Increasing Deployment of Small-Scale, On-farm Anaerobic Digestion Plants

Introduction

The UK Government is committed to seeing a substantial increase in the use of Anaerobic Digestion (AD) to generate renewable energy from waste. This paper begins to explore the implications of that position with relation to the small-scale, on-farm AD sector. We look at the existing status of the industry and explore some of the barriers blocking wider-scale deployment of the technology. A key barrier is the financial viability of on-farm AD systems and we outline an approach to quantify that barrier through detailed modelling of the profitability of farm-scale AD plants.

Policy Environment

To enable the growth of the AD sector as a whole, the UK Government has published the AD Strategy and Action Plan and included AD within the remit of several financial incentive schemes.[1]

Anaerobic Digestion Strategy and Action Plan

The Strategy and Action Plan included a range of actions, over a third of which had been completed by July 2012, including the establishment of a £10m loan fund intended to provide debt finance for AD projects and an Innovation Fund to stimulate potential new AD technologies.[2] The Strategy and Action Plan is continuing to support the development of the sector through a range of outstanding actions.

Financial Subsidies

The government also provides mechanisms to directly improve the profitability of AD plants. This support is provided through four instruments:

- Feed-in Tariffs (FiT)
- The Renewable Heat Incentive (RHI)
- The Renewables Obligation (RO)
- The Renewable Transport Fuel Obligation (RTFO)

Only one of these instruments can be claimed for any given unit of energy produced. If a plant has received other government financial support it can only claim the RO.

Feed-in Tariff

Feed-in Tariffs provide payments for small-scale generators of electricity.[3] They aim to increase the uptake of small-scale renewable electricity generation. Electricity generated by the combustion of biogas is eligible for a FiT. The tariff is broken down

[1] Anaerobic Digestion Strategy and Action Plan (2011)
[2] Anaerobic Digestion Strategy and Action Plan: Annual Report on Progress 2011/12 (2012)
[3] DECC (2010), Feed-in Tariffs. Government's Response to the Summer 2009 Consultation

by bands depending on the capacity of the installation. Once a contract is agreed, the rate is guaranteed for twenty years and increased each year in line with inflation. The current level of subsidy is given in Table 1.

Total installed capacity (kW)	Rate (p/kWh)
0 to 250	15.16
Over 250 to 500	14.02
Over 500	9.24

Table 1: FiT rates for projects accredited before 31st March 2014[4]

In addition to the Feed-in tariff, any surplus electricity sent to the wider distribution network will be purchased by the energy supplier either at a negotiated price, or at a guaranteed minimum export tariff of 4.64p/kWh. The plant operator would also be able to use the energy generated to offset any electricity used locally, which would normally be sold to them at a price well above the level of the export tariff.

Renewable Heat Incentive

The RHI provides financial support for the generation of usable heat in order to reduce UK carbon emissions.[5] It is structured in a similar way to the FiT, providing subsidy per kW of heat produced. Only heat which is used in a purposeful way (including heating the digester) attracts a subsidy. Table 2 gives the current rate of subsidy.

Total installed capacity (kW)	Rate (p/kWh)
0 to 200	7.1

Table 2: RHI rates as of April 2013

The RHI also has a mechanism for incentivising the injection of purified biogas into the natural gas grid. However, the capital costs associated with this process make it inappropriate for small-scale on-farm use and it is not considered further here.

Renewables Obligation

The RO is a requirement on energy suppliers to source a proportion of the electricity they provide from renewable sources, including AD.[6] It operates through the provision of certificates (ROCs) to producers of renewable electricity, which can then be traded. Because the ROCs can be traded, the level of subsidy provided to an AD plant by the RO is not fixed. For the purpose of this paper we will assume that AD plant operators will choose the FiT in preference to the RO.

[4] Ofgem (2013), Feed-in Tariff Payment Rate Table for Non-Photovoltaic Eligible Installations for FIT Year 4 (2013/14)
[5] DECC (2011), Renewable Heat Incentive
[6] Ofgem (2010), Renewables Obligation: Guidance for Generators

Renewable Transport Fuels Obligation

The RTFO is a support mechanism for renewable transport fuels. It is possible to upgrade biogas to be used as a transport fuel. However, this use of biogas is uncommon. It is associated with large fixed costs which make it inappropriate for small-scale farm-based AD plants and the overall level of subsidy is lower than the RHI.[7]

Environmental Permitting and Planning Permission

AD plants accepting waste are regulated by the Environment Agency. Large plants will also require planning permission. Plants which are only processing material sourced from on the farm and are less than 465m^2 in size are eligible for permitted development and do not need to apply for full planning permission. Small on-farm AD plants fall under the T24 environmental permit exemption.[8] The plant operator has to register the exemption but there is no charge for this process. To qualify for the T24 exemption the plant must:

- Digest only crops, slurries and manures
- Have a thermal input to the biogas burner of less than 400kW
- Retain the input material in the digester for at least 28 days
- Have a digester not larger than 1,250m^3

On-farm AD plants which do not meet these criteria may fall within the remit of the Standard AD permit if they:

- Process less than 100 tonnes of material per day
- Process only waste from farm activities

The Standard Permit has various requirements, including that the plant has a means of capturing any spilled or leaked digestate or waste and that its operator is recognised as competent through membership of an approved scheme.[9] It costs £1,600 to make an application for a standard permit, with an additional recurring annual charge of £1,500. If the conditions of the Standard Permit are not met, an application can be made for a bespoke permit.

Digestate produced from slurry is classed as waste, unless the digestate is to be spread on agricultural land or the AD plant has been certified to produce digestate which reaches the PAS110 standard.[10]

Discussion Questions: *Does this accurately represent the policy environment? Are there other significant factors to consider?*

[7] IEE Green Gas Grids, Biomethane Market Matrix Draft Summary Report
[8] Environment Agency (2010), Anaerobic Digestion and Environmental Permitting
[9] Environment Agency (2012), Standard rules SR2012 No 10
[10] Environment Position Statement 29, http://www.environment-agency.gov.uk/static/documents/Research/PS_029_AD_of_agricultural_manures_and_slurry_final.pdf

Existing Deployment

Anaerobic digestion plants processing agricultural and other wastes can be found in most European countries. There is a considerable variability in systems and uptake.

UK

Number of non-sewage AD plants	Average generation capacity	Total capacity	Main feedstock
102[11] (57 processing farm wastes)	850 kWel (730 kWel for farm waste processors)	88,500 kWel (electricity demand of 230,000 UK households, equal to 0.8% of all UK households[12])	Food waste, maize and grass silage, slurry, manure

The British system is characterised by the use of food waste in AD. There are also a considerable number of on-farm plants, representing 40% of all non-sewage plants.

There are 24 on-farm AD plants which mostly use a combination of crops and slurries in roughly equal weight. These are medium sized plants with an average generation capacity of 340 kWel. We estimate that these plants feed roughly 140 kt of crops into their digesters. To grow this amount of crops, roughly 3,300 ha of arable land is needed. This represents 0.05% of arable land in the UK.

There are some small scale AD plants solely using slurry and manure, mainly providing heat to the farmer. The last of these plants was built in 2006, before the introduction of FiT and under a different regulatory regime. There are also six crop only AD plants, requiring crops grown on roughly 3,300 ha. These plants mostly accept maize grown on contracted land.

DECC assume a growth in AD capacity of around 20MW per year.[13] This would take total AD capacity to 70MW by 2015. Previous Defra research estimated that the potential generation could be as high as 550 MW.[14] This would make use of farm and food waste and crops. The analysis suggests that if only farm waste is used then this potential drops to 206 MW.

Germany

Number of non-sewage AD plants	Average generation capacity	Total capacity	Main feedstock
7,600	420 kWel	3.2 MWel (electricity demand of 5,200,000 German households, equal to 13% of all German households)	Maize silage, slurry and manure

[11] Based on AD plants on the 'Official biogas plant map', http://biogas-info.co.uk/maps/index2.htm
[12] Based on Ofgem (2011) Typical domestic energy consumption. Available at: http://www.ofgem.gov.uk/Media/FactSheets/Documents1/domestic%20energy%20consump%20fig%20FS.pdf
[13] DECC (2012), FiT Comprehensive Review Phase 2B, consultation response impact assessment
[14] Defra project code AC0409. Report published as AEA/ADAS (2011) Implementation of anaerobic digestion in England and Wales balancing outputs with minimal environmental impacts.

Until recently, the German system was dominated by the use of crops as feedstock. The amount of food waste entering AD plants is relatively small, representing only 7% of the total feedstock weight.

Most on-farm plants have high crop incorporation rates, and all AD plants together use more crops than slurry. In 2012 the German agency (Fachschaft Nachwachsende Rohstoffe - FNR) responsible for the promotion of renewable energy generation estimated that roughly 800,000 ha of maize were grown specifically as an energy crop.[15] This is 6.8 % of all arable land in Germany.

Grants for the construction of AD plants have been available in the past, but recently subsidy has only been available through the German FiT structure. This was revised in 2012 following concerns about the need to import animal feed and nitrate pollution associated with the cultivation of crops being grown to feed the plants. The FiT structure is complex and incentivises the use of different feedstocks for different bonus payments and operators must record feedstock use. There is also a minimum heat utilisation rate of 35%, in addition to digester heating.

AD plants with less than 500 kWel attract a base rate of 14.3ct/kWh. A bonus of 6 ct/kWh is paid for electricity produced from maize and a bonus of 8 ct/kWh is paid for electricity produced from slurry. The tariff is then calculated based on the energy contribution of the respective feedstock. For example, a plant using 30% maize and 70% slurry would attract a final subsidy of 18p/kWh. A specific band exists to encourage the building of small scale AD plants using slurry as the main feedstock. These plants are required to process at least 80 % slurry and to be smaller than 75 kWel. They are paid 22p/kWh.

During 2013, the FNR estimates that the number of AD plants will grow by almost four percent to 7,900. These installations will have a total generation capacity of 3.4GW.

Denmark

Number of non-sewage AD plants	Avg. generation capacity	Total capacity	Main feedstock
81 (21 centralised, 60 on farm)	2,300 kWel	138,500 kWel (electricity demand of 239,000 Danish households, equal to 11 % of all Danish households)	Slurries, manures, slaughtering wastes, glycerol

The Danish system is well known for its large centralised AD (CAD) plants and on-farm plants.

None of the AD plants used crops, but incorporate other waste streams from abattoirs, fish processors, as well as sewage sludge and household waste. In

[15] See http://mediathek.fnr.de/grafiken/pressegrafiken/maisanbau-in-deutschland.html

aggregate the feedstock of AD plants consist to roughly 80% of slurries and 20% other organic wastes.

The Danish AD system has two notable features. First, the nature of CAD plants which are jointly owned and run by farmers. Second, the widespread use of district heating systems in Denmark, which facilitate the use of heat and present operators with an additional revenue stream.

The Danish incentive system has used a mixture of grant and FiT and all existing AD plants were built when grants were available. Denmark increased its FiT in March 2012 to 41.4 ore/kWh (roughly 4.8 p/kWh), which is very low compared to the UK and Germany.

Denmark has an ambitious policy goal of using 50 % of all Danish slurry in AD plants (currently only 6 % is used), which would require 40-50 new large biogas plants. This would also increase the amount of electricity supplied tenfold, to 1.4MW, covering not only the electricity demand of households, but also parts of industry.

***Discussion Questions**: Does this section accurately summarise the situation in Denmark, Germany and particularly the UK? Do we need to look at any other country example?*

Advantages of Anaerobic Digestion

An AD plant provides benefits to the owner of the plant, but also to society as a whole. The benefits accruing to the business should be taken into account in the decision to build the plant, but those accruing to society need not be.

Business Benefits

The major benefits to the farmer are that AD plants enable them to efficiently manage their slurry whilst also opening up a new income stream. The income is generated by selling electricity.[16] The current Feed-In Tariff regime guarantees a price per kWh for 20 years. As long as the AD plant is operating properly the farmer has a very low variability of the income stream. This can therefore be a good complement to the core farm business which may exhibit greater income fluctuations. The existence of the AD plant also effectively increases the income generated from the farmer's cattle.

Electricity produced and consumed on farm is not only rewarded by FITs but also lowers the farmer's electricity bill. Even if small scale electricity production is not

[16] See amongst others The Andersons Centre(2010) A Detailed Economic Assesment of Anaerobic Digestion Technology and Its Suitability to UK Farming and Waste Systems or Royal Agricultural Society of England (2011) A Review of Anaerobic digestion Plants on UK Farms - Barriers, Benefits and Case Studies

viable, the biogas can be used to heat the farm house, dairying and livestock buildings, lowering spending on fossil fuels.[17]

Farmers report qualitative improvements to their slurry management processes. Digestate has a lower dry matter content as slurry, which makes it easier to pump. Furthermore, the nutrient content of digestate is more homogenous compared to slurry, which makes it easier to incorporate in nutrient management plans.

Digesting slurry also increases the farmer's flexibility in their spreading decisions. During digestion chemical compounds responsible for odour are in part broken down and it is expected that spreading digestate sparks fewer smell complaints.[18] There is also anecdotal evidence that cattle can be brought earlier on to treated pastures.[19]

The digestion process also kills many pathogens and weeds.[20] Research funded by the Scottish Government[21] reports that thermophilic digesters or digesters with a pasteurisation stage are very effective in reducing pathogens. The lower temperatures in mesophilic digesters demand longer retention times to reach similar outcomes to thermophilic digesters.

An often cited benefit is the higher nutritional value of digestate compared to slurry. The nitrogen content of digestate does not change, but its availability to crops is increased. The Andersons Centre claims that the proportion of available nitrogen increases from 35% in slurry to 60% in digestate.[22] WRAP points out that the use of a band spreader is necessary to make use of the higher nitrogen availability.[23] This could be particularly relevant for farmers in nitrate vulnerable zones (NVZs), where fertiliser application is bound by the nitrogen content of the fertiliser and increased nitrogen availability could lead to increased grass yields.[24]

Discussion Questions*: Are there other benefits to the farm business which we should consider? Are there any quantified or scientifically robust examples we can draw on for the non-financial benefits?*

Wider benefits to society

AD decreases a range of emissions, which helps to decrease the costs which pollution from agriculture imposes on society.

[17] See amongst others The Andersons Centre, 2010 or Royal Agricultural Society of England, 2011
[18] The Andersons Centre (2010, p.9)
[19] Royal Agricultural Society of England (2011)
[20] The Andersons Centre (2010, p.9).
[21] Anon (2003) Anaerobic digestion, storage, oligolysis, lime, heat and aerobic treatment of livestock manures
[22] The Andersons Centre (2010), p49
[23] WRAP (2012) Using quality anaerobic digestion to benefit crops
[24] There is anecdotal evidence described in Royal Agricultural Society of England (2011)

Methane (CH_4) and nitrous oxide (N_2O) are potent greenhouse gases (GHG). AD plants produce a direct and indirect reduction in the emission of both gases.[25] The direct reduction is mainly due to preventing CH_4 from venting into air from slurry storage. This is counteracted by slightly higher N_2O emissions from the application of digestate[26], but it is likely that the reductions in CH_4 outweigh the increase in N_2O. The indirect reduction is from offsetting fossil fuels used in generating electricity and heat.

Ammonia has adverse effects on human health. AD plants prevent ammonia from venting into air from slurry stores but ammonia is released when the digestate is spread onto fields. International evidence shows increased ammonia emissions from digestate application, compared to slurry application, but this evidence is not directly applicable to the UK because of different soil and climatic conditions. Research project WR1212[27] is currently underway to estimate an ammonia emission factor for the UK, though current published estimates based on the Manner NPK model suggest that there is no significant increase in ammonia emissions from spreading digestate rather than slurry.

Leaching of nitrates into watercourses causes damage to water quality through eutrophication. A reduction in nitrate leaching could be attained by effectively using digestate instead of synthetic fertiliser.[28]

Electricity produced from AD can reduce the need to build other electricity generation capacity. Society benefits from this as new power plants would take up resources for construction, and may generate more air pollution than an AD plant.

With the economy in recession, creation of jobs is also valued as a positive contribution to society. For AD plants, the effect on job creation is ambiguous as on farm plants only require little work time and will likely not create new jobs. It is also unclear if the job creation along the supply chain exceeds the job creation of an alternative investment. Furthermore, depending on the country of production this increase could take place either in the UK or abroad.

***Discussion Questions**: What other wider benefits to society are there? What evidence is there to support the benefits listed?*

Barriers to Deployment

Using anaerobic digestion to process farm wastes creates benefits beyond just those which accrue to the owner of the AD plant. These benefits are not part of the business decision to build a plant so lead to fewer AD plants than is optimal for

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[25] See amongst others The Andersons Centre (2010) and Royal Agricultural Society of England (2011)
[26] See Manner NPK, available at: http://www.planet4farmers.co.uk/Manner
[27] co funded by Defra, Wrap and Zero Waste Scotland
[28] See Defra research project CC0240

society. The government is committed to seeing a significant expansion of waste-based AD plants. The AD Strategy and Action Plan forecast a potential capacity of 3-5TWh by 2020 from all AD plants. There is currently capacity to generate about 1.5 TWh. This section considers the barriers which are preventing the significant deployment of the technology at the farm scale.

Financial Barriers

The decision to build, maintain and run AD plants is largely a private one, based on the expected profitability of the plant. This section examines the financial barriers to building an AD plant. In the past, some plants have been built when capital grants have been available and this is particularly apparent for Danish AD plants. More recently, the government's FiT and RHI programmes of subsidies based on payments for electricity and heat have provided significant additional financial income for plant owners. Table 3 gives a list of barriers which affect the profitability of an AD plant. For any given potential plant, any one of the barriers listed might be the deciding factor but the table attempts to identify those barriers which are likely to be most important overall.

Item	Barrier	Importance
f1	Electricity grid connection. Cost increases with plant size and varies considerably, depending on local circumstances	High (n/a if heat-only)
f2	Cost of digester and associated equipment	High
f3	Cost of CHP	High (n/a if heat-only)
f4	FiT degression & associated capacity caps DECC plans to reduce the FiT rates for all AD plants to take into account expected reductions in the cost of AD and other renewable energy sources.	High
f5	No RHI above 200kW	Low Limited available use for heat even if it would attract RHI
f6	Unvalued methane abatement	Low Limited relevance to pure financial viability
f7	Lack of market for digestate Digestate currently has no financial value, despite its potential use as a fertiliser.	Low For on-farm AD it's reasonable to assume land is available to accept the digestate instead of slurry.
f8	Eligibility of digester heating for RHI This use of the AD heat output does not currently attract RHI subsidy.	Low DECC is already planning to address this

Table 3: Financial barriers to deployment of farm-scale AD

***Discussion Questions**: Is this a comprehensive list of the financial obstacles? Are the relative importance ratings appropriate?*

Modelling of Profitability

In order to establish the relative importance of the factors listed in Table 3 in the profitability of a typical small-scale AD plant, we are constructing a financial model of such a plant. The model will provide sensitivity analysis to show how the viability of the plant changes as different costs are varied. The modelling of the benefits of the plant only includes income from the various financial incentives and any offset energy use.

The model is based on a small farm with 120 dairy cows (plus followers) and 66 ha of land. In the baseline scenario, slurry is collected during the six months the cows are kept indoors. This is compared with four scenarios, in which the farmer installs an AD plant:

1. **Slurry only AD:** AD plant is fed only on slurry. The biogas is either used to run a boiler (15kWth) or a CHP unit (6kWel / 9kWth). The AD operation generates revenues in form of RHI, FITs and helps the farmer to avoid costs of fossil fuels and electricity.
2. **Mixed feedstock AD:** AD plant uses additional crops (30 % of feedstock) to increase the biogas yield. The dairy cows are kept outdoors only for the dry period which frees land to grow maize as an energy crop. The biogas is used to run a CHP unit (59kWel / 96kWth). The AD operation attracts RHI, FITs and avoids costs in fossil fuels, electricity and fertiliser.
3. **Crop only AD:** The farmer abandons the dairy herd and only maintains a small beef herd. The freed land (60ha) is used to grow maize, which is the sole feedstock of the AD plant. The biogas is used to run a CHP unit (130kWel/214kWth). FITs is the main contributor to the income stream, but the AD plant also enables some fossil fuel, electricity and fertiliser savings.
4. **Centralised AD:** Five neighbouring dairy farmers build a common AD plant. The plant operates on 50 % slurry and 50 % maize. The slurry is sourced from the existing farm dairy herds and the maize is bought in. The slurry and digestate is transported by road between the farms and AD plant. The biogas is used to run a CHP unit (481kWel / 428kWth).

The assumptions underlying the model are listed in the annex to this paper. The methodology does not attempt a full life-cycle analysis (LCA) of the environmental effects of the AD systems, though it should provide a way to cross-check some components of the current Defra research project underway which will undertake an LCA of different AD systems. We hope to use information from the AD Roundtable event on the 29th April 2013 to inform the development of the model and have final outputs from it by the end of May 2013.

***Discussion Questions**: Are the assumptions in the annex appropriate and reasonable? Are there other sources of information we can draw on to inform the modelling process?*

Non-Financial Barriers

There are a number of non-financial barriers to the deployment of AD and these are presented in Table 4, following the same format as Table 3.

Item	Barrier	Importance
n1	Availability of land for spreading digestate In the absence of a market to accept digestate, plant operators must find appropriate land on which to spread the digestate.	Low For on-farm AD it's reasonable to assume land is available to accept the digestate
n2	Access to finance If a potential AD plant is expected to be profitable then it ought to be able to attract debt or equity investment. However, potential investors may be put off by the relative novelty of the technology.	High Unless working capital is available some source of finance is vital
n3	Planning permission Larger AD plants require planning permission and may be subject to local opposition or delays by planning system	Low Many plants fall within permitted development rules and there is a significant pipeline of AD plants with planning permission already received
n4	Lack of uses for heat output A key output of the AD process is heat but it is often difficult to find a suitable use for that heat	Medium Ability to utilise heat attracts RHI which can transform the financial viability of the plant
n5	Environmental permitting The environmental permitting regime has various different requirements which can have varying impact on the viability of an AD project.	Low Risk-based exemptions and standard permits already exist
n6	Availability of off-farm feedstock (waste and crops) Feedstock source from off the farm may either present permitting problems if it's a waste, or be expensive otherwise	Medium Only relevant for some plants
n7	Complexity and associated risks with the technology Examples of existing plant failures might make potential operators and investors reluctant to proceed	Low Plants will have insurance against catastrophic risks & principles not too dissimilar to standard slurry storage issues

Table 4: Non-financial barriers to deployment of farm-scale AD

Discussion Questions*: Is this a comprehensive list of the non-financial obstacles? Are the relative importance ratings appropriate?*

Conclusion

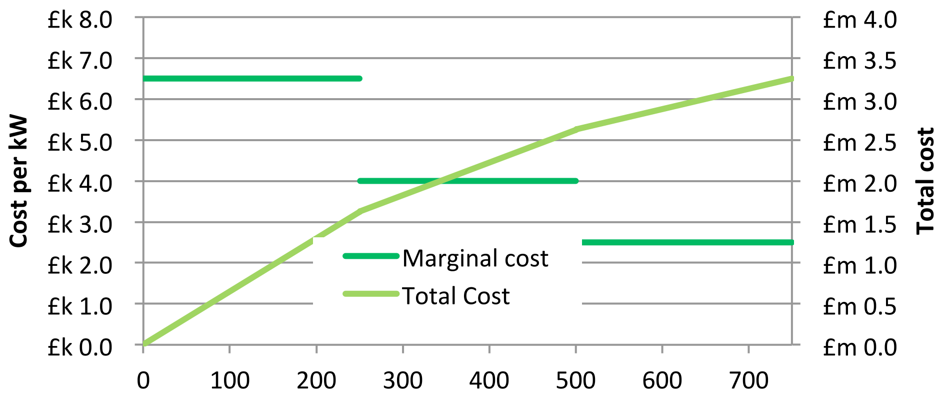
The number of AD plants in the UK is significantly below the technical scope for such plants. This is true for large-scale plants, as illustrated by the comparison with Germany and Denmark. It is also true for very small-scale on-farm plants. Only a few plants like this are operational and none have been built in recent years. It is clear that there are significant barriers to the deployment of on-farm AD plants. A key barrier is the cost associated with the plants and further work to model the profitability of such plants will give more information on exactly where the sensitivities lie.

Annex: Modelling assumptions

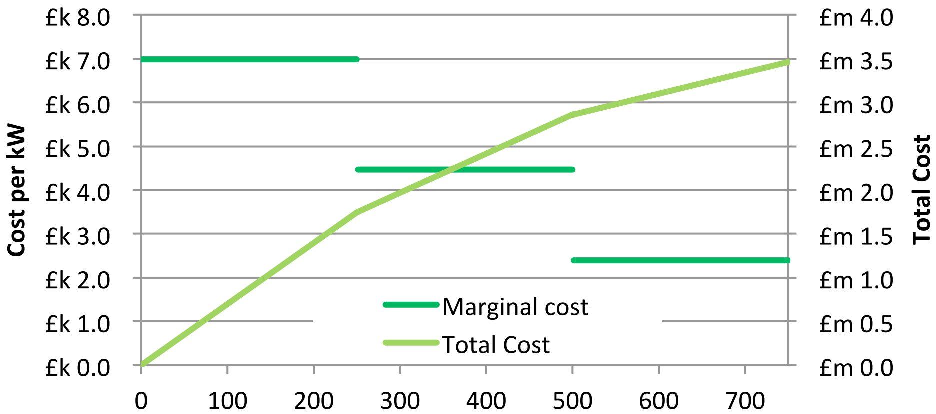
Capital costs

There is little robust information on capital costs available and in addition those costs that do exist vary substantially. The modelling therefore takes the approach of using the rule of thumb cost estimates from various AD research projects and deriving cost functions with decreasing unit costs. The charts below give an overview of the different cost estimates.

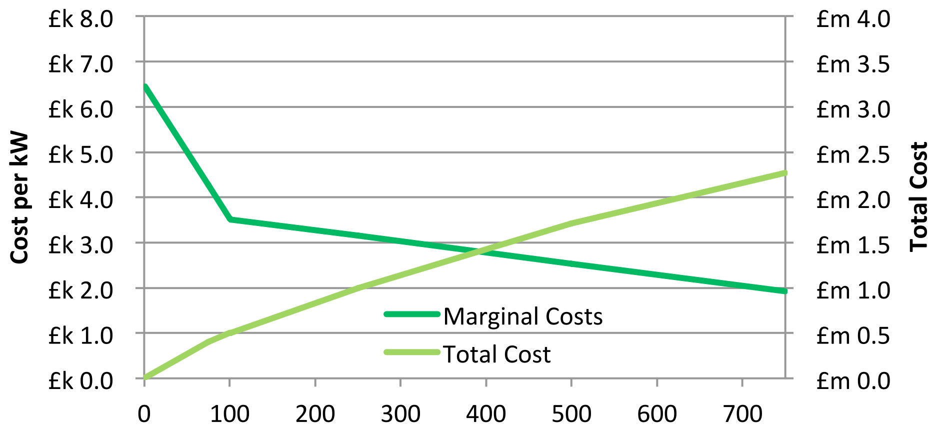
NNFCC (based on electric generation capacity) Rule of thumb: 2,500 to 6,500 £/kWel



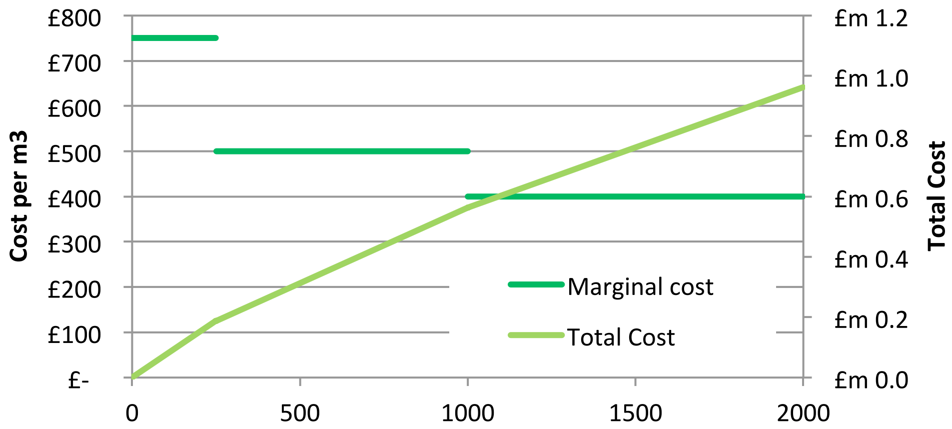
ARUP (based on electric generation capacity) Rule of thumb: 2,396 to 6,985 £/kWel



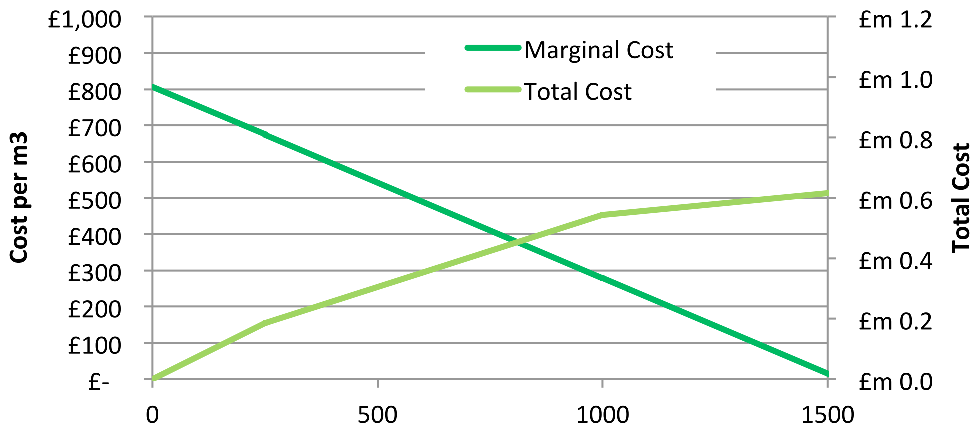
FNR (based on electric generation capacity)



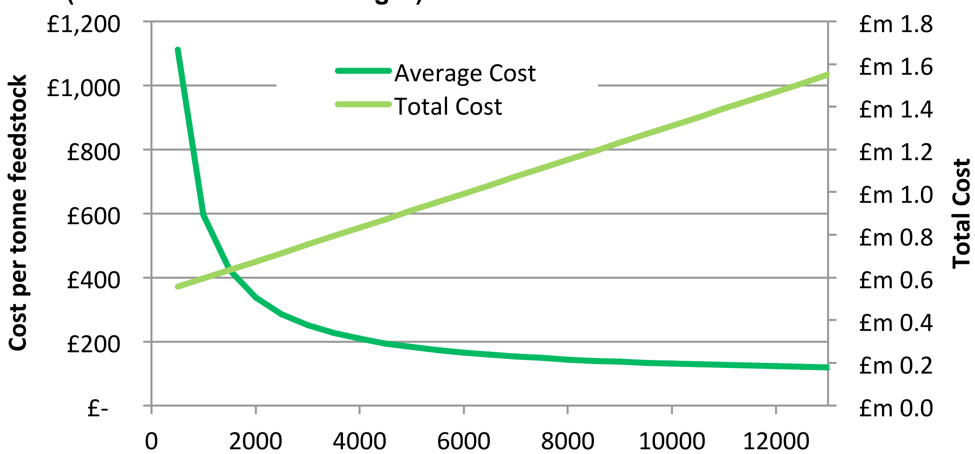
NNFCC (based on digester size) Rule of thumb: 400 to 750 £/m³



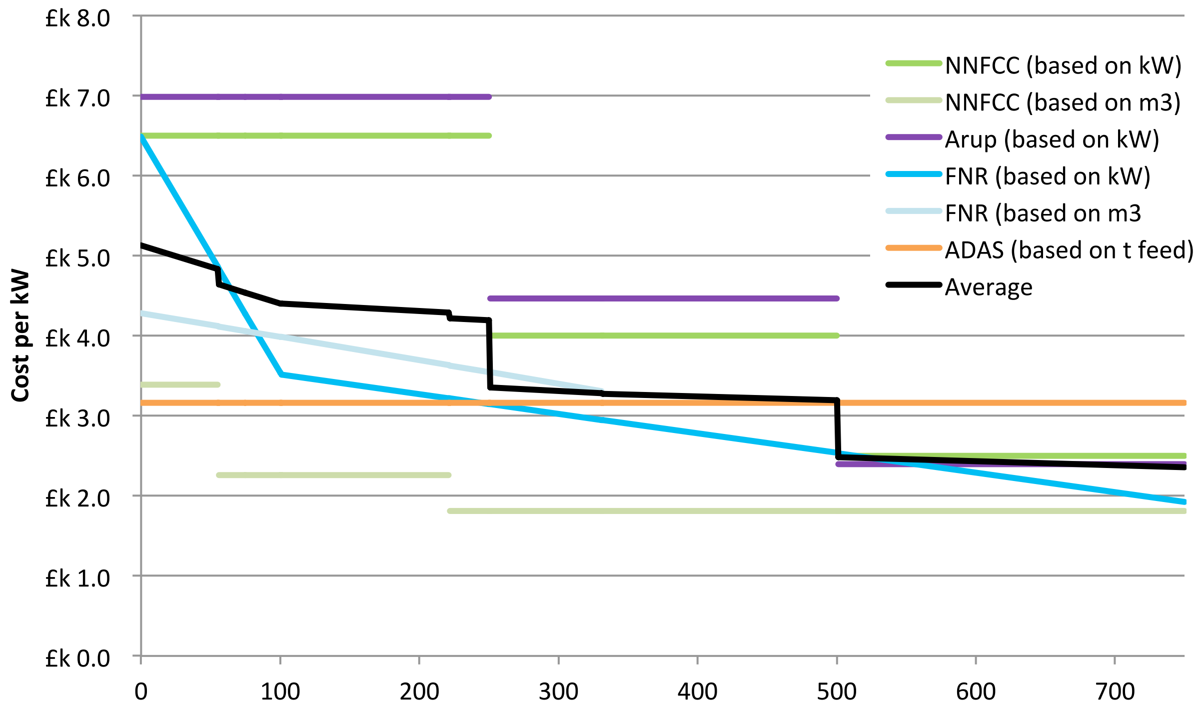
FNR (based on digester size)

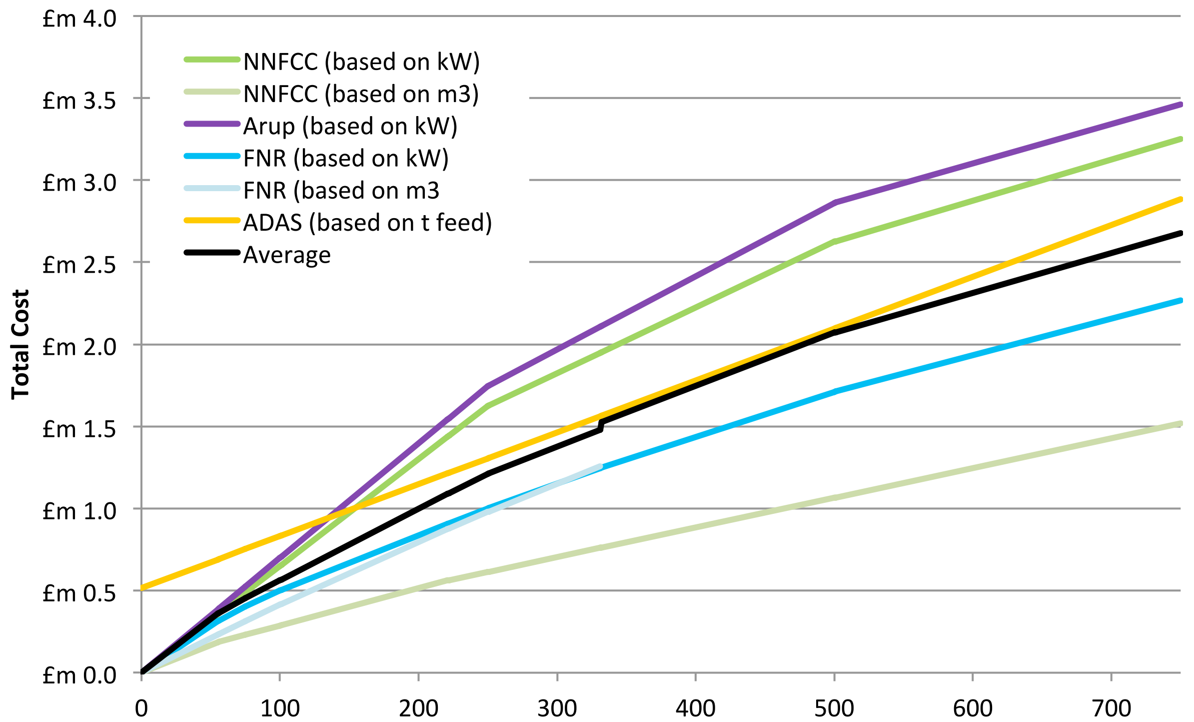


ADAS (based on feedstock weight)



The capital costs are then estimated as the average of all methods (for AD plants with CHP) or as the average of NNFCC (digester only) and FNR (digester only) for AD plants operating only a boiler. For ease of comparison, the following chart compares all marginal costs based on a digester feeding 30 % maize and 70 % dairy cow slurry. Note that FNR (based on m3) can only be used up to 1500 m^3 and breaks up accordingly.





Operational costs

Similar to the capital cost, estimates of operational cost vary greatly and we use rule of thumb estimate for this work. The assumptions on operational costs are as follows:

CHP		
Lifetime	10 years	
Uptime	8000 hrs/year	
Maintenance costs	1 p/kWh	Andersons Centre (2011)
Maximum efficiency of CHP (el + th)	80 %	Andersons Centre (2011)
Digester		
Maintenance (annual)	3 % of digester capital costs	Andersons Centre (2011)
Insurance (annual)	1 % of total capital costs	Andersons Centre (2011)
Parasitic heat	6% of digester heat	
Parasitic electricity	6 kWh/tonne of feedstock	
Fugitive emissions	2.5 % of total biogas	
Flare Efficiency	90 % of burnt biogas	
Labour requirement		
Full time equivalent	Slurry only: 0.125 Mixed feedstock: .25 Crop only: 1 Community AD: 2	
Annual Wage	£ 22,173 + £6,652(overhead) = £28825	ONS (2012) Annual Survey of Hours and Earnings, Median income occupational group 8 (Process, plant and machine operatives)
Other		
Price for Maize	£25/tonne	
Price for digestate	£0/tonne	
Transport of Digestate/Slurry (Community AD only)		
Transport costs	£3/tonne	AC0409, p.26
Size of lorry	20 tonnes	AC0409, p.15
Average travelling distance	4 km	
Average fuel consumption	9.7 miles per gallon (29 l/100km)	DfT (2011) Avg. fuel consumption of HGV

Financing cost

		Range for sensitivity analysis	
		Minimum	Maximum
Debt share	60%	0%	80%
Interest rate	6%	4%	12%
Payback time for digester loan	20 yrs		
Payback time for CHP loan	10 yrs		