On-Farm Anaerobic Digestion as an Integral Part of Profitable and Sustainable Farming in the UK

August 2011

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Note: This report is an expansion of a presentation given by Roger Hellawell of Masstock Farm Consultancy at the REA Biogas meeting in December 2010. Based on a detailed analysis, the presentation aimed to investigate the costs and benefits, and thus viability, of agricultural AD. This report is intended to be a contribution to the wider debate on the use of non-waste feedstocks in AD rather than a complete overview of all the issues. It does not necessarily represent the views of the REA or its members.
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1.0 Executive Summary

The use of crop feedstocks¹ in on-farm anaerobic digestion (AD) systems, and their potential to displace crops grown for food, is currently the subject of intense debate. This report offers an analysis of the use of crop feedstocks and seeks to demonstrate that a significant expansion in on-farm AD, including the use of such crop feedstocks, can be both sustainable and profitable.

Government has rightly incentivised the development of the AD industry though financial instruments such as the Renewables Obligation (RO), Feed in Tariff (FiT) and the Renewable Heat Incentive (RHI) and crop feedstocks are an eligible form of biomass for AD plants which claim these financial incentives. Government, on the other hand, has hesitated to support the use of crop feedstocks over concerns that they may displace food for human consumption; this report argues that AD need not significantly impact on food production in the UK.

On-farm AD has the potential to produce significant amounts of renewable energy, provided that climatic conditions and differences in farm characterisations are taken into account. Many farms have readily available slurries for use in AD but require the addition of sustainable grown crops to the feedstock mix both to increase gas yields and to improve the yields of other crops in rotation – termed ‘break crops’.

Break crops such as forage maize are currently generating a fraction of the market value of wheat or rape; however when the value of the renewable energy produced from these break crops is added they become as profitable as other more conventional farming rotations.

The use of break crops for farm AD also confers significant farming benefits including the displacement of mineral fertilisers, improvements in soil quality and the reduction of greenhouse gases from emissions from slurries and manures, contributing to the overall sustainability of the farm. These benefits, it could be argued, are not fully factored into the current FiTs which, even after the recent uplift, remain inadequate to support substantial increases in the uptake of smaller scale on-farm AD projects.

The National Farmers Union (NFU) has set a modest target of 1,000 farm based AD plants by 2020. Even if all these plants used crop feedstocks this would still only occupy a small fraction of the available agricultural land. Furthermore, the use of AD within the agricultural cycle would increase the productivity of that land. In addition, studies show that there are over 860,000 ha of marginal and idle lands² in the UK that could be used to produce crop feedstocks for use in AD.

This report shows that wheat production in the UK currently outweighs demand and that most exports of wheat from the UK are for animal feed rather than for human consumption. This supports the argument that wheat production in the UK has little impact on global food stores and therefore has no effect on world food shortages. A more effective strategy would be to work to improve crop yields in other countries (e.g. Russia) where there is a massive opportunity to increase productivity and ease world hunger.

The UK has an obligation to support the uptake of renewables to achieve its 2020 targets and the use of crop feedstocks in AD can play a significant role in reaching these targets without significantly displacing food for human consumption.

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¹ Crop feedstocks are crops or grasses grown purposely for the production of renewable energy.
² Marginal and idle lands are lands that are unsuitable for food production due to poor soil quality but could grow crops for non-human consumption.
2.0 Introduction

As emissions of greenhouse gases (GHG) rise, along with global average temperatures, the imperative to reduce harmful emissions becomes more urgent. As part of an overall strategy to curb future emissions, the EU has established legally binding targets in the Renewable Energy Directive (RED); the UK’s target is to produce 15% of its energy from renewables by 2020 and 80% by 2050 (EU, 2009). To achieve this goal, the Renewable Energy Strategy (RES) for the UK estimates that 10-20 TWh per year (1250-2500 MWe installed capacity) needs to be generated domestically (DECC, 2009). Consequently, the UK Government has launched programmes and incentives to promote the renewables industry and started to make significant progress towards achieving renewable energy targets. The Coalition Government supports anaerobic digestion (AD) as a significant contributor towards the UK’s renewables targets.

The National Farmers Union (NFU) believes that the UK Government should aspire to a target of 1,000 farm based AD plants (typically 500 kWe but some more and some less) coupled with 200 larger waste feedstock facilities (typically 1.5 MWe) to produce about 800 MWe of generating capacity, thus contributing 6 TWh per year of electricity (NFU, 2009). The introduction of the RHI in 2011 has also opened up the opportunity for biomethane injection to gas grid as an attractive alternative to the generation of electricity from CHP.

In a survey conducted by Farming Futures (2011), 26% of arable farmers reported that the effects of climate change are already altering land use patterns and a further 61% expect similar impacts over the next 10 years. This shows that climate change is a significant issue for farmers and agriculture in the UK and that urgent action is necessary to reduce emissions from farming and thereby make farming a more sustainable, profitable and environmentally friendly enterprise. In the Agricultural Industry GHG Action Plan: Framework for Action report published by the NFU, targets have been set to reduce emissions of methane (CH₄) and nitrous oxide (N₂O) from manures and slurries through better overall management, and more importantly to the renewables targets, from the deployment of on-farm AD systems (NFU, 2010). The report shows that 1,000 farm based AD plants processing and abating emissions from 20% of all UK manures would lead to a reduction of emissions on the scale of 0.55-0.6 Mt CO₂ yr⁻¹ by 2020 (NFU, 2010). The emissions reduction is an estimate because of the uncertainty of the level of uptake from smaller-scale on-farm AD as a result of the relatively low Feed-in Tariff (FiT) levels that do not properly support smaller farm based AD projects.

This report is an expansion of an original presentation given by Roger Hellawell of Masstock Farm Consultancy (which has working relationships with over 60% of the UK farming industry) at a meeting of the REA Biogas sector group in December 2010. Based on a detailed analysis, the presentation aimed to investigate the costs and benefits, and thus viability, of farm based AD. This report is intended to be a contribution to the wider debate on the use of non-waste feedstocks in AD rather than a complete overview of all the issues. It does not necessarily represent the views of the REA or its members.

The report re-examines the food versus fuel question to demonstrate that the production and use of crop feedstocks for AD can be both sustainable and profitable. It will focus on several topics affecting on-farm AD including: current Government views and policies regarding AD, regional climate patterns, characterisation of UK farms (including holding sizes and supply and demand issues), types of AD feedstocks and their profitability, the benefits of the addition of new break crops...
into crop rotations, the potential of crop feedstocks to displace food production, AD plant models and examples, and the impact of energy cropping on food prices.

3.0 Government Policies and Views on Crop Feedstocks for AD Systems

The release of DEFRA’s action plan for Accelerating the Uptake of Anaerobic Digestion in England: an Implementation Plan (DEFRA, 2010a), the Renewable Heat Incentive (RHI) and the Feed-in Tariff (FiT) represent major steps by the UK towards achieving its renewable energy goals through investment in AD systems. However, in all these documents there are some unanswered questions regarding the production of crop feedstocks for use in AD systems.

3.1 DEFRA’s AD Strategy & Action Plan 2011

Under the Coalition Government DEFRA has developed an AD Strategy & Action Plan which, in its final version, does recognise a role for the restricted use of break crops for supplementing slurries and manures for on-farm AD. However, the strategy still fails to embrace the full scope of opportunities available in the use of crop feedstocks for on-farm AD.

3.2 Renewable Heat Incentive (RHI)

The recently implemented Phase 1 of the RHI has incentivised both biomethane injection to grid and heat production (<200 kWth) at 6.5 p/kWe (DECC, 2011a). However, DECC\(^3\) also raises some concerns related to the use of energy grown crops as follows:

“We recognise that, at farm scale, some energy crops may be required in combination with slurries and that such crops can be grown as part of the normal agricultural rotation. Furthermore, there is land available which is not suitable for the production of food crops but which may, therefore, is used to supply energy-crop only AD plants. It is not our policy, however, to encourage energy crops–based AD, particularly where these are grown to the exclusion of food producing crops (DECC, 2011a).”

3.3 Feed-in Tariff (FiT)

The FiT, first introduced in April 2010, gave support for AD at 11.5 p/kWh for installations under 500 kWe and 9 p/kWh for installations larger than 500 kWe (DECC, 2010b). The recently released fast-track review of the FiTs has increased the level of support for AD by raising tariffs to 14 p/kWh for all installations under 250 kWe, 13 p/kWh for installations in the range of 250-499 kWe and retains rates at 9 p/kWh for all installations larger than 500 kWe. Although this increase has provided a modest boost to the AD industry a further increase in the FiTs for AD (e. g. more along the lines of the levels of support for wind power) would spark further growth of farm based AD. However, this scheme highlights the same issue raised in both the RHI and supported by DEFRA that “it is not our policy, however, to encourage energy crops–based AD, particularly where these are grown to the exclusion of food producing crops” (DECC, 2011b).

The reluctance of Governmental bodies to formally support the inclusion of crop feedstocks, despite uncertainties as to whether such cropping in fact has an adverse impact on food crops, is

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\(^3\) DECC – Department of Energy & Climate Change
undoubtedly a barrier to the development of a burgeoning industry. The production of food and fuel is seen as competitive rather than complementary; however it is crucial to the renewable energy future of the UK to understand the effect on biogas production from AD of regional differences such as local climate patterns, farm infrastructure, varying biogas yields from different feedstocks, profitability of arable rotations, and the UK position in the global market for food. This report seeks to stimulate a re-examination of the debate on food versus fuel and to demonstrate that the production and use of crop feedstocks for AD can be both sustainable and profitable.

4.0 Characterisation of UK Farms and Farm Production

Not all farms in the UK will be suitable for the use of on-farm AD. However, many farms could contribute significantly to renewable energy targets if regional differences are recognised and utilised appropriately.

4.1 Regional Climate Patterns in the UK

An important factor to take into consideration when examining the potential for smaller scale on-farm AD, are the regional climate characteristics of the UK.

Figure 1: (a) Average sunshine duration in the UK from 1971-2000. (b) Average rainfall amount in the UK from 1971-2000 (MetOffice, 2010).

As shown in Figure 1, the greatest proportion of the rainfall is in the Western part of England and Scotland and the majority of the sunshine is correspondingly in the East and South. These patterns, allied to topography and soil types, result in differing predominant farming types in the two regions. The majority of ruminant livestock is on the Western side of the country where grass production is prevalent. Most of the crop production and much of the non-ruminant livestock (i.e. pigs and poultry), occur on the Eastern side of the country. The pig and poultry sector are found in the main
cereal producing areas on the Eastern side because historically their function was to add value to cereals for farm profitability.

These climatic differences within UK farming support the idea of splitting AD into two categories. Firstly, a pig and poultry base with an arable crop contribution. Secondly, a ruminant slurry and manure base, with potentially grass as the high dry matter contributor to overall feedstock. This differentiation, while not exclusive, highlights important regional differences in feedstock supply.

The first category includes large-scale pig farms, where AD would be of particular value in GHG reduction, and land available for digestate use under NVZ (nitrogen vulnerable zone) regulations should be abundant within the locale; however sourcing additional feedstocks of high dry matter material will inevitably mean diverting some land use from arable crops (e.g. cereals) to crop feedstocks for AD (e.g. maize). As discussed in more detail in Section 5.2, slurry-only plants are not a viable option; therefore, unless some arable land is used for energy crop production, substantial proportions of slurry will remain untreated, which is unacceptable in terms of GHG generation.

In the second category, where ruminants predominate, farm structure is the overriding issue. Where farm size allows, there may be additional areas surplus to that required for the livestock enterprise which would be available to produce additional feedstock. However, farm size and structure within the ruminant livestock sector is largely characterised by the smaller family farm which leaves little room for feedstock crop production; this is discussed further in the next section.

4.2 Size of Farm Holdings in the UK

In order to investigate the potential for on-farm AD in the UK, an understanding of the availability of land for the production of feedstocks is important. Table 1 is a chart of total area on current farm holdings.

<table>
<thead>
<tr>
<th>Total Area on Holdings (ha)</th>
<th>Number of Holdings (Thousands)</th>
<th>Hectares (Thousands)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 20</td>
<td>198.1</td>
<td>925.8</td>
</tr>
<tr>
<td>20 &lt; 50</td>
<td>48.9</td>
<td>1,619.5</td>
</tr>
<tr>
<td>50 &lt; 100</td>
<td>36.0</td>
<td>2,567.4</td>
</tr>
<tr>
<td>≥ 100</td>
<td>41.5</td>
<td>12,345.3</td>
</tr>
<tr>
<td>Total</td>
<td>324.5</td>
<td>17,458.0</td>
</tr>
<tr>
<td>Average Area</td>
<td></td>
<td>53.8 (ha)</td>
</tr>
<tr>
<td>Average Area on Holdings with ≥ 20 ha</td>
<td></td>
<td>130.8 (ha)</td>
</tr>
</tbody>
</table>

As shown in Table 1, the average of holding area in the UK is 53.8 hectares (ha). The average area on holdings with ≥ 20 ha is 130.8 ha.

While there are many farms with sufficient land available to produce crop feedstocks for AD, this land is often not allied to slurry producing farms; the UK dairy industry is predominantly made up from family farm enterprises, where all land is utilised for cattle. Co-operation between these farms is frequently advocated, however, there are significant practical problems such as business structure and agreements, the logistics of transporting feedstock either as slurry, manure or crop and gas collection for central generation.
5.0 Feedstocks

The selection of feedstock is very important for the efficient production of biogas from on-farm AD systems. The cost of feedstock put into the digester is a key performance issue where it directly affects the cost of biogas output. Furthermore, the relationship between various feedstock carbon concentrations affects the capital cost per kWe of plant output capacity through vessel size and retention times.

It is worth noting that the waste (or merchant) model of AD currently gains significant benefit from gate fee income; feedstock in this case is a revenue stream rather than a cost. It is a matter for debate as to whether gate fees will remain at their current levels. In Germany for example, gate fee income has all but disappeared because of feedstock competition. Nevertheless, the merchant model is an example where Government has recognised the environmental benefits of AD and has supported through taxation the diversion of waste from landfills for use in AD. In contrast they have failed to similarly recognise the multiple environmental benefits of using AD on-farm (e.g. improved soil, increased yields, etc...) and appropriately incentivise agricultural AD.

5.1 The Problem of Using Food Wastes as Feedstocks on Farm

It has been argued by Government that using crop feedstocks in AD systems is unnecessary as there are ample amounts of food wastes available for digestion along with on-farm slurries. However, there are unique technical complexities associated with the use of food waste in AD including biosecurity, storage, pre-treatment and impact on the composition of digestate as well as planning and permitting hurdles. The treatment of food wastes also demands the installation of specialised handling equipment for which the costs for on-farm AD can be prohibitive. Food wastes vary widely in their composition and therefore will have significant impacts on the nutrient composition of the resulting digestate. Furthermore, waste streams are inconsistent and supply varies locally. These problems make the widespread use of food wastes (outside of specialised plants) inherently problematic and therefore not often a very attractive or viable option for on-farm AD. Nevertheless, Government has adopted a policy of overall waste reduction, whilst at the same time classifying AD as an “energy from waste technology” (Foresight, 2011). Such a narrow classification does not appear to support a long term AD industry when the overall goal of Government is to reduce the generation of food waste in the UK.

5.2 Gas Yields from Feedstocks

As shown in Figure 2, different feedstocks have widely varying gas yields when used in AD systems (for a more complete list of possible feedstocks see Appendix 1).
Slurry in particular is a very low biogas yielding feedstock; its primary advantage on-farm is that it is free. As seen in Table 2, the amount of slurry needed to produce equivalent gas yields as forage maize (a potential energy crop) or even manures, is 5-10 times as much.

Table 2-Comparison of feedstock types and amount needed to reach the same gas yields (adapted from Masstock, 2010).

<table>
<thead>
<tr>
<th>Feedstock Type</th>
<th>Dry Matter (%)</th>
<th>Fresh Amount (t or m³)</th>
<th>Gas Yield/unit Fresh Weight (m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cattle Slurry</td>
<td>9</td>
<td>10,000</td>
<td>173,250</td>
</tr>
<tr>
<td>Cattle Manure</td>
<td>25</td>
<td>1,925</td>
<td>173,250</td>
</tr>
<tr>
<td>Forage Maize (@ 40t/ha)</td>
<td>32</td>
<td>981</td>
<td>173,250</td>
</tr>
</tbody>
</table>

The disparity between the energy produced from slurries and from crop feedstocks is due to the available carbon which is converted to methane. Slurries have less energy content in comparison to crop feedstocks because much of the energy in the feed given to livestock is lost in the form of sugars, carbohydrates and fats absorbed by the animal. Energy content is also related to percent dry matter in each tonne of input. While manures contain high dry matter compared to slurry; because of the lignin content of plant material (most commonly straw), there is interference with the assimilation of the cellulose by bacteria thus reducing its gas producing potential.

It is suggested by some that at the ‘smaller scale’ (a farm with roughly 120-130 cows) the most economically attractive option, given current support, is a slurry-only plant that doesn’t utilise crop feedstocks and that at a medium scale (230 cows) a 70% slurry and 30% energy crop is the best option. However, these estimates seem to significantly overestimate the energy capacity of slurries. At 9% dry matter it would take between 1,500 and 2,000 cows (dependant on the cow feeding regime) to produce 75% of the energy for a 250 kWe plant. This number of cows is much larger than...
the average dairy herd in the UK which is about 120 cows, so this model is unlikely to be a viable option.

Feedstock additional to slurry is imperative to provide sufficient biogas output. For example the slurry from 200 cows would only produce 6.4% of the biogas needed for a 250 kWe plant; another 100 ha of maize would be required to bring that plant to full capacity. Therefore, it is essential to include higher biogas yielding feedstocks (e.g. maize silage, grass silage, etc...) to enable slurries to be used economically in AD.

To put the debate of slurry only plants and the use of crop feedstocks into perspective; meeting the NFU aspiration of 1,000 plants of 500kWe capacity would take 6 million dairy cows or 20 million pigs, yet, there are only 1.86 million dairy cows and 4.7 million pigs in the UK. Therefore, the use of slurries as the main feedstock with minimal supplementation from crop feedstocks in these plants is not feasible.

5.3 Gross Margins of Arable Crops

The common objection to the use of crop feedstocks is the displacement of food crops. To address this competitive rather than complementary position the sustainability of current arable cropping must be understood.

There are indications that the UK farmer is likely to receive a reduced Single Farm Payment in the future as the European Union Common Agricultural Practices (CAP) negotiations continue. Thus the profitability achievable by individual crops will be an increasingly important factor as farmers attempt to make profits without a directly paid subsidy. Figure 3 shows the gross margins from several different crops that can be planted following first wheat.
From Figure 3, we can see that the most profitable crop is the first wheat (winter wheat) followed by break crops of winter oilseed rape and winter linseed. Yields of successive plantings of wheat (second wheat) yield 2-3 tonnes/ha less than first wheat yields.

As shown in Figures 3 and 4, because wheat and oilseed rape are the most profitable crops, farmers are incentivised to grow them either in close rotation or wheat in succession which may cause negative environmental impacts to the farm. This issue is further discussed in Section 6.

### 6.0 Benefits of the Addition of New Profitable Break Crops for Farms

Cereals (e.g. wheat, barley and oats) are currently the main crop types grown in the UK, followed closely by oilseed rape; this is primarily a result of the profitability of these crops as was shown in Section 5. This profitability encourages farmers to grow close rotations of wheat and rape (rape as the break crop) or otherwise wheat in succession. Growing wheat in succession however, results in declining yields of wheat from about 10 tonnes/ha to about 7.5-8 tonnes/ha, reducing overall gross margins by about £300/ha as shown in Figures 3 and 4.

What is of growing concern to the sustainability of UK farming is that the practice of growing only wheat and rape in close rotation or wheat in succession increases risk of weed infestations and disease resistance break down. Particular examples of this are the resistance of blackgrass to herbicides and the rapid breakdown of some wheat varieties resistance to yellow rust.
Close rotation cropping practices may also result in reduction of yields over the long term and an increased dependence on the use of mineral fertiliser to enhance yields, increased crop protection product use and adverse effects upon ecology and soil health.

The addition of a new profitable break crop would have significant farming benefits all of which are remedial to the issues raised. In addition to the direct environmental benefits on the farm, break crops have a higher percent dry matter content giving high biogas yields. Thus break crops used in AD have significant potential to increase the sustainability of the farm and contribute significantly to farm profits.

6.1 Additional Benefits of Changes in Crop Rotations

The digestate produced from the AD process can be used as an organic fertiliser. A change from the common rotation of first wheat, second wheat and oilseed rape to a new rotation of first wheat, rape, first wheat and maize or grass silage would provide significant advantages including:

- Use of organic fertiliser (derived from the digestate as result of AD) can displace 85% of the need for chemical based fertilisers, which reduces hazards to NVZs and reduces carbon emissions.
- Returning organic material to the soil increases nutrients, leading to overall soil improvement that can then lead to increases in average yields in other crops.
- Improve the sustainability of farms.

The argument against these changes in crop rotations is that in this example wheat has been reduced from two crops in three years and to two crops in four years, therefore less food is being produced. The question of food displacement is addressed in Sections 8.1 and 8.2 but it is worth noting at this stage that the immediate effect on one of the wheat crops is to increase yield by some 2-2.5 tonnes/Ha as it changes from second wheat to first wheat.

6.2 Profitability Comparisons of Crop Rotation Options

If a break crop which is intended to be used as an AD feedstock is introduced into a crop rotation it should ideally be of comparable profitability to the original crop choice. Therefore in order to compare profitability, the value of the subsequent biogas produced by the break crop must be incorporated.

As was shown in Figures 3 and 4, profitability drivers encourage farmers to grow wheat as a main crop and oilseed rape as the preferable break crop. The economic comparisons of these crops can be seen below in Table 3.
Table 3—A comparison of net margins of the main crop winter wheat and selections of current break crops, oilseed rape and winter beans. The proposed new profitable break crop, forage maize, for subsequent use in AD is also included for comparison (crop prices are based on November 2011 futures as of 17th November 2010) (HGCA, 2010; adapted from Masstock, 2010).

<table>
<thead>
<tr>
<th>Crop</th>
<th>Yield (t/ha)</th>
<th>Price/Value (£/t)</th>
<th>Sales (£/ha)</th>
<th>Cost of Growing Crop (£/ha)</th>
<th>Gross Margin (£/ha)</th>
<th>Overhead Costs (£/ha)</th>
<th>Net Margin (£/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Winter Wheat</td>
<td>10</td>
<td>155</td>
<td>1550</td>
<td>617</td>
<td>933</td>
<td>488</td>
<td>445</td>
</tr>
<tr>
<td>Oilseed Rape</td>
<td>3.5</td>
<td>405</td>
<td>1417</td>
<td>527</td>
<td>890</td>
<td>482</td>
<td>408</td>
</tr>
<tr>
<td>Winter Beans</td>
<td>4</td>
<td>170</td>
<td>680</td>
<td>280</td>
<td>400</td>
<td>480</td>
<td>-80</td>
</tr>
<tr>
<td>Forage Maize</td>
<td>40</td>
<td>*</td>
<td>2228</td>
<td>947</td>
<td>1281</td>
<td>596</td>
<td>685</td>
</tr>
</tbody>
</table>

*Price/Value Calculation of Forage Maize: Value of maize at 1 ha (at 40 t/ha) plus energy value of 13,500 kWh at 16.5 p, thereby valuing its generation potential in kWh by FITs rates plus export tariff.

Table 3 shows again that wheat is grown as a profitable main crop and oilseed rape as a profitable break crop whereas winter beans (which is also grown as a break crop) can actually make a loss. However, when a new break crop (such as maize) which provides a viable high energy feedstock for AD, is introduced into the crop rotation system, the additional income from energy production of biogas increases profitability to a level comparable with the highest value crops. This is clearly illustrated in Table 3.

The maize now becomes an additional profitable break crop whilst conferring all the advantages of extended rotations and increasing yields of first wheat as discussed in Section 6.1. Table 4 below illustrates the increases price of wheat and oilseed rape necessary to provide the same net margin achieved for forage maize with the energy value included.

Table 4—Chart of required price/values for winter wheat and oilseed rape required to match net margins of forage maize with the value of energy incorporated.

<table>
<thead>
<tr>
<th>Crop</th>
<th>Yield (t/ha)</th>
<th>Price/Value (£/t)</th>
<th>Sales (£/ha)</th>
<th>Cost of Growing Crop (£/ha)</th>
<th>Gross Margin (£/ha)</th>
<th>Overhead Costs (£/ha)</th>
<th>Net Margin (£/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forage Maize</td>
<td>40</td>
<td>56</td>
<td>2228</td>
<td>947</td>
<td>1281</td>
<td>596</td>
<td>685</td>
</tr>
<tr>
<td>Winter Wheat</td>
<td>10</td>
<td>179</td>
<td>1790</td>
<td>617</td>
<td>1173</td>
<td>488</td>
<td>685</td>
</tr>
<tr>
<td>Oilseed Rape</td>
<td>3.5</td>
<td>484</td>
<td>1694</td>
<td>527</td>
<td>1167</td>
<td>482</td>
<td>685</td>
</tr>
</tbody>
</table>

As shown in Tables 3 and 4, to achieve parity with maize (with the value of energy incorporated), the price of wheat would have to rise from £155/tonne to £179/tonne and oilseed rape from £405/tonne to £484/tonne. Current oilseed rape prices are capped by the price which fuel companies are currently prepared to pay to incorporate the oil into diesel (estimated at £440/tonne). Therefore oilseed rape, as a high value break crop, has a limited ability to contribute to whole farm profitability.
It follows that an alternative break crop must maintain a profitability level comparable with wheat and rape to encourage the farmer to adopt a sustainable crop system. The combination of capped rape price and current volatile wheat prices encourage wheat mono-cropping and a further push factor towards increasing wheat acreage at the expense of land currently used for pasture. This land use change can be seen as environmentally damaging.

At the time of writing the volatility of crop values, as a result of global supply shocks (to be discussed further in Section 9.1), has pushed wheat and rape prices to levels close to the inflation prices in Table 4. It follows that in order to make growing forage maize as a break crop competitive, it must be as profitable as growing and selling oilseed rape and wheat at these high prices. The introduction of AD into the farm system forms a viable strategy to provide environmental benefits underwritten by the long term security of income from renewable energy exports.

6.3 Maize Silage vs. Grass Silage as a Break Crop

Maize silage and grass silage are often mentioned as some of the most commonly grown potential AD feedstocks because of favourable climate and soil conditions in the UK. For example a 40 tonne/ha maize crop costing £74/tonne of dry matter (i.e. 0.65p/MJ) to produce, is equivalent in energy terms to a 45 tonne/ha crop of grass costing £70/tonne dry matter (i.e. 0.65p/MJ) (Masstock, 2010).

The livestock industry in the UK is under increasing pressure from rising costs in feed, fuel and fertiliser. Sheep and beef enterprises are particularly under pressure to promote better environmental stewardship while trying to expand in an effort to reduce overall feed costs. Pig and poultry businesses, which are highly dependent upon cereal feeds, are at an increasing risk of becoming unprofitable as feed costs soar ever higher.

However the ability to grow high yielding grasses on a wide variety of soils (including currently marginal and idle lands) coupled with the incorporation of both grasses and maize into arable rotations for use as feedstock for AD, provides opportunities for these livestock sectors to diversify into energy production.

6.4 Benefits of Digestate as a Replacement for Mineral and Cattle Slurry Fertilisers

Essential soil nutrients such as nitrogen, phosphorous and potassium all are conserved in the digestion process and therefore the digestate retains the original nutrient levels of the given feedstock. This digestate has the potential to displace 85% of mineral fertiliser application on farms. In comparison to the use of cattle slurries for fertiliser, the crop available nitrogen within digestate is 60% whereas cattle slurries are only 35% (Redman, 2010a); hence the use of untreated slurries requires additional nitrogen mineral fertilisers to top up the nutrient deficiencies. Using digestate as a fertiliser instead of slurries results in on-farm savings of £27.39/ha (at £225/tonne and 34.5% dry matter) (Redman, 2010a).

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4Wheat is selling at 200 £/tonne on spot market as of April 2011 (HGCA, 2011).
6.5 The Farm Resilience Plan

For many farmers the long term viability of the farm (known as a ‘resilience plan’) is one of the most important concerns. In looking ahead the biggest concern is not the immediate profitability of crops but rather future threats to the farm. These threats include:

- Getting enough nutrients in the soil. In light of oil price volatility, costs of mineral fertilisers are on the rise. Using digestate as fertiliser can guarantee the farmer a source of soil nutrients in the future.
- Costs to power the farm (in light of rising energy prices). AD can guarantee a sustainable source of electricity.
- Costs to heat the farm (in light of rising energy prices). AD can guarantee a sustainable source of heat needed to operate many operations on the farm.
- Soil carbon reserves, soil erosion and infiltration capability of the soil (all of these issues can be improved by using break crops for AD that improve soil quality along with spreading digestate for fertiliser).

As shown, the issues most pressing to the resilience plan of a farm are those that can be addressed through the use of on-farm AD.

7.0 AD Plant Models

The two principal models for AD in the UK are the on-farm model and the merchant (waste) model.

![Diagram of two AD plant models](image)

Figure 5: Description of the two models of AD plants, the waste model and the on-farm model (Masstock, 2010).

The farm model utilises grown crops along with manures and slurries and uses the energy produced for on farm electricity and heat while exporting the surplus to the grid. The waste (or merchant) model typically utilises imported wastes and gains revenue from gate fees, along with electricity exported to grid and heat used locally or biomethane gas that is injected into the grid.

Typically the waste (merchant) model is of an output size to achieve a favourable capital cost per kWhe generated and consequently an internal rate of return attractive to equity and debt.
investment. Conversely, farm infrastructure and electricity supply infrastructure frequently preclude projects greater than 300 kW\text{e} installed capacity. At this scale many farm opportunities have been lost due to the higher cost per kW\text{e} installed capacity and the cost of supplementary feedstock (i.e. an energy crop) when revenues were provided at the initially declared FiT rate. The revision of FiTs has improved the economics of farm scale AD, but the returns on investment are still inadequate to enable significant borrowing even with land collateral; self finance is almost always beyond the reach of a farm business.

7.1 Small Family Farms

Under the current FiT scheme small-scale on-farm AD using both slurries from an average sized dairy herd (120 cows), in addition to crop feedstocks, is not profitable enough to encourage wide-scale increased uptake. An increase in the farm based AD FiT, would help to make this small scale implementation of AD a viable option. If this stimulus was provided to family type farms in the UK, then the potential would be (500 x 250kWe x 8000 hours) or 1,000 GWh per year of electricity.

8.0 Displacing Food for Crop feedstocks?

It is suggested by some that the introduction of break crops for AD will displace food for human consumption and negatively impact national and global food stores. This report suggests that domestically, the effect of the use of crop feedstocks in AD systems need not be to displace food but rather act as an incentive to use available lands and resources in the UK more effectively and increase de-centralised renewable energy. Furthermore, the contribution to long term sustainability will enhance food crop yields in the future.

This report will take two popularly used feedstocks, maize and grass silage, as examples of the potential to displace food crops.

8.1 Grass Silage for AD, Displacing Food?

As an example and assuming that the total feedstock was sourced from grass silage, to reach the NFU aspiration of 500 MWe capacity on farm (1000 x 500 kWe plants) would require roughly 235,000 ha of grass silage (at 55 tonne/ha yield) to grow the required feedstocks. In the UK there are 1.226 million hectares (mha) of temporary grassland and 9.901 mha of permanent grassland available for production and a study conducted for DEFRA (Turley et al., 2010) estimated the total area of marginal and idle lands at 860,000 ha; this area has the potential to produce about 4.8 million tonnes (mt) of biomass for bioenergy production (including biogas). These marginal and idle lands can be found all across the country and, as a result of degraded soil quality, remain largely unused for any agricultural purposes; thus they have the potential to supplement or supply grass silage for AD without displacing any arable land used for food production in the UK.

In addition, a diminishing area of existing grasslands is now required for cattle grazing since the dairy herd has dropped by 479,000 since 2000 and at approximately 240,000 cows is now 50% of previous stocking levels. In the same period, beef breeding herds have dropped by 216,000 since 2000 to about 205,200 (Masstock, 2010; Turley et al., 2010). This reduction in cattle numbers has effectively released 278,000 ha of grassland grazing (at 2.5 cows/ha), which alone is more than adequate to
accommodate the 235,000 ha of land required to grow sufficient feedstocks to support the NFU aspiration; this area amounts to only roughly 20% of the 11 mha total available grassland in the UK (Masstock, 2010; Turley et al., 2010). It is not suggested, of course, that grass would be the dominant feedstock for on-farm AD, but the use of grasslands to produce a proportion of feedstock for AD need not displace cattle herds or lands currently used for food production; there is no competition between food and fuel in this scenario.

8.2 Maize for AD, Displacing Food?

As a further example, a total of 220,000 ha of maize silage (at 50 tonne/ha yield with co-digestion of available slurries) would provide sufficient feedstocks to achieve the NFU aspiration of 1,000, 500 kWe capacity farm scale AD plants. Given that there is an area of 4.431 mha of arable land in the UK, with 1.015 mha of it being used for break crops (such as second wheat or oilseed rape), the use of 220,000 ha for maize silage should be feasible given the yield increases as a result of planting maize as a break crop.

As shown in Figure 3 second wheat has reduced yields of 2-3 tonne/ha in comparison to first wheat (winter wheat). By displacing 220,000 ha of second wheat for forage maize for AD, 1.65 mt of wheat is lost (at national average wheat yield of 7.5 tonne/ha). However, because of the 2 tonne/ha improvement in first wheat yields on this same land, an additional 440,000 tonnes of wheat is produced together with the economic benefits of forage maize itself. If all land used for wheat production in the UK (1.84 mha) utilised a crop rotation that included forage maize as a break crop instead of oilseed rape, the 1-2 tonne/ha improvement in crop productions, made possible because of more fertile soil, would lead to an increase of 1.84 to 3.68 mt of wheat produced, making up for any wheat production initially displaced for energy crop production.

As with grass silage, some varieties of maize thrive on land unsuitable for arable crops and can grow on soils with medium to poorer soil quality that is unsuitable for grain or rapeseed. Thus maize, used as a break crop or grown on marginal lands, does not need to displace any food destined for human consumption.

9.0 Supply/Demand of Wheat in the UK and Global Impacts

Wheat is the primary crop grown in the UK and therefore is a critical to food supply, industrial processes, livestock feed and export. UK wheat supply currently outweighs domestic demand; in 2009/2010 supply equalled 18,082,000 tonnes while demand was only 13,795,000 tonnes (Masstock, 2010). Of the 4,287,000 tonnes of surplus some 2,427,000 tonnes was exported and the remaining 1,860,000 tonnes carried over to the succeeding harvest year. Demand within the UK for 2010/2011 is estimated at 7,406,000 tonnes for human and industrial use and 6,700,000 tonnes for animal feed. As industrial crop use increases, primarily due to ethanol production, UK exportable surplus is predicted to fall to around 800,000 tonnes for 2010/2011.

The International Grains Council (IGC) (2011) world estimate of wheat production is 649 mt for 2010/2011 of which 123 mt will be traded globally. Total grains production is estimated at 1,726 mt for 2010/2011 of which 243 mt will be traded (IGC, 2011). In essence UK wheat has little impact
upon global supply and demand for food. The major wheat export is wheat for animal feed rather than human consumption. This new demand for animal feed is being driven by rapidly increasing human consumption of meat, particularly in China where the sales of beef, poultry and pork almost doubled between 1994 and 2006 (Foresight, 2011). Thus, increases in global consumption of meat will have far more impact on the displacement of grains for human consumption than demand for feedstocks for AD in the UK.

9.1 Comparing Global Wheat Yields

The impact of UK food production on global supply should be seen in the context of international supply and demand. A report by Foresight (2011) highlights the challenges in feeding a projected 9 billion population by 2050 and the allied challenge of achieving this target sustainably.

The UK is the highest yielding producer of wheat across the globe, as shown below in Figure 6.

![Figure 6-Average wheat yield of Countries producing more than 300,000 tonnes (Masstock, 2010)](image)

The UK temperate climate coupled with advances in technology and investment has resulted in the UK having the highest yields per hectare of land in the world. However, supply shocks that occurred in 2010/2011 had little connection with the UK and were essentially due to adverse weather events in Russia, Canada, Southern Europe and Australia.

While the climate of these lower yielding countries is a significant factor in the levels of global grain production, the transfer of existing knowledge and technologies and an increase in investment in regions such as the Russian Federation and parts of Africa could significantly increase their yields and thus have a major impact on global production. Therefore, the solution to global food shortages does not lie in controlling the production and exports of the UK. The emphasis should be placed on increasing yields in regions where the potential for increased yields is the greatest. For the UK, the
export of knowledge and expertise and the free movement of capital would make a far greater contribution to easing world hunger than restricting the use of crops in agricultural AD.

9.2 The Impact of Energy Cropping on Food Prices

In 2008, prices of wheat (as an internationally traded commodity) almost doubled from £83.60/t in July 2006, to £168.30/t in July of 2008 (HGCA, 2011). This increase in the price of wheat coincided with a significant rise in bread prices from 80p/loaf to 124p/loaf (Malcolm, 2008). Price increases in basic food commodities disproportionally affect the poor and as some claim, the exacerbation of world food shortages and world hunger. Some have attributed this inflation largely to the growth of energy cropping for bioenergy; however this was not the overriding factor. As previously mentioned poor harvests in Europe, Australia and the Ukraine, coupled with prevailing government policies in the EU, US and China significantly reduced buffer grain stocks thus causing a significant increase in prices due to high demand and limited supply, also known as a supply shock (Malcolm, 2008).

The real culprit of world hunger is poverty, as the Director General of the UN Food and Agriculture Organization (FAO) Jacques Diouf stated, “Our planet produces enough food to feed the entire planet. But tonight 854 million men, women and children will go to sleep on an empty stomach” (Malcolm, 2008). The FAO recognises that the main cause of hunger in the developing world is poverty caused by the lack of resources to buy food or produce it.

10.0 Conclusion

To date the UK Government has primarily supported AD plants that use wastes to produce energy. At the same time the Government is encouraging the overall reduction in wastes over the coming years (Foresight, 2011). Building the AD industry solely on wastes is therefore not a sensible option and other alternatives including the use of a diversity of crop feedstocks need to be recognised and given more support.

The Government has shown support for the use of perennial crop feedstocks in the UK Biomass Strategy (DEFRA, 2007). The strategy recommends the use of 800,000 ha of land for production of crops to use in biomass schemes, ensuring in this case that there is no displacement of crops for food. To properly support a viable farm based AD industry, only 220,000 ha of land is needed and this initial displacement of land would be more than made up for by increases in yields from the soil benefits of introducing new break crops. The analysis shows that UK production of wheat has little impact on global stores of wheat and that the response to world food shortages should be to increase yields in those regions of the world with the greatest potential (e.g. Russia). The report shows that the use of crop feedstocks for AD need not displace food and that the goal in the UK Biomass Strategy to “promote innovation and low-carbon technology development so biomass can deliver relatively higher energy yields” (DEFRA, 2007) can also be applied to the AD industry given the acceptance of sustainable crop feedstocks in AD systems.

In summary, there are large areas of land in the UK which can be used for crop feedstocks without displacing food. Sustainable farming is about profitable break crops and better soil management in conjunction with increasing the productivity of farm lands. This report has shown that the sustainable domestic production of crop feedstocks for AD need not significantly displace food for human consumption, but could result in the utilisation UK lands more effectively and efficiently.
UK has an obligation to support the uptake of renewables and must urgently adopt a viable strategy to achieve these goals, hence it is vital to realise the full potential of renewable energy from on-farm AD.
Appendix 1-List of Possible Feedstocks for AD Systems (Redman, 2010b)

<table>
<thead>
<tr>
<th>Crop Feedstocks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barley grain, barley straw, barley straw ammonia treated, barley straw NaOH treated, cauliflower, clover hay (first cut), field bean grain, fodder beet, fodder carrot, grain peas, green maize (milk-ripe), green mustard (before flower), grass silage, maize grain silage (crimped seed), maize silage, meadow grass (green), meadow hay, oat grain, oats fodder flower, oat straw, oat straw NH₃ treated, rye grain, sugar beet (fresh), sunflowers (green start of flowering), wheat flakes, wheat straw, wheat straw NaOH treated, wheat straw NH₃ treated and whole-crop wheat.</td>
</tr>
<tr>
<td>Other/Waste Feedstocks</td>
</tr>
<tr>
<td>Baking wastes, brewers waste, butter milk (fresh), cheese wastes, clover (first cut in flower), corn gluten, glycerine, leftovers (average fat), leftovers (fat-rich), leftovers (low-fat and wet), linseed oil, maize grain (dry), mixed grain, molasses (sugar beet), oat bran, old bread, palm kernel pellet, potato flakes, potato peeling wastes, rapeseed oil, rolled oats, skimmed milk (dry), skimmed milk (fresh), sour whey (fresh), soy oil, soybean seeds (steam-heated), sugar beet (dried and shredded), sugar beet tops (clean), sunflower cake (cold-pressed), sunflower oil, sunflower seed, vegetable wastes, wheat bran, wheat chaff, wheat germ, wheat grain, wheat semolina bran, and whole cow’s milk (fresh).</td>
</tr>
</tbody>
</table>

References Cited


from:


Farming Futures. (2011) Your Sector: Crops. [Online]. Available from:


Hopwood, L. (2010) Farm –Scale Anaerobic Digestion Plant Efficiency. NNFCC.


