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A critical appraisal of the effectiveness of UK perennial energy crops policy since 1990

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A B S T R A C T

Energy crops are cultivated primarily for bioenergy production, but can also have wider benefits to agriculture and the environment. Policies put in place in the UK and Europe have promoted bioenergy and the growth of energy crops. Despite the various policy support mechanisms the cultivation of perennial energy crops has proceeded at a low rate. This study rigorously analyses some of the key UK bioenergy policies since 1990 to assess why perennial energy crops have not fulfilled their potential. The UK energy crops market is scrutinised and shows the industry is still nascent compared to Government aspirations. Case studies of both successful and unsuccessful projects are evaluated to reveal how effective different policies have been in establishing UK perennial energy crops. This original review shows significantly that none of the projects, initiatives or schemes described can be viewed as an absolute success. The main obstacles that have hindered progress include: the lack of long term supportive energy crops policy, the failure of headline projects and organisations, the lack of competitiveness of long term perennial crop options compared to annual crops, bureaucracy of schemes, over-ambitious projects, and large-scale support schemes tending to favour imported biomass rather than support domestic supply.

25 years of failed energy crops policy suggests there needs to be a long term strategy. Future support for the sector must join up policy between different Government departments to recognise multi-functional benefits of perennial energy crops. Support mechanisms could aim to provide a competitive advantage for local supply and use, and improve management of cashflows during establishment. The risk burden should be shared between suppliers and end-users. Smaller-scale projects using established technologies are required with energy crops introduced in a phased manner. Supply-side measures need to be balanced with demand-side incentives to link supply with end-user markets.

Contents

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1. Introduction

Plants have been used for food, fuel, fodder, and fibre for thousands of years [1]. In recent decades there has however been an increasing need to make more efficient use of biomass resources due to fossil fuel depletion, global climate change, and energy security [2,3]. Bioenergy offers a potential solution to these societal challenges by offering a renewable alternative to fossil fuels, a reduction in greenhouse gas emissions, and the potential for locally produced energy that assists in developing rural communities [4]. Policies have therefore been implemented in the UK and Europe to promote bioenergy and the growth of energy crops [5–9]. Perennial energy crops are highlighted by several Government reports and strategies as offering significant potential for sustainable bioenergy development [3,4,10,11]. Despite the various policy instruments, grants, and incentives implemented, the cultivation of perennial energy crops has proceeded at a low rate [12–14]. This study reviews key policies since 1990 that could have led to the development of a viable perennial energy crops sector within the UK. An assessment of the energy crops supply market is conducted with a critique of case studies to evaluate the lessons learned and effectiveness of different policies and bioenergy projects.

1.1. Perennial energy crops

Perennial energy crops remain in cultivation for several seasons and are grown primarily for their energy content although they often have broader advantages. The ideal energy crop has efficient solar energy conversion resulting in high yields, needs low agro-chemical inputs, has a low water requirement and has low moisture levels at harvest [15], which makes miscanthus and short rotation coppice (SRC) particularly promising [16]. Plants with perennial growth habits have the benefits of low establishment costs (when averaged across the rotation) and fewer annual operations are therefore required [17].

Using woody biomass for renewable energy can make a positive contribution to climate change targets and to the mitigation of greenhouse gas emissions [18]. Increasing locally sourced energy reduces dependency on fossil fuels and improves energy security [19]. SRC can also bring a wide range of environmental benefits to farms and rural situations which are summarised in Fig. 1.

1.2. Policy aspirations for perennial energy crops

Across Europe and in individual countries policy makers are aware of the need for perennial crops in order to reach future renewable energy and climate change targets. For instance, the European Environment Agency estimated that the environmentally compatible arable land area available for energy crops will reach 19 m ha by 2030 [10]. The 2012 UK bioenergy strategy estimates that miscanthus and short rotation coppice (SRC) could occupy between 0.62 m and 2.8 m ha by 2050 [3]. Nevertheless, current UK plantings of these perennial crops are estimated to be around 16,000 ha [25] which is a long way from policy ambitions and estimates. Indeed the remaining plantations could be 10–15% lower than this based on evaluations of crop removals due to issues encountered in the industry [24,25].

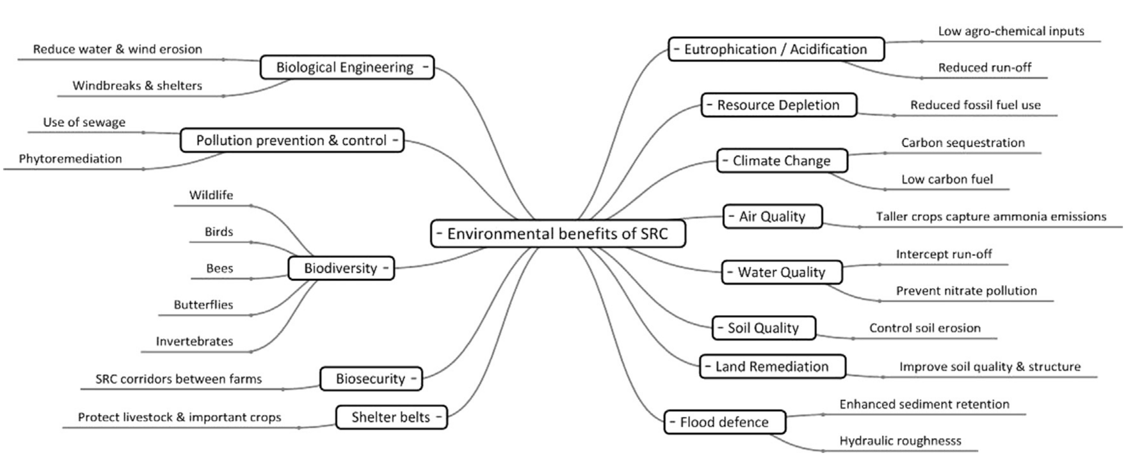

Fig. 1. Summary of the potential multi-functional environmental benefits of SRC [16–24].

1.3. Aims and objectives

The overall aim of this study is to review and assess the development of the supply market in the UK for perennial energy crops. Specific objectives are to:

i) Review and analysis of the different policies implemented to support the development of the energy crops market in the UK since 1990.
ii) Evaluate the success of bioenergy projects which have resulted from policy intervention.
iii) Discuss and assess the effectiveness of policies in achieving plantings of perennial energy crops in the UK.
iv) Review the lessons learned from policy measures and the relative achievement of different bioenergy projects to appraise the effectiveness of Government support for perennial crops.
v) Make policy recommendations for the future development of the sector.

2. Methods

The approach adopted for this appraisal of UK perennial energy crops policy is based predominantly on qualitative assessment methods. A comprehensive review is performed in Section 3 of the key policies, strategies, and reports that have influenced the UK perennial energy crops sector since 1990. Key policies are reviewed in terms of the impact they have had on supporting and developing the supply market for perennial energy crops. The review includes a critique of bioenergy projects which have been implemented and an assessment of the number of hectares planted with SRC and miscanthus. Each policy is assessed to consider:

- Whether the policy provided direct support (e.g. supply side initiatives such as a financial incentive to grow perennial energy crops) or indirect support (e.g. demand side initiatives such as support for capital investment or energy generation).
- Did the policy lead to the establishment of perennial energy crops.
- Has the policy achieved its objective in relation to energy crops.

Where Government intervention has not been effective, this study has reviewed literature, interviewed stakeholders, and analysed the details of the policy to assess the reasons why. The wider context of each policy is considered including the timing, macroeconomic situation, farmer attitudes, commodity prices, and other factors which influence decisions around planting energy crops. Several Freedom of Information (FoI) requests to the UK Government and a complimentary study funded by the Energy Technologies Institute (ETI) has provided additional understanding of the extent to which each policy has led to the establishment of SRC or miscanthus [25].

Alongside the policy review in Section 3, various bioenergy projects associated with each policy intervention have been assessed. For each policy reviewed examples of both successful and unsuccessful projects are analysed. This provides additional context to the relative impact of each policy on the energy crops industry.

The discussion in Section 4 provides extra context and assessment of the policy review to further understand the lessons learned. The paper concludes with some recommendations for future energy crops policy, based on the findings of the research described in the preceding sections.

3. Bioenergy policy review

Policy development for bioenergy can be traced back to the first oil crisis in the 1970s which saw a push for the growth of renewable energies and many governments supported the expansion of novel non-food crops for heat and power [26]. In the EC, bioenergy research programmes were developed in the 1980s and early 1990s including AIR, FAIR, JOULE, APAS and ALTENER [27]. The UK also had some research into biomass crops and technologies, but policy development for bioenergy really emerged when the Non Fossil Fuel Obligation (NFFO) was introduced (see Section 3.1.1) [28].

In 1992, the Earth Summit in Rio called for alternative sources of energy to replace the use of fossil fuels which are linked to global climate change [29]. The summit also outlined the forest principles and the climate change convention which in turn led to the Kyoto Protocol [30,31]. As a consequence of these milestones, bioenergy and energy crop production have received increasing attention from policy makers since 1990. Throughout the 1990's it was expected that energy crops along with wind would supply the majority of the UK's renewable energy outputs by 2010 [32].

Climate change is now near the top of the political agenda both in the UK and abroad, with the UK Government setting targets to reduce greenhouse gas (GHG) emissions by 80% over 1990 levels by 2050, with identifiable progress being made by 2020 [33]. The UK has also agreed to an EU target to produce 15% of the UK's energy from renewable sources by 2020 [34]. The renewable energy targets in the UK envisage that biomass will deliver about 30% of the renewable target [35]. Indeed various Government strategies produced in the last 20 years indicate strong support for biomass and energy crops (see Table 1). Fig. 2 presents some of the

Table 1
Reports, strategies and schemes over the last 20 years indicate the UK Government's high aspirations for energy crop planting.

Publication or scheme	Year published/initiated	Energy crop planting aspiration (ha)	Year by which this could be achieved	References
The National Biomass Energy Strategy	1996	790,000	2025	[36]
England Rural Development Plan	2000	125,000	2010	[37]
Energy Crops Scheme	2000	24,000 (SRC) 5000 (Misc)	2008	[38]
DTI/Carbon Trust 'Renewables Innovation Review'	2004	350,000	2020	[39]
RCEP 'Biomass as a Renewable Energy Resource'	2004	7 m	2050	[40]
Biomass Task Force	2005	800,000	n/a	[41]
Energy Crops Scheme 2	2007	60,000	2015	[42]
UK Biomass Strategy	2007	350,000	2020	[4]
2050 Pathways Analysis	2010	350,000–4.2 m	2050	[43]
UK Bioenergy Strategy	2012	40,000 0.93–3.63 m	2020 n/a	[3]

primary policies, strategies, reports and scheme implemented during this period that are relevant to the development of the perennial energy crops sector.

3.1. Large-scale support schemes for bioenergy and other renewables

Large-scale support schemes have been introduced over the last 25 years to support the development of renewable and low carbon energy technologies. These schemes promote bioenergy projects either through financial incentives for energy generators or legislative obligations on large electricity suppliers.

3.1.1. Non Fossil Fuel Obligation (NFFO)

The NFFO was set up in order to subsidise nuclear power stations following deregulation of electricity utilities in 1989 [44]. NFFO also stimulated the market for renewable electricity by imposing on electricity companies an obligation to buy a certain quantity of non-fossil fuel generated power. The intention was that any increase in costs brought about by immature technologies (such as biomass power using gasification) would be countered by a tax on coal-derived electricity. Between 1990 and 1999 the Government made 5 NFFO orders in England and Wales. There were similar arrangements in Scotland (Scottish Renewables Obligation or SRO) and Northern Ireland (NI NFFO) (see Table 2).

NFFO dictated that novel higher efficiency technologies were used. The combination of this and essentially a new feedstock in SRC meant that projects were hampered from the start [45]. Of the 10 projects proposed under NFFO 3 and 4 only one was built (Project ARBRE) and this never became fully operational [46]. Other projects failed to get planning permission or achieve financial closure. Two small CHP facilities were developed in Northern Ireland but these never really progressed beyond test facilities.

Although ARBRE ultimately failed, it did lead to significant areas of SRC being planted in Yorkshire and Humber and the East Midlands regions. Over 40 farmers were convinced to plant SRC

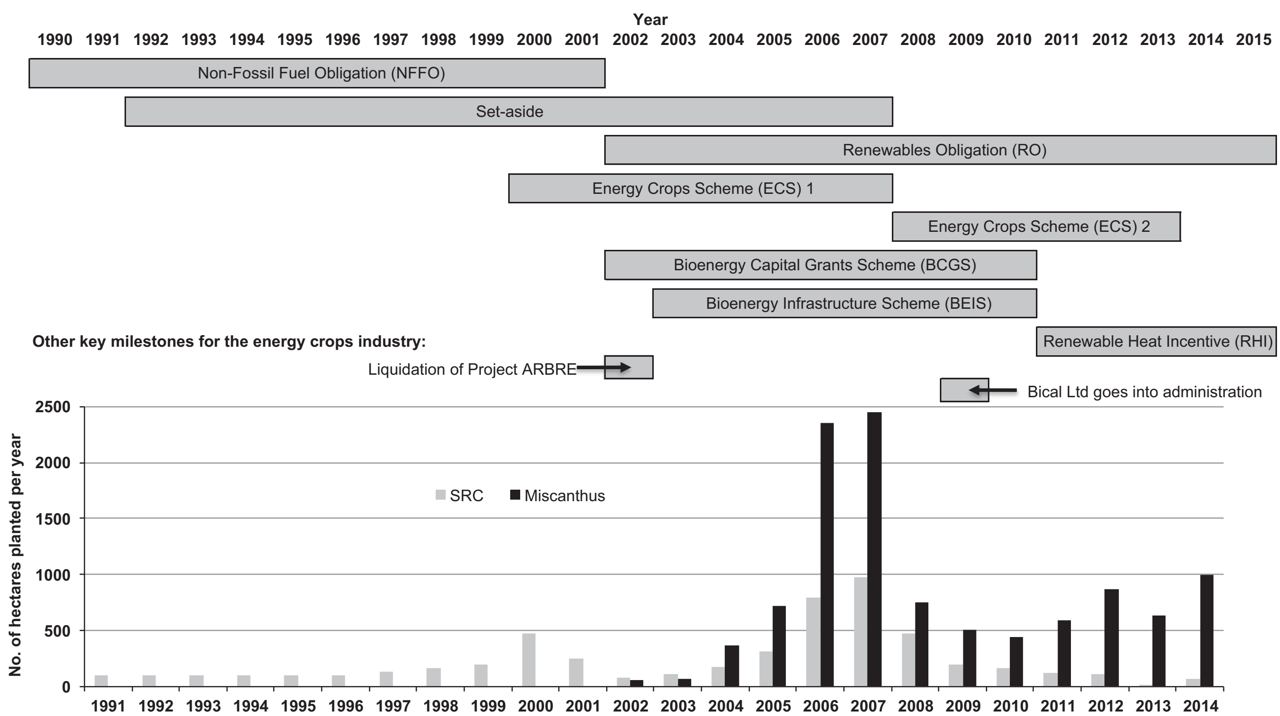

Fig. 2. UK Policy timeline, key milestones and perennial energy crop plantings 1990–2015.

Table 2
Summary of the different rounds of the NFFO, SRO and NI NFFO [48].

	Year	Number of contracts	Capacity (MW)	Energy crop projects	Capacity (MW)	Energy crop projects that went ahead
England and Wales						
NFFO 1	Sept 1990	75	152	0	0	/
NFFO 2	Oct 1991	122	472	0	0	/
NFFO 3	Dec 1994	141	627	3	19	1[a]
NFFO 4	Feb 1997	195	843	7	67	0
NFFO 5	Sept 1998	261	1177	0	0	/
Scotland						
SRO 1	Dec 1994	30	76	0	/	/
SRO2	Mar 1997	26	104	0	/	/
SRO 3	Mar 1999	53	140	0	/	/
Northern Ireland						
NI NFFO 1	1994	20	16	0	/	/
NI NFFO 1	1996	10	16	2	0.3	2[a]

[a] See Table 3.

and 1100 ha of the 2000 ha goal were committed [47]. This was as a result of a good contract being offered and the low price of cereal grains at the time. However, as the plant did not become operational growers were left in an uncertain situation and were forced into developing alternative markets. The impact of this failure on the SRC industry in the UK cannot be underestimated as it has since been much more difficult to convince farmers to grow this crop [25]. It is estimated that 1750 ha were planted due to the NFFO and 42 ha for the NI NFFO project (see Table 3) [48,49].

3.1.2. *Renewables Obligation (RO)*

UK Electricity generation from renewable sources was incentivised by the Renewables Obligation (RO) introduced in 2002. This is an obligation for UK electricity suppliers to source a fixed percentage of their electricity from renewable sources [55]. Renewables Obligation Certificates ("ROCs") were issued to renewable energy generators, initially at one ROC per MWh. These have a value of £43.30 per ROC in 2014/15 prices [56]. The RO originally aimed to encourage miscanthus and SRC to be cultivated for co-firing with coal and in dedicated biomass plants [57].

The initial rules for co-firing looked highly favourable for energy crops. For the first 4 years of the scheme (until end March 2006) any biomass could be co-fired with coal. After this cut off point 75% of the biomass used would need to be derived from energy crops until co-firing ceased to be eligible in 2011 [58]. However, this meant that demand would greatly outstrip supply based on 1300 MW of co-firing (the maximum level allowed) 145,000 ha of harvested energy crops would be required by 2006/07 [57]. At the time the scheme was being launched there was only around 2000 ha of energy crop planted so this was deemed impossible to achieve in the short timeframe. As a result the RO co-firing rules were amended in 2003 as follows [57–60]:

- Until end of March 2009: any biomass.
- Between April 2009 – March 2010: minimum 25% energy crops.
- Between April 2010 – March 2011: minimum 50% energy crops.
- Between April 2011 – March 2016: minimum 75% energy crops.

The definition of energy crops under the RO was “a plant crop planted after 31st December 1989 and grown primarily for the purpose of being used as a fuel” [61]. This was sufficiently wide enough to enable co-firers to source large quantities of cheap energy crop imports [62].

Only a few power stations decided to look at the potential of home grown energy crops. Drax Power Station in Yorkshire began testing SRC woodchip in the summer of 2004 [63]. It was thought that if trials were successful that willow-based biomass could provide 5% of the station's fuel by 2009 and provide a market for 40,000 ha of energy crops. However, following the demise of the Yorkshire based ARBRE project it was much more difficult to get local farmers to grow willow and by 2007 Drax were setting their sights on miscanthus as their energy crop of choice [64]. At this time a contract was signed with the company Bical to supply 300,000 t per year up until 2016. This would have created a market for 20,000–30,000 ha of miscanthus. Similarly Bical had announced plans to supply Aberthaw Power station in South Wales with 100,000 t per year in September 2008 [65]. However, BICAL went into administration in December 2009 largely as a result of the hiatus period following the end of Energy Crops Scheme 1 (see Section 3.2.2).

The demise of Bical had a significant impact on farmer confidence and as a result interest in planting fell (see Fig. 2). Drax set up its own Green Shoots Programme in 2009 to stimulate UK supply chains and latterly another company called Terravesta has taken on many of the old Bical contracts [66].

Table 3
NFFO 3 and NI NFFO projects involving energy crops.

Project	Location	Capacity (MWe)	Amount of biomass required (odt/year)	Amount of energy crop required (hectares)	Crop	Project outcome	References
ARBRE	Eggborough, Yorkshire	8	43,000	2000	SRC/Forestry residues	Project ARBRE was built but never successfully commissioned. The failure was due to three unfortunate developments: the withdrawal of the main company that initiated and financed the project; bankruptcy of the turnkey contractor appointed to oversee the project; and technical problems with gasification.	[46]
Ambient Energy	Eye, Suffolk	5.5	32,500	2500	SRC/Forestry residues	Received planning permission but did not go ahead.	[50]
	Cricklade, Wiltshire	5.5	32,500	2500	SRC/Forestry residues	Planning application was rejected. The plans received negative opposition from the local community and terminated by the Council on the grounds of significant visual harm, i.e. "would cause demonstrable harm to the amenity and rural character of the countryside, significantly impacting on the open landscape of the area by virtue of the proposal's scale and design".	[51,52]
Brook Hall Estate	Londonderry/ Derry	0.1	~500	42	SRC	Successful demonstration project. Accumulated over 20,000 h of operation by June 2006 with a 60% load factor.	[53]
B9 Energy Biomass Ltd Blackwater Museum	Armagh	0.2	~1000	~100	SRC/Forestry residues	Only one 100 kW unit installed using forestry residues. Demonstrated potential but struggled to produce enough gas or of the right quality. B9Energy Biomass became insolvent in 2005.	[53,54]

In 2009, the Government introduced additional incentives for renewable electricity production designed to improve the economics of projects involving less mature or emerging technologies such as offshore wind and dedicated biomass. Instead of getting a single ROC for each MWh of electricity produced, generators using energy crops could claim double ROCS (see Table 4). This had a small impact on domestic energy crop supply. Table 5 shows that by 2012/13 around 41,000 t of energy crops were being co-fired and 15,000 t used in dedicated plants [68–71]. Based on ECS applications co-firing markets resulted in 6572 ha of planting [72]. The ROC banding was consulted on in 2012 and a decision made to remove the energy crop uplift for standard co-firing effectively signalling the end of Government support for the co-firing of domestic energy crops [73].

3.1.3. Contracts for Difference

Under the Electricity Market Reform (EMR), Contracts for Difference (CfD) are the new mechanism to replace the RO [74]. As these are aimed at large-scale production, it is understood that most biomass projects under CfD will import feedstocks due to the limited availability in the UK, which will not help the market for UK energy crops [75]. Nonetheless, there are some positive signs for the biomass industry with 3 of the 8 contracts awarded in 2014 going to biomass power [76]. Drax, Western Europe's largest power station, have announced plans to convert to 100% biomass, however it is expected that the majority of feedstock will be imported [75].

Table 4
ROC banding introduced in 2009 to promote emerging bioenergy technologies [67].

Generation type	ROCs/MWh
Co-firing of biomass	0.5
Co-firing of energy crops	1
Co-firing of biomass with CHP	1
Co-firing of energy crops with CHP	1.5
Dedicated biomass	1.5
Dedicated energy crops	2
Dedicated biomass with CHP	2
Dedicated energy crops with CHP	2

3.1.4. Renewable Heat Incentive (RHI)

The RHI is a Government programme that gives financial incentives to increase the uptake of renewable heat. It provides a subsidy, payable for 20 years, to renewable heat generators. By December 2014 the Non-Domestic RHI has introduced over 1 GW of installed capacity with over 6000 approved installations, 98.7% of which use solid biomass [77]. This is a clear success in increasing the amount of generation equipment and heat production, but so far it is uncertain if this is having any impact on the domestic supply of perennial energy crops. The scheme is a demand side measure with no requirement for UK feedstocks, although biomass sustainability criteria may ultimately mean that biomass needs to be locally produced with low GHG emissions [78].

A freedom of information request was lodged with the scheme administrator Ofgem in August 2014 to find out the different types of fuel cited in RHI applications [79]. Table 6 shows shows that energy crops were being used in the fuel mix of 155 projects (3.6% of the accreditations at that time) although as the sole fuel in only 73 applications.

Table 5
Usage, planting and locations for co-firing and dedicated biomass under the RO [68–71].

	Power station	Area planted (hectares)	Amount of energy crops used (tonnes)				Total
			2010/10	2010/11	2011/12	2012/13	
Co-firing	Aberthaw	0	97	0	0	0	97
	Cottam	356	2061	1848	0	0	3909
	Didcot A	412	10	0	0	0	10
	Drax	5624	26,974	25,291	34,339	40,124	126,728
	Fiddlers Ferry	0	0	276	2076	825	3177
	Kingsnorth	0	2843	543	0	0	3386
	Sub-total	**6392**	**31,985**	**27,958**	**36,415**	**40,949**	**137,307**
Dedicated biomass	Eccleshall	962	319	522	65	0	906
	Elean	313	0	25,343	13,068	13,250	51,661
	Stevens Croft	128	1260	2134	5529	1740	10,663
	Western Wood Energy	0	0	0	241	0	241
	Wilton 10	150	5309	0	2692	0	8001
	Sub-total	**1553**	**6888**	**27,999**	**21,595**	**14,990**	**71,472**
	Total	**7945**	**38,873**	**55,957**	**58,010**	**55,939**	**208,779**

Table 6
Fuels used in RHI accredited projects up to the end of August 2014 [79].

Biomass type	Total number of accredited applications mentioned as the sole fuel	% Of total	Total number of accredited applications mentioned with other fuel types	Total number of accredited applications in which fuel is mentioned	% Of total
Agricultural residues	63	1.58	64	127	**2.92**
Energy crops	73	1.83	82	155	**3.56**
Waste/recycle wood	88	2.20	110	198	**4.55**
Wood chip	1,421	35.59	107	1528	**35.09**
Wood logs	617	15.45	137	754	**17.31**
Wood pellets	1,642	41.12	226	1868	**42.89**
Other	89	2.23	14	103	**2.32**
Total	**3993**	/	**740**	**4733**	/

A recent questionnaire returned by 106 energy crops growers suggested that this group of farmers are much more likely to have a biomass boiler (36.5%) compared to farmers in general (8%) [25,80]. More SRC growers were found to own a biomass boiler than miscanthus growers and also use their own fuel, and 79% of SRC growers with a biomass boilers use their own fuel compared to 42% of miscanthus growers [25].

There is reason to believe that the RHI could be having a positive effect on energy crop planting levels. A freedom of information request was lodged with Natural England (who administrate the Energy Crops Scheme) in August 2014 to find out the intended end use for energy crops being planted in 2014 and 2015 [81]. Out of 2393 ha of proposed planting 1064 (44.4%) was intended for self-supply and local heat markets. 47 out of 91 applicants were intending to use their crops for heating. This equates to a 20-fold increase in interest in growing these crops for heat in 2014/2015 compared to previous years (see Table 7 and Figs. 3 and 4).

3.2. Grant schemes for energy crop establishment and utilisation (2000–2010)

Between 2000 and 2002 a £100 m package of measures was announced by the UK Government to support the energy crops sector. This package included:

- Bioenergy Capital Grants Scheme (£66 m).
- Energy Crops Scheme (£29 m).
- Bioenergy Infrastructure Scheme (£3.5 m).

3.2.1. Bioenergy Capital Grants Scheme (BCGS)/New Opportunities Fund

The BCGS was designed to act as a market ‘pull’ incentive through the provision of capital grants. It was hoped that the funding would support the establishment of up to six power stations and numerous heat and CHP projects to the industrial, commercial, and community sectors [82]. A grant of up to 40% of the cost was available to pay for biomass conversion equipment. This scheme was jointly funded by Department of Trade and Industry (DTI) and the National Lottery's New Opportunities Fund (NOF). The reason for the latter was the recognition that energy crops could play an important role in developing and sustaining rural communities.

In total six rounds of grants were awarded between 2003 and 2010. By the end of the scheme four dedicated electricity and seven CHP projects were supported with an installed electrical capacity of 101.3 MW [88]. In addition, 215 biomass heat projects with an installed capacity of 111.1 MW were supported [88]. Overall the scheme can be viewed a success. However, in reality it did very little to stimulate the market for energy crops.

In round 1 of the scheme £17.96 million was awarded to five projects aiming to use energy crops as fuel (see Table 8) [89]. If all these had gone ahead it would have provided a market for 45,300 ha of energy crops. Of these only Eccleshall was ever commissioned. All the others failed because of planning failures, local opposition, market failures and finance issues. Although the Eccleshall project in part led to 962 ha of miscanthus being planted in the west Midlands ultimately the project progressed without energy crops as part of the fuel mix.

Round 2 of the scheme was funded through the NOF. On this occasion two biomass power stations were funded (see Table 9).

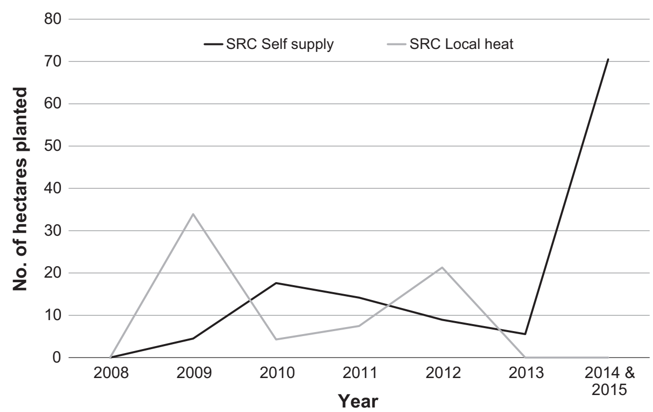

Fig. 3. SRC crop areas under the ECS intended for self-supply heating and local heat markets [72,81].

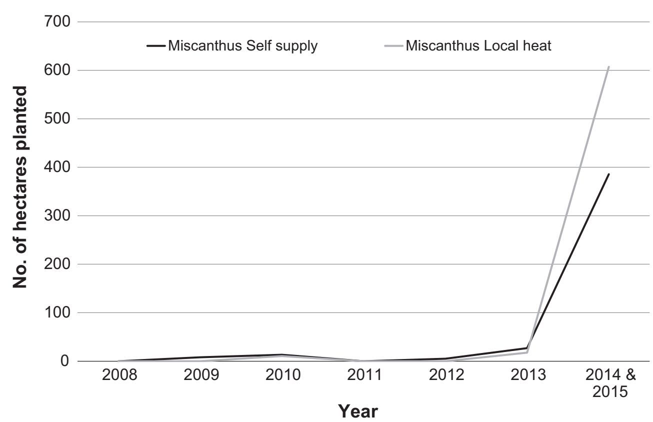

Fig. 4. Miscanthus crop areas under the ECS intended for self-supply heating and local heat markets [72,81].

Table 7
Energy crop areas and number of applicants intending on using their crops for heat use 2008-2015 [72,81].

Year	Energy crops intended for self-supply and local heat markets					
	Miscanthus		SRC		Total	
	Applicants	Area (hectares)	Applicants	Area (hectares)	Applicants	Area (hectares)
2008	0	0	0	0	0	0
2009	1	8	5	38.70	6	46.7
2010	3	24.05	4	21.91	7	45.96
2011	0	0	2	21.65	2	21.65
2012	1	5.05	2	30.22	3	35.27
2013	6	44.62	3	5.56	9	50.18
2014 and 2015[a]	38	993.14	9	70.50	47	1063.64

[a] The figures for 2008–2013 represent crop areas that were planted. The figures for 2014 and 2015 are based on the number of applications received and authorised. Natural England cannot be sure how many of these projects go ahead until they receive the payment claims.

Table 8
BCGS Round 1 projects involving energy crops.

Project	Grant awarded (£m)	Amount of energy crop required (ha)	Project outcome	Refs.
Winbeg, Winkleigh, Devon (21.5 MWe)	11.5	37,500 (Miscanthus)	Torridge District Council refused planning permission for the scheme on 4th April 2006 claiming "the scale of the proposed development was such that it was likely biomass would have to be supplied from a wide area throughout the South West, resulting in excessive transport distances from source farms. It also claimed that the scale of the scheme could potentially undermine small-scale biomass schemes, which would be in conflict with the sustainable development objectives of the Devon Structure plan".	[83]
Roves Energy, Sevenhampton, Wiltshire (2.5 MWe)	0.96	5000 (SRC)	Project did not go ahead. It was intended that heat from the CHP would be used to produce processed fuel for Didcot Power Station. Despite initial interest, RWE Npower didn't fully commit to the project and offered just £26/tonne for wood chip for their co-firing operation. This was insufficient to make the project financially viable.	[84]
Charlton's Energy, Frome, Somerset (7.0 MWe)	2.00	1250 (Miscanthus)	Project did not go ahead. The technology provider Ecotran Energy Ltd went into liquidation. The project has tried to be resurrected with Compact Power and latterly with Bioflame but both of these companies also went into liquidation. Getting the technology to work at this scale was problematic.	[85]
Bronzeoak, Dimmer, Somerset (7.0 MWe)	3.7	750 (SRC)	Project did not go ahead. There was a great deal of public opposition to the proposed plant. Bronzeoak is still aiming to develop a plant onsite (at some point) although it is not clear whether this will involve energy crops.	[86]
Eccleshall, Staffordshire (2.65 MWe)	0.48	1500 (Miscanthus)	Plant successfully commissioned and still running in October 2014. Miscanthus has only played a very minor part as a feedstock due to price competition from Drax Power Station. Instead the project is using low grade wood chip which is cheaper. Grant was paid back in 2009 in order to benefit from ROC banding.	[87]

The initial intention was for these projects to support the planting of 7750 ha of SRC but less than 300 ha was planted. Only Steven's Croft is still using SRC although as a very small part (< 1%) of the fuel mix.

The majority of projects funded under BCGS Rounds 3, 4, 5 and 6 involved small-medium scale biomass heat. A total of £22,756,201 was awarded to 217 projects [88]. Very few of these projects involved energy crops as the fuel.

Changes in Government policy such as ROC banding (see Section 3.1.2) and the RHI (see Section 3.1.4) were brought in in 2009 and 2011. Power stations funded under early rounds of the scheme and heat projects installed after July 2009 could benefit from these incentives as long as they paid their grants plus interest back to the Government. In total 32 projects (including Wilton 10, Steven's Croft and Eccleshall) paid back a sum of £31.95 million to the treasury [90,92]. As a result the scheme which set out to distribute £66 million only spent 20.7 million (see Table 10).

There was an underspend in round 4 of the BCGS and this was used to support projects in the SW of England as part of the Bioheat project [93]. £1.88 million of funding was awarded to 16 projects although a large portion of this was paid back [94]. Only one project (160 kW boiler at Holt Farms) used energy crops as the fuel source [95].

3.2.2. Energy Crops Scheme (ECS)

The ECS supported the planting of miscanthus and SRC for use in biomass heating, combined heat and power (CHP), and power stations. It was introduced to provide an incentive for farmers by subsidising the expensive establishment costs of perennial energy crops. Introduced in 2000 the ECS ran for 2 periods, firstly from 2000 to 2006, and then again from 2007 until 2013 when the scheme was closed due in part to the closure of the Rural Development Programme for England (RDPE) [96]. There was a hiatus period of 17 months between the schemes which severely damaged industry confidence [58,66] and is largely thought to have led to the demise of Bical, the single largest organisation involved in the energy crops sector [24]. The total funding pot set aside for ECS 1 (2000–2006) and ECS 2 (2007–2013) was £76 million but both schemes were significantly undersubscribed. Originally ECS 1 intended to support the planting of 24,000 ha of SRC and 5,000 ha of miscanthus [38]. Just 8191 ha were planted [12]. ECS 2 was designed to stimulate the planting of around 40,000 ha of energy crops, however by the end of 2013 just 3952 ha had been planted [72].

In total ECS 1 and ECS 2 supported the planting of:

- 12,143 ha of energy crops in total.
- 9719 ha of miscanthus (80% of the total).
- 2424 ha of SRC (20% of the total).

The majority of planting occurred in areas close to power markets in East Midlands and Yorkshire and Humber. The East Midlands has 2576 ha of miscanthus (27% of total) and 916 ha of SRC (37% of the total) whilst Yorkshire and Humber has 2307 ha of miscanthus (24% of total) and 620 ha of SRC (25% of the total) [97].

With only 17.6% of the total budget spent it shows that the ECS failed to deliver.

Despite several reports indicating a critical role for energy crops in meeting renewable energy and climate change targets the significant underspend has resulted in an apparent lack of political will to support a future ECS [97].

There are a number of reasons cited for failure of the ECS. Unlike similar schemes for planting trees (e.g. English Woodland Grant Scheme, The Farm Woodland Premium Scheme) after the initial establishment grant there was no additional support. As a result farmers had to wait 4–7 years for the investment to be paid

Table 9
BCGS Round 2 projects involving energy crops [90].

Project	Grant awarded (£m)	Amount of energy crop required (ha)	Project outcome	Refs.
E.On Steven's Croft, Lockerbie (44 MWe)	18	4750 (SRC)	Plant successfully commissioned and still running in October 2014. Grant was paid back in 2009 in order to benefit from ROC banding. Between 2009/10 and 2012/13 10,663 tonnes of SRC has been used in the plant equivalent to just 0.88% of the total feedstock consumed.	[68–71]
Sembcorp Utilities Wilton 10, Middlesborough (35.2 MWe)	11.9	3000 (SRC)	Plant successfully commissioned and still running in October 2014. Grant was paid back in 2009 in order to benefit from ROC banding. The plant experienced various problems (e.g. erosion of fuel handling equipment and slagging) when using SRC and "fuel chip" (a brown, barky chip). The amount of SRC being used was not substantial enough to warrant major technical changes. As a result the plant no longer accepts SRC as a feedstock. The plant was contracted to accept the large volume of fuel chip and managed to address this by paying more for the fuel supplier to remove the bark.	[91]

Table 10
Grants awarded under the 6 rounds of the Bioenergy Capital Grants Scheme (BCGS) [88,89,91,92].

Round	Total grant awarded (£m)	Total grant taken up (£m)	Total grant paid back (£m)	Overall BCGS grant spend (£m)
1	25.89	7.73	0.48	7.25
2 (NOF)	29.9	29.9	29.9	0
3	5.53	5.53	0.21	5.32
4	1.74	1.74	0.03	1.71
5	6.85	6.85	1.18	5.67
6	0.91	0.91	0.15	0.76
Totals	**70.82**	**52.66**	**31.95**	**20.71**

back and up to 10 years to make a profit. This presents a poor investment compared to alternative options. Other issues included the application and payment process being too protracted and bureaucratic and the agreement being too prescriptive in forcing growers to sign up with end users before they even planted the crop.

Another issue with the ECS was that the funding was only supposed to support energy crop establishment and therefore there was no provision for using the funding for vital infrastructure support (such as harvesting machinery). However, this should have been possible as £10 million of the projected ECS underspend was awarded to the Forestry Commission to set up their Woodfuel Woodland Improvement Grant (Woodfuel WIG) in 2011 [98].

3.2.3. *Bioenergy Infrastructure Scheme (BEIS)*

The BEIS was a market 'push' incentive that provided grants to help the development of the supply chain required to harvest, process, store, and supply biomass to end-users. The first round of the scheme ran from 2005–2008 and was worth £3.5 million. Rounds 2 (2008) and 3 (2009) of the scheme had short application windows but offered up to 100% funding for projects [99].

The BEIS was designed to fill a funding gap. ECS 1 was set up in England under the EUs rural development legislation for forest growers and therefore was able to provide machinery grants for willow growers. However, this did not cover grass-based fuels like miscanthus or residue sources such as forestry co-products, straw and sawmill waste. The BEIS covered all these sources and was also available in Scotland, Wales and N. Ireland. When ECS 2 was introduced it no longer covered infrastructure. As a result only willow related infrastructure was eligible under subsequent rounds of the BEIS. Round 2 and 3 covered England only.

The scheme was open to businesses, local authorities and charities and spent nearly £7 m on 79 projects (see Table 11). The

Table 11
Projects supported under BEIS rounds 1–3 [99].

Biomass type	Number of projects	Amount of funding awarded
Woodfuel	63	£5.06m
SRC	4	£0.55m
Miscanthus	12	£0.98m
Total	**79**	**£6.59m**

BEIS can be considered a success as it helped to provide crucial infrastructure for the biomass supply sector and most of the funds available were spent. Nevertheless, its popularity demonstrates that much more funding is required and the limited budget was not enough to stimulate large increases in energy crop growth.

Of the 4 SRC projects supported two harvesters were grant funded – one in Northern Ireland and one in Nottinghamshire. Of the woodfuel projects 37 were awarded funding for wood chippers.

Round 3 of the scheme provided support for just 6 projects before being terminated by the new Coalition Government in July 2010. This was a result of the introduction of austerity measures to deal with the public spending deficit [100]. Unfortunately, this decision meant that two applications for SRC harvesters were not supported. One of these applications was for a harvester and screening facility to service 380 ha of SRC planted in the south of England. The BEIS offered the only chance to provide this essential support. Four years later there is still no local provision of harvesting machinery and growers have to rely on one or two harvesting contractors making the long and expensive journey from the North of England. The energy crops grower questionnaire carried out by the ETI suggests that 8.4% of the energy crops area has been removed [25]. 38% of the area removed was in the South of England. The inference is that the lack of locally available machinery coupled with a lack of viable markets has left growers with no choice but to remove their crops.

3.3. *Agricultural schemes*

3.3.1. *Set-aside*

Set-aside is a term for land that farmers are not allowed to use for any agricultural purpose. Introduced by the EEC in 1992, set-aside was part of a package of reforms of the Common Agricultural Policy (CAP) to prevent over production [101]. It applies only to farmers growing crops. Energy crops could be grown on set-aside land without affecting eligibility for SPS payment, offering substantial encouragement to growers. In 2007/08, for example, over 90,000 ha were used for non-food crops, although this was mostly oilseed rape [102]. Significant rises in grain prices across Europe in

2007 meant the EU decided that for the 2008 harvest the set-aside rate would be zero. The timing of this at a time when momentum in the industry was increasing combined with high commodity prices, the demise of Bical, and the ECS hiatus period was very unfortunate. The grower's questionnaire carried out by the Energy Technologies Institute suggested that only 17% of growers planted energy crops on set-aside [25].

3.3.2. Energy aid payment scheme

All crops grown for biofuels markets on non set-aside land were eligible for an Energy Aid Payment introduced in the CAP reform of 2003 [103,104]. SRC and miscanthus were designated as honorary non-permanent crops, allowing them to be grown in decoupled areas making them eligible for a €45/ha annual carbon credit payment [105]. Over the 6 years of the scheme 507,000 ha of 'energy crops' were supported by this scheme in the UK but only 8560 of SRC and miscanthus [103]. This equates to 1.7% of the total, whereas 98.3% of the funding went towards winter oilseed rape (see Table 12).

4. Discussion

Section 3 has reviewed several policies in detail by analysing the projects supported, their success, and what the impact was on energy crop plantings. This section discusses the review in further detail to summarise the key findings and the implications for future policy-making.

4.1. Assessment of policy effectiveness

From the policy review, 8 major national policies were identified as having a policy objective to support the cultivation of energy crops either directly or indirectly. Table 13 summarises these results and shows that whilst all policies have achieved some establishment of energy crops, most of these policies were not effective in supporting the development of the perennial energy crops industry. Indeed, plantings of energy crops are a long way from the policy aspirations outlined in Table 1.

The NFFO was effective in terms of the establishment of SRC for project ARBRE but its ultimate failure damaged confidence in the industry. Banding in the RO had some impact on plantings mainly for co-firing however the timing of its introduction and subsequent removal was not well conceived. For instance, the Gallagher review in July 2008 highlighted the potential issue of indirect land-use change, this came just before ROC banding was introduced for energy crops [106].

The amount of domestic energy crops is insignificant compared to the volumes of imported biomass [68]. Whilst still in its infancy, the RHI does show potential for the cultivation of perennial energy crops. It is too early to conclude, but if support for growers was combined with the RHI then this could lead to an effective combined demand-side and supply-side policy.

Both the BCGS and ECS ultimately failed to deliver a significant increase in perennial energy crop cultivation and were significantly underspent. The BCGS stimulated a large number of installations but had minimal impact on supply. Whilst these grant schemes had many favourable aspects, their design, bureaucracy, and limitations meant that they would need to be enhanced and developed to be considered a success in future. In contrast, the BEIS can be considered an effective energy crop support policy, albeit on a limited and highly oversubscribed budget. One criticism of the BEIS is that grants were not issued on the basis of importance of machinery.

Set-aside did support the introduction of energy crops on land that would have been previously uneconomical to grow upon. It is difficult to predict if set-aside will ever be available in the future, but given the constraints of land availability then it is not realistic

Table 12
UK area supported by Energy aid payment scheme (hectares) [103].

Crop	2004	2005	2006	2007	2008	2009	Total
SRC	0	436	881	759	280	188	**2544**
Miscanthus	0	0	1959	1943	1557	557	**6016**
Winter OSR	10,862	39,865	75,155	240,293	46,719	85,711	**498,605**
Total	10,862	40,301	77,995	242,995	48,556	86,456	**507,165**
% energy crops	0.00	1.08	3.64	1.11	3.78	0.86	**1.69**

Table 13
Results of assessment for achieving establishment of perennial energy crops and effectiveness of policy.

Policy/strategy/report	Direct/ Indirect	Achieve establishment?	Effective energy crop support policy?
Non-Fossil Fuel Obligation (NFFO)	Indirect	Limited (see Tables 2 and 3)	No – not enough incentive for domestic supply
Renewables Obligation (RO)	Indirect	Limited (see Table 5)	No – imports more attractive than domestic
Renewable Heat Incentive (RHI)	Indirect	Limited (see Tables 6 and 7)	Potentially – too early to assess. Miscanthus use has been affected by need for emissions certificates and lack of clarity regarding absence from Biomass Suppliers List
Bioenergy Capital Grants Scheme (BCGS)	Direct	Limited (see Tables 8– 10)	No – capital grants mainly spent on generation infrastructure
Energy Crops Scheme (ECS)	Direct	Moderate (achieved some planting but < 20% of intended plantings)	No – long payback period and no assistance for delayed cashflow
Bioenergy Infrastructure Scheme (BEIS)	Direct	Limited (see Table 11)	Yes – popular scheme but limited funding pot and restrictions minimised potential impact
Set-aside	Indirect	Limited (other non-food crops were more popular)	Potentially – however poor timing and unlikely to be possible in future
Energy Aid Payment Scheme	Direct	Limited (other non-food crops were more popular)	No – encouraged the cultivation of annual crops over perennials

to consider this policy further. The energy aid payment scheme was not successful for perennial energy crops as most of the expenditure went on oilseed rape [103].

Previous studies have assessed the effectiveness of some policies introduced to support energy crops. For example, it is identified that policies implemented do not effectively incentivise carbon reduction for crop growth [107], existing policies have insufficiently incentivised farmers to diversify [108], and the economics of perennial energy crops are poorly assisted through policy design [109,110]. The evolution of bioenergy policy has shown that innovative polices are crucial to developing the nascent industry [111]. Frameworks to increase the uptake of perennial energy crops based on reviewing previous policy effectiveness have been proposed [112]. Potential policies for perennial energy crops to achieve carbon abatement and deliver a source of low carbon electricity have been evaluated [113]. There are also good prospects for energy crops policy rewarding biodiversity and ecosystem services [23].

4.2. Industry confidence in perennial energy crops

Farmers are interested in diversification options and have been willing to plant energy crops (albeit in relatively small areas or on marginal land) when there are good, long term contracts available and appropriate market conditions (e.g. low price of cereals). The two projects that led to the most planting were the ARBRE project and co-firing at Drax. Only ARBRE (55%) and Eccleshall (64%) got anywhere near the target amount of planting and of these, the former was mothballed and the latter, whilst successful is using only a fraction of miscanthus as feedstock [46,47]. Only Drax is using a significant quantity of UK energy crops but this is less than 1% of its annual biomass input [68].

The planting of energy crops has always been a risk for farmers and the typical situation is that there is low initial uptake followed by greater uptake as neighbouring farmers are convinced that their neighbours are making something out of it. This organic growth has been completely thwarted by huge confidence blows to the industry such as ARBRE failing in 2002, Bical going bankrupt in 2009 and the hiatus period between ECS 1 and 2 (2006–2008) [24]. Aside from these major incidents there have been numerous other smaller impacts on confidence. For instance during ECS 1 and 2 there have been 20 contracts offered by end users and intermediates [97]. Only a few of these were still honouring these after 3 years. Currently there are only four contracts available to energy crop growers (Drax, Ely, Terravesta and Iggesund). As a result of this the nascent energy crops industry has been stopped in its tracks several times. After a major setback the growth of the industry takes a lot longer as new entrants try to win back the confidence of farmers.

Government incentives for renewables in recent years have tended to focus on energy generation as opposed to feedstock supply [55,77,114,115]. The Renewable Transport Obligation (RTFO) and Renewable Heat Incentive (RHI) have seen an increase in annual crops going into bioenergy production. This is partly due to incentives being favourable for technologies that favour crops such as wheat (for bioethanol), oilseed rape (for biodiesel), and maize (for anaerobic digestion) [103]. Farmers have tended to prefer annual crops over perennial energy crops as they fit in with arable rotations, are seen as less risky, and allow greater flexibility with changing commodity prices [14].

For a confident long-term industry to develop and thrive, farmers and growers require improved incentives and time to develop the sector [116,117]. Appropriate contracts need to be offered to farmers to reduce risks and overcome the liquidity constraints of perennial energy crops [110,118]. Industry confidence in the market is crucial to farmers making the decision to cultivate energy crops [119].

4.3. Over ambitious policy-making

Many of the failures of energy crops policy have been brought about by trying to run before the industry could walk. NFFO required novel technology and novel feedstocks, a very risky combination that added to the problems of ARBRE. The initial RO co-firing rules were startlingly optimistic and impossible to achieve. Consequently, it appears the energy end users managed to argue for better terms for imported biomass. Some policies were good such as the energy crops uplift for co-firing and double ROCS for power plants running on energy crops but were badly timed – the announcement of the latter came just after Bical had gone bankrupt and the more bureaucratic ECS2 was coming into force. As a result this excellent policy had limited impact on the energy crops sector.

ECS2 was more time consuming and bureaucratic than ECS1 and was operated by Natural England who were new to this role. Woodland creation schemes operated by the Forestry Commission were designed to succeed – they frequently adjusted the offer in order to spend the money whereas Natural England resolutely stuck to plan A [97]. Aside from one small change (increasing the establishment grant from 40% to 50%) the conditions of the grant stayed the same. This meant a significant underspend and what is perceived as a significant failure. The introduction of the RHI and the recent interest shown by farmers in growing their own fuel for heat indicates that there was an appetite for energy crops but the opportunity to harness this by continuing the grant was lost.

4.4. Future development of the sector

The energy crops sector has shown resilience with new entrants entering the industry and helping the sector bounce back. However, the progress has been much slower than even the most conservative of estimates [120]. At this point if we are to achieve even a moderate uptake by 2020 and move to a reasonably sized industry by 2030 and beyond then growing energy crops needs to be easy, financially viable and low risk.

If there is an establishment scheme such as a local ECS then there needs to be better terms and support. For instance, an establishment grant with interim payments whilst the crop is establishing. Also, the application process would need to be streamlined and bureaucracy minimised. This would provide a more level playing field with woodland creation grants.

If there is no energy crops establishment scheme then there needs to be more favourable terms from the end users such as an additional incentive for local supply. It might have been possible to have an energy crops uplift as part of the RHI providing an incentive for local supply. However, the tariff rates have already been degressed substantially so this would seem unlikely. Nonetheless, the next review of the RHI could consider this.

The Government have frequently sought the advice of specialists to provide impartial advice in reports. Unfortunately it has been rare for any of the energy crop specific recommendations to be acted on. When it comes to energy crops the Government's chosen method of consultation is perhaps destined to fail the sector. There are very few actors in the industry and even fewer who have the resources to respond to detailed consultations. On the other side there are well organised and well-funded lobby groups (food crops, conservation bodies, forest sector, other renewable technologies, fossil fuels, waste) that are able to sway policy in different directions. One of the key issues is that the Government has not published reviews of their schemes and policies, and therefore the specialist advice and reviews are often not utilised effectively. It is apparent that Government departments need to work together more closely for more consistent policies going forward [113].

In order to mitigate the food system effects of bioenergy production on crop land, energy crops could be grown on marginal lands that have limited potential for food production [121], or cultivate for alternative land management such as flood defense. Using marginal land provides a useful policy message, however farm-level decisions over the use of land are complex and dynamic. Relative crop yields, machinery ownership decisions, the wider policy environment and farmer attitudes towards the production of energy crops combine to influence the uptake of perennial energy crop production [13,122]. With current policies it is apparent that a substantial number of farmers are not interested in growing perennial energy crops [14,108]. To incentivise energy crops further, government should develop more innovative policies which demonstrate a greater understanding of the complexities of farm-level decision making [122]. Key considerations for future policy include the use of sustainability assessments that are acceptable to a wider number of stakeholders [123], ensuring the carbon benefits of bioenergy projects [14,18,124], and developing more sophisticated economic incentives [97,112].

5. Conclusions and policy implications

Since, 1990 none of the projects, initiatives or schemes described can be viewed as an absolute success for the energy crops sector. The main obstacles that have hindered progress include: the lack of long term supportive energy crops policy, the failure of headline projects and organisations, the lack of competitiveness of long term perennial crop options compared to annual crops, bureaucracy of schemes, the inability of the voice of the energy crops industry to be heard when pitted against larger sectors, and the reluctance of Government to heed recommendations of independent authorities.

25 years of failed energy crops policy suggests that there needs to be a long term strategy and action plan adopted – an energy crops road map towards 2020, 2030 and 2050 targets/aspirations is required. Future support for the sector should consider joining up policy between different Government departments to recognise multifunctional benefits of perennial energy crops. The burden of risk should be shared between suppliers and end-users with local authorities and Local Enterprise Partnerships (LEPs) perhaps providing the support for local heat markets.

Key lessons to learn for future policy-making include developing smaller-scale projects that use established technologies, introduce energy crops in a phased manner so local supply can develop at a steady pace, ensure that supply-side measures are balanced with demand-side incentives, provide grants on the basis of importance of infrastructure, design establishment grant schemes so they manage cashflows more effectively and be linked with end-user markets, provide a competitive advantage for local supply compared to imports, and the administration of schemes could be streamlined.

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