives a top-up to bring the total ground rent up to a level between the rent and the 4–6% revenue mark. These figures are roughly in line with ground rent estimates provided by the NFU at £1,830–£3,050/ha/year (NFU, 2015).

Higher per hectare profits are possible where land managers have the means to invest in solar PV installations themselves. While still a high barrier to entry for most land managers, capital costs decreased over 80% between 2010 and 2020. Total start-up cost estimates vary from £550,000 for a small community solar farm to over £55 million for large-scale solar farms (The Eco Experts, 2022).

Table 10 summarises estimates of different categories of costs expressed per megawatt and per hectare.

In addition to size and capacity, start-up costs vary by location (including slope and infrastructural access on a site), the type of PV technology, and whether there is sufficient capacity in the local distribution network (The Renewable Energy Hub, 2023).

Despite the high start-up costs, annual operational and maintenance costs are relatively low, around 20–25% of the 'levelised cost of electricity' (a measure of the total cost over lifetime) (Steffen, 2020). Electricity inverters and control parts need to be replaced every 10 years while the PV panels themselves should last for 30–50 years, albeit with a loss in efficiency of around 0.4–0.5% per year (NFU, 2015; Solar Power Portal, 2018). However, these panels require cleaning and checks three to four times per year, costing roughly £12,000 per megawatt of capacity installed over their lifetime (Lumify Energy, 2024a).

Table 10 Per megawatt and per hectare cost estimates for solar energy

Cost type	Cost/MW	Cost/ha	Notes	Source
Panels/installation	£375,000 <sup>1</sup>	£188,000– £234,000	Panels and inverters, excluding labour	(Solar Fast, 2023)
	£229,800	£114,000– £144,000	Panels only, excluding labour	(Addland, 2023)
	£977,000– £1.22m	£488,000– £764,000	Panels only, excluding labour	(NFU, 2015)
Grid connection	£49,000– £244,000	£24,000– £153,000	Upgrades to electricity transformers or grid connections	(NFU, 2015)
	£100,000	£50,000– £63,000	Based on £200,000 for a 2 MW installation	(Lumify Energy, 2023b)
	£122,000– £2.1m	£61,000– £1.3m	Estimated cost in Wales	(Welsh Government and Ricardo Energy & Environment, 2015)
Maintenance and operations	£12,000	£6,000– £7,500	3–4 cleanings and checks/year, over lifetime.	(Lumify Energy, 2024b)
	20–25% of total lifetime cost	20–25% of total lifetime cost	Lifetime cost calculated at 'levelised cost of electricity'.	(Steffen, 2020)
Decommissioning after 30–50 years	3–20% of installation cost	3–20% of installation cost	Average expected decommissioning costs.	(Thunder Said Energy, 2023)

Note: Costs per hectare are calculated assuming that 1 MW requires 1.6–2.0 ha of land (NFU, 2015; Addland, 2023). All figures published before 2023 are updated to 2022/23 prices.

<sup>1</sup> This figure was stated as £375,000/MWh by Solar Fast (2023), however 'MWh' has been interpreted as erroneous, with the intended meaning being £375,000/MW (because the former would imply infeasibly high start-up costs).

The annual return-on-investment (ROI) is estimated at around 10–20%, leading to the start-up cost being repaid within the first 5–10 years (Solar Fast, 2023).

Assuming a conservative initial investment per hectare of £237,500–£296,900 based on the above figures<sup>4</sup>, a 10% ROI over a 30-year period would lead to an average annual net income of £15,800–£19,800/ha/year. A 20% ROI would lead to £39,600–£49,500/ha/year net income.

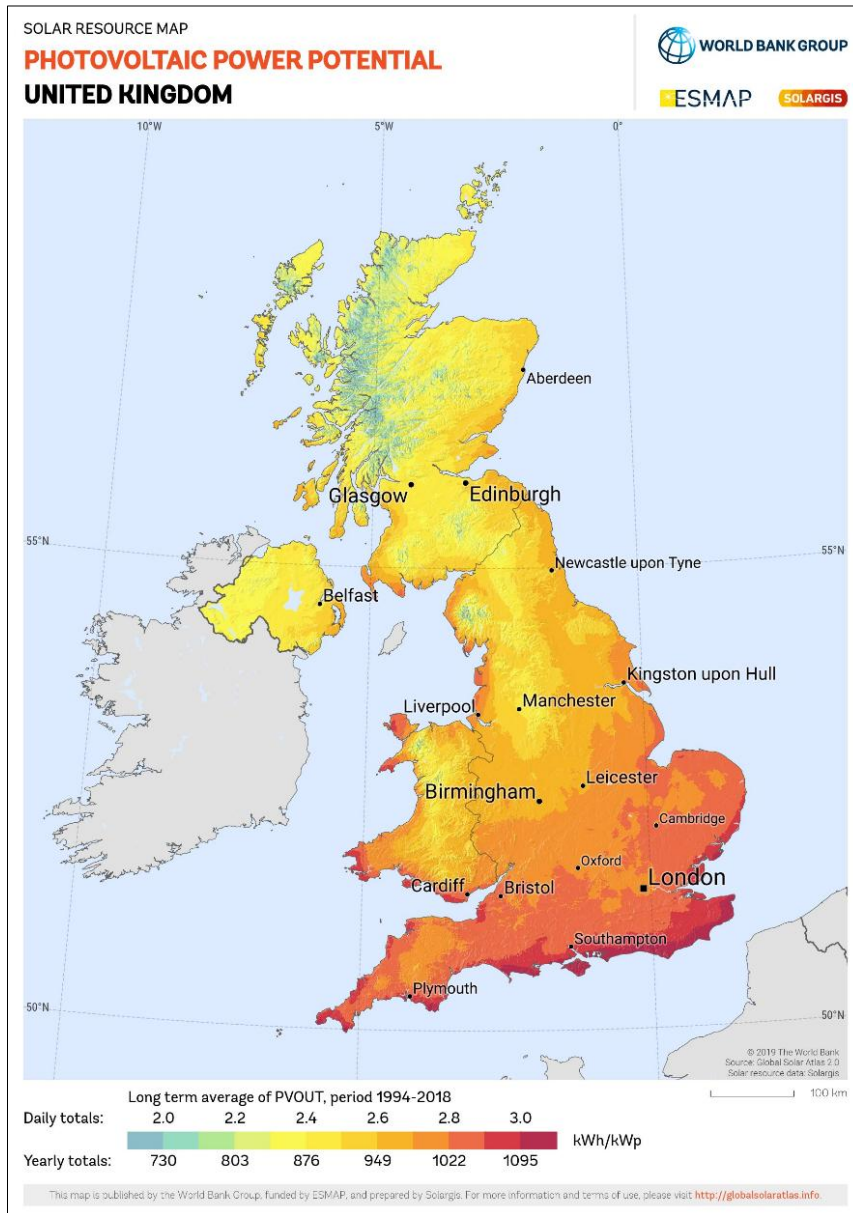
Spatial factors evidently affect electricity and income generation potential. Such factors include regional distribution network charges, slope and orientation of the site, network connection constraints, as well as the proportion of electricity used on-site (Biggins *et al.*, 2023).

Photovoltaic power output (PVOUT) likewise varies according to weather and climatic conditions: Figure 10 shows the long-term average daily and yearly PVOUT across the UK based on 1994–2018 climate data (The World Bank and Solargis, 2023). In general, the further south and east a site is, the higher the average PVOUT.

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<sup>4</sup> £187,500–£234,400 for PV equipment plus £50,000–62,500 for grid engineering, with land and labour costs excluded.

Figure 10 Photovoltaic Power Potential across the UK



Source: The World Bank and Solargis (2023)<sup>5</sup>

Based on this PVOU data, Table 11 presents estimates for low, average, and high scenarios of potential revenue and net returns across England. Incorporating the costs outlined in

<sup>5</sup> Creative Commons Attribution license (CC BY-SA 4.0). Solar resource map © 2021 Solargis.

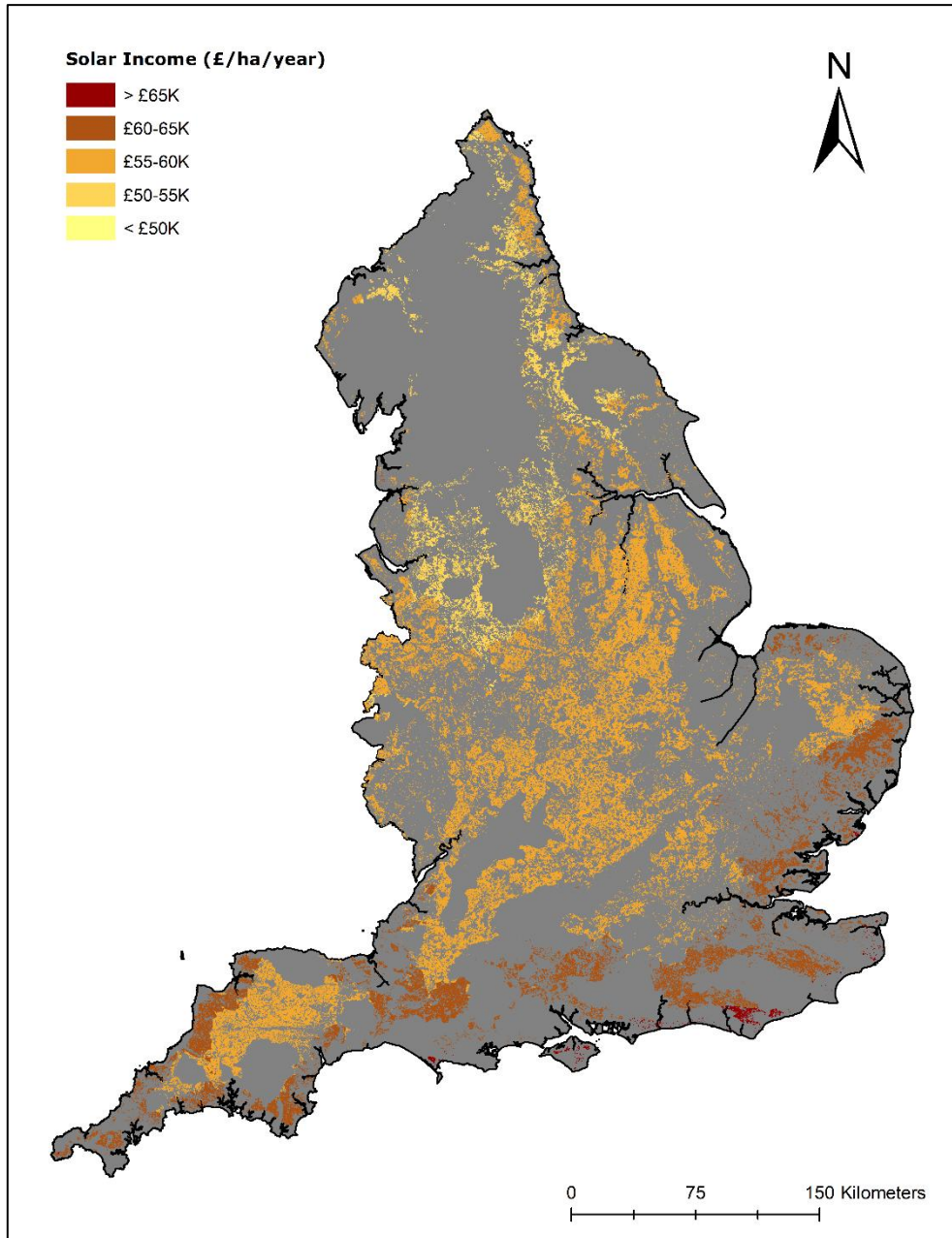
Table 10, this would lead to an estimated net revenue range of £44,700–£69,100, with an average of £57,100.

Table 11 Annual revenue, average costs, and net returns across the range of photovoltaic power potential in England (landowners’ own investment)

	Lower bound	Upper bound	Average
PVOUT (kWh/kWp/day) (The World Bank and Solargis, 2023)	2.32	3.08	2.73
Power capacity per hectare (kWh/ha/year) based on 1.6– 2.0ha/MW (NFU, 2015; Addland, 2023)	500.0	625.0	562.5
Revenue (£/ha/year)	£52,800	£84,900	£67,300
Total costs (£/ha/year)	£6,100	£15,800	£9,800
Net returns (£/ha/year)	£44,700	£69,100	£57,100
Note: Average total costs equal the sum of installation, maintenance, and operational and decommissioning costs, averaged over assumed solar panel lifetimes of 30–50 years. Net return estimates assume 100% of electricity is exported at a price of £0.12/kWh.			

It is also important to consider whether areas suitable for woodland creation overlap with areas of high potential for solar energy generation. Figure 11 shows the estimated annual per hectare solar income obtainable in areas deemed to be of low sensitivity for woodland creation, assuming the average annual cost of solar panels over a 40-year lifetime to be £9,800 and average land take to be 1.8 ha/MW. To complement the figure, Table 12 sets out for each estimated solar energy income category, the corresponding PVOUT figures and the estimated percentage of the total low sensitivity to woodland creation area falling under each category. Just over 85% of the low sensitivity to woodland creation area in England has an estimated opportunity cost from solar energy of £55,000–£65,000/ha/year (where the landowner invests themselves), mostly in low altitude regions of the South and Midlands.

Figure 11 Estimated solar income per hectare per year (landowners' own investment) across areas of low sensitivity to woodland creation in England (£/ha/year)



Sources: (i) ONS Geography (2023a)<sup>6</sup>; (ii) The World Bank and Solargis (2023)<sup>7</sup>

<sup>6</sup> Office for National Statistics licensed under the Open Government Licence v.3.0. Contains OS data © Crown copyright and database right 2024. OS AC0000814847.

<sup>7</sup> Creative Commons Attribution license (CC BY-SA 4.0). Solar resource map © 2021 Solargis.

Table 12 Estimated solar energy income categories, corresponding PVOUT, and the estimated proportion of England’s low sensitivity area for woodland creation under each solar energy income category

Categories of solar energy income per hectare per year (£/ha/year)	PVOUT (kWh/kWp/day)	Area of low sensitivity to woodland creation (thousand ha)	% of low sensitivity woodland creation area
< £50,000	< 2.42	0.39	0.01 %
£50,000–£55,000	2.42 – 2.63	333.00	11.80 %
£55,000–£60,000	2.63 – 2.83	1,880.00	66.60 %
£60,000–£65,000	2.83 – 3.03	589.00	20.90 %
> £65,000	> 3.03	21.20	0.75 %

Note: Solar energy income categories are own calculations based on PVOUT following the same method described in Table 11, with the exception of using average figures for land area per megawatt and average PV lifetime, rather than ranges, in order to avoid overlapping income categories.

Regardless of income potential, it is important to note that solar farms can only be constructed in certain locations and hence do not necessarily represent a widespread opportunity cost. Firstly, even where grid connections exist, there must be sufficient capacity in the local distribution network. Secondly, larger solar farms (>50 ha) with fewer field borders are more likely to be economically viable than smaller sites. There must also be access to a road for construction purposes and the land should be flat or south-facing, with low flood risk. Planning permission is less likely to be granted on high quality farmland (Agricultural Land Classification 1, 2 or 3a), within green belts, or neighbouring many homes (Strategic Land Group, 2022).

Finally, solar energy generation is challenging to combine with woodland creation as shading will reduce electricity output and hence returns. As a means to maximise income, solar fits better with livestock farms and/or agri-environmental schemes. Around 95% of land used for solar panels can support vegetation growth, and around four to eight sheep per hectare or around 2000 chickens, laying hens,

and geese per hectare can graze underneath solar panels, similar to stocking rates on conventional pastures (BRE, 2014).

#### 4.2.3.2 Wind

As with solar energy, land managers can receive ground rents for allowing developers to install wind turbines on their land. Ground rents have historically been determined as a percentage of developers’ gross revenues from sales (turnover rent), at around 4%, although few have been built in recent years (NFU expert judgement, 2023). However, other forms of lease agreements are possible, such as fixed rents, hybrid rents (guaranteed minimum rent plus a bonus payment based on developer profits), or generation rent (rent based on the amount of electricity produced) (Lumify Energy, 2023c). Lease terms typically last 20–25 years to match planning permission timeframes, although modern turbine lifespans can be up to 35 years, opening up the option to renegotiate terms at the end of the initial lease (Lumify Energy, 2022, 2023a).

Table 13 below shows potential ground rents for 100 kW, 1 MW, and 4.26 MW turbines based on electricity production figures from Renewables First (2024a) and a rent agreement based on 4% of developer gross revenues (for assumptions see the note below the table).

Table 13 Estimated per hectare ground rents for onshore wind under various turbine capacities

Turbine capacity (MW)	Energy produced per turbine per year (MWh/year) (Renewables First, 2024a)	Per hectare ground rents (£/ha/year)
0.1	280–407	£470–£683
1	2,185–2,955	£565–765
4.26	10,660–16,980	£536–853

Note: Assumes an SEG price of £0.12/kWh, total land area requirements of 18.6–28.6 ha/MW and landowner rents equal to 4% of developer gross revenues. Ranges also represent wind speeds of 5–8 m/s, except the 1 MW turbines which assume a maximum wind speed of 7 m/s.

While installation costs for turbines are a major barrier to most landowners, much higher profits are achievable from onshore wind power for land managers able and willing to invest themselves (with greater risks involved). Table 14 shows estimates of the installation, operation, and maintenance costs for turbines ranging from 100 kW to 4.26 MW in capacity (Renewables First, 2024b). Roughly 69% of the project cost is made up of the cost of the turbine itself (NREL, 2020), with other costs including environmental work to support planning applications, upgrades to the electrical grid, and site works such as access roads, foundations, and cabling costs (Renewables First, 2024b).

Table 14 Installation, operation, and maintenance costs for various turbine capacities

Turbine capacity (MW)	Project installation costs per turbine	Operation and maintenance costs per year per turbine
0.1	£441,000	£8,000
1	£1,457,000	£68,000
4.26	£4,225,000	£251,000
Source: (Renewables First, 2024b)		

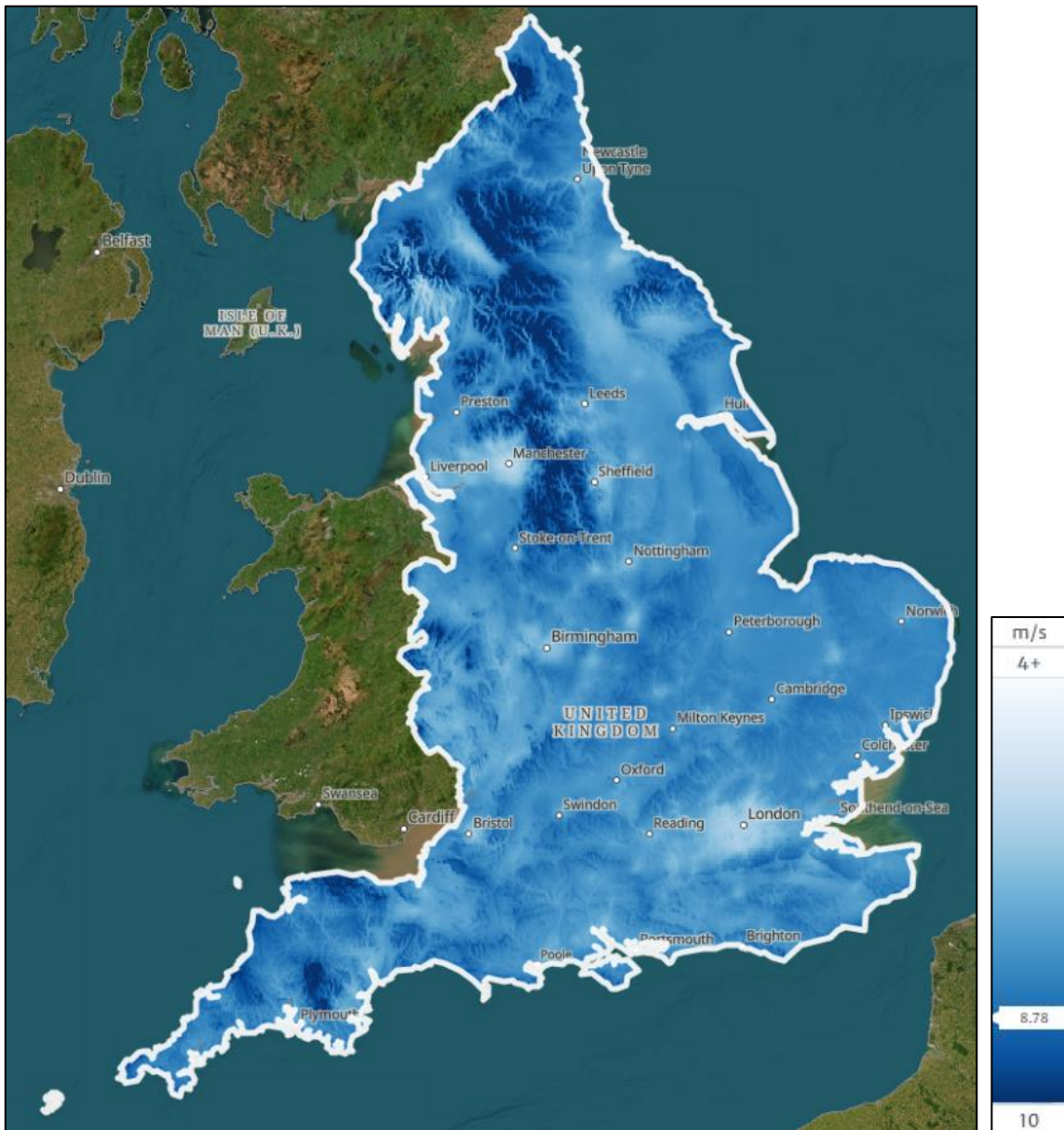
Based on expected annual revenues per turbine for various wind speeds and turbine capacities, Table 15 presents estimated per hectare annual net income from onshore wind energy generation (computed as annual revenue minus installation and maintenance costs, spread over a typical 20-year contract agreement). It should be noted that the electricity prices underlying the predicted annual revenues vary from those used in the rest of this report (see the footnotes to Table 15 for details).

Table 15 Per hectare net income estimates (£/ha) based on per turbine income revenue estimates allowing for installation and maintenance costs

Turbine capacity (MW)	Average annual net income (£/ha/year)			
	5.0 m/s	6.0 m/s	7.0 m/s	8.0 m/s
100% of electricity consumed on-site:				
0.1	£208	£975	£1,670	£2,020
1	£8,500	£17,400	£26,400	N/A
4.26	£48,800	£83,000	£116,000	£146,000
100% of electricity exported:				
0.1	-£804	-£560	-£351	-£211
1	-£3,540	-£1,120	£1,400	N/A
4.26	-£1,840	£8,120	£17,900	£26,400
Source: (Renewables First, 2024b)				
Note: Estimates assume 2026 electricity import rates start at 24p/kWh and export prices start at 8p/kWh with a 5% annual increase until 2030 and 2% annual increase thereafter (Renewables First, 2024b). Assumes the optimal turbine spacing of 28.6 ha/MW for 100 kW, 18.6 ha/MW for 1 MW and 22.4 ha/MW for 4.26 MW (for more information, see 'Section 4.2.2.2').				

As can be inferred from Table 15, the income generation potential of wind turbines and wind farms varies considerably between sites. In particular, revenues depend upon the windiness of the site, the proportion of electricity used on-site, as well as electricity export and import prices (Renewables First, 2024b). Areas with speeds of 5.0–8.5 m/s are suitable for wind turbines, with higher wind speeds within this range returning higher power and income generation potential (Renewables First, 2022). The Global Wind Atlas (2024) provides a dataset for average wind speeds in England, showing that northern and western regions of the UK generally experience higher speeds (Davis *et al.*, 2023). Figure 12 shows an example of wind speeds at 50m. Proximity to an existing grid connection with sufficient capacity as well as road access also affect where wind farms can be constructed (Renewables First, 2024a).

Figure 12 Map of annual average wind speeds in England (m/s)



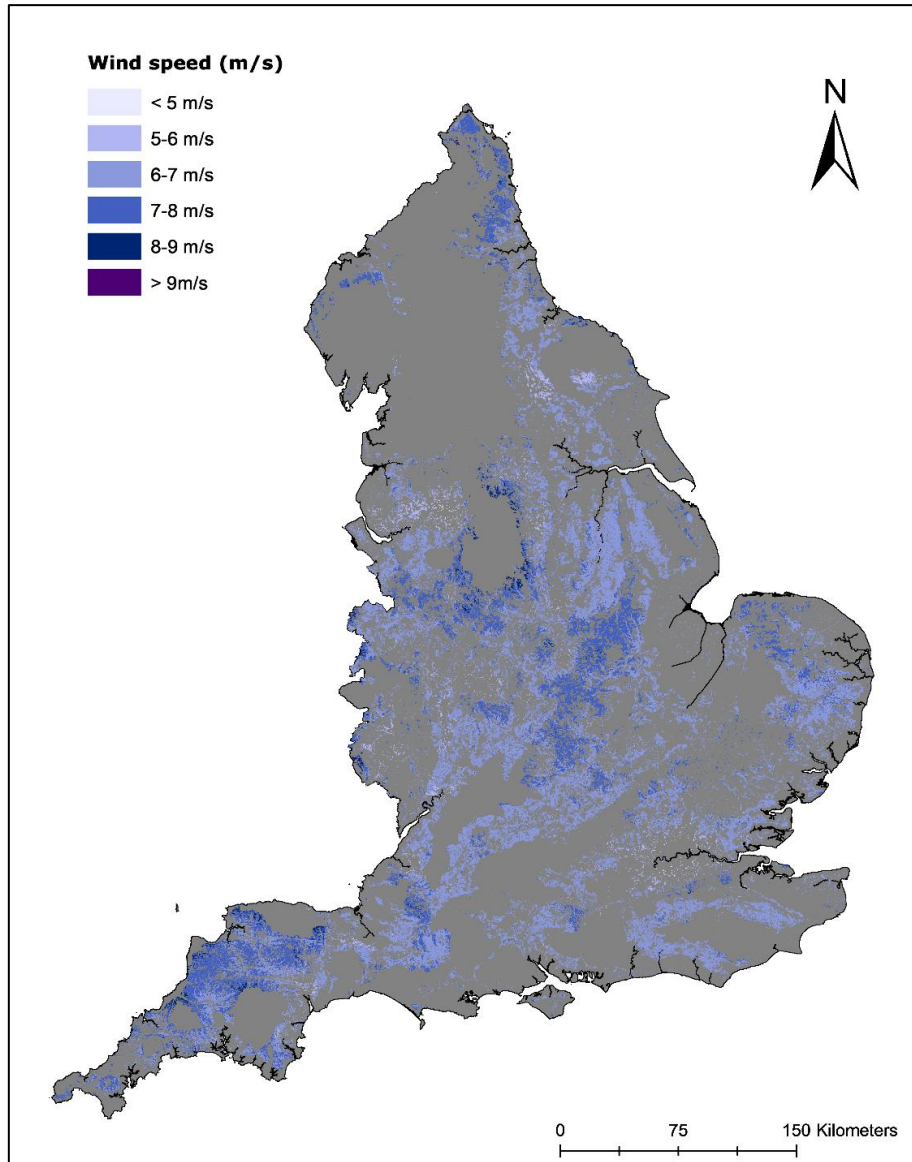
Source: Global Wind Atlas (2024)<sup>8</sup>, Davis et al. (2023)

<sup>8</sup> Data obtained from the Global Wind Atlas version 3.3, a free, web-based application developed, owned and operated by the Technical University of Denmark (DTU). The Global Wind Atlas version 3.3 is released in partnership with the World Bank Group, utilising data provided by Vortex, using funding provided by the Energy Sector Management Assistance Program (ESMAP). For additional information: <https://globalwindatlas.info>

As with solar, it is worth considering to what extent areas of high potential for onshore wind energy generation coincide with areas of low sensitivity to woodland creation. Figure 13 therefore superimposes the wind speed map in Figure 12 upon a map of low sensitivity for woodland creation, offering a rough indication of the opportunity costs of woodland creation from wind energy generation. Given the variety of factors involved (e.g. ground rents versus own investment, spacing between turbines, turbine capacity and height) and a lack of revenue data for top wind speeds for 1 MW turbines, mapping of precise financial opportunity costs has not been attempted. The previous tables presented within this section provide indicative wind income estimates corresponding to specific wind speeds. Table 16 shows the estimated proportion of low sensitivity area for woodland creation corresponding to each wind speed bracket.

Onshore wind returns only represent an opportunity cost for woodland creation if the presence of turbines precludes woodland creation, or reduces the number of trees planted or were somehow to reduce their growth. As only 1–2% of the total land area of wind farms is taken out of alternative land uses, onshore wind is commonly combined with agriculture, hence boosting agricultural returns. Combined wind and forestry operations are not yet commonly undertaken in England, although specific cases are emerging in Scotland, such as the Whitelee Forest and Clocaenog Wind Farm projects. Forest environments create additional complexities for wind projects and require turbine tower heights to be roughly 100–120 m (typically associated with turbine capacities above 3 MW) to avoid risks from rotors becoming obstructed by tree regrowth and because trees can lower wind speeds 15–40 m above the forest canopy. However, forestry combinations can also provide benefits to wind energy projects in the form of an additional income source and reduced visual impact (Renewable Energy World, 2011).

Figure 13 Estimated wind speeds across areas of low sensitivity to woodland creation in England



Sources: (i) ONS Geography (2023a)<sup>9</sup>; (ii) Global Wind Atlas (2024)<sup>10</sup>, Davis et al. (2023)

<sup>9</sup> Office for National Statistics licensed under the Open Government Licence v.3.0. Contains OS data © Crown copyright and database right 2024. OS AC0000814847.

<sup>10</sup> Data obtained from the Global Wind Atlas version 3.3, a free, web-based application developed, owned and operated by the Technical University of Denmark (DTU). The Global Wind Atlas version 3.3 is released in partnership with the World Bank Group, utilising data provided by Vortex, using funding provided by the Energy Sector Management Assistance Program (ESMAP). For additional information: <https://globalwindatlas.info>

Table 16 Estimated average wind speed categories and the estimated proportion of England’s low sensitivity area for woodland creation under each category

Average wind speeds (m/s)	Corresponding area of low sensitivity to woodland creation (million ha)	% of low sensitivity woodland creation area
< 5 m/s	2.7	0.09 %
5–6 m/s	109	3.87 %
6–7 m/s	1,870	66.2 %
7–8 m/s	800	28.3 %
8–9 m/s	41.8	1.48 %
> 9 m/s	1.6	0.05 %

#### 4.2.3.3 Dedicated bioenergy crops

Recent information suggests average net returns from miscanthus can vary from £500/ha/year for a good site to £300–350/ha/year for a poor site, while £250–£350/ha/year can be expected for SRC (NFU expert judgement, 2023). This is a similar level to published estimates in the literature of £491/ha/year for miscanthus and £285/ha/year for SRC (in 2022/23 prices) (Convery *et al.*, 2012). Typical crop lifespans in the UK are around 20 years for miscanthus (annual harvests) and 22–30 years for SRC (harvests every three to four years) (Glithero, Wilson, and Ramsden, 2013).

The profitability of miscanthus and SRC also varies considerably between regions. Farm-scale modelling of miscanthus and SRC in the UK shows that the cost of transport is a key determinant of profitability due to the crop’s low energy density. As a result, certain regions close to bioenergy power stations dominate the market: the south-west for miscanthus and north-west England for SRC (Alexander *et al.*, 2013). The west of England also provides a better climate for SRC than the east (NFU expert judgement, 2023).

#### 4.2.3.4 Battery energy storage systems (BESS)

Alder King & Conrad Energy (2023) state that annual ground rents vary from £1,250 to £2,000/MW depending on location, capacity, and technology. The

estimated land required ranges from 0.013 ha/MW for smaller sites (calculated based on 0.2–0.4 ha for 15–30 MW) to 0.016 ha/MW for larger sites (0.8–2.4 ha for 50–150 MW). Based on this, the income generated per hectare can be estimated at £96,200–£153,800/ha/year for small sites and £78,125–125,000/ha/year for larger sites. Lease terms typically last 20–35 years (Alder King and Conrad Energy, 2023; Atria Energy, 2024). However, BESS is only viable on sites close to a grid connection and substation and the extent to which they create an opportunity cost that impacts woodland creation is also limited by the small maximum site size.

Interestingly, it rarely seems to be financially viable for land managers to co-locate BESS with other renewable energy infrastructure such as solar PV installations. While Biggins *et al.* (2023) report results of a mixed integer linear programming optimisation model finding that storage installed alongside solar improves profits compared with only solar, they find the increase in revenues is insufficient to offset the high setup costs in most cases. Their study also highlights how regional variations in revenues generated from solar energy increase substantially when energy storage is included due to the different charges applied by the UK's 14 distribution network operators.

## 4.3 Biodiversity Net Gain (BNG)

BNG is a policy which came into force in February 2024, obliging housing developers to create or fund the creation of habitats to replace the 'biodiversity units' (BUs) lost due to their new developments, plus an additional 10%. BUs are measured according to Natural England's biodiversity metric. BNG creates new incentives for land managers across England to plant woodlands or other biodiverse habitats. It therefore can represent both an opportunity and an opportunity cost for woodland creation. All financial figures in this section from before 2023 are reflated to 2022/23 financial year prices, unless stated otherwise.

### 4.3.1 Policy background

Where the loss of existing wildlife habitats cannot be avoided, developers have three options. In order of preference, they should (i) create new habitats at the development site, (ii) create habitats off-site, or (iii) as a last resort, buy statutory credits from the Government. Statutory credits will fund large-scale, high value habitat creation through long-term nature-based solutions, orchestrated by the Government. All three can be used together to meet developers' BNG requirements, by following the order of steps known as the 'biodiversity gain hierarchy' (Defra, 2024q).

Where landowners create a woodland and there is no obligation to do so, it may be possible to stack EWCO grants and BNG, although EWCO additional contributions cannot be claimed (though the position remains under review) (Forestry Commission, 2022b). BNG can also be stacked with nutrient credits and sold to the same (or different) housing developers, although timeframes vary – nutrient credits can be sold for up to 125 years whereas BUs cover a 30-year period. Landholdings receiving AES or ELMS payments (SFI, CS, ES, or LR) may also sell BUs and nutrient credits for habitat enhancements over and above a baseline which accounts for the AES or ELMS agreement (Defra and Natural England, 2024). BUs and nutrient credits can only be stacked with credits from the Woodland Carbon Code (WCC) and Peatland Code where the land manager can demonstrate further

enhancement of the habitat without affecting the carbon value of the site (Defra and Natural England, 2024). However, qualifying for the WCC and Peatland Code requires passing an investment additionality test, which may not be feasible with a high level of BNG income.

Once the 30-year BNG agreement comes to an end, land managers are free to decide how best to use the land. With the exception of woodland habitats (considered a permanent LUC), they are free to revert to the previous land use. Further financial incentives under BNG are likely to be in place to incentivise maintenance or further enhancements to the land (compared with an updated baseline at the 30-year mark). After the end of the 30-year contract, it may also be possible to sell further biodiversity enhancements on emerging voluntary biodiversity credit markets. While returning the land to agriculture and other uses is possible for non-woodland habitats, any stacking with environmental markets with longer timeframes, such as nutrient neutrality markets, could limit options. Woodlands created under BNG are unlikely to reach their full size and biodiversity potential in 30 years, potentially allowing more BUs to be sold under a new baseline and agreement without major investments beyond continued maintenance (Defra, 2023f).

### 4.3.2 Land cover

Market analysis conducted for Defra forecasts a demand of 6,223 BUs per year from development in England based on an assumption that 1 BU is lost to development per hectare (Eftec, 2021).

This would translate into 1,556 ha/year required for BNG, including 389 ha/year in off-site locations (as 25% of BUs are expected to be delivered off-site). This is based on Defra expert opinion that one hectare could generally be expected to deliver 2–6 BUs (4 BU/ha as a mid-point) under Biodiversity Metric 4.0 (Defra, 2025). It should be noted however that Savills (2021) quotes Defra to expect BNG in England to cover a considerably larger area of 5,400 ha/year (including 1,300

ha/year in off-site locations), equivalent to roughly 0.01% of the land area of England each year.

### 4.3.3 Potential returns

As the compliance market was only launched in February 2024, there remains a high degree of uncertainty when gauging the potential returns from BNG.

Uncertainty is associated with BU prices, the cost of delivering BUs, and the achievable range of BUs per hectare for different habitat types.

As of October 2024, the price of a BU (off-site) ranged from £30,500-£57,125 for woodland habitats and £26,700-£41,375 for non-woodland habitats excluding 'lakes and ponds' and 'other watercourses' (for which BU prices are substantially higher) (Table 17). These prices represent one-off payments for a 30-year contract, with upper bounds representing average BU prices in the south of England (Coventry to Isle of Wight) and lower bounds representing those in the North of England (Birmingham to Northumberland) (Biodiversity UK, 2024). The full range of BU prices will likely be wider to the extent that prices also vary according to individual site conditions and potential, as well as according to supply and demand in each local planning authority (LPA) (Eftec, 2021). BU prices are expected to stabilise and fall slightly as the market becomes more established (FPCR, 2023; Broad, 2024). It is worth noting that high distinctiveness habitats (e.g. lowland mixed deciduous woodland and native pine woodlands) may be more sensitive to supply and demand as biodiversity losses must be compensated on a like-for-like basis by biodiversity gains in the same habitat and of high or very high distinctiveness. Biodiversity losses in medium distinctiveness habitats (including woodlands and forests that fall within this category) can be compensated with a biodiversity enhancement from within the same broad habitat category (grassland, heathland, woodland, arable, inland water, coastal, urban, and 'sparsely vegetated' land) of medium or higher distinctiveness (Townsend Chartered Surveyors, 2022; Defra, pers comm, 2025).

Table 17 BU prices of different BNG habitats and categories (defined by woodland/non-woodland and level of distinctiveness)

Habitat category	Habitat type	BU price range (October 2024)
Non-woodland; medium distinctiveness	Heathland and scrub	£29,500–£31,500
	Other neutral grassland	£26,700–£27,200
	Individual trees	£31,500–£35,200
Non-woodland; high/very high distinctiveness	Traditional orchards	£38,900–£42,700
	Lowland meadows	£37,225–£41,375
Woodland; medium distinctiveness	Woodland and forest (medium)	£30,500–£32,800
	Wet woodland	£35,350–£40,825
Woodland; high distinctiveness	Woodland and forest (high)	£46,200–£49,300
	Mixed deciduous woodland	£54,500–£57,125
Other	Lakes /ponds non-priority habitat	£60,375–£65,625
	All watercourses	£149,625–£164,575
<p>Note: Traditional orchards are categorised as ‘non-woodland habitats’ for the purposes of this table, though in certain cases (e.g. a site greater than 0.5 ha with trees with the potential to reach 5m and 20% canopy cover), they can also be categorised as woodlands under the Forestry EIA Regulations (Forestry Commission, 2024b).</p>		

The prices of statutory BNG credits are set deliberately high to be uncompetitive with market prices and to represent a ‘last resort’. Two credits are required to be bought for every one BU lost through development, with value-added tax (VAT) also charged. Prices start at £42,000 per credit, rising up to £125,000 for high

distinctiveness habitats (including some woodlands<sup>11</sup>) and £650,000 specifically for lakes (Defra, 2024o).

Market analysis undertaken for Defra in 2021 predicted average costs of delivery per hectare at £36,783/ha over 30 years (creation, enhancement, and maintenance). Estimated delivery costs vary significantly between habitat categories and sources, with scrub at the lower end of the scale (around £10,000/ha for creation and maintenance), ponds at the upper end (around £300,000/ha for creation, maintenance, and monitoring), and woodland establishment costs intermediate, ranging from £11,500 to £112,000/ha (Eftec, 2021).

There is currently little robust evidence on the number of BUs generated per hectare of habitat created, with most estimates published prior to the market's launch. In this report, a range of 3–6 BU/ha is assumed for non-woodland habitats and 2–5 BU/ha for woodland habitats to represent a range that is likely to be consistently feasible, based on Defra expert opinion and rough estimates published by the private sector (Knight Frank, 2023; CLA, 2024; Defra, pers comm, 2025). The figure for woodland habitats is slightly lower than for non-woodland habitats because woodlands are unlikely to reach their full growth potential within the 30-year period (Defra, 2023h). It is worth noting that there have been wider estimates of 3–10 and 1–9 BU/ha to represent the full possibility range across all habitat types (Defra, 2021a; Knight Frank, 2023), with sites initially in poorer condition likely to produce more BUs per hectare (CLA, 2024).

Based on a combination of the above figures, Table 18 presents estimated BNG net income per hectare (equivalent to the NPV) in terms of the full upfront payment for the 30-year contract minus the delivery cost, and the EAVs. Mid-points are in

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<sup>11</sup> The following woodland habitats are considered high distinctiveness: lowland beech and yew, lowland mixed deciduous, native pine, upland birchwoods, upland mixed ashwoods, upland oakwood, wet woodlands. Wood-pasture and parkland is considered very high distinctiveness (Townsend Chartered Surveyors, 2025).

parentheses. Separate estimates are given for woodland and non-woodland habitats, and habitats of medium and high/very high distinctiveness.

The average (mid-point) EAV estimates for wider woodland and non-woodland habitats are similar at £6,338 and £6,490/ha respectively, while the average incomes associated with medium distinctiveness habitats lie £2,200–£2,350/ha below their high distinctiveness counterparts. Focusing on the averages alone, however, could be misleading given the large potential income range in each category.

Table 18 Estimated net income per hectare from BNG, disaggregated by woodland and non-woodland habitats and medium and high habitat distinctiveness (mid-points in parentheses)

Habitat category	BU Price	Cost of delivery (£/ha)	BU/ha	NPV (£/ha)	EAV (£/ha/year)
Medium distinctiveness non-woodland habitats	£26,700–£35,200	£36,783	3–6	£43,317–£174,417 (£102,492)	£2,355–£9,483 (£5,573)
High/very high distinctiveness non-woodland habitats	£37,225–£42,700			£74,892–£219,417 (£143,048)	£4,072–£11,930 (£7,778)
<b>Non-woodland habitats</b>	<b>£26,700–£41,375</b>			<b>£43,317–£219,417 (£116,386)</b>	<b>£2,355–£11,930 (£6,490)</b>
Medium distinctiveness woodland habitats	£30,500–£40,825		2–5	£24,217–£167,342 (£88,036)	£1,317–£9,099 (£4,787)
High distinctiveness woodland habitats	£38,900–£57,125			£41,017–£248,842 (£131,261)	£2,230–£13,530 (£7,137)
<b>Woodland habitats</b>	<b>£30,500–£57,125</b>			<b>£24,217–£248,842 (£116,561)</b>	<b>£1,317–£13,530 (£6,338)</b>

An alternative option for land managers involved in BNG who are risk-averse or lack suitable expertise or capacity is to lease the land to a specialised intermediary organisation that accepts liability and provides expertise for the creation of habitats and BUs. For instance, the Environment Bank offers land managers up to £800–£900 per year in forward-funded or annual payments, of which around £200–£240 is rent and the rest payments to manage the habitats. The Environment Bank targets marginal land with poor biodiversity that is at least 20 ha in size (Toovey, Diggins, and Riches, 2022; Environment Bank, 2024).

Examples of woodland creation for BNG are currently sparse given the recent introduction of BNG credits. However, a case study is available from Tomorrow's Forest (no date), a private tree planting and habitat restoration company in the UK. The company began creation of a wet woodland in 2020 by planting 23,959 trees on 2 ha of land in Somerset, following a high-density planting method, known as the Miyawaki method (Webber, 2022), to mimic natural regeneration. This led to an estimated BNG uplift of 10 BUs, highlighting the high returns that landowners can potentially derive from creating woodlands for BNG. These high returns could be strengthened further if other income streams, such as the sale of wood products from thinning and wider land diversification strategies (e.g. recreational holiday lettings), are utilised simultaneously (Defra, 2023g).

## 4.4 Woodlands

To provide a benchmark for comparing the opportunity cost estimates presented in Sections 4.1 to 4.3, it is useful to consider the potential financial returns from woodland creation. Initially this section provides a brief overview of financial incentives currently available to support woodlands, along with a summary of historical land cover. This is followed by a presentation of potential returns from the creation of woodland of three broad types: productive conifers, productive broadleaves, and native broadleaves.

### 4.4.1 Financial incentives

In 2021, Defra launched the EWCO in support of government tree planting targets outlined in the ETAP 2021–2024 (Defra, 2021c) and Environmental Improvement Plan 2023 (Defra, 2023c). The scheme provides a range of grants to cover capital payments, woodland maintenance, and additional infrastructure (Forestry Commission, 2023a), and it is set to be integrated into the CS scheme under ELMS in 2025.

Several other grant schemes also provide payments for tree- and woodland-related activities. For example, the Woodland Creation Planning Grant (WCPG) helps fund production of a UKFS (UK Forestry Standard) compliant woodland creation plan (Forestry Commission, 2024c), and the Tree Health Pilot scheme helps woodland managers slow the spread of pests and diseases (Forestry Commission, 2023d).

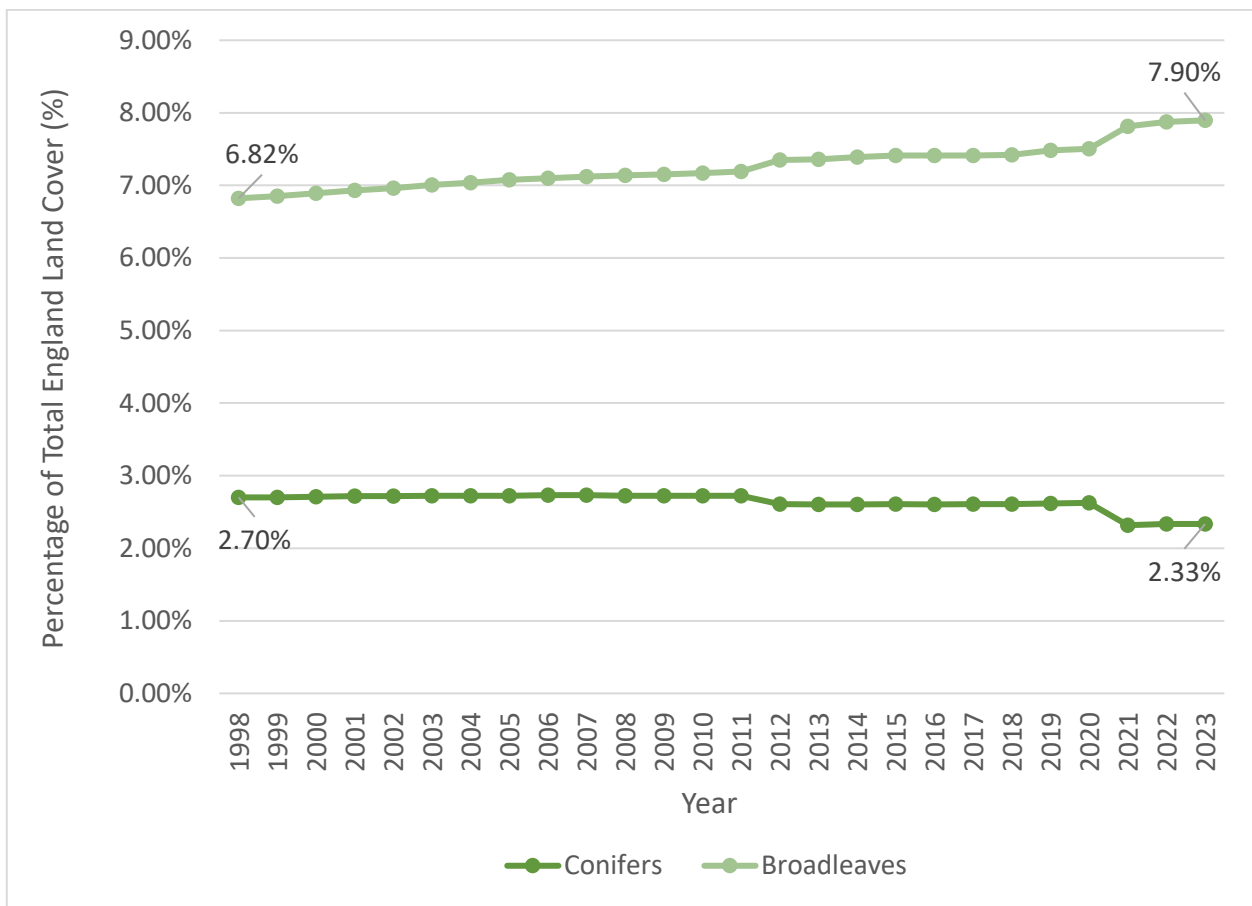
Private finance can also supplement, or in some cases substitute, public grants. This can include sale of carbon credits under the WCC (providing a woodland creation project meets additionality requirements), or sale of biodiversity credits under the BNG scheme (see 'Section 4.3').

### 4.4.2 Land cover

As of March 2023, woodland cover in England amounted to approximately 10% (1.333 million ha) of the country's total land area (Forest Research, 2023a) when expressed as a proportion of land area to high water, excluding inland water

(13,031,047 ha) (ONS Geography, 2023a). Of this, broadleaves and conifers accounted for 7.9% and 2.3% of total England land area respectively. Figure 14 below illustrates that, since 1998, the proportion of land occupied by broadleaved woodlands has increased by roughly 15%, while the amount occupied by conifer woodlands has decreased by roughly 14% (Forest Research, 2023b).

Figure 14 Percentage of England’s land area (%) covered by broadleaved and conifer woodlands between 1998–2023



Source: Forest Research (2023b)

Note: Forestry statistics published by Forest Research correspond to the year ending 31st March (e.g. March 2021–April 2022). These statistics also include mixed woodlands, with ‘mixed mainly conifer’ and ‘mixed mainly broadleaved’ woodlands assigned to conifers and broadleaves respectively (Forestry Commission, 2016, pp. 4–9).

These changes over time may be explained by a range of factors. These include: changes in tax treatment of woodlands in 1988 (House of Commons, 2023, p. 12); shifts in policy in favour of a more balanced mix of conifer species with broadleaved species (Defra, 2021c; House of Commons, 2023, p. 12); and introduction of the WCC facilitating sale of forest carbon sequestration credits – with more credits issued for woodlands with no timber harvesting.

### 4.4.3 Potential returns

#### 4.4.3.1 Source of estimates

Estimated returns from woodland creation in this report were derived solely from Forestry Commission publications (Haw, 2017; Forestry Commission, 2023b, 2023c). A broader range of estimates were initially collated using the authors' knowledge of existing studies and after a rapid search for new studies. However, the diverse assumptions adopted underpinning the estimates (e.g. whether grant, timber, and carbon income are included) hampered deriving representative averages of financial returns for each woodland type. Instead, it was decided that using estimates from studies underpinned by a single set of assumptions for each woodland type (rather than a wider range of estimates underpinned by varying assumptions across studies) would be most useful for the purposes of this study.

The original estimates were adapted by assuming income from the sale of carbon credits based upon a carbon price of £25/tCO<sub>2e</sub>, roughly equivalent to the WCC's 2023 part-year volume-weighted average price per Pending Issuance Unit (PIU) (WCC, n.d.). Estimates were also computed for a carbon price of £0/tCO<sub>2e</sub> to reflect scenarios with no carbon income, as well as carbon prices of £50/tCO<sub>2e</sub> and £75/tCO<sub>2e</sub> to assess the effects of higher prices on the relative returns from the different woodland types. The latter prices are, at the time of writing, rare within the voluntary carbon market, but not unheard of. For example, Kent Wildlife Trust's [Heather Corrie Vale project](#) to transform an abandoned golf course to broadleaved woodland with heathland, scrub, and grassland has reportedly sold Wilder Carbon

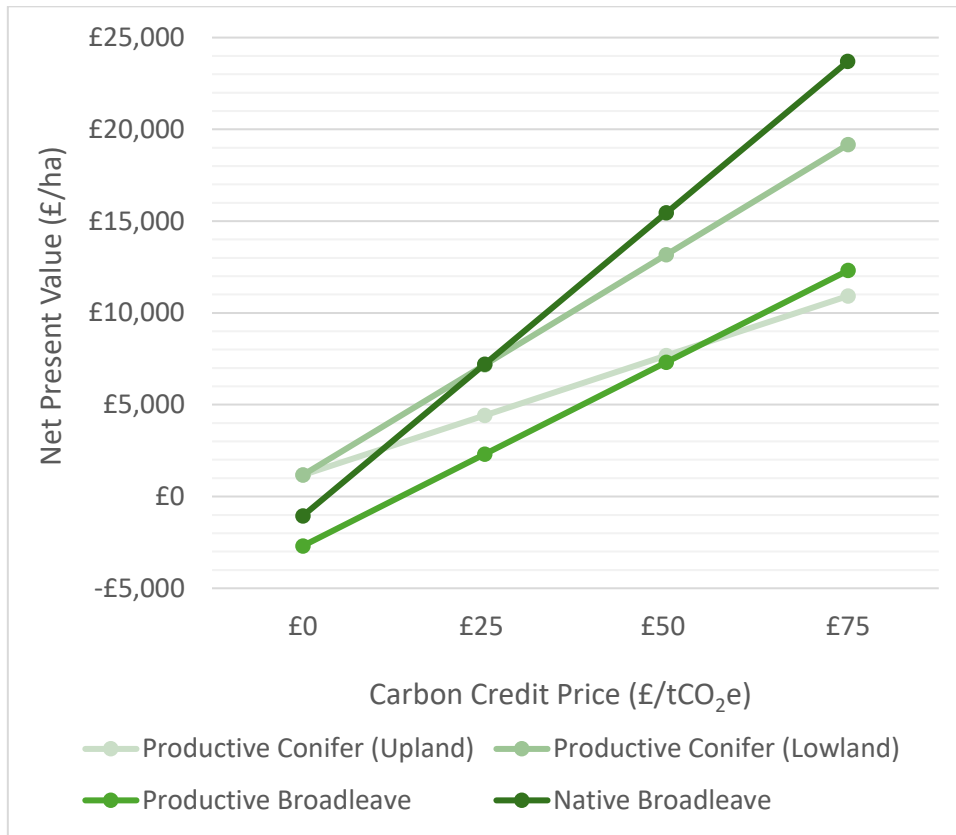
credits for £75/tCO<sub>2e</sub>, and the [Nattergal project](#) sold carbon credits generated from rewilding at €100/tonne.

### 4.4.3.2 Forestry returns

Figure 15 presents NPV estimates adapted from Haw (2017) for the different woodland types over a single rotation period. If no carbon income is assumed, productive conifers are the only woodland type that achieves a positive NPV. At a carbon credit price of £25/tCO<sub>2e</sub>, native broadleaved woodlands yield the highest NPV (£7,197/ha), albeit only slightly greater than that for lowland productive conifers (£7,170/ha). This is followed by upland productive conifers (£4,420/ha) and productive broadleaved woodlands (£2,308/ha).

As the price of carbon credits increases, native broadleaves remain the most profitable and lowland productive conifers the second most profitable. However, the rankings shift at roughly £55/tCO<sub>2e</sub> such that productive broadleaves become the third most profitable and upland productive conifers the fourth. The margin by which native broadleaves have a higher NPV rises as the price of carbon credits increases. These results are driven by the levels of claimable carbon sequestered under the WCC associated with each woodland type, with native broadleaved woodlands having the highest levels, followed by lowland productive conifers, productive broadleaves, and upland productive conifers (Haw, 2017).

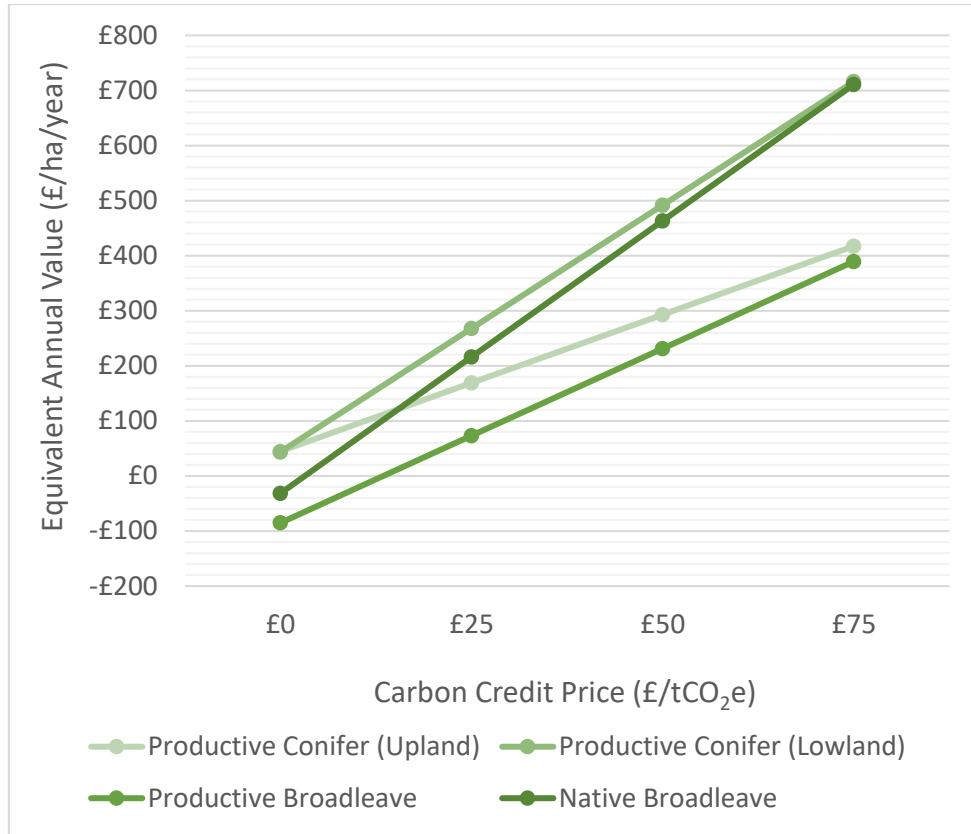
Figure 15 NPV estimates for different woodland types (£/ha) at different carbon credit prices



To account for differences in timeframes assumed for the different woodland types, which range between 52 years and an indefinite period, EAVs were computed. These estimates are depicted in Figure 16.

At carbon credit prices below £75/tCO<sub>2</sub>e, lowland productive conifers consistently have the highest EAV. This is followed by upland productive conifers, native broadleaves, and productive broadleaves. It is worth noting, however, that as carbon credit prices increase, the margin by which lowland productive conifers have a higher EAV than native broadleaves decreases. The same holds true when comparing upland productive conifers with productive broadleaves. Beyond roughly £75/tCO<sub>2</sub>e, native broadleaves would be expected to have the highest EAV, followed by lowland productive conifers, productive broadleaves, and upland productive conifers.

Figure 16 Equivalent Annual Value estimates for different woodland types (£/ha/year) at different carbon credit prices



To supplement the above estimates adapted from Haw (2017), estimates of financial returns from two recent woodland creation case studies published by the Forestry Commission were also adapted to reflect a carbon credit price of £25/tCO<sub>2</sub>e. This was done to obtain a set of estimates that are more reflective of woodland creation grant rates under EWCO, which provides higher grant payments compared with the legacy scheme.

One case study corresponds to a 10ha productive broadleaved woodland in north-east England (Forestry Commission, 2023b) and the other to a 100ha productive conifers and broadleave woodland in the south of England (Forestry Commission, 2023c). Allowing for a £25/tCO<sub>2</sub>e carbon price, the former yields a NPV of £6,435/ha and EAV of £274/ha, whilst the latter yields a NPV of £7,761/ha and EAV of £331/ha, both of which are higher than the estimates derived from Haw (2017) at an equivalent carbon price.

## 4.5 Comparing the alternative land-use options

To facilitate comparisons of returns from woodland creation with estimates of the opportunity costs, financial returns from the various alternative land use options are also expressed as annual values. Further details on the approach adopted as well as associated assumptions and implications can be found in the Appendix. Figure 17 presents indicative annual opportunity cost estimates for agriculture, renewable energy, and BNG, along with the estimated average financial returns for woodland creation. Meanwhile, Table 19 ranks these estimates from highest to lowest, and Table 20 provides further detail on corresponding minimum and maximum estimates (where available).

Financial returns from woodlands based on estimates adapted from Haw (2017) are lower than those for most alternative land uses – at least if diversification income is included. Figure 17 shows that returns from woodlands are among the least profitable of the different land uses at a carbon price of £25/tCO<sub>2</sub>e, with only two out of the thirteen alternatives (lowland and LFA grazing livestock) having lower average annual returns in some cases than some of the woodland types. It also indicates that in each case upland productive conifers and productive broadleaves have lower annual returns than all other land uses.

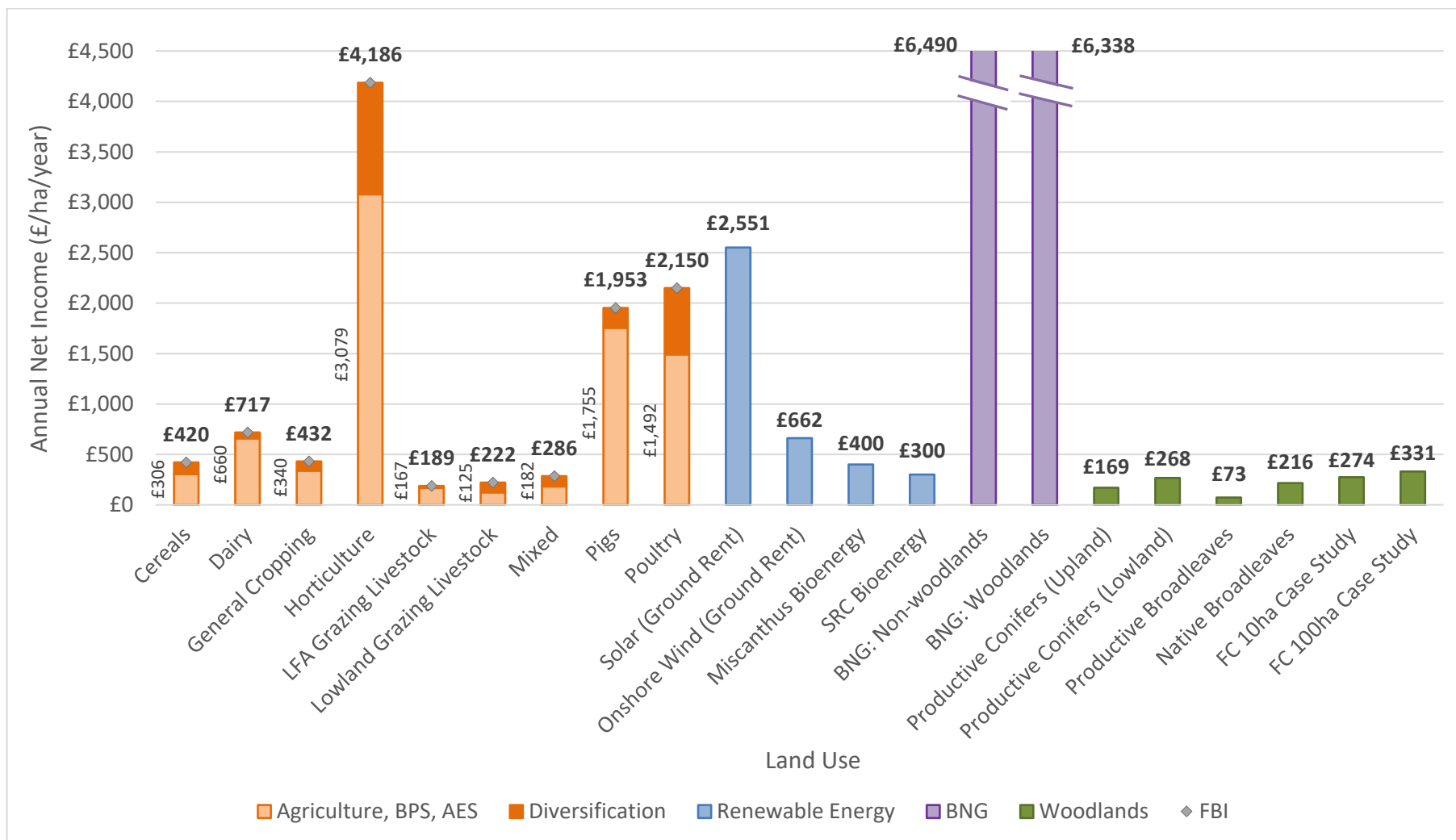
If diversification income is excluded from the opportunity cost estimates – that is, assuming it is not strictly tied to agricultural land use and would not be lost under woodland creation, which is arguably a realistic scenario in some cases (see Appendix A1.30 for more details) – returns from woodland creation are slightly more favourable. One additional land use (mixed farms) in this case has lower average returns than woodland creation. However, upland productive conifers and productive broadleaves remain the two land uses with the lowest annual returns.

Focusing instead on estimated returns in the two more recent Forestry Commission case studies and incorporating EWCO grant payments (levels applicable in February 2023) – so arguably more closely reflecting current returns from woodland creation – woodlands appear more profitable. Financial returns estimated for the 100ha

woodland creation case study are higher than two further land uses (SRC for bioenergy and cereal farms) if diversification income is excluded from the opportunity cost estimates.

Horticulture, pigs, and poultry, as well as solar, onshore wind, and BNG offer substantially higher potential returns to land managers than woodland creation. It should be noted however that Figure 17 does not show the wide ranges of estimates for some land uses and the restricted eligibility of land for several of the renewable energy technologies (see 'Section 4.2.3'). Nevertheless, even at the lower end of the range in returns (Table 20), both solar ground rent and BNG for non-woodland habitats remain substantially more profitable than woodlands for timber and carbon, with lower bound annualised estimates around £2,220/ha and £2,355 (3BU/ha at £26,700/BU) respectively compared with roughly £331/ha for the Forestry Commission 100-ha mixed productive conifer and broadleaves case study. The lower bound estimate for wind ground rent is closer to the returns for the Forestry Commission 100-ha case study at £470/ha (for 100 kW turbines).

Figure 17 Average annual returns (inclusive of government grants) estimated for agriculture, renewable energy, BNG, and woodland creation (£/ha/year)



Note: The bar heights for each land use category have slightly different meanings. For agriculture, they represent the five-year average FBI for 2017/18–2021/22, with the vertically oriented numbers representing FBI less income from diversification (i.e. sum of agriculture, BPS, and AES income categories). For renewable energy and BNG, they represent the ‘midpoint’ of the ranges (i.e. an average of the lowest and highest estimates computed), rather than a mathematical mean across all estimates (where there are more than two – as in the case of onshore wind ground rents). For woodland creation, they represent a single estimate corresponding to each woodland category or case study. The min-max ranges, where available, for the annualised net returns are shown in Table 19s.

Table 19 Ranking of estimates for the various land uses, with and without agricultural diversification income

Ranking	Annualised Net Returns (£/ha/year)			
	Agricultural Diversification Income INCLUDED		Agricultural Diversification Income EXCLUDED	
1	BNG: Non-woodlands	£6,490	BNG: Woodlands	£6,490
2	BNG: Woodlands	£6,338	BNG: Non-woodlands	£6,338
3	Solar (ground rent)	£2,551	Solar (ground rent)	£2,551
4	Onshore wind (ground rent)	£662	Onshore wind (ground rent)	£662
5	Dairy	£717	Dairy	£660
6	General cropping	£432	Miscanthus bioenergy	£400
7	Cereals	£420	General cropping	£341
8	Miscanthus bioenergy	£400	Forestry Commission case study: 100-ha productive conifers and broadleaves	£331
9	Forestry Commission case study: 100-ha productive conifers and broadleaves	£331	Cereals	£306
10	SRC bioenergy	£300	SRC bioenergy	£300

11	Mixed	£286	Forestry Commission case study: 10-ha productive broadleaves	£274
12	Forestry Commission case study: 10-ha productive broadleaves	£274	Productive conifers (lowland)	£268
13	Productive conifers (lowland)	£268	Native broadleaves	£216
14	Lowland grazing livestock	£222	Mixed	£182
15	Native broadleaves	£216	Productive conifers (upland)	£169
16	LFA grazing livestock	£189	LFA grazing livestock	£167
17	Productive conifers (upland)	£169	Lowland grazing livestock	£125
18	Productive broadleaves	£73	Productive broadleaves	£73

Table 20 Annualised net returns (inclusive of government grants) to all land uses (£/ha/year)

Land Use	Annualised Net Returns (£/ha/year)		
<b>Agriculture</b> <sup>1, 6</sup>	<b>Average</b>	<b>Min</b>	<b>Max</b>
Cereals	£420	£306	£692
Dairy	£717	£198	£909
General cropping	£432	£331	£594
LFA (less favoured areas) grazing	£189	£123	£247
Lowland grazing	£222	£154	£273
Mixed production	£286	£148	£375
<b>Renewable Energy</b> <sup>2</sup>	<b>Midpoint</b>	<b>Min</b>	<b>Max</b>
Solar ground rent	£2,551	£2,224	£2,878
Onshore wind ground rent	£662	£470	£853
Miscanthus bioenergy	£400	£300	£500
SRC bioenergy	£300	£250	£350
<b>BNG</b> <sup>2, 4, 5</sup>	<b>Midpoint</b>	<b>Min</b>	<b>Max</b>
Non-woodland habitats, medium distinctiveness	£5,573	£2,355	£9,483
Non-woodland habitats, high or very high distinctiveness	£7,778	£4,072	£11,930
Woodland habitats, medium distinctiveness	£4,787	£1,317	£9,099
Woodland habitats, high distinctiveness	£7,137	£2,230	£13,530
<b>Woodland creation</b> <sup>3, 4</sup>			
Productive conifers (Upland)			£169
Productive conifers (Lowland)			£268
Productive broadleaves			£73
Native broadleaves			£216
Forestry Commission case study: 10-ha productive broadleaves			£274
Forestry Commission case study: 100-ha productive conifers and broadleaves			£331

<sup>1</sup> The average estimates for agriculture represent the mean annual FBI per hectare from 2017/18 to 2021/22, adjusted to 2022/23 prices. Min and max figures represent the minimum and maximum averages in particular regions of England.

<sup>2</sup> The midpoint estimates for renewable energy and BNG represent the average of min and max estimates rather than an arithmetic mean of a sample of estimates. The min and max estimate are in turn based on ranges found in the literature, online sources, and/or reports.

<sup>3</sup> The estimates for woodland creation are not averages and do not have a min-max range. Instead, they correspond to a specific set of assumptions (see 'Section 4.4.3').

<sup>4</sup> Estimates for BNG and woodlands are in the form of Equivalent Annual Values (EAV). For more details, see 'Section 3.3' and 'Appendix'.

<sup>5</sup> The habitats assumed under BNG are: medium distinctiveness non-woodlands (heathland and scrub, other neutral grassland, individual trees); high or very high distinctiveness non-woodlands (traditional orchards, lowland meadows); medium distinctiveness woodlands (medium distinctiveness woodland and forest, wet woodland); high distinctiveness woodlands (high distinctiveness woodland and forest, mixed deciduous woodland).

<sup>6</sup> Estimates for horticulture, pigs, and poultry farms are omitted because they occupy relatively little land and are deemed less of an opportunity cost, with spatially disaggregated data unavailable for these.

Overall, the relatively high financial opportunity costs of woodland creation found in this study appear consistent with the handful of previous studies that have studied the financial viability of woodlands and found them to be generally less economically attractive than agriculture. This is the case for studies that have adopted an 'income approach' – e.g. García De Jalón *et al.* (2018), Hardaker *et al.* (2018a), and O'Neill *et al.* (2020). It is also the case in a recent study by Rosales *et al.* (2024) who adopted a 'rental approach'. The authors found that under current voluntary carbon credit prices, only roughly 35% (159,922.07 ha) of agricultural land in England deemed promising for commercial (primarily coniferous) forestry (454,694.67 ha) is 'economically viable for woodland creation' in the sense that the potential afforestation value is higher than the existing agricultural value (King's College London, 2024; Rosales, M'Hallah and Kelly, 2024, fig. 4). These findings are not surprising as UK subsidy schemes are argued historically to have benefited agriculture more than forestry. For example, Bateman *et al.* (2022, sec. 3.3.1) note that the £500m in NCF funding for ETAP 2021–2024 (a portion of which funds

EWCO grant payments) represents only 'just over 3% of the £3 billion paid in agricultural subsidies each year'.

There are a few additional factors that are important to keep in mind when interpreting the above findings. Firstly, it is important to note that averages mask a potentially wide range of net returns, and the opportunity costs of woodland creation under arable and livestock farming may be lower on portions of more marginal agricultural land.

Secondly, it is also important to consider the amount of land dedicated to each land use. While solar PV and onshore wind offer considerably higher financial returns, Table 21 shows that their historical land take has been significantly lower than woodlands and agriculture, and they continue to remain relatively low at the time of writing. This means that the high opportunity costs of these two renewable energy technologies only apply to a very small amount of land in England.

Thirdly, the estimates will likely change as time passes. On the one hand, the financial returns from woodlands will likely be higher than reported in this study as a larger array and higher rates of payments under EWCO have been introduced since the estimates used were originally published. For example, grants for woodland maintenance have increased incrementally from £200/ha in 2022 to £400/ha as of April 2024 and have also extended from 10 to 15 total annual payments. This suggests that the financial returns from woodlands are currently likely to be more comparable with the average returns from agriculture. On the other hand, the returns from agriculture may either increase or decrease as ELMS continues to replace CAP grants. If average agricultural grant income increases in line with higher ELMS payment rates announced in 2024 despite a decline in BPS payments (see 'Section 4.1.1' for more details), the extent by which agricultural returns exceed those of forestry may instead increase. While the direction of change remains unclear, changes in subsidies could have a large impact on returns from agriculture relative to those in forestry given that income from agricultural

grants constituted, on average, a significant proportion (51%) of FBI from 2017/18 to 2021/22.

Table 21 Proportion of England's land area occupied by the different land uses

Land Use	Percentage of Total England Land Cover			% Change from 2014 to 2023 <sup>3</sup>
	2014	2023	Future Targets <sup>2</sup>	
Conifer woodlands	2.600%	2.330%	12.00%	-10.4%
Broadleaved woodlands	7.390%	7.900%		6.9%
Cereals	21.900%	23.300%		6.1%
Dairy	6.710%	5.700%		-15.1%
General cropping	10.300%	11.700%		14.3%
LFA grazing	9.160%	9.510%		3.8%
Lowland grazing	11.400%	9.860%		-13.5%
Mixed production	7.430%	6.370%		-14.3%
Solar photovoltaic (PV)	0.020%	0.090– 0.110%	0.29– 0.37%	~ 233.3%
Onshore wind (direct impact area <sup>1</sup> )	0.250– 0.390% [0.003%]	0.410– 0.630% [0.005%]	0.82– 1.26% [0.011%]	~ 57.6% [58.1%]
Miscanthus & SRC	0.003%	0.005%		25.0%

<sup>1</sup> The direct impact area of onshore wind represents the actual amount of land area taken out of alternative land uses by wind turbines, allowing for the possibility that agriculture and/or forestry continues between wind turbines.

<sup>2</sup> The combined conifer and broadleaved woodland cover target for 2050 is given in the Environmental Improvement Plan 2023 (Defra, 2023c). For renewable energy, future land take estimates are based on 2024 Government targets to triple solar energy capacity and double onshore wind capacity by 2030 (see 'Section 4.2.2').

<sup>3</sup> This is a measure of the percentage change in percent of land cover.

Fourthly, the price of carbon credits generated from woodlands plays an important role in determining their relative profitability. Through some preliminary exploratory analysis, Table 29 in the Appendix shows, all else constant, the price of WCC credits (PIUs sold upfront) required for the different woodland types to achieve the same level of returns as the alternative land uses (i.e. to 'break even'). For the purposes of the current thought experiment, it is assumed that the WCC investment additionality criteria are satisfied in all cases. Providing this simplifying assumption holds, the carbon prices required are the lowest amongst grazing livestock and mixed farms, as well as SRC for bioenergy, and the highest amongst solar and onshore wind ground rent, as well as BNG. Further analysis, however, would be required to provide more realistic estimates that account for current investment additionality rules and their associated effects on grant income claimed, as well as subsequent impacts on levels of carbon credit prices required for returns from woodlands and alternative land uses to 'break even'.

WCC Pending Issuance Units in the UK were sold at an average of £24.15/tCO<sub>2</sub>e in 2023 (WCC, n.d.), However, the price of carbon credits in the voluntary market has been increasing globally in recent years (Forest Trends Association, 2023). All else being equal, a continued upward trend in carbon credit prices is likely to prove favourable for woodland creation. The same can be said for timber and wood product prices which have also been on an upwards trend in the UK and globally over the past two decades (FAOSTAT, 2023; Forest Research, 2023d). These upward trends may be enhanced by prospects of the WCC being incorporated into the compliance market by way of admittance into the UK Emissions Trading Scheme (UK Government, 2023, chap. 7), which Rosales *et al.* (2024) have shown may significantly increase the price of WCC credits under certain conditions. However, it is currently unclear to what extent such admittance would have knock-on effects on the payment of woodland grants. To the extent that higher carbon prices impact whether woodland creation projects pass the investment additionality

test, grant payments claimed might be expected to fall for woodlands whose carbon credits are expected to be traded within the compliance market.

Lastly, it is crucial to reiterate that BNG can pose an opportunity for woodland creation rather than solely being an opportunity cost. Barring additionality constraints, estimates suggest equally high returns can be made on average when compared with BNG for non-woodland habitats (Figure 17), with high distinctiveness woodlands potentially generating up to £13,530/ha/year (5 BU/ha at £57,125/BU; Table 20).

## 5 Discussions

### 5.1 Financial premiums for woodland creation

While the estimates presented in Section 4.5 provide a straightforward representation of the additional financial returns necessary for woodland creation to become the most financially attractive land use option, they may not fully capture the actual returns necessary to induce woodland creation. This is due to the existence of other economic and non-economic factors that could pose barriers. Consequently, even on plots of land where woodland creation would ensure the highest profits, overcoming additional barriers – e.g. through additional monetary payments – may be necessary for woodland creation to occur.

For the purposes of this study, such additional returns over and above direct financial opportunity costs are defined as a 'financial premium' required by landowners. This section briefly discusses some of the other economic, social, and cultural barriers to woodland creation that may contribute to the existence of such a financial premium.

#### 5.1.1 Start-up costs

Land managers could be expected to consider the start-up costs, and funding to cover them, when comparing the potential returns from alternative land uses. For woodlands, these costs include those for initial planning and establishment, with available funding including grants under the WCPG and EWCO. Grants available under the WCPG are restricted to projects with a minimum woodland size of 5 ha, while not all capital cost items are eligible for grant funding under EWCO.

By contrast, start-up costs related to agricultural activities are not usually covered by grants. Specific exceptions include capital items under ELMS when agricultural practices are changing to become more sustainable (Defra and RPA, 2024b, sec. 2.3, 2024a), and the Farming Equipment and Technology Fund which provides grants for capital items to boost productivity or improve animal health and welfare

(RPA, 2024a). Similarly, start-up costs for renewable energy tend not to be covered by grants, with ensuing cash-flow barriers mentioned in the literature for solar, wind, bioenergy, and anaerobic digestion (Sutherland and Holstead, 2014; Tidy, Wang and Hall, 2015; von Hellfeld *et al.*, 2022). This is however less of an issue in the case of land managers receiving ground rents as energy developers tend to take on the start-up and maintenance costs, hence eliminating much of the risk that land managers would otherwise face.

On the face of it, the issue of start-up costs seems less prominent for woodland creation given the availability of grants. However, it is important to remember the generally much longer time-lag in receiving financial returns from forestry compared with agriculture and renewable energy generation. This is discussed further in 'Section 5.1.5'.

### 5.1.2 Labour requirements

Family farm labour, which could otherwise be employed in other profitable activities, may also be considered an important opportunity cost of woodland creation, separate to the land opportunity cost considered in 'Section 4'.

Estimates based upon data from the 2023 June Agricultural Survey (Defra, 2024I) show that family labour (i.e. 'farmers, directors, partners, and spouses', both full- and part-time) constitute an arguably significant portion of England's agricultural work force – roughly 61%. Variations exist between farm types, with horticulture farms having the lowest proportion (20%), and LFA and lowland grazing livestock farms the highest (82% and 78% respectively).

Assuming that family farm labour is utilised rather than hiring contractors, woodland creation can in principle 'free up' the time of these family members for other income-generating activities compared with agriculture. This is because while the initial phases of woodland creation often involve high labour requirements, once trees have become established, the amount of labour required for maintenance activities usually declines (Forestry Commission, 2023b). This is in contrast to

agriculture which requires high recurring annual labour input, with an average of roughly 53 hours/ha/year for arable farms (which are highly capital-intensive) or 3792 hours/ha/year for horticultural crops (which often need to be picked by hand) (own calculations based on the Farm Management Handbook 2023/24 (Beattie, 2023)). Studies by Bell & Greaves (2010) & Flack *et al.* (2022) tested the aforementioned assumption and find that inclusion of the value of unpaid family labour in financial calculations does indeed make woodland creation appear more financially favourable compared with agriculture.

Similarly to woodland creation, most renewable energy technologies require minimal labour input once up and running (e.g. vegetation maintenance and occasional cleaning for solar panels), with the exception of anaerobic digestion which can require 2 hours/day for a 50kW digester, increasing linearly up to 5.5 hrs/day for a 500 kW digester (Jones and Salter, 2013).

Given the above findings, woodland creation is likely to represent very low costs in the form of family labour, especially in the long run. It should be noted, however, that additional work for family members can be perceived as beneficial in certain cases. For example, 23% of farms participating in England's entry-level Environmental Stewardship (ES) scheme and 68% of those on the equivalent higher-level scheme were found by Mills (2012) to report a higher workload as a result of participation, often intensifying boundary work and scrub management. As 74% of additional work was undertaken by on-farm workers and family members rather than contractors, the ES scheme was seen positively as providing work for underemployed workers, especially during the less busy autumn and winter periods.

### 5.1.3 Tax treatment

Each land use is also subject to different tax treatment. As highlighted by Tillhill (2019), the three primary taxes of concern for forestry are Income/Corporation Tax, Capital Gains Tax (CGT), and Inheritance Tax (IHT). In the case of woodlands

managed for commercial purposes (i.e. for interest of profits), the timber trading aspects are essentially exempt from Income/Corporate Tax and CGT (Forestry Commission, HM Revenue & Customs and Natural England, 2023), while the entire property can also be relieved from IHT through Business Property Relief (BPR) and/or Agriculture Property Relief (APR) if the woodland is ancillary to farmland (Tillhill, 2016). For amenity woodlands, the exact tax treatment is more complex and depends whether any commercial activities also occur on the land (Buckingham and Townsend, 2021). Nevertheless, they can also be exempt from IHT under certain circumstances through 'heritage relief' (HMRC, 2022a, sec. 5.7) or through the separate 'woodland relief' (HMRC, 2022a, sec. 5.8; RICS, 2023, sec. A1.3). It is worth noting, however, that regardless of whether woodlands actually qualify for IHT relief in a particular instance, IHT can constitute an important perceived barrier to woodland creation (Staddon *et al.*, 2021).

With regards to the tax treatment of the production and sale of ecosystem service units arising from woodland creation, particularly carbon credits, it is clear VAT is non-chargeable (HMRC, 2022b) and relief from IHT via APR and BPR is available (HM Treasury, 2024b, pp. 21 & 27). However, further clarity is needed on the intricacies of tax matters in this domain, and a specialised working group is being established by the Government to address this (HM Treasury, 2024b).

Like forestry, agriculture can also be exempt from IHT through APR and/or BPR under certain circumstances (HM Treasury, 2023, pp. 16–20). In addition, it can similarly be exempt from CGT in various ways, such as through principal private residence relief and business asset roll-over relief (Speke, 2023). There will also be an extension of the existing scope of APR starting from April 2025 to include land managed under ELMS and EWCO (Defra, 2024g; HM Treasury, 2024b, pp. 19–21, 2024a).

It is therefore arguable that there are no immediately clear tax advantages of either forestry and agriculture, with any merits depending on the specifics of the

case. Tax advantages may be more likely to accrue to parties intending to acquire land for woodland creation, although perceived tax disadvantages are likely to remain a barrier to woodland creation, at least until perceptions change to reflect actual tax specifications.

In the case of renewable energy, once it becomes the primary income stream from the land rather than agriculture (notably also in most cases of livestock grazing around solar panels and wind turbines), inheritance tax reliefs such as APR and BPR are lost through the land becoming an investment asset, although APR only covers agricultural revenues in any case (Farrer&Co, 2023b). Regarding BNG, receiving a lump sum payment can have different tax implications compared with income being spread annually. A lump sum payment may mean expenses are no longer tax-deductible. Finally, BNG's effect of raising the value of the land could subject income to both CGT and income tax (Evelyn Partners, 2023).

Overall, tax treatments seem the least favourable for renewable energy and BNG, while similar for forestry and agriculture, hence rendering taxation benefits a small cost, or potential benefit, of creating woodlands, particularly in the case of farmers who already own and manage land. However, landowner perceptions of tax treatment may well remain an important barrier to woodland creation, with qualitative evidence suggesting perceptions of tax specifications can be among the top factors affecting the willingness of farmers to create woodlands in the UK (Eves *et al.*, 2015). A review of the current tax treatment of woodlands, as suggested by the Climate Change Committee (Wentworth and Jordon, 2021), could therefore prove useful in improving perceptions of the tax treatment of woodlands. It could also help inform landowners of the implications of recent changes, such as the confirmed extension of APR to environmental land management agreements and the reduction in IHT threshold announced in the Autumn Budget 2024 (HM Treasury, 2024a), as well as in considering potential reforms. In relation to the latter, care would be needed to ensure that the appropriate stakeholders benefit from changing the tax system (Dandy, 2012, p. 54; Westaway *et al.*, 2023) – e.g.

farmers who are stewards of the land rather than investors with no interests in land management.

#### 5.1.4 Permanence of land use change

The permanence of a LUC also impacts its attractiveness. Of all the land uses considered in this report, woodlands are arguably most impacted by the irreversibility of land use. This is due to regulations that make it mandatory in most cases to restock woodlands after felling (Forest Research, 2023c, pp. 2 & 9).

Agriculture can be returned to its original land use if it is not tied to any contract, for example a share rental contract, and it can be changed to other land uses such as dwellings, woodlands, and renewables, subject to planning permissions being granted. Similarly, renewables can be returned to their original use at the end of the contract period (in the case of ground rents) if desired, as can BNG unless it entails the creation of woodland habitats (see 'Section 4.3.1' for more information on BNG policy at the end of the contract).

Studies of landowners' decision making behaviour in Ireland and the UK suggests that the permanence of the LUC can deter them from planting woodlands (Staddon *et al.*, 2021, p. 43). Attempts have been made to estimate a monetary value of this irreversibility (e.g. see Behan *et al.* (2006)), and this could be taken to be a 'financial premium' for woodland creation. This topic is discussed further in 'Section 5.2'.

#### 5.1.5 Future uncertainty and risk, and long time horizons

While the discount rate applied to the opportunity cost estimates in 'Section 4' (through use of EAVs) aims to account for the inherent time value of money and foregone interest payments, two further issues are also associated with the extended time horizons in forestry.

Firstly, while risk and uncertainty are important features of agriculture (e.g. fluctuations in market prices and weather), woodland creation requires a greater

level of forward-planning and ability to absorb risk and uncertainty over longer periods. Climate change and pests and diseases pose particularly uncertain threats – especially when considering the long-time horizons typical in forestry. In contrast, landowners may be able to receive guaranteed ground rents from energy developers for hosting certain forms of renewable energy on their land.

Secondly, the annual nature of agricultural harvests allows landowners to regularly adapt their land use to changing conditions. Conversely, longer periods before timber can be harvested and the permanence of woodland creation entail a loss of flexibility to adapt to changing conditions. Opting for renewable energy or BNG also entails a loss of flexibility compared to agriculture, often requiring a commitment to a given land use for at least 25–30 years (unless it is a case of mixed land use whereby renewables and agriculture co-exist), though with LUC to a non-woodland habitat involving less loss of flexibility than woodland creation because it is not permanent.

It should also be noted that the discount rate of 3.5% assumed in calculations in this study is towards the lower end of the spectrum of those assumed in other forestry studies. Studies from Germany have used discount rates of 1.5% (adjusted for inflation) (Möhring and Rüping, 2008) and 4.2% (Moog and Borchert, 2001), while forest valuers in New Zealand reportedly apply discount rates of 6–10% (average 7.1%) to post-tax cash-flows (Manley, 2018). It is not too dissimilar from the central time preference estimate of 4.1% (range of 0–7%) found for a broad range of foresters and forestry enterprise owners in Germany (Sauter and Mußhoff, 2018).

Some land managers may focus on returns over shorter horizons (e.g. over three to five years), effectively assuming higher discount rates, and this has implications for the results of this study. Generally, as the discount rate increases, the returns to agriculture, renewable energy, and BNG are all likely to become increasingly more attractive than woodland creation – and by a greater extent than estimated in

this report. This is because income from these land uses can be obtained either on an annual basis, or as an upfront lump-sum payment in the case of BNG, whereas fewer income streams (e.g. WCPG, most EWCO grants, and carbon income generated through sale of PIUs) are available upfront for woodland creation, with income from the sale of timber and WCUs only accruing later in time. The opposite also holds true. As the discount rate falls, the gaps between higher returns associated with alternative land uses and those associated with woodland creation also decrease (Hardaker, 2018b). Further research is required to determine precise effects of variations in discount rates on the opportunity costs of woodland creation, particularly given that the estimates of forestry returns presented in this study are adaptations of existing estimates rather than new computations.

### 5.1.6 Land value impacts

Studies of land manager perceptions of barriers to woodland creation have shown that the impact of woodland creation on land values is also an important consideration (Eves *et al.*, 2015; RFS, 2020; Staddon *et al.*, 2021). However, detailed evidence on the impacts of LUC to woodlands on land values from published academic or grey literature appears sparse.

In the short-term, it is generally accepted that land values decline following the planting of woodlands (Bell and Greaves, 2010, sec. 2.4) and this can be attributed to the permanence of woodland creation (RICS, 2023, p. 43). In the long-term, it is less clear how land values evolve as planted woodlands continue to mature and how they compare with counterfactual scenarios of continued agricultural production. While there is some rudimentary evidence indicating that the total capital value (i.e. underlying land plus any natural capital and man-made infrastructure) of woodlands tends to exceed underlying land values pre-planting once woodlands have matured (Bell and Greaves, 2010, sec. 2.4), no evidence was found identifying causal factors explaining the increase in the value of forest land over time apart from tree growth.

In-depth research is required to provide better evidence of the impacts of woodland creation on land values and the extent to which these affect landowners' willingness to create woodland and any financial premium required. Such research could also help shed light on relationships between market values for commercial forests and farmland, which are expected to continue diverging, with the former rising relatively consistently and the latter remaining stagnant over the past ten years (Adamson *et al.*, 2024, fig. 5; Hewson-Fisher *et al.*, 2024, fig. 6). Furthermore, it may be important to disentangle the effects of 'marriage values' (see Glossary) whereby the woodlands planted combine with existing property assets to generate synergies (e.g. through sporting and amenity) that increase the value of the whole property beyond the increase in the value of the woodlands 'in its own right' (RICS, 2023, p. 36).

A rapid search found no evidence of significant impacts of adopting renewable energy technologies on land in the UK. Instead, existing studies seem to focus on impacts of renewable energy on residential property prices (e.g. Gibbons (2015) and Elmallah *et al.* (2023)), or in one study, the impact on nearby agricultural land values in the USA (Abashidze and Taylor, 2023). However, one study reports that a solar farm can raise the value of the land it sits on, possibly as soon as or before planning permission is granted, although the land is likely to revert to its previous value following decommissioning of the installations (RICS, 2018, p. 20). As existing evidence is sparse, additional research is similarly required on the impacts of adopting renewable energy technologies on land values.

### 5.1.7 Socio-cultural factors

Besides these economic-related factors, socio-cultural factors in the form of values, attitudes, and behaviours have also been identified as influential on land managers' willingness to create woodlands. These include, for example, the desire by farmers to maintain agricultural land as 'productive' land (Lawrence, Dandy and Urquhart, 2010; Lawrence and Dandy, 2014), the concept of self-identity whereby farmers

identify more as farmers rather than foresters (Staddon *et al.*, 2021), as well as trees being viewed as more within the domain of landlords in the case of tenant farmers (McConnachie *et al.*, 2023). Such cultural identities and attitudes can be reinforced by 'path dependence' or 'cognitive lock-in' whereby the likelihood of involvement in woodland creation-related activities is determined by the level of previous involvement (Barnes *et al.*, 2022).

Evidence also suggests that in upland regions or on marginal land, where agriculture tends to be less profitable, farmers may more commonly aim for 'profit sufficiency', i.e. a sufficient level of net income to continue the current land use in the mid-term, rather than profit maximisation (Convery *et al.*, 2012). Thus, even where expected woodland returns exceed the opportunity costs, socio-cultural factors may play a role inhibiting their creation.

Socio-cultural factors likewise interact with decisions to adopt renewable energy. For example, Convery *et al.* (2012) quote livestock farmers in Cumbria expressing the view that the gross margins of dedicated bioenergy crops would have to be considerably higher for them to undertake LUC due to strong personal and cultural attachment to livestock grazing. A further case study in north-east Scotland showed that wind turbines can have high cultural capital compared to AES as the 'production' of environmental goods is easily visible to peers (Sutherland and Holstead, 2014). Motivations vary considerably between land managers and uptake of SRC and miscanthus has historically depended on farmers' willingness to experiment with innovative land uses (Alexander *et al.*, 2013). Willingness to adopt is in turn affected by social factors, with younger land managers and those with more education most likely to adopt renewable energy (Sutherland and Holstead, 2014; Sutherland *et al.*, 2016).

These findings all highlight the importance of understanding the variety of socio-cultural values and land manager attitudes towards woodland creation (Ambrose-Oji, 2019; McConnachie and Marshall, 2022; Westaway *et al.*, 2023) and the

consequent need to tailor financial incentives and other policy instruments to address the associated barriers.

## 5.2 Quantification of financial premiums

Monetising some of the wider economic, social, and cultural barriers to woodland creation is challenging and hence quantifying the exact level of financial premium required for woodland creation is also difficult. However, the cost to land managers of land use irreversibility and reduced flexibility in decision-making associated with longer timeframes for forestry returns has previously been valued monetarily using Real Options Analysis (ROA). This is a significant step in the right direction for quantifying the overall financial premium required to create woodlands as these are among the most important wider barriers and are ignored when considering discounted cashflow (DCF) estimates derived using standard capital budgeting techniques (i.e. an 'income approach').

ROA involves dynamic, stochastic investment decision modelling and is a potentially more representative approach for determining whether landowners require a financial premium to create woodlands. This is because, unlike standard capital budgeting, it does not assume that land managers have perfect foresight of the future and allows them flexibility in making decisions in the face of uncertainty (which can be considered a form of 'intertemporal opportunity cost' in itself) (Musshoff, 2012; Regan *et al.*, 2015; Abdul-Salam, Ovando and Roberts, 2022). It therefore accounts for different option values that exist when deciding whether or not to invest in woodland creation and hence more accurately reflects decision making. For example, there could be the option to wait for more information before investing in woodland creation and remain flexible about when investment is initiated (Regan *et al.*, 2015). Evidence suggests that such option values can be significant, even for forestry (Schatzki, 2003; Frey *et al.*, 2013; Reeson, Rudd, and Zhu, 2015; Yemshanov *et al.*, 2015).

In general, the application of ROA to analyse a broad range of investment decisions has indicated that the expected financial returns required for an investment to occur are often higher than suggested when standard capital budgeting is adopted (Regan *et al.*, 2015). This has been shown to be the case in the context of forestry, as highlighted by Ginbo *et al.* (2021) in their systematic review of the applications of ROA to climate change mitigation and adaptation. The authors showcased a range of studies covering various countries, including Australia, Brazil, Canada, India, Sweden, and the USA. However, no studies were found to have applied ROA to the adoption of woodland creation in the UK. The most relevant study identified was by Abdul-Salam *et al.* (2022) on the adoption of agroforestry in the Scottish Uplands, which identified significantly higher carbon prices required than suggested through use of standard capital budgeting. The study did not, however, provide an estimate of an overall financial premium for forestry.

Despite the lack of studies on forestry in the UK, some inferences can be drawn from ROA studies of other countries. Focusing on Ireland, Wiemers & Behan (2004) found that the average returns necessary to trigger conversion from livestock grazing to forestry was approximately £599/ha/year (€590 in 2001€). Given an expected return for the former land use of approximately £304/ha/year (or £124/ha/year after accounting for opportunity costs of family farm labour), this translates to a financial premium for forestry (i.e. profit margin over agriculture) of roughly 97% (or 383% after labour cost adjustments). Building on the study of Wiemers & Behan, Behan *et al.* (2006) found using ROA and econometric analysis that the country-wide profit ratio between forestry and agriculture needed to increase by 14% if the Government's target of increasing tree planting rates from 14,000 ha/year to 20,000 ha/year were to be achieved. This increase was inferred from an estimated model coefficient which suggests that a 1% increase in profit ratio results in roughly a 3% increase in area of woodlands planted in the long run (based on data for the period of 1986–2001).

Wolbert-Haverkamp & Musshoff (2014) implement a similar ROA approach in Germany, finding that the returns from SRC required to trigger conversion from rye farming (i.e. general cropping) is approximately £897/ha/year (€910 in 2014€) for a risk neutral farmer (assuming no option to reconvert the land). Given an expected gross margin of £368/ha/year for rye farming, the financial premium for SRC over rye would roughly equate to 144%. It is worth noting as well that the aforementioned investment trigger is approximately 52% higher than the one suggested by regular DCF analysis. This is similar to the finding by Mei & Clutter (2015) that in accounting for the possibility of delaying investment into pine plantations in the USA, the threshold timber price for investment in the land use was 40% higher than the regular breakeven entry price.

Estimates of the overall percentage financial premium required by land managers to undertake woodland creation in the UK will require more in-depth analysis of landowners' decisions to create woodlands in the UK context in the face of uncertainty and permanence of LUC to woodlands. The percentage uplift required could also be expected to depend on the extent to which the joint production and sale of multiple ecosystem benefits is permitted as nature markets continue to evolve. This is important because the business case for afforestation of agricultural land becomes more attractive the wider the range of ecosystem services that can be sold (Strange, Jacobsen and Thorsen, 2019).

It is important to keep in mind the other barriers set out in 'Section 5.1' too, particularly the socio-cultural barriers. Potential landowner typologies (i.e. groupings according to common characteristics, values, and attitudes; e.g. see Ambrose-Oji (2019) and Eves *et al.* (2015)) could be used separately to estimate the financial premium required for each. While various studies have explored the effects of risk aversion on option values, a brief review on ROA found no studies exploring interactions between landowner typologies and premiums.

Alternative approaches to ROA include contingent valuation or choice experiments (stated preference methods) that could enable identification of the full financial premium – potentially also estimated for different landowner types (Pearce and Ozdemiroglu, 2002). Future research could scope application of ROA, contingent valuation, and choice experiments, as well as how existing landowner typologies could be applied or extended in determining UK woodland creation premiums.

## 6 Conclusions & recommendations

This review explored and quantified the financial opportunity costs of woodland creation in England. It focused on examining net income (expressed in the form of annualised net returns per hectare) from alternative land uses, and comparing them with a limited set of existing estimates for three woodland types – productive conifers, productive broadleaves, and native broadleaves.

The analysis found that the agricultural opportunity costs of woodland creation tend to be relatively high, with returns from woodlands for the most part either lower, or just comparable with returns for most farm types considered. Exceptions to this include livestock grazing farms (both LFA and lowland), mixed farms, and SRC for bioenergy which give lower average net returns than the highest estimate for woodlands, found in the Forestry Commission 100ha productive conifer and broadleaved woodland case study. These four alternative land uses together represent just over 25% of England's total land cover as of 2023. In the case that diversification income is not lost by undertaking woodland creation, cereal farms were also found to be less profitable on average than the Forestry Commission 100ha case study. Regardless of whether diversification income is considered, dairy farms were found to always be more profitable than all woodland types. This is also the case for horticulture, pigs, and poultry, although the land cover of these farm types is significantly lower and hence they arguably do not pose such an important opportunity cost.

The FBI estimates used in the analysis incorporate BPS payments. Thus, estimates of agricultural opportunity cost estimates are likely to change once BPS payments are entirely replaced by ELMS. The exact nature of such changes, and hence the future returns from agriculture relative to woodland creation, remain unclear; although as the majority of farm types have historically been heavily reliant on BPS payments for maintaining a net positive FBI, the impact on agricultural opportunity costs could be very significant.

The opportunity costs associated with solar, BNG, and to a lesser extent wind energy generation, were found to be relatively high. The estimated average net returns from solar and BNG in most cases exceed those from woodlands by an order of magnitude or more. However, legal and spatial factors may restrict eligibility for renewable energy generation, and comparisons of average figures mask the high heterogeneity and uncertainty of estimates in all three cases. Nonetheless, without very high carbon prices that are currently rare in the voluntary carbon credit market, woodlands are not financially competitive even when comparing with the lower range of returns from these alternative land uses. It is worth noting, however, that woodland creation is one of several habitat options under BNG, and hence BNG could also incentivise woodland creation instead of strictly posing as an opportunity cost. In cases where woodlands are created for generating BUs, woodland creation has potential to generate some of the highest financial returns amongst alternative land uses, rendering opportunity costs for most alternatives relatively low by comparison.

The review also briefly considered the potential for combining the alternative land uses with woodland creation and tree-planting more broadly. Shading from trees render the combination with solar energy impractical, while factors such as the reduction of visual disamenity make the combination of woodlands with onshore wind turbines potentially desirable, albeit more complex to set up. As for the combination of agriculture and trees – i.e. agroforestry, the somewhat sparse evidence available suggests that financial returns have tended to be lower than those from agriculture, and sometimes forestry, alone in the recent past. This is especially the case given the lack of private markets for ecosystem services applicable to agroforestry at present. Nevertheless, there is a possibility that recently introduced agroforestry grant offers under ELMS have improved expected financial returns from the land use, but further analysis is required. These findings therefore highlight the need for further research on the economics of combining onshore wind and/or agriculture with tree planting or woodland creation.

The review also briefly discussed several other economic, social, and cultural factors that could create a barrier to woodland creation. Most notably, these include the permanence of woodland creation, long timescales before generating returns, and some land manager beliefs and attitudes towards woodland creation. Although evidence for the UK and England in particular is currently lacking, a 'financial premium' for woodland creation over and above any opportunity costs may be required to incentivise transition from other land uses.

There are several limitations to the research undertaken in this study. While estimates of income foregone from agriculture were based on actual national statistics, estimates for the other land uses were calculated and derived mainly using hypothetical scenarios underpinned by different assumptions. For renewable energy generation and BNG, reliable estimates of actual returns were found to be sparse within the academic and grey literature, rendering the need for rough calculations. These included, for example, assumptions of an average power generation capacity and the number of BUs that can be generated in one hectare of land. In addition, the study did not collect detailed information on the timings of cashflows for these land uses, hence specific assumptions were also needed to derive estimates of annual net returns (e.g. BNG income and costs are received and incurred upfront).

For woodlands, estimates were obtained from two sources reflecting very specific sets of assumptions (e.g. regarding timber prices and level of grant income). This renders it difficult to generalise the findings to the myriad of woodland types and growing conditions that exist and the array of different assumptions that could be adopted concerning factors such as establishment, management, and harvesting. Nevertheless, the estimates reported are considered to provide a useful basis for comparing the returns from alternative land uses for the purposes of this review.

The review found the financial opportunity costs in England to be relatively high compared with returns from woodland creation. This indicates, all else being equal,

that higher returns from forestry are likely to be required if the gap in financial returns is to be closed and more trees and woodlands planted in England. This could potentially be achieved through more generous levels of grant support for woodland creation – something which has been improving in recent years with the introduction of EWCO and periodic increases in payment rates in real terms. It could also be achieved through the channelling of more private and blended finance into woodland creation, including through further development of nature credit markets (e.g. the development of a Woodland Water Code (Brook *et al.*, n.d.)) and establishing financial mechanisms to help overcome landowners' cashflow barriers and barriers to large-scale investment in woodland creation.

The following are recommendations for future research needed to strengthen the existing evidence base:

**Recommendation 1: Explore development of spatially explicit approaches to estimating the opportunity costs of woodland creation.** For example, econometric methods could potentially estimate opportunity costs of woodland creation at a high spatial resolution based on explanatory variables such as climate, topography, and soil quality (see description of the 'model approach' in 'Section 3'). Results could also be compared with those obtained from other approaches such as the 'rental approach' as robustness checks. Constraints such as the location of high-sensitivity areas for woodland creation (Forestry Commission, 2024a) could be considered to allow for a more holistic understanding of opportunity costs. Exploration of these approaches would need to consider data availability.

**Recommendation 2: Use a broader range of more precise, location-specific, woodland return estimates when comparing opportunity costs.** For example, this could be achieved via the Cashflow Scenarios Model and/or App currently under development under the NCF Economics of Woodland Creation project. Use of more refined estimates could support more targeted policy actions to encourage

woodland creation in locations with the least gap between woodland creation returns and opportunity costs.

**Recommendation 3: Conduct additional research into the net returns available to land managers from mixed land uses (e.g. agroforestry and combinations of renewable energy generation with agriculture or forestry) in exploring further opportunity costs of woodland creation.** Economic modelling potentially could be used to explore the impact of new agroforestry grants under ELMS on the relative profitability of agroforestry, for example.

**Recommendation 4: Consider conducting additional research on the existence and value of any 'financial premiums' that exist for woodland creation in England, focusing on the perceived cost to landowners of loss of flexibility due to the irreversibility of woodland creation as a land use, as well as impacts of tree planting on value of underlying land.** Potential approaches to explore include using ROA, to help better understand landowner decision-making under uncertainty, and stated preference methods to quantify the level of financial premiums required by landowners. The extent to which landowner and land manager types and motivation impact any financial premium could also usefully be explored.

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# Appendices

## A1.1 Abbreviations & glossary

Table 22 Abbreviations

Abbreviation	Description
AES	Agri-environment Scheme
APR	Agricultural Property Relief
BESS	Battery Energy Storage System
BNG	Biodiversity Net Gain
BPR	Business Property Relief
BPS	Basic Payment Scheme
BU	Biodiversity Unit
CAP	Common Agricultural Policy
CCL	Climate Change Levy
CfD	Contracts for Difference
CGT	Capital Gains Tax
CHP	Combined Heat and Power
CS	Countryside Stewardship
DCF	Discounted Cash Flow
EAV	Equivalent Annual Value
ECS	Energy Crops Scheme
ELMS	Environmental Land Management Scheme
ES	Environmental Stewardship
ETAP	England Trees Action Plan

EWCO	England Woodland Creation Offer
EWGS	English Woodland Grant Scheme
FBI	Farm Business Income
FBS	Farm Business Survey
FBT	Farm Business Tenancy
FiT	Feed-in Tariff
GDP	Gross Domestic Product
GGGS	Green Gas Support Scheme
GGL	Green Gas Levy
IHT	Inheritance Tax
IRR	Internal Rate of Return
LFA	Less Favoured Areas
LPA	Local Planning Authority
LR	Landscape Recovery
LUC	Land Use Change
NCF	Nature for Climate Fund
NFU	National Farmers' Union
NPV	Net Present Value
PES	Payments for Ecosystem Services
PIU	Pending Issuance Unit
PV	Photovoltaic
PVOUT	Photovoltaic Power Output
REPD	Renewable Energy Planning Database
RHI	Renewable Heat Incentive

RO	Renewables Obligation
ROA	Real Options Analysis/Appraisal
ROC	Renewables Obligation Certificate
ROI	Return on Investment
RPA	Rural Payments Agency
SEG	Smart Export Guarantee
SO	Standard Output
SRC	Short Rotation Coppice
UKFS	UK Forestry Standard
VAT	Value Added Tax
WCC	Woodland Carbon Code
WCPG	Woodland Creation Planning Grant

Table 23 Glossary

Terms	Descriptions
Battery Energy Storage Systems (BESS)	Battery banks within steel units to draw electricity from the national grid when there is a surplus and export back to the national grid during periods of peak energy demand (Alder Kind & Conrad Energy, 2023b).
Cereal Farms	"Holdings on which cereals, combinable crops and set aside account for more than two thirds of the total Standard Output (SO) and where set aside alone does not account for more than two thirds of the total SO" (FBS, 2014).
Dairy	"Holdings on which dairy cows account for more than two thirds of their total SO" (FBS, 2014).
Dedicated bioenergy crops (miscanthus and SRC)	Miscanthus and willow (in the form of short rotation coppice (SRC)) are the primary perennial bioenergy crops grown in the UK specifically for heat and electricity markets and are burnt at

	power stations/combined heat and power (CHP) units/heating systems (Defra, 2021b).
Farm Business Income (FBI)	Farm Business Income represents the net financial returns to unpaid labour (farmers) and on their capital invested in the farm business, including land and buildings.
General Cropping	"Holdings on which arable crops (including field scale vegetables) account for more than two thirds of their total SO excluding holdings classified as cereals; holdings on which a mixture of arable and horticulture crops account for more than two thirds of their total SO excluding holdings classified as horticulture and holdings on which arable crops account for more than one third of their total SO and no other group accounts for more than one third" (FBS, 2014).
Horticulture	"Holdings on which fruit (including vineyards), hardy nursery stock, glasshouse flowers and vegetables, market garden scale vegetables, outdoor bulbs and flowers, and mushrooms account for more than two thirds of their total SO" (FBS, 2014).
Income category/cost centre	Categories of income relating to agricultural land use. Those used in the FBS are: (1) Agriculture; (2) Agri-environment and other Payments; (3) Diversification out of Agriculture; (4) Basic Payment Scheme.
LFA Grazing Livestock	"Holdings on which cattle, sheep and other grazing livestock account for more than two thirds of their total SO except holdings classified as dairy. A holding is classified as a LFA holding if 50 % or more of its total area is in the LFA." (FBS, 2014)
Lowland Grazing Livestock	"Holdings on which cattle, sheep and other grazing livestock account for more than two thirds of their total SO except holdings classified as dairy. A holding is classified as lowland if less than 50 per cent of its total area is in the LFA"(FBS, 2014)
Marriage Value	'An additional element of value created by the combination of two or more assets or interests where the combined value is more than the sum of the separate values.' (RICS, 2021, p. 11).
Mixed Farms	"Holdings in which none of the above categories is responsible for more than 2/3 of SOs. This category includes mixed pigs and poultry farms as well as farms with a mixture of crops and livestock (where neither accounts for more than 2/3 of SOs)" (FBS, 2014).

Pig Farms	"Holdings on which pigs account for more than two thirds of their total SO" (FBS, 2014).
Poultry Farms	"Holdings on which Poultry account for more than two thirds of their total SO" (FBS, 2014).
Option Value	The value placed on something in recognition and anticipation of the possibility of it being used in the future in the face of uncertainty.
Rotation period	The period of time between planting and harvesting in timber production.
Share Rental Contracts	Crop-share arrangements refer to a method of leasing cropland where the production is shared between the landowner and the operator. Other income items, such as government payments and crop residue, are also often shared, as are some of the production expenses (Farm Management Program, no date).

## A1.2 Research methodology

This study was conducted in accordance with guidance published by Collins *et al.* (2015) on production of Quick Scoping Reviews and Rapid Evidence Assessments. Evidence was obtained from a mix of academic and grey literature. It was collected through searches performed in Scopus and web search engines including Google, Google Scholar, and Microsoft Bing, as well as through use of citation chasing. Where necessary, evidence was also obtained through supplementary ad-hoc searches to obtain broad insights on specific topics. The following sub-sections contain the search terms and strings adopted at the outset of the study for each of the alternative land uses covered.

### A1.2.1 Agriculture

Table 24 shows the search terms relating to each search area for agricultural land purposes. These search strings were limited to those published after 2010 and only belonged to economic or finance subject areas. Search strings were filtered for temperate zone countries to limit reports/studies relevant to only countries with respective climatic conditions.

Table 24 Search terms for agriculture

Alternative land use	Agriculture	Economic Aspect
Woodland	Cereal	"Opportunity cost"
Forest*	Dairy	"Income foregone"
Tree	Grazing	Income
	Mixed	Financ*
		"Net Income"

### A1.2.2 Renewable energy & Biodiversity Net Gain

Search strings were created by identifying distinct search areas from the research questions to which related search terms belonged. Table 25 and Table 26 show the search terms relating to each search area, for renewable energy and BNG respectively. For renewable energy, studies were limited to those published from the UK after 2010 in economic or business subject areas. Exclusion terms were included to filter out many papers relevant only to tropical countries. The search returned 296 results.

Table 25 Search terms for renewable energy

Alternative land use	Renewable Energy	Economic aspect	(Excluding)
Woodland	Renewable	"opportunity cost"	Tropic*
Forest*	Solar	"income foregone"	Smallhold*
Tree	Wind	Income	Global*
Land	Bio*	Margin*	
On-farm		Profit*	
Agricultur*		Economic*	
		Financ*	

Given BNG is a relatively new policy, the search was widened to any biodiversity-related opportunity costs. Studies were limited to those published from the UK after 2010 in any subject areas. The same exclusion terms were included to filter out many papers relevant only to tropical countries. The search returned 142 results.

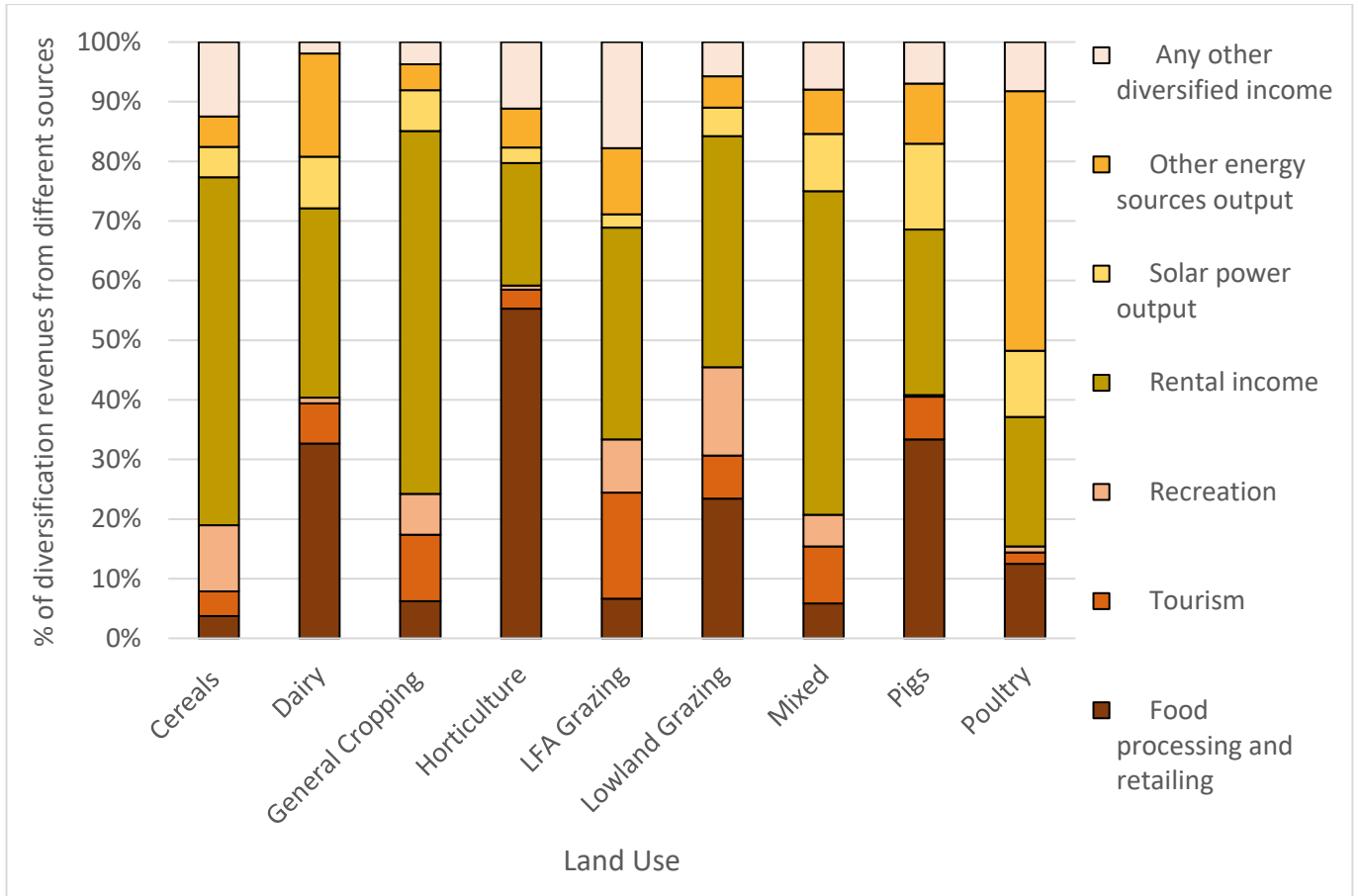
Table 26 Search terms for BNG

Alternative land use	Biodiversity	Economic aspect	(Excluding)
Woodland	biodiversity	"opportunity cost"	Tropic*
Forest*	Agri-environment*	"income foregone"	Smallhold*
Tree		Payment*	Global*
Land			
On-farm			
Agricultur*			

## A1.3 Farm Business Income from diversification

Diversification plays a significant role in boosting the income for agricultural enterprises, with the form that this takes varying considerably. Figure 18 shows the different sources of diversification revenues and their relative proportions for each FBS farm type. For instance, over 50% of diversification revenues in horticulture are related to food processing and retailing, while most diversification revenues on arable farms stem from rental income. Note that this data only provides a rough indication of the dependence of diversification on agricultural production as it relates to revenues only rather than net income. Cost and land use data specific to diversification activities is not available in the FBS.

Figure 18 Proportion of total revenues from agricultural diversification attributed to different activities for each FBS farm type, averaged across 2017/18–2021/22



Diversification activities and income may not be strictly tied to agriculture and hence may not be lost when creating a woodland. This is particularly true for activities related to recreation, rentals, and tourism, and to a lesser extent with activities such as food processing and retailing. Furthermore, woodland creation itself carries unique opportunities for diversification including, in some cases, potential for production of high value non-timber forest products such as truffles (Thomas, 2023).

## A1.4 Renewable energy subsidy payments

### A1.4.1 Feed-in Tariff

Feed-in Tariff (FiT) subsidies could be made to generators of solar, wind, anaerobic digestion, or hydro installations below 5 MW capacity or micro-CHP below 2 kW. They are made up of (i) a generation tariff and (ii) a feed-in tariff. The generation tariff is a fixed rate of income per kWh generated, no matter whether consumed onsite or exported to the grid. Its level depends on the type of technology used, when the technology was installed (as payments were subject to depression over time as the costs of installation decreased), the energy efficiency of the property (for homeowners), and the size of the system (smaller systems are paid more) (DECC, 2012). The feed-in tariff is a tariff paid for surplus energy exported to the National Grid. In 2023, it was 7.0p/kWh for any technology installed after 1st August 2012 (Ofgem, 2024a).

Table 27 sets out the range of generation tariffs received by the main technology types from January 2023, the range showing the maximum and minimum possible tariffs received under the scheme for certain technology types/capacity (the highest rates for those installed in 2010/11 and the lowest for 2018/19).

Table 27 FiT generation tariffs for renewable energy technologies as of Jan 2023

Technology type	Capacity	Payments (p/kWh, 2023, RPI adjusted)
Solar PV	100 kW – 250 kW	2.13 – 48.46
	250 kW – 1 MW	1.68 – 48.46
	1 MW – 5 MW	0.19 – 48.46
Standalone solar PV		0.06 – 48.46
Wind	100 kW – 500 kW	1.95 – 30.99
	500 kW – 1.5 MW	1.95 – 15.64
	1.5 MW – 5 MW	0.59 – 7.36
AD	≤ 250 kW	5.67 – 19.10
	> 250 kW, ≤ 500 kW	5.38 – 19.10
	> 500 kW, ≤ 5MW	1.94 – 14.90
Source: (Ofgem, 2024)		

#### A1.4.2 Renewables Obligation

The Renewables Obligation (RO) was a non-obligatory scheme open to new applicants between 2002–2017. Participating electricity suppliers aim to obtain a target level of certificates (ROCs) in proportion to their total electricity supply, the target rising annually. Suppliers that fail to reach the target are required to pay a buy-out fee (£59.01/ROC in 2023/24 (Ofgem, 2023) which is consequently distributed among the electricity suppliers which do achieve the target level as well as small-scale renewable energy generators. Suppliers can either invest in renewable energy themselves or buy ROCs from either supplier who have exceeded the target or small-scale renewable energy generators. One ROC equals 1 MWh of electricity for onshore wind, 667 kWh for CHP bioenergy and 500 kWh for AD. As ROCs are tradable, land managers generating renewable energy may achieve

higher profits selling ROCs on private auction markets to energy suppliers at risk of missing the target than waiting for a share of the buy-out fund (Redman, 2010).

The ROC tariffs received in Q1 of 2022/23 are set out in Table 28 (Ofgem, 2023).

Table 28 ROC tariff rates received in Q1 of 2022/23

Technology	Capacity	Tier	Tariff rate range (p/kWh)
Bioenergy	< 200 kW	Tier 1	11.03–3.07
		Tier 2	2.89–0.80
	≥ 200 kW, < 1 MW	Tier 1	6.76–3.34
		Tier 2	2.89–2.34
	≥ 1 MW	Tier 1	3.34–1.25
		Tier 2	2.89–2.34
Solid Bioenergy CHP			5.15–4.85
Solar Thermal Collectors			12.53–11.77
Biomethane <sup>12</sup>		Tier 1	9.39–5.22
		Tier 2	5.50–3.08
		Tier 3	4.25–2.37
Biogas combustion	< 200 kW		9.38–5.09
	≥ 200 kW, < 600 kW		7.37–3.99
	≥ 600 kW		2.78–1.28
Source: (Ofgem, 2023)			

<sup>12</sup> Until Jan 2015, all capacities of biomethane received a tariff rate of 9.38p/kWh, after which a tiered system was introduced as well as tariff rate depression.

### A1.4.3 Renewable Heat Incentive

The non-domestic Renewable Heat Incentive (RHI), open to new applicants from 2011–2021, aimed to help deliver the UK’s 2020 goal of providing 12% of heating energy from renewable sources. The RHI pays incentives in quarterly instalments, usually over 20-year contracts for a range of technologies including biomass boilers, solar thermal, combined heat and power systems (CHP), biogas-combustion systems and biomethane production for injection into the national gas distribution network (Ofgem, 2021). Tariff rates were subject to degression, such that technologies installed earlier in the programme (and experiencing higher costs) receive higher tariff payments. Tariff rates are also tiered, whereby payments are made at higher rates until a certain threshold (e.g. until the heat equivalent of operating at full capacity for 15% of the year) has been reached (Renewables First, 2022).

### A1.4.4 Energy Crops Scheme

The Energy Crops Scheme (ECS) ran from 2007 to 2013 as part of the Rural Development Programme for England, providing one-off payments to cover 40% of the actual establishment costs of miscanthus and short rotation coppice (SRC) crops (Natural England, 2007).

## A1.5 Exploratory 'break-even' carbon credit prices

Table 29 Carbon credit prices (£/tCO<sub>2e</sub>) for woodlands to achieve same returns as other land uses

Alternative Land Uses	Woodlands					
	Haw (2017)				Forestry Commission Case Studies	
	Productive Conifers (Upland)	Productive Conifers (Lowland)	Productive Broad-leaves	Native Broad-leaves	10ha	100ha
Cereals	£76	£42	£80	£46	£43	£36
Dairy	£98	£54	£97	£57	£56	£50
General Cropping	£78	£43	£82	£47	£44	£38
LFA Grazing Livestock	£29	£16	£43	£22	£15	£7
Lowland Grazing Livestock	£36	£20	£48	£26	£19	£12
Mixed	£49	£27	£59	£32	£26	£19
Solar (Ground Rent)	£504	£280	£416	£261	£301	£299
Onshore Wind (Ground Rent)	£124	£69	£118	£70	£72	£66
Miscanthus Bioenergy	£72	£40	£77	£44	£40	£34
SRC Bioenergy	£51	£29	£61	£33	£28	£21
BNG	£1,398	£775	£1,118	£709	£838	£848

### Notes:

1. Values in the table are ranked on a Red-Yellow-Green colour scale, with dark red indicating higher values and dark green indicating lower values.

2. The carbon credit prices derived do not account for investment additionality and should be seen as exploratory only.
3. It is assumed that PIUs are sold up front, in year 0 for estimates from Haw, and in year 5 for estimates from the Forestry Commission. Given this discrepancy, caution should be taken when comparing estimates across the two sources.

Table 29 above provides estimates of carbon credit prices (WCC PIUs sold upfront) at which the annual returns of woodlands and alternative land uses presented in this report are equal (i.e. 'break even'). They were derived through exploratory analysis by solving a system of static mathematical equations, and hence do not account for investment additionality and any associated effects on levels of grant payments claimed, and hence on the level of carbon credit prices required for returns from woodlands and alternative land uses to be equal. Caution should therefore be taken when interpreting the estimates.

## A1.6 Calculation of annualised net returns

To facilitate comparisons of financial returns from land uses with different time horizons and cashflow timings, a commonplace approach when using Discounted Cashflow Analysis is to express returns in an annualised form such as by using the EAV measure (e.g. see Hardaker, 2018). In this study, EAVs were computed using the following formulas and respective assumptions.

### A1.6.1 Formulas

$$EAV = \frac{r \times NPV}{1 - (1 + r)^{-T}}$$

$$NPV = \sum_{t=0}^T \frac{Net\ Income}{(1 + r)^t}$$

Where,

NPV = Net Present Value

r = Discount Rate (3.5%)

T = Time frame of land use

### A1.6.2 Assumptions & implications

#### A1.6.2.1 Woodlands

Estimates of EAVs were not reported in the Forestry Commission publications cited and needed to be computed. Assumptions associated with the woodland types and financial returns are available in the respective publications.

#### A1.6.2.2 Biodiversity Net Gain

EAV estimates for BNG were computed by first estimating NPVs on the assumption that all income and costs are received and incurred upfront in the current period (i.e. Year 0) over a time horizon of 30 years. As a result, it is worth noting that the estimates of NPV and hence EAV produced could potentially either over- or underestimate actual values. This is because in some cases landowners are paid by

developers in stages, or by results, rather than an upfront lump sum payment (Defra, 2024f), such that the income stream received in future periods should be discounted as part of the NPV and EAV estimations. It is also because any costs associated with habitat creation and management will very likely be incurred in multiple years over the lifetime of BNG contracts rather than purely upfront.

### A1.6.2.3 Agriculture & renewable energy

EAV estimates were not computed for these land uses as the study did not collect detailed information on timing of cashflows for these land uses. For agriculture, it was assumed that the use of a 5-year average FBI estimate accurately reflects the annual income that farmers receive. For renewable energy, it was assumed that lifetime net income is equally distributed across the time frame of the land use, and simple (non-discounted) averages were computed to derive an estimate of annual net returns.

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