On-Farm Anaerobic Digestion: a dissection of policy barriers to uptake

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As you will soon discover, this paper is at a ***very*** *early stage of development. Please send any comments and questions you may have about it to the authors, but please do not quote it without our permission. We have much work to do! NB for clarity we put most Tables and Figures at the end of the paper. We incorporate into the main body of the paper only those Tables that are central to the accompanying analysis.*

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Abstract

In recent years, the multifunctionality of farming activities and diversification of on-farm income sources have increasingly included the generation of renewable energy. The uptake of on-farm anaerobic digestion, however, continues to lag behind other renewable energy sources, notably wind and solar. The purpose of this paper is to provide an in-depth analysis of the policy barriers that might explain this relative absence of anaerobic digestion from UK farming. This is doubly important, given that anaerobic digestion is not only a potential source of renewable energy, but also a means of waste management within certain farming systems. The analysis draws on a mixed-methods research project, with data from 153 responses to a questionnaire sent to farmers in Nottinghamshire and Derbyshire in March 2016; 18 in-depth interviews with stakeholders in the anaerobic digestion sector; and a workshop that brought together stakeholders in a round-table discussion. The qualitative data are coded and then analysed utilising a model of policy analysis that distinguishes between three levels of policy means and policy ends. The findings of this analysis provide important insights into the challenges of devising a policy that can effectively promote on-farm anaerobic digestion.

Keywords: Anaerobic Digestion, Policy Incentives, Renewable Energy, Waste Management

JEL Codes: Q12, Q42, Q48

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1. Introduction

Farmers and farming activities are becoming highly diversified. Data from the 2017/18 Farm Business Survey (FBS) (DEFRA, 2018b), show that 22% of farm income in England came from 'diversified activities' (£680mn out of a total of £3.09bn). This averages-out at £18,700, across the two-thirds of English farms that have diversified incomes – although there will be considerable cross-farm variation in this. Tables 1 and 2 provide further information about outputs and income from diversification. They also indicate the range of activities that make up this category of enterprise. In the present paper, we are particularly focused on farmers' engagement with renewable energy (RE) generation, especially anaerobic digestion (AD). AD offers farmers important business and other opportunities, notably: generating RE to substitute for purchased energy; generating RE to sell off-farm; as a means of waste management; and generating digestate/fertiliser to use and/or sell off-farm.

Tables 1 and 2 show clearly that solar is the dominant on-farm RE generation technology, located on about twice the number of farms as all other RE sources together and generating over twice the total output and income.[3] By the end of 2016 there were just 279 on-farm AD plants (IEA Bioenergy, 2018: 62). With FBS data, albeit for 2017/18, indicating 5,300 farms generating 'other' RE (including several different RE sources), AD uptake is modest. The purpose of the present research is, simply, to try to understand why. Our primary research question is, specifically: what are the policy drivers of on-farm AD uptake and what changes are needed to increase uptake?

The basis of this paper, helping us to answer this question, is extensive fieldwork conducted in the East Midlands counties of Derbyshire and Nottinghamshire, in 2016 and early 2017. Data collection has been undertaken in three stages: a (large-N) survey of farmers, followed by (small-N) interviews and a workshop, with multiple stakeholders. The particular focus of the analysis presented in this paper is policy. In undertaking this analysis, we employ a framework that allows us to disaggregate our unit of analysis, policy, into policy means and policy ends, each then divided into the meta, meso and micro levels. This allows us to dissect and understand

[3] Unfortunately, AD data are not provided separately.

‘policy’, as a concept, with considerable nuance. From this, we can identify precisely where the policy challenges lie in promoting the greater uptake of on-farm AD in the UK.

To this end, in the next section we review the extant research in this area. We then summarise the main findings of our fieldwork, focusing in particular on policy issues. Next, we introduce the framework within which our data will be analysed, after which we offer our initial analysis. We conclude with a summary of our main findings and what they mean for policymakers, the AD sector and farmers.

2. Literature Review – On-Farm AD Uptake in the UK (very preliminary!)

There are several different literatures that refer to on-farm AD – notably general RE generation, on-farm RE generation, general AD uptake and on-farm AD uptake. Moreover, these literatures are all located with the overarching body of research on climate change mitigation and the transformation of the UK energy mix. We consider briefly below those aspects most relevant to our subsequent analysis.

2.1 Background – UK Energy Policy in Context

UK energy policy is embedded in a complex multilevel governance structure. Domestically, the UK committed, in the 2008 Climate Change Act, to reduce greenhouse gas (GHG) emissions by 35% below 1990 levels by 2020, and 80% by 2050, (DECC, 2012; UK Government, 2014; DEFRA, 2014, 2015). This domestic commitment exceeds its international obligations: regionally, a 20% reduction committed to via the 2009 European Union (EU) Renewable Energy Directive (RED)[4]; and globally, the Kyoto Protocol. There is also an important local role (see, *inter alia*, DEFRA, 2018a, especially Chapter 6), but in our analysis we focus only on key local functions shown in our fieldwork to be particularly pertinent to AD.

In 2017, UK GHG emissions were already 43% below 1990 levels.[5] Under the RED, the UK also committed to delivering a 15% share of renewable energy in gross final energy

[4] We do not analyse the possible implications of Brexit in this paper. Our focus is the domestic UK renewable energy transition – the commitment to which is greater in existing domestic UK policy than in its international commitments. Assuming no backsliding on those domestic and global commitments, we expect Brexit to have limited impact on our analysis.

[5] https://www.theccc.org.uk/tackling-climate-change/reducing-carbon-emissions/how-the-uk-is-progressing/ (last accessed 7 November 2018).

consumption by 2020. By 2017, the UK had achieved a figure of 10.2% (BEIS, 2018b). Energy generation data (BEIS, 2018a) show that renewables had about a 24% share of the total in 2017. Within that, roughly 50% of electricity generation came from renewable sources. That said, the contributions of different RE sources to this total vary considerably. By 2017, RE generation was dominated by wind (50%), solar photovoltaics (12%) and bioenergy (32%), with bioenergy dominated by plant biomass (20% of total RE; data from BEIS, 2018b). Under the Kyoto Protocol, meanwhile, the EU committed to an 8% reduction in emissions by 2012, rising to 20% by 2020 (both relative to 1990). Individual member state commitments vary, but UK commitments are also 8%/20%.[6] In short, the UK has performed well in terms of GHG emissions reductions, but the RE mix remains unbalanced with some technologies, notably AD, under-exploited.

2.2. AD as a Waste Management System

AD has been used in the treatment of sewage for over a century and has been present on UK farms since the 1970s. It is thus a technology known to be able to treat wastes, including the by-products and waste products of farming.[7] The significance of this can be seen by considering the Waste Hierarchy (Figure 1). Farm wastes, such as slurry, cannot really be **reduced**. Slurry can be **reused**, as a fertiliser, but there are practical limits to this, including having land area appropriate to slurry volume, and having continuous demand to match continuous supply – the latter also being affected by seasonal variations in the demand for the nutrients that slurry offers. Slurry cannot be **recycled**, but such farm wastes have to be dealt with. In terms of Figure 1, we thus position our focus at **recovery**. Specifically, this refers to recovery of energy from the (erstwhile) waste…which is where AD comes in. Finally in the context of Figure 1, farm waste is not something that can be deposited in **landfill**. Indeed, the handling of farm waste is particularly important in the context of its pollution potential. Indeed, the Environment Agency (2018, p. 13) reports that agriculture is in the top 3 of regulatory sectors for pollution incidents – and the only one showing an increase in incidents in 2017-18, of 13%.

The significance of these dual aspects of AD – and the need to reflect both in policy – is a major theme of our subsequent analysis. AD as a source of RE generation refers to a key output

[6] http://unfccc.int/files/kyoto_protocol/application/pdf/kp_doha_amendment_english.pdf

[7] We use the word 'waste' in this paper as a convenient shorthand, recognising that this may be a misnomer: 'An organic waste is merely an organic resource that is being handled inappropriately' (Bywater, 2011: viii).

from AD. AD as a means of waste management, however, focuses on inputs into the AD process. Moreover, the balance of the two is critically important. To introduce an example that will be explored further below, if the emphasis is on AD as a source of RE, then it is possible that policy will promote the growing of so-called ‘energy crops’, crops with food and feed uses that can be grown specifically as an input into AD units. This has been seen in, for example, Austria and Germany (Bywater, 2011), where policy incentives have encouraged both the adoption of AD and the growing of energy crops for AD. In 2016, there were 8,200 on-farm units in Germany (IEA Bioenergy 2018: 30). This raises concerns over possible food v fuel conflicts (see below).

The IEA Bioenergy report (2018: 11) also identifies another issue, experienced in Austria. AD units that rely on energy crops, such as maize, are purchasing inputs that are subject to the vagaries of global commodity markets. With maize prices relatively high in recent years, the IEA reports that there are difficulties running AD units profitably. They are now looking at alternative substrates to input into their AD units. This raises an important point that we return to at the end of the paper. Whilst we are focusing our attention on the policy dimension of limited AD uptake, we must also recognise that there exist a number of factors that, collectively, limit the scope for AD expansion.

2.3. Anaerobic Digestion – primary research into on-farm adoption in the UK

The extant literature most closely related to the present paper’s research focus is very limited. The three key studies all have a slightly different analytical focal-point: Tranter et al. (2011) sought to establish the energy-generating potential from on-farm AD (farmers across England were surveyed); Tidy et al. (2015) studied six farms with AD already adopted (in the South West region of England); and Röder (2016) focused on the possible land-use implications from growing energy crops for AD (on farms in the East of England region). All three studies therefore also utilise different methods of data collection: Tranter et al., 2011 (large-n questionnaire data); Tidy et al., 2015 (small-n comparative case study); and Röder, 2016 (interviews, site visits and observation). Our mixed methods approach complements and extends these, as discussed below.

Common findings across the three studies include AD needing to deliver an adequate ‘return’ or ‘profit’. The generation of RE is recognised as relevant, although Röder (2016) finds evidence that this is seen as a benefit more than a driver. Waste management is also seen as an important factor. These studies find similar barriers, including set-up costs, planning processes, an uncertain and unstable policy environment affecting returns, lack of information about AD and availability of feedstocks for AD units.

An issue we return to below is that of growing energy crops (notably maize), specifically for use in AD units. In contrast to the intense debates around land-use and land-use change in the context of growing feedstocks for biofuels (Ackrill and Kay, 2014), the issue was seen quite differently in the context of AD. Tidy et al. (2015, p. 274), when identifying possible ways of boosting AD uptake, include increasing FiTs…'to recognise energy crop costs'. Röder (2016, p. 79) found that stakeholders were sanguine about using farmland to produce energy crops:

> *Farmers also argued that land has always been used for non-food crops, e.g. for animal feed, malting or other industries. For them land use or even food-fuel conflict as such does not exist as different crops have different functions within the agricultural system and land use is therefore multifunctional. The interviewed farmers raised also concerns that the amount of food wasted along the supply chain is a much bigger land user than energy crops.*

That said, this positivity (or absence of criticality) is questioned in both the academic literature (Lijó et al., 2017) and in UK policy documents (DECC/DEFRA, 2011).

In the research that is reported below, our research questions and research design take inspiration from the factors identified above from other studies, but ours is the first to seek an in-depth and unified understanding of the potentially multiple policy factors that might be holding back on-farm AD; and how policy might reduce those barriers. Tranter et al. (2011), writing some years ago, focused on the potential for on-farm AD; our intention now is to try to understand why on-farm AD uptake *remains* modest, despite that potential.

3. Anaerobic Digestion in the East Midlands – Overview of Fieldwork

Our research involved a three-stage mixed methods design – an approach that stands in contrast to most other papers in the relevant literatures introduced earlier. First, we distributed a questionnaire to farmers in the East Midlands counties of Derbyshire and Nottinghamshire. This combined open and closed questions, generating primarily qualitative responses. The regional National Farmers Union (NFU) office, on our behalf, sent questionnaires to its 1,586 registered members in these counties, in March 2016.[8] 153 usable questionnaires were received back, a response rate of 10% (lower than Tranter et al., 2011, but comparable to Maye et al., 2009, cited by Tranter et al.). Responses were evenly distributed between farmers in Nottinghamshire and Derbyshire, 78-75 respectively. A profile of respondent characteristics is provided in Tables 3 and 4, and Figure 2.

Second, we conducted 18 in-depth interviews with AD stakeholders (see Table 5 for details). To ensure consistency, all interviews were conducted by one researcher. They were all audio recorded and then transcribed by the researchers. Where necessary, follow-up contact was made to clarify particular responses. The interviews were semi-structured, guided by the project research questions, the academic literature and a preliminary analysis of the survey data. The third stage of data collection consisted of a workshop of AD stakeholders, held at Nottingham Trent University in January 2017. Participants represented the farming and AD industries, local authorities and academia.

(More to add, hopefully with cross-reference to an article currently with a journal following a second round of R&R)

4. Dissecting Policy – A Framework for Analysis

A critical part of policy analysis is being able to determine precisely our unit of analysis: policy. More specifically policies, typically, are made up not only of different component parts, but also different types of component. In order to be able to explore potential policy (in)effectiveness and propose policy changes with the aim of delivering a different outcome, we must be able to distinguish the different components of our particular policy. To this end, in the present paper we draw upon the work of Ben Cashore and Mike Howlett. Table 6 sets out their decomposition of policy. Drawing on Hall (1993), they identify three distinct levels of policy, labelled in Table 6 as the micro, meso and meta levels. Cashore and Howlett then distinguish between policy ends and policy means – something that Hall refers to, but does not develop.[9]

[8] This may lead to a slightly biased sample, as not all farmers will be members of the NFU.

[9] As a result, Hall's work remains known principally for distinguishing between more modest and endogenous first order (micro) and second order (meso) changes on the one hand, and exogenous third order (meta) paradigm change on the other.

Using the Cashore and Howlett 2*3 matrix, we can take a policy and explore what it is trying to achieve and how it is trying to achieve it. From this, we can also analyse policy dynamics over time in a more nuanced way, as we can also disaggregate what we mean by 'policy change' – both *ex post* and in terms of forward-looking policy recommendations. Note also that whilst this framework has been used before in the analysis of agricultural policy (Kay and Ackrill, 2010), it remains underutilised generally in the analysis of policy. In practice, it is important to note that this is a framework, not a theory. Its use requires a degree of interpretation of different aspects of policy, given also that our research design includes the analysis of both interviews and qualitative responses to open questions on the questionnaire. That said, it is being used as the basis for analysing specific policies. As a result, we adopt not an interpretivist epistemology, but a critical realist approach: whatever people's opinions and concerns may be, they are analysed in the context of 'real' policies.

Table 6: A Taxonomy of Policy Decomposition

		Policy Level		
		Governance Mode	*Policy Regime*	*Programme Settings*
		Meta-level	*Meso-level*	*Micro-level*
		High-level abstraction	*Programme-level operationalisation*	*Specific on-the-ground measures*
Policy Component	**Policy Ends**	**Goals:** abstract general policy aims	**Objectives:** operationalisable policy objectives	**Setting:** Specific policy targets
		The most general macro-level statement of govt aims and ambitions in a specific policy area	The specific meso-level areas that policies are expected to address in order to achieve policy aims	The specific on-the-ground micro-requirements necessary to attain policy objectives
	Policy Means	**Instrument Logic:** general policy implementation preferences	**Mechanisms/Instruments:** Policy tool choices	**Calibrations:** Specific policy tool calibrations
		The long-term preferences of govt in terms of the types of organisational devices to be used in addressing policy aims	The specific types of governing instruments to be used to address programme-level objectives	Specific policy tool The specific 'settings' of policy tools required to attain policy targets

Sources: Adapted from Cashore and Howlett, 2007: 536; Howlett and Cashore, 2009: 39; Howlett, 2011: 17.

5. On-Farm Uptake of AD: A Critical Policy Analysis

In this section, we shall consider AD in the context, first, of the three levels of policy ends, going from the, highest, meta-level to the lowest, micro level of analysis. We shall then repeat this for policy means.

5.1 AD, Policy Ends and Policy Means – an Introduction

When considering the **Policy Ends** for AD, what are the policy **Goals** towards which AD can contribute? AD fits into two broad policy ambitions – the generation of RE and the management of waste and pollution. One of the question-marks over AD arises from this very fact. Specifically, to what extent are these two broad goals reflected in policy design and implementation? The principal policy **Objective** of on-farm AD policy concerns on-farm AD uptake. In this, however, we are interested not only in the promotion of on-farm AD, but also the factors that represent limitations to its potential uptake (more might be better in theory, but there are important practical limits to this). At the micro-level, the concern of policy **Settings** is to promote AD uptake. AD must be affordable and economically viable, without which it will not find a place in the farm business. In addition, however, it must be practical for the farmer to obtain the necessary permissions to install AD on-farm and to operate it effectively.

As for **Policy Means**, what is the **Instrument Logic** required to deliver on the Policy Ends? The need for on-farm economic viability suggests that incentives are needed. That said incentives – especially fiscal incentives, are not always appropriate. Indeed, we can extend the spirit of the Tinbergen Principle to say that not only do we need at least as many instruments as targets, we also need *appropriate* Instrument Logics. In our present study, we also need regulatory interventions. We do not argue that having two distinct policy Goals for AD, in the language of our analytical taxonomy means that we must, as a general principle, have at least two Instrument Logics. Rather, we argue for the appropriateness of having at least two distinct instrument logics in our specific case.

From this, we can identify a range of **Mechanisms/Instruments** as the policy tools of choice. Possible incentives can include access to credit, grants and subsidies for the purchase of AD units; and feed-in tariffs (FiTs) for the sale of RE generated on-farm back into the national grid. Regulatory measures include oversight of the nature of planning processes, the movement of feedstocks into and between farms to use in AD units, the use of digestate as a fertiliser and controls on pollution, nitrate runoff and the like. Turning to policy instrument **Calibrations**, again a distinction must be drawn between the fine-tuning of incentives and regulations. Examples regarding incentives include the interest rates, collateral requirements and payback period, the precise terms by which grants and subsidies are offered, and the level of FiTs. With regulatory interventions, are they mandatory or voluntary, what level of pollution, nitrate runoff, etc might be permissible, are regional variations required, etc?

5.2 The Uptake of On-Farm AD in the East Midlands – an Initial Analysis

In what we hope, by the time of the AES Conference, will be an accepted and forthcoming paper, we present a wide-ranging analysis of the drivers and challenges of on-farm AD uptake in the East Midlands. A detailed content analysis and coding exercise in this earlier, related, research led to the identification of three sets of themes in the interviews and qualitative questionnaire answers (Table 7). In the present paper, our focus on policy takes us into all three themes and several sub-themes.

Table 7: Analytical Themes of Barriers to on-farm AD in the East Midlands

Main Themes	Sub-Themes
Institutional and Political Barriers	Planning and regulatory complications
	Multi-level governance (MLG) complications
	Opposition of local communities
	Stability of regulations and regulatory measures
Awareness of AD	Awareness of AD technologies and regulations
	Awareness of UK government's RE incentive measures
Economic and Technical Barriers	Supply of feedstock to on-farm AD
	Grid connectivity
	Availability of finance
	Type and size of farms and farming business

The first finding to report from our research is that all stakeholders interviewed – and farmers both interviewed (small-N) and surveyed (large-N) – argued for the active engagement of policymakers in the promotion of AD. There is, in short, a strong demand for policy support for AD. The rest of this section considers, in greater detail, current policy 'supply', its limitations and where more policy action is felt to be needed from AD stakeholders. We base this discussion around the structure of our policy taxonomy set out in Table 6, looking first at the **Policy Ends**.

Considering first the broad policy **Goals** relating to AD, our fieldwork found participants' levels of awareness of and support for AD, as both a source of RE generation and waste management, were mixed. Across the range of issues raised by our research, farmers and other stakeholders identified similar concerns and hopes, but there was one concern expressed particularly by farmers concerning AD as means of waste management – having a constant, year-round, supply of liquid farm wastes to make the AD viable. This is particularly so if animals are kept outside in the spring-autumn period. As we shall see later, the distinction between RE generation and waste management is a key concern in terms of distinct policy needs. Notably, whilst AD-based RE generation can be 'fuelled' by farm wastes, and whilst farm wastes can be used to generate RE, policy rarely appears to recognise and promote this symbiosis.

The principle policy **Objective** under consideration is also the focus of our main research question – the uptake of on-farm AD. Our research found an important qualification to this objective, however, that needs to be reflected in policy design – the limits to on-farm AD uptake. This is influenced, first, by its incompatibility with many types of farming activity. 56% of respondents to our survey concluded that it was not appropriate for their farm business. Even where it is compatible, the aforementioned issue of reliable and steady feedstock supply can limit its viability.

An emergent theme of the research relates to the interplay between the two primary Goals and the principal Objective set out above: the nature of feedstocks to be used in AD units. The implication of the two Goals, when considered jointly, is that on-farm AD utilises on-farm wastes. At the Objectives meso-level, several participants referred to concerns over the growing of energy crops specifically to use in the AD unit for RE generation. Two sets of questions follow. The first is what other wastes can be utilised in on-farm AD, what can be done to facilitate this and what limits might there be to this? Secondly, can or should energy crops be grown for use in AD units and should policy promote this?

The responses to the first set of questions include using farm wastes from other farms and using off-farm food wastes. The aforementioned issue of summer grazing and year-round supply of feedstock is not solved if other farms also keep their animals outside in the summer. To consider the use of off-farm food wastes, we return to the waste hierarchy in Figure 1. Food waste is handled either via recovery or disposal.[10] Whilst there has been government discussion over food waste collection[11], this has cost implications. Moreover, the transportation of wastes onto farms, whether from other farms or the delivery of food wastes, raises both traffic and emissions concerns. The same issues would apply were the supply of farm wastes to off-farm AD units be considered.

Regarding the growing of energy crops as an AD feedstock (see also Röder, 2016), our research showed sharply contrasting views. The majority view was against this in principle, although two farmers in our survey were growing crops to supply AD units and pointed out the farming has long been about more than just growing food for people to eat. An important question in the current context is whether the growing of energy crops for AD should be supported by policy instruments. As noted earlier, policy incentives have led Germany in particular to have a very large number of on-farm AD units, with energy crops widely-grown for use in these units. Some of our participants specifically used the German case to illustrate what they did not want to see happen in the UK. The crucial distinction here is between farmers who choose to grow energy crops for sale to AD unit operators as part of their normal business, and those who do this motivated by policy incentives.

Next, we consider policy **Settings**. Above we identified three key aspects from our research – affordability, economic viability and practicality. One specific issue with affordability was the concern expressed by tenant farmers that they would be investing a large amount of money in someone else's business. Economic viability has links with one theme running through both Goals and Objectives – the availability of a regular and reliable supply of feedstock to use in the AD unit. With practicality, the dominant concern was the details of the planning process, including costs, uncertainty of outcome and opposition based on 'not in my back yard' and 'anti-stuff' arguments.

[10] Food waste is defined by the EU Fusions Project as any food, and inedible parts of food, removed from the food supply chain to be recovered or disposed (including composted, crops ploughed in/not harvested, anaerobic digestion, bio-energy production, co-generation, incineration, disposal to sewer, landfill or discarded to sea). See: https://www.eu-fusions.org/index.php/about-food-waste/280-food-waste-definition

[11] https://www.bbc.co.uk/news/science-environment-46571391

We turn now to **Policy Means**. Having set out what policy seeks, or should be seeking, to achieve we now focus on how this can best be delivered. This, it will become clear, is a lot less straightforward than identifying the key themes running through the different levels of Policy Ends. There are two dominant **Instrument Logics** at play in the promotion of on-farm AD: incentives and regulation. Whilst both generating energy from renewable sources and improving the management of wastes have considerable societal value, their delivery cannot be presumed simply by farmers 'doing the right thing' via their farm businesses. In the context of both the meta-level and meso-level policy Ends set out above, our research confirmed the need for both approaches to instrument design in delivering more on-farm AD. In this regard we recall the merit-good argument for government intervention in a market. Without policy intervention there may be on-farm AD uptake, but it will be below a socially-optimal level.

Mechanisms/Instruments are the tools policymakers use to deliver policy outcomes. Reflecting earlier discussion these can be considered in relation both to incentives and to regulation. In addition, we argue that another form of policy action is required in order to deliver greater on-farm AD uptake – the supply of information. Lack of information constitutes a market failure that could result in a -sub-optimal outcome – in this case, low on-farm AD uptake. Our research confirmed widespread concerns over a lack of information and understanding around key aspects of AD and AD adoption, as reflected in the following discussion around individual Mechanisms/Instruments. In the questionnaire, before exploring these issues through open-ended questions, we sought to understand farmers' awareness of a range of incentive- and regulation-based *policy instruments*. Responses are summarised in Figure 3. In addition, 21% of respondents to the questionnaire gave lack of information about AD *technology* as a barrier to adoption.

Respondents highlighted a range of incentives they consider necessary for greater AD uptake. Access to credit, grants and subsidies were all mentioned as means to overcome the significant financial barriers to adoption. For those farmers for whom AD adoption and economic viability are based on sale of energy to the grid, FiTs and grid connectivity are important instruments. Two key areas of regulation are seen as central to the AD adoption decision – planning and feedstock movements. No participant argued for the removal of planning regulations, but there was strong support for a more relaxed approach to planning that at present for on-farm AD.

One perceived problem with the planning system is common across farmers – a lack of information and understanding of both the AD technology and processes, and the planning requirements. Even those who are not 'anti stuff' campaigners are concerned about odours and the implications for traffic volumes. Several respondents highlighted the cost and time implications of making a potentially unsuccessful planning application as being a barrier to AD adoption. Overlapping these concerns are the rules, regulations and restrictions governing the movement of farm and food wastes. The movement of wastes raises traffic and emissions concerns. More generally, there are the regulations that might prevent the movement of material that could be used as a feedstock in AD units. Some questioned whether these were overly restrictive, especially concerning the movement of wastes between farms.

Consideration of policy **Calibrations** is central to the effectiveness of both incentives and regulations. They determine the feasibility of investing in AD and of its economic viability. Equally as important however, as our respondents made clear, was that they were concerned not only with the levels of policy support, but also its stability. If policy calibration changes regularly, the uncertainty created will, of itself, inhibit investment. Events of recent years mean we can take this a step further: ongoing conditions of austerity mean that financial support might even be withdrawn altogether. What are small sums in the context of total UK public expenditures are critically important to individual farmers trying to make investment decisions.

With regulation, Calibration can mean different things. It too can take on the meaning of specific values, for example permitted levels of liquid farm waste runoff, nitrate levels in water courses, whether there is need or merit in setting regional variations in such indicators, etc. It can also have a broader meaning, specifically whether the policy is mandatory or voluntary. Generally, the notion of 'regulation' refers to mandatory policy targets. That said, even a voluntary approach to 'regulation' has been shown to deliver significant policy responses (*inter alia*, Ferrero Ferrero and Ackrill, 2016).

6. Discussion, Conclusions and Policy Implications (again, very preliminary)

Below, we summarise our analysis in Tables 8 and 9. Table 8 draws on the general principles surrounding on-farm AD adoption set out above. Table 9 then summarises key findings from the analysis of fieldwork data. We then offer an initial consideration of what these findings tell us and what the possible policy implications might be that arise from them.

Table 8: Policy Ends, Policy Means and On-Farm Anaerobic Digestion Uptake – a summary of key themes

	Governance Mode	Policy Regime	Programme Settings
Ends	***Goals***	***Objectives***	***Settings***
	Renewable energy generation Waste and pollution management	Increased on-farm AD uptake (recognising the notional upper limit)	Affordable to adopt Practical to adopt Affordable to run
Means	***Instrument Logic***	***Mechanisms/Instruments***	***Calibrations***
	Incentives (fiscal) Regulation	(*Incentives*) - credit/grants/subsidies for AD purchase - feed-in tariffs (*Regulation*) - planning process - feedstock movements - digestate use as fertiliser - controls on pollution, runoff, etc.	(*Incentives*) - interest rates - collateral requirements - payback periods - grant/subsidy terms and conditions - feed-in tariff levels (*Regulation*) - mandatory versus voluntary - acceptable pollution/runoff levels - regional variations

Table 9: Policy Ends, Policy Means and On-Farm Anaerobic Digestion Uptake – a summary of policy implications

	Governance Mode	**Policy Regime**	**Programme Settings**
Ends	***Goals***	***Objectives***	***Settings***
	Awareness levels uneven across stakeholders Inconsistent or total lack of policy recognition between the two goals	Recognition of where AD is feasible as part of the farm system – and where it is not Use, or not, of energy crops in AD units Transportation of feedstocks between/onto farms	Assurance of supply of feedstocks Challenges for tenant farmers Cost of AD unit Return on investment
Means	***Instrument Logic***	***Mechanisms/Instruments***	***Calibrations***
	Promotion of social goals through private actions requires steering through incentives and regulation Merit-good argument for policy action	(*Incentives*) Supply of information about AD – addressing both policy and technological aspects Help to purchase AD Grid connectivity FiTs to promote the supply of surplus energy to the grid (*Regulation*) A robust but enabling planning process Appropriate regulation of feedstock and digestate movements	(Incentives) - interest rates - collateral requirements - payback periods - grant/subsidy terms and conditions - feed-in tariff levels Stability of incentives (*Regulation*) Clear, practical and stable regulation

The first point to note from Table 8 is that the key focus of this research, promoting the on-farm adoption of AD, is located at the Policy Regime level – it does not represent the Governance Mode, the highest level of policy ends. This confirms that AD is itself a means to an end; with the analysis presented here, in effect, nested within higher-level ambitions around addressing climate change and environmental degradation.

Considering first Policy Goals, we find that across stakeholders there is unevenness around awareness of AD, both at the technical and policy levels, which will undermine the ability to deliver greater AD-uptake. The question of information, however, occurs elsewhere as well, with concern over a lack of understanding amongst those involved in the process of granting planning permission and local rural communities near farms where AD units are being proposed. The second issue to arise when considering Policy Goals is that there is concern amongst some stakeholders that the distinct aspects of RE generation and waste management are not considered in a joined-up way. This is then reflected in both Regime-Level and Programme-Level Policy Means, where multiple incentives and regulations are in place, but without substantive consideration of the extent to which the two Policy Goals are linked symbiotically.

Policy Implications

- Coordinated information gathering and dissemination for all stakeholders
- Coordinated (Policy Means) Instrument Logic, within and across Policy Instruments and their Calibration

Considering next Policy Objectives, a contribution to the Policy Goals being achieved can be made by greater on-farm uptake of AD. Underlying many responses from our fieldwork, however, is the issue of AD only being suitable for some types of farming system – even before we consider other practical considerations such as affordability and economic viability. This is underpinned by one of the dominant practical considerations surrounding AD-uptake – the availability of feedstocks. Related to this, two particular issues arose: the growing of energy crops for use in AD units and the movement, both onto farms and between farms, of wastes that can be used as AD feedstocks. Our fieldwork revealed strongly divided opinions on the growing and use of energy crops for AD. It also revealed widespread belief amongst stakeholders, especially farmers, that the restrictions on the movement of wastes, onto and between farms, are excessive. From the perspective of planners and local communities, however, greater movement of wastes would have traffic implications. Farmers operating in the Peak District National Park in our survey highlighted the specific constraints they face in their activities.

Policy Implications

- To determine whether to regulate the use of energy crops in AD units, or to decide whether or not to provide policy incentives for their growing and use in AD
- To review the rules on the movement of wastes, including the traffic implications of any changes

Programme Settings require that AD is both practical and affordable to adopt, and economically viable to operate. To be practical, there needs to be an assured supply of feedstock. Another aspect that came out of our research was the availability of AD units of a size appropriate to the size of farm and scale of specific activities. A wide range of stakeholders raised the issue of affordability of the AD unit, with a number of Policy Mechanisms or Instruments identified (and shown in Table 9) as being desired in order to boost AD uptake. Tenant farmers raised specific concerns about their situation.

Policy Implications

- Ensure affordability of AD as a technology
- Support the development of a range of scales of AD units

As for the Policy Means, with the detailed examples set out in Table 9, here we reiterate one observation arising out of our fieldwork and already stated several times. We believe that AD suffers from a failure to design Policy Mechanisms and Instruments, and to Calibrate them, in a way that reflects the dual Policy Goals that AD can deliver. This can involve revising what some see as overly-restrictive limits on the movement of wastes, whilst providing more financial incentives and support, justified by the triple-whammy of more RE generation, enhanced waste management and reduced pollution impacts of farming.

Tranter et al. (2011) looked at the potential for on-farm AD in the UK. That same year, Bywater (2011: 36) called for 'a single and definitive point of information for regulations surrounding anaerobic digestion'. The Waste and Resources Action Programme (WRAP) and the Anaerobic Digestion and Bioresources Association (ADBA) are active in this area, yet the fact remains: the uptake of on-farm AD remains very modest. Policy, as we have shown using the framework of Cashore and Howlett, is multidimensional. Policy responses therefore need to be several, coherent and consistent. Our aim with this analysis is to demonstrate this argument for on-farm AD. We also hope that, in our dissection of policy into three levels of Policy Ends and Policy Means, we have shown how we can enhance our understanding of 'policy' as a dependent variable, and how we can approach the design of welfare-enhancing policy change in a more nuanced and targeted way.

This work also, we believe, helps to identify key practical and policy issues that others can investigate in greater detail. Much of the (limited) literature about on-farm AD adopts a quantitative modelling approach to estimating its potential. From our research, we see that RE generation potential is both determined and limited by feedstock availability, especially the availability of wastes. Wastes can be brought-in from off-farm, but that has transportation and emissions implications. Another issue is the extent to which on-farm AD can generate energy that can be substituted for energy bought-in. All of these questions, revealed through our qualitative analysis, would benefit from further quantitative analysis. It is clear that AD-uptake remains modest. Work is still needed to provide an evidence-base capable of assisting policymakers to change this situation.

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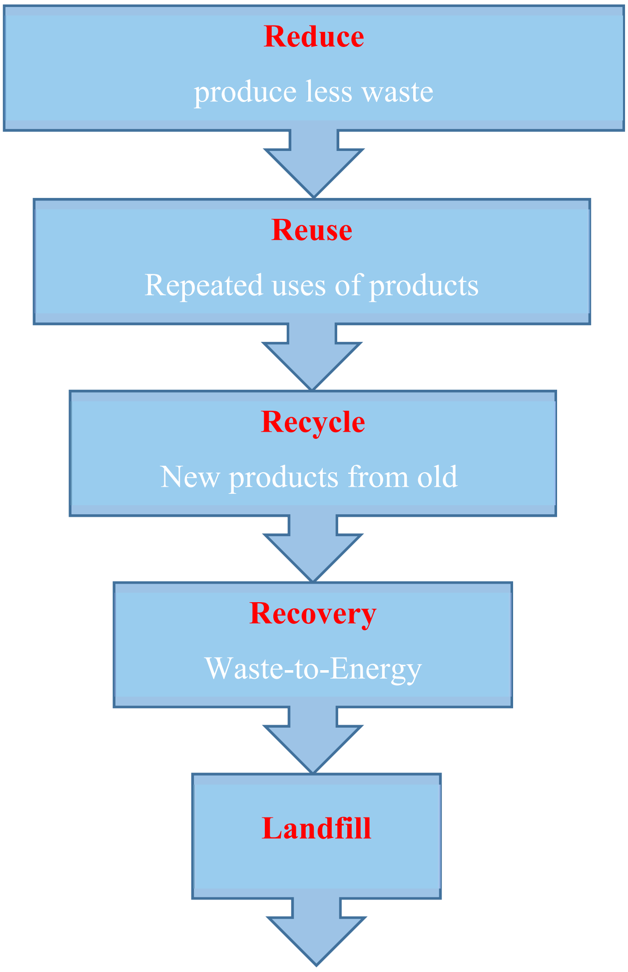
Figure 1: The Waste Hierarchy



Tables

Table 1: Income from diversified enterprises, England – 2017/18

	No. of farms	% of farms	Total Farm Business Income for these farms (£m)	Income of diversified enterprise (£m)	Average enterprise income(a) (£/farm)
Farm Business income (incl. diversification)	54,700		3,090		
Farms which engage in:					
Diversified enterprises (all kinds)	36,100	66%	2,400	680	18,700
letting buildings for non-farming use	24,400	45%	1,880	450	18,500
processing/retailing of farm produce	5,900	11%	270	70	11,600
sport and recreation	7,400	14%	600	30	3,900
tourist accommodation and catering	3,500	6%	240	20	7,000
solar energy	11,500	21%	910	20	2,100
other sources of renewable energy(b)	5,300	10%	440	50	8,600
other diversified activities	5,300	10%	370	30	6,200

Source: DEFRA, 2018b: 20.

Notes: (a) Average here refers to the mean calculated over farms which have that enterprise.

(b) Other sources of renewable energy includes power generating, wind turbines, anaerobic digestion and renewable heat initiatives.

Table 2: Value of output from diversified enterprises, England – 2017/18

	No. of farms	% of farms	Total Farm Business Output for these farms (£m)	Income of diversified output (£m)	Average enterprise output[a] (£/farm)
Farm Business output (incl. diversification)	54,700		17,360		
Farms which engage in:					
Diversified enterprises (all kinds)	36,100	66%	13,620	1,250	34,500
letting buildings for non-farming use	24,400	45%	10,650	640	26,000
processing/retailing of farm produce	5,900	11%	1,700	160	27,100
sport and recreation	7,400	14%	3,040	70	9,400
tourist accommodation and catering	3,500	6%	1,380	70	21,500
solar energy	11,500	21%	5,750	80	7,000
other sources of renewable energy[b]	5,300	10%	2,730	130	24,800
other diversified activities	5,300	10%	1,860	100	18,200

Source: DEFRA, 2018b: 20.

Notes: (a) Average here refers to the mean calculated over farms which have that enterprise.

(b) Other sources of renewable energy includes power generating, wind turbines, anaerobic digestion and renewable heat initiatives.

Table 3: Profile of Questionnaire Respondents

Descriptive Statistics		Number	%
Farm Location	Nottinghamshire	78	51
	Derbyshire	75	49
Farmer Gender	Male	141	92
	Female	12	8
Age of Farmer	Less than 30	4	3
	30-39	8	5
	40-49	27	18
	50-59	52	34
	60-64	24	16
	65 and over	37	24
	Prefer not to say	1	0
Highest Formal Academic Qualification	None	30	20
	GCSE	20	13
	NVQ	14	9
	A Levels	9	6
	University Degree	42	28
	Masters	4	3
	Doctorate	2	1
	Other	44	30
Type of Farm	Arable	56	37
	Livestock	51	33
	Mixed	46	30
Farm Ownership	Owned by you	88	57
	Shared ownership	29	19
	Rented	16	10
	Other	20	13
Annual Farm Turnover	Less than £10,000	8	5
	£10,000 - £19,999	6	4
	£20,000 - £29,999	4	3
	£30,000 - 49,999	8	5
	£50,000 - £74,999	9	6
	£75,000 - 99,999	10	7
	£100,000 - £149,999	14	9
	£150,000 - £199,999	11	7
	£200,000 and over	61	40
	Prefer not to answer	22	14

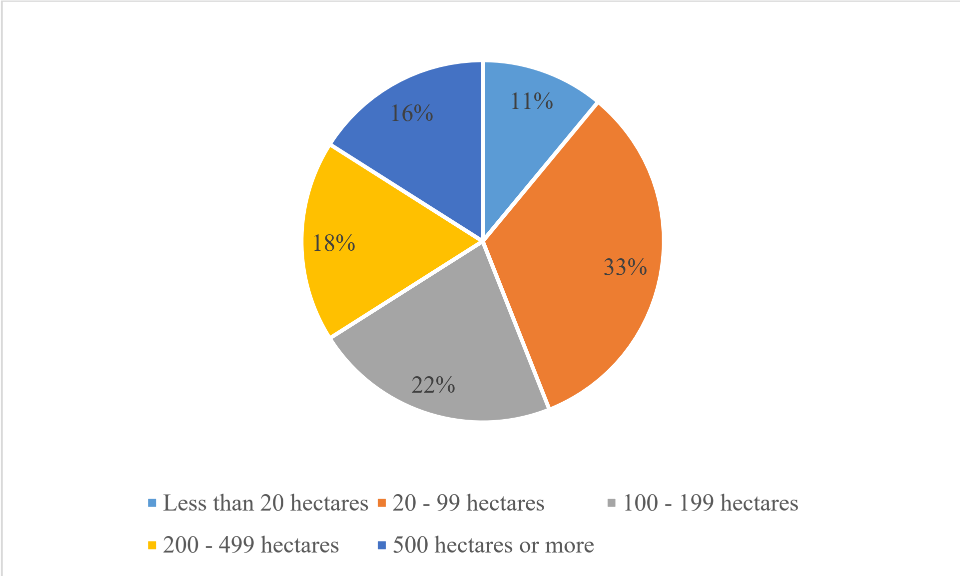
Table 4: Distribution of Animal-Based Farms in the Questionnaire Sample

Number of:	0	1-9	10-19	20 - 29	30 - 49	50 - 99	100 +	N
Dairy Cows	4	1	0	0	0	6	21	32
Cattle, non-dairy	0	7	4	10	8	14	21	64
Sheep	2	1	2	1	3	6	25	40
Pig	4	3	1	0	0	0	5	13
	0	**1- 999**	**1,000-49,999**	**50,000 - 99,999**	**Over 100,000**	**N**		
Chickens	3	16	4	2	0	25		

Table 5: Interview Details

Interview Date	Interviewee profession	Code	Years of Experience	Interview duration	Mode of Interview
02-Aug-16	NFU – Trade association	NFU1	4 years in NFU – 30 Years as farmer	33 mins	Face-to-face
03-Aug-16	Farmer - Owner	FARM1	40 years	46 mins	Face-to-face
05-Aug-16	Farmer - Partner	FARM2	13 years	40 mins	Face-to-face
08-Aug-16	Farmer - Partner	FARM3a FARM3b	42 years	27 mins	Face-to-face
09-Aug-16	Farmer - Partner	FARM4	45 years	26 mins	Face-to-face
11-Aug-16	Farmer - Partner	FARM5	60 years	34 mins	Face-to-face
11-Aug-16	AD Installer – Managing Director	ADOP1a ADOP1b	20 years	47 mins	Face-to-face
12-Aug-16	Farmer - Partner	FARM6	60 years	27 mins	Face-to-face
15-Aug-16	Farmer - Owner	FARM7	30 years	22 mins	Face-to-face
16-Aug-16	Farmer - Owner	FARM8	35 years	40 mins	Face-to-face
17-Aug-16	Farmer - Owner	FARM9	36 years	34 mins	Face-to-face
18-Aug-16	ADBA – Policy Officer	ADBA1	5 years	52 mins	Face-to-face
22-Aug-16	Farmer - Owner	FARM10	50 years	47 mins	Face-to-face
22-Aug-16	AD Plant Director	ADOP2	10 years	49 mins	Face-to-face
02-Sep-16	AD Plant Marketing Director	ADOP3	10 years	36 mins	Telephone
08-Sep-16	AD Industrial Regulator – Environmental Agency	GOV1	20 years	65 mins	Face-to-face
19-Sep-16	Senior Advisor for Waste Industry – Env. Agency	GOV2	12 years	26 mins	Telephone
23-Nov-16	Farmer – Owner and Councillor	CONS1	27 years	34 mins	Face-to-face

Figure 2: Size Distribution of Arable Farms in the Questionnaire Sample



Note: 115 farmers responded to this question. This exceeds the number of farmers who self-identified as having arable or mixed farms (56 and 46, respectively).

Figure 3: Awareness of UK Government RE Policy Measures and Instruments