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Outline Feasibility of Centralised Anaerobic Digestion Plants linked to Dairy Supply Chain

Report to

Dairy UK
Institute of Grassland and Environmental Research
Department for Environment Food and Rural Affairs

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Executive summary

Dairy UK and AEA Energy & Environment have undertaken a high level assessment of the feasibility of centralised anaerobic digestion (CAD) in the dairy processing sector. This was based on the identification of 10 potential sites that could host centralised anaerobic digestion plants. The work comprised technical, economic and environmental assessments.

This work has confirmed our previous findings that centralised anaerobic digestion plants, based at or close to industrial dairy sites, have the potential to be economically attractive, as several positive factors would combine in their favour, with payback periods as low as 3 years. This is because they can be designed to co-treat organic wastes from industrial dairy sites along with animal wastes from nearby livestock farms and other food manufacturing wastes. As the cost of landfilling will continue to rise due to the Landfill tax, producers of industrial food waste will increasingly need outlets such as AD plants. Inclusion of these will help to increase the viability of the CAD by providing a diverse feedstock and by providing an additional income stream to the plant operator.

The successful exploitation of CAD depends on gaining the full economic benefit of the outputs combined with full exploitation of ancillary benefits. Generation and utilisation of biogas is one of the key benefits of adopting anaerobic digestion process for treating biodegradable wastes. The Government already provides incentives that contribute to improving the economics of biogas utilisation, through the Renewable Obligation, Climate Change Levy (CCL) exemption and Enhanced Capital Allowance. There is potential for additional energy income from the sale of heat generated from the combined heat and power (CHP) scheme, but this would depend on the development of infrastructure to deliver the heat to where it is needed within a few hundred meters. Assessment of land use around the 10 identified potential CAD sites showed that there would be sufficient area to return digestate to land within a 7.5 km radius.

The CAD schemes can provide the industrial dairies with several environmental benefits that will also help them to consolidate or secure new market outlets. For instance, a significant proportion of their carbon footprint could be reduced –which will help those dairies to link up favourably with C-labelling schemes which are being planned by retail chains and the Carbon Trust.

For Dairy UK this would be a pioneering way forward to take steps along the way to deliver the first few CAD plants identified in this study. Some suggestions are made for Dairy UK to develop and implement the projects, including:

- Undertaking detailed feasibility evaluation for each of the sites – by taking into account other food wastes (e.g. from breweries, fruit processing and packaging etc) from the locality, to prepare a business case.

- Engaging with AD plant suppliers as well as water companies and waste management contractors to understand how they would compete for the supply of AD services (i.e. towards build, own and operation).

The UK Government should consider supporting the initial CAD projects to reduce the perceived financial risks, associated with the lack of supply chains, infrastructure and confidence in the technology.

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1 Introduction

1.1 General

Anaerobic digestion (AD) is an effective means of treating the organic sludge arising from on-site treatment of wastewaters at industrial dairy sites. It also increases the disposal options for this material by introducing the option of turning this waste into a feedstock for renewable energy generation. However, AD of dairy waste alone suffers from high acid concentration leading to AD process inhibition among other operational problems, which can require high capital and operating costs to overcome them. This has hitherto led to AD proving uneconomic in many dairy applications. This situation can be improved by moving towards a larger AD plant that can be designed to co-treat wastes from other parts of the dairy supply chain and potentially other food chains as well. This is because using mixed wastes overcomes many of the technical problems and enables larger plant to be constructed, with a higher specific efficiency.

This report has been prepared by Dairy UK and AEA Energy & Environment on the feasibility of establishing centralised anaerobic digestion (CAD) plants where organic wastes from industrial dairy sites could form an integral part of the plant feedstock along with animal wastes from nearby livestock farms.

This report comprises five sections, as outlined below:

Section 1 deals with background, aims, objectives and approach of this high level assessment of potential CAD schemes.

Section 2 deals with the scope and assessment of CAD plants and deals with the two key issues of digestate and biogas use.

Section 3 outlines the techno-economic assessment of the 10 CAD plants.

Section 4 discusses the role of specific partners in taking the CAD plants further, and

Section 5 outlines principal conclusions and suggests a pathway for the development of CAD projects.

1.2 Background

The Defra study AC0402, 'Assessment of methane management and recovery options for livestock wastes' concluded that on-farm digestion of these wastes is currently uneconomic, largely due to the lack of any economic drivers for the treatment of animal wastes. However, this report concluded that a small number of large CAD plants may be economic if the feedstock included 17% or more of gate-fee generating industrial waste, based on £48 per tonne as gate fee. The main challenges of the CAD model were primarily economic and the uncertainty of the equipment and maintenance supply chain and market for products. In particular, to return the digestate to land and productive use of heat are a challenge. Clearly, this past work identifies that the successful exploitation of CAD depends on gaining the full economic benefit of all the products from the process, including the heat and electricity outputs combined with full exploitation of ancillary benefits.

This project was based on the examination of circumstances around selected dairy operations, where these situations would apply. The particular features of these sites were a ready demand for electricity and heat and a close proximity to farms with adequate quantities of livestock slurry and manure. In undertaking this study we have been working with Dairy UK, which represents over 90% of the UK dairy industry including all of the major industry players. Their members control some 125 sites, 60 of which are large sites that produce organic sludge (containing between 3% and 25% DM) from on-site effluent treatment processes that is disposed of off-site. The cost of this waste management on these sites can vary from £25 to £50 per tonne, with disposal cost trends rising.

At the same time, these dairy companies are facing increases in energy costs for both heat and electricity and pressures from retailers to reduce carbon footprint of their products. This is causing industrial dairy companies to look for new cost effective waste disposal pathways and at the same time look at the supply of electricity and heat to their site in terms of cost, but also the carbon emissions associated with generation.

Centralised AD plants co-located at or nearby dairy sites would offer all of these benefits, with the major additional benefit of the electricity being renewable, providing a major reduction to the carbon footprint of the business when the market is demanding such an approach. Such a synergy offers additional benefits, which include reduced transport costs associated with waste sludge disposal and concomitant reductions in carbon emissions relative to the current situation. There are also wider benefits at the farm level, related to nutrient management and storage requirements.

1.3 Aims and Objectives

The prime aim of this task was to undertake a high level assessment of the feasibility of CAD in the dairy processing sector and to outline an optimum development pathway for up to five sites.

The specific objectives of the task were:

1. To identify geographical areas with a combination of large concentrations of livestock and industrial dairy sites and to identify five potential CAD sites in the UK.

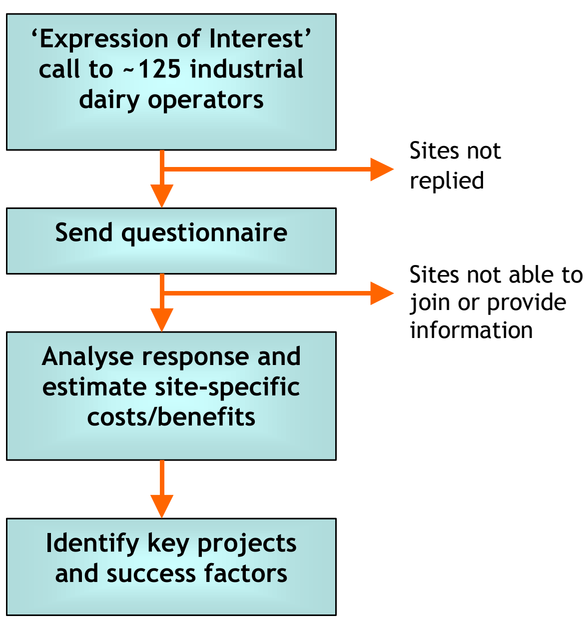
2. To assess the benefits offered by each of the CAD locations and evaluate the likely opportunities based on economic and environmental benefits from the CAD schemes.

3. To outline the development pathway for up to five CAD plants.

1.4 Approach & Methodology

The steps involved in this high-level assessment are illustrated in Figure 1-1. Dairy UK has been instrumental in providing direct access to data and insight into the sector to inform this feasibility study.

Figure 1-1 Schematic showing the key steps of the work programme



The initial request to join this project was sent to operators of some 125 industrial dairy processing sites. From these around 15 site operators who had expressed provisional interest were sent a simple questionnaire to complete. 10 sites provided preliminary information through this route to aid the analysis presented in this report.

Figure 1-2 Location of current industrial dairy sites

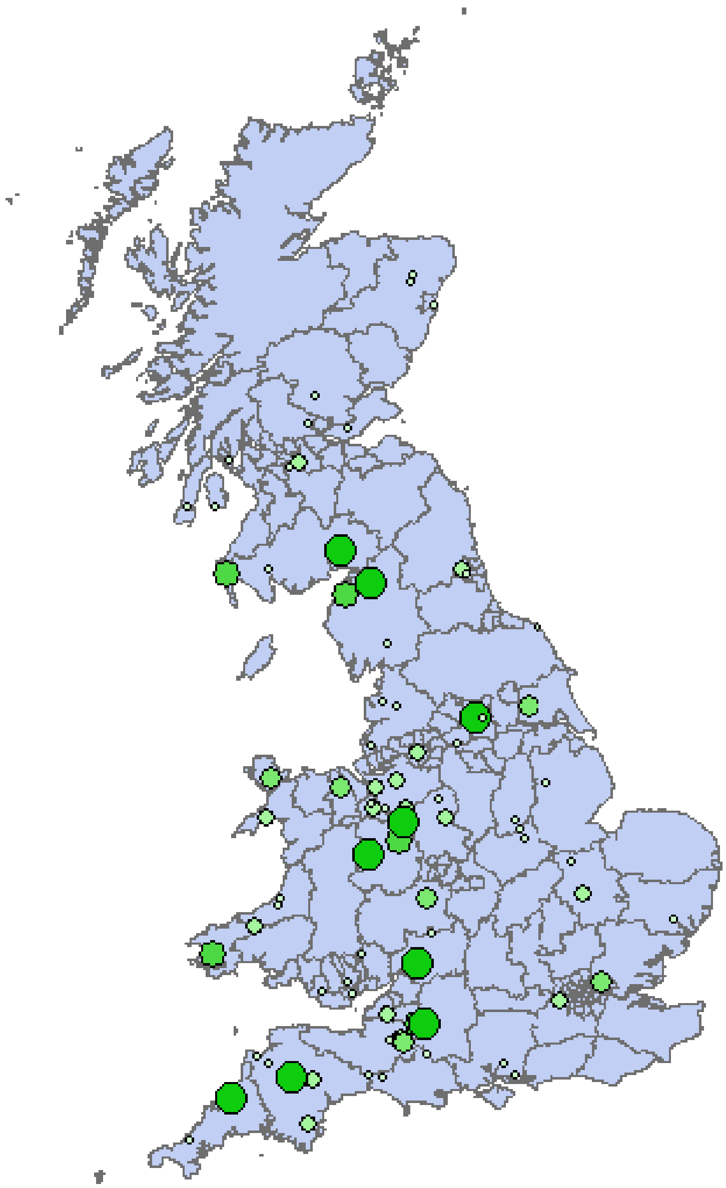
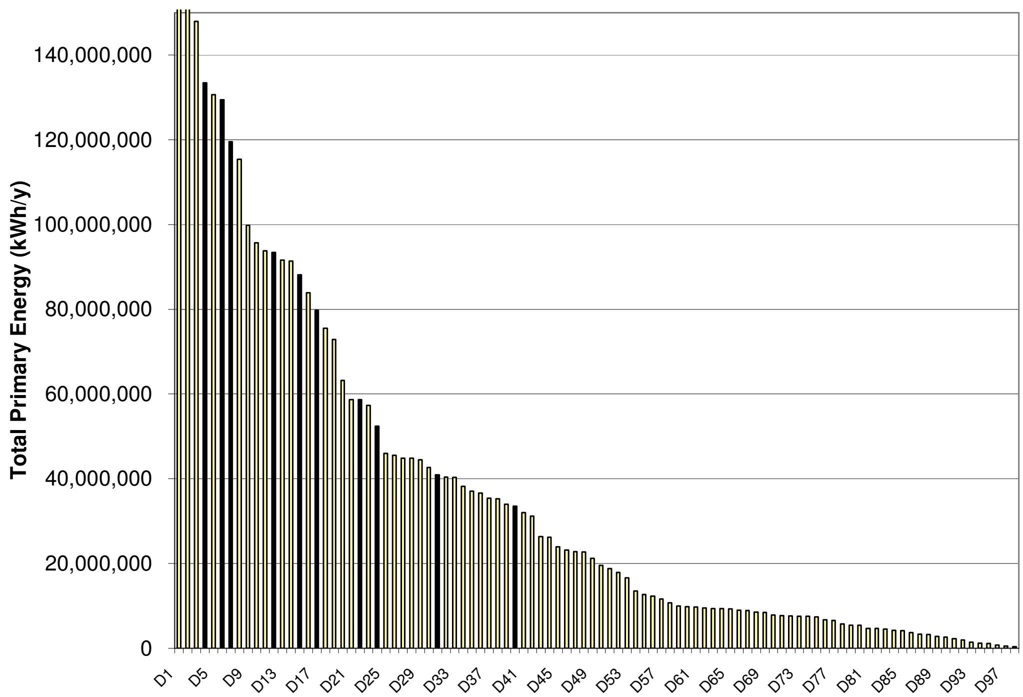


Figure 1-2shows the location of current industrial dairy sites, scaled according to their primary energy use. Figure 1-3 ranks these sites according to energy demand, showing in black the 10 sites from which specific information was received. It should be noted that data for some of the sites were received in aggregated form.

Figure 1-3 Total primary energy consumption by industrial dairy sites[1]



The 10 selected sites were renumbered (from 1 to 10) for ease of reference and to keep anonymous the sites' identification. Dairy UK has informed the relevant companies the site number associated with the CAD plant associated with their operation.

The overall analysis comprised technical, economic and environmental assessment of CAD schemes based on the 10 sites, as outlined in Sections 2-4. The steps included: estimation of waste feedstock composition[2], undertaking key material and energy balance based on these arisings data, estimation of the size and cost of key capital items and estimating operating costs and incomes associated with each of the potential CAD schemes. The overall economics, in terms of internal rate of return and payback time, as well as other parameters are further discussed.

[1] Data of some of the sites were plotted, as received, in aggregated form. The bars highlighted in black represent the 10 sites for which the scope for CAD has been explored in this study.
[2] By considering the sludge produced by treating the site's own wastewater and livestock wastes in the area.

2 Assessment of CAD plants

When considering the feasibility of CAD plants, a key element that is often overlooked or excluded is the use of heat from any combined heat and power (CHP) scheme based on biogas. Obtaining heat from such a renewable source is a valuable means of reducing the carbon footprint of industrial processes, including dairy processing operations. This is of particular value if the site is impacted by the EU Emissions Trading Scheme (ETS) or the newly proposed Energy Performance Commitment (EPC), both of which are 'cap and trade' schemes based on a carbon allocation with trading to buy carbon credits if the cap is exceeded, or the sale of carbon credits if the cap not reached.

The approach taken in this study ensures that the heat use is designed in from the start of the assessment, by considering locations of CAD plants, which are either at or close to the industrial dairy processing operations.

2.1 Waste feedstock

Dairy UK provided data on energy consumption and locations of industrial dairy processing sites. These have been used to assess the livestock concentrations in the locality of the 10 sites and estimate the potential livestock waste that could be made available. Statistical data relating to livestock numbers and potential wastes were used (same as those used in Defra study AC0402 'Assessment of Methane Management and recovery Options for Livestock Wastes', December 2005) to identify the quantity of wastes that could be co-treated.

Based on the CAD analysis provided in Defra study AC0402[3], the locality was defined as 2.5km radius for dairy cattle and intensive pig rearing; however, for egg layer waste it was 7.5km radius. The greater radius for sourcing layer manure reflects the greater dry matter content and hence greater potential value as a feedstock per tonne of layer manure compared with cattle or pig slurry. However, even if the dairy site is found to be towards one side or corner of the grid (see Figure 2-1 and the site position, denoted by 'D', within the centre grid), it was assumed to be at the centre for the purpose of the calculations.

Figure 2-1 Illustration of the catchments of livestock wastes, in relation to industrial dairy site, marked 'D'

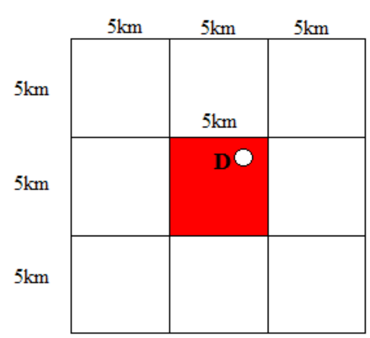


Table 2-1 provides livestock numbers and quantity of wastes associated with the 10 sites being considered, in terms of industrial dairy sludge/waste and livestock wastes.

While this assessment is based on the wastes associated with the dairy supply chain, it is also possible to bring-in other food chain wastes. Inclusion of non-toxic waste will help to increase the viability of the CAD – by providing a diverse feedstock[4] and by providing an additional income stream to the plant operator.

[3] Which used 2004 Census data aggregated into 5km by 5km grids. The 2.5km straight-line distance was assumed to be 3.8km road distance (i.e. 150%) for livestock wastes sourced from within the grid.
[4] This generally helps to ensure a nutrient rich and stable feedstock for anaerobic digestion process.

Table 2-1 Livestock numbers and quantity of wastes associated with the potential CAD sites

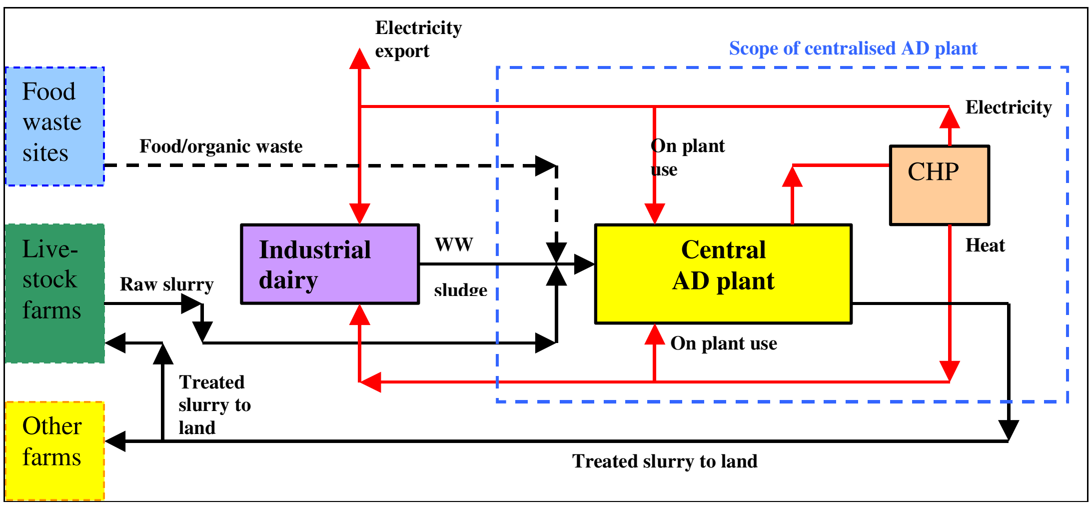
	Unit	CAD1	CAD2	CAD3	CAD4	CAD5	CAD6	CAD7	CAD8	CAD9	CAD10
Dairy cattle (~2.5km radius)	Number	3,138	1,074	208*	7,161	7,161*	2,442	2,442*	208	1,688	4,228
Intensive pigs (~2.5km radius)	Number	1,683	1,803	4,615*	11,170	11,170*	66	66*	4,615	298	8,835
Egg layers (~7.5km radius)	Number	260,869	9,748	24,978*	56,226	56,226*	9,475	9,475*	24,978	57,187	90,263
Industrial dairy – wastewater treatment sludge	kg/d	23,188	29,800#	4,050	1,130#	9,816#	11,927	6,915	475	4,128	3,333
Quantity of waste – cattle	kg/d	166,314	56,927	11,013	379,533	379,533	129,426	129,426	11,013	89,459	224,084
Quantity of waste – pig	kg/d	7,571	8,113	20,768	50,265	50,265	299	299	20,768	1,339	39,758
Quantity of waste - layers	kg/d	30,000	1,121	2,872	6,466	6,466	1,090	1,090	2,872	6,577	10,380
Total waste	**kg/d**	**227,073**	**95,961**	**38,703**	**437,394**	**446,080**	**142,742**	**137,729**	**35,128**	**101,502**	**277,555**

*** Due to lack of data these were estimated by judging dairy cattle population to be similar to another plant but then also taking the same pig and poultry population**
 # Value of wastewater sludge is estimated, by extrapolating from similar plant(s)

2.2 The CAD system

The centralised AD system was defined as illustrated in Figure 2-2. It shows that the CAD plant can co-treat wastes from a variety of food processing sites, alongside that from dairy processors. It generates stabilised waste which is often referred to as digestate and methane rich biogas. The digestate can be re-used back on diary farms as well as other farms in a way that can help to reduce the use of artificial fertilisers; whereas, the biogas can be used in a combined heat and power scheme to generate electricity and heat, both of which can be used on the dairy processing plant.

Figure 2-2 Schematic depicting waste and energy flows within and around centralised AD plant



2.3 Digestate use

2.3.1 More rational use of digestate

Livestock slurry, being predominantly water (*c.* 2-10% dry matter), has a low value-to-weight ratio. Hence there is little incentive to transport it from the farms on which it is produced, and where nutrients may be in surplus, to neighbouring farms where the nutrients could be used more efficiently. However, if slurry from nearby farms is used as a feedstock for a CAD plant it will have to be transported to a central point. Having been digested at the CAD, there is no reason why the digestate would have to be returned to the farm of origin. Instead, it could be sent to farms where it could be used to reduce purchases of mineral fertilizers. This re-allocation of slurry nutrients would:

- have advantages for farm nutrient balances (by transferring nutrients from farms that have a surplus to those that need to apply fertilizers);
- help farms with a high ratio of livestock to land comply with NVZ rules by making it easier to export surplus manures.

2.3.2 Greater consistency

It is often difficult to sample livestock slurries in order to obtain a representative sample for analysis. This is particularly the case with cattle slurry which has a large proportion of fibrous material and is viscous. The difficulty in obtaining representative samples, and hence in obtaining reliable analysis of the nutrient content of slurries, may be a barrier to farmers fully utilizing the crop nutrients available therein. Digestion reduces the dry matter (DM) content of slurry by *c.* 50 % (Chatigny et al., 2004; Pain et al., 1990), hence digestate should be more homogenous and easier to sample than fresh livestock slurries. The potential advantages arising from this are:

- analysis could be done on each batch and the results made available to potential users;
- reliable sampling should improve farmer confidence in the reliability of liquid manures as a source of N.

2.3.3 Pathogen control

Transfer of pathogens to land following manure spreading is an increasing cause for concern. While numbers decrease during storage, the frequent replenishment of stores on farms with fresh, and therefore contaminated excreta, means that average pathogen numbers at spreading are still large. However, the use of discrete batches for AD means that digestate, with greatly reduced numbers of bacteria, may be stored separately prior to land spreading, hence reducing the risk of pathogen transfer to crops. Sung and Santha (2003) reported a decrease in numbers of faecal coliforms and salmonella of between 3 and 8 orders of magnitude following after combined thermo- and mesophilic digestion.

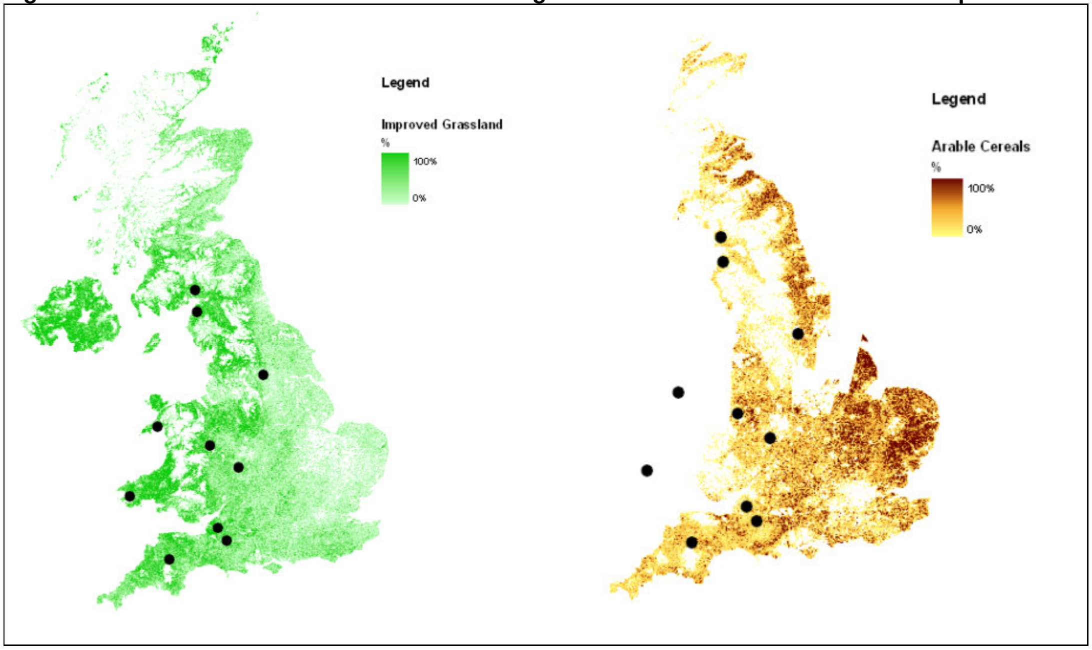
2.3.4 Nutrient Budgeting

Comparison of anaerobically digested slurry (ADS) with conventionally stored slurry (CS) shows the following trends:

- Increased pH of ADS;
- Reduced DM concentration of ADS;
- Increased proportion of N in the form of ammonium-N (NH_4-N), which is readily-available to crops, in ADS;
- Decreased amounts of volatile fatty acids (VFA) in ADS.

These changes in slurry characteristics mean that ADS should be a better source of N for crops and less likely to cause nuisance from unpleasant smells (reduced VFA content) during and after spreading to land. A potential disadvantage is that the greater pH and NH_4-N concentration of ADS increases the potential for emissions of ammonia (NH_3). However, the reduced DM concentration of ADS, and consequent reduction in viscosity, will, by increasing the infiltration rate of the slurry into soil following application to land, tend to decrease emissions of NH_3, and thus at least partially offset the impacts of other changes in slurry composition. Field experiments in which comparative measurements have been made of NH_4-N emissions from CS and ADS reported no significant difference in NH_4-N emissions between ADS and CS (Chatigny et al. 2004; Pain et al., 1990). Field measurements by Pain et al. (1990) also confirmed that odour nuisance was 70-80% less following spreading of ADS than spreading of CS.

Figure 2-3 Grassland and arable land in the UK together with the locations of the 10 CAD plant sites



2.3.5 Potential CAD sites and digestate use

Table 2-2 gives the available agricultural land area and total N in the digestate together with the average N loading to agricultural land in both the 5 x 5 and 15 x 15 km grids surrounding the potential site of the suggested CAD plant. These results are based on the following assumptions.

- Livestock manure would potentially only be available for digestion from dairy cattle, fattening pigs and laying hens within the grid squares. Manures from beef cattle, other types of pigs and poultry and sheep have not been taken into account as excreta from those livestock are typically handled with litter.

- Information on livestock numbers was available to us only for England. For the proposed sites in Wales and Scotland we assumed the livestock numbers were the same as those around potential English sites for which we believe the density of livestock, based on emission maps, will be similar. We accept that such an approach will only give a rough approximation to the actual livestock numbers, but this exercise is meant to be a preliminary one to highlight potential benefits and problems.

- We have assumed all dairy and intensive pigs are housed on systems that handle manure as slurry. This is likely to be an over-estimate but allows us to err on the side of caution and reduces the risk of under-estimating the subsequent N loading to land from application of digestate.

- Estimates of total-N in the manures were taken from NARSES estimates of the N in the manures after being removed from buildings and hard standings (Webb and Misselbrook, 2004).

- Estimates of the N in dairy processing effluent were taken from the report of Bosworth et al.

- The agricultural area to which digestate could be applied was taken to be the area of arable crops and improved grassland within the grid squares. In practice not all this agricultural land will be suitable for spreading the digestate. Organic manures should not be applied to land that is within 50 m of a spring, well or borehole, within 10 m of any watercourse or to land with a slope of > 16°. Liquid manures should not be applied to any part of an SSSI or to land in an ESA or a National Nature Reserve. Defra project ES0128 estimated that *c*. 12% of agricultural land would not be able to accept liquid organic manures because of those exclusions. Assuming that proportion applies to the land around the potential CAD sites the available area should still be adequate to accept the digestate.

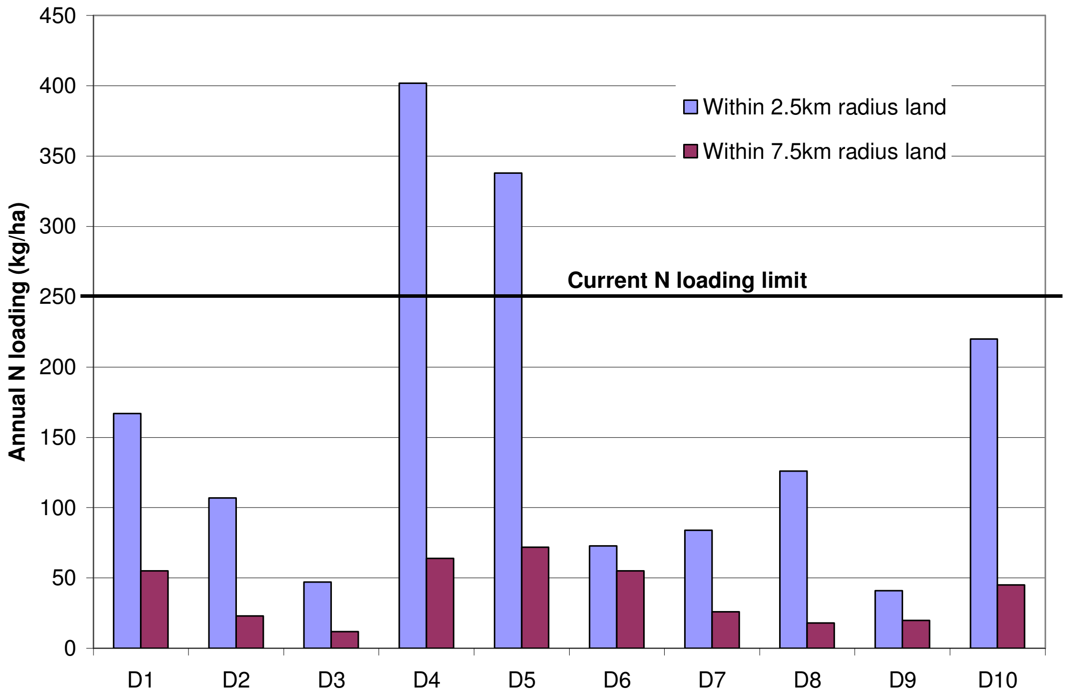
Table 2-2 N content in digestate, agricultural land area and potential N loading

Site	5 x 5 km grid			15 x 15 km grid		
	N in digestate (kg)	Available land (ha)	N loading (kg/ha)	N in digestate (N)	Available land (ha)	N loading (kg/ha)
D1	271,904	1628	167	595,037	10,868	55
D2	75,781	708	107	168,943	7335	23
D3	67,659	1453	47	97,127	8348	12
D4	504,928	1255	402	865,242	13,568	64
D5	504,928	1495	338	865,242	11,948	72
D6	133,961	1835	73	355,851	6514	55
D7	133,961	1593	84	355,851	13,844	26
D8	67,659	538	126	97,127	5490	18
D9	92,685	2258	41	303,192	15,143	20
D10	342,977	1558	220	538,493	12,015	45

For sites 3 and 5 while data was available on the area of improved grassland none were available for the area of arable land. For the purposes of this report the area was taken to be 0.

Figure 2-4 further illustrates the potential N loading within 5 x 5 km area and with 15 x 15 km area. It shows that there is enough available land to receive all the digestate without exceeding the current Defra Code of Good Agricultural Practice to avoid land receiving more than 250 kg/ha N per year from livestock manure and excreta, except for D4 and D5 . However, there are two caveats to this finding. First, that there will also be manures to be spread from other livestock, e.g. beef cattle. Second, that the limit includes returns due to grazing. Hence the area within 5 km of site D10 may also be insufficient to be able to receive all the digestate in addition to other manures that will not be used in the CAD. Second, around 40% of the excreta produced by cattle are deposited during grazing (Webb and Misselbrook, 2004) and these returns also need to be taken into account. Only at D10 are these grazing returns likely to lead to total N addition from livestock excreta exceeding 250 kg/ha. However, extending the potential area to a 15 x 15 km grid should enable the digestate to be spread without exceeding the 250 kg/ha limit even though there will be further additions from other manures and from grazing deposits.

Figure 2-4 Potential N loading around CAD sites



2.4 Biogas use

Generation and utilisation of biogas is one of the key benefits of adopting anaerobic digestion process for treating biodegradable wastes. The Government already provide incentives that contribute to improving the economics of AD including:

- The Renewable Obligation
- Climate Change Levy exemption
- Enhanced Capital Allowance

Market economics in the UK now favours the use of biogas for electricity generation. This is because AD is included in the Renewables Obligation as an 'advanced conversion technique' and thus the electricity generated by it is eligible for Renewable Obligation Certificates (ROCs). Currently the market for ROCs is undersupplied and so the values are around 5p/kWh. This, plus the wholesale value of the electricity makes every kWh of electricity from an AD plant potentially worth over 8p/kWh. This, combined with the relative ease with which electricity can be transported compared to gas, makes the electricity market very attractive.

The current energy market is highly volatile, and although prices are likely to remain high, the perceived risk in this market is high. However provided a steady supply of waste is available, AD has an advantage in being a 'base load' generator. It has the capacity to add to security of energy supply and also to add to local grid stability in rural areas where this has been a traditional problem. For distributed generation as a whole, there can be technical problems and costs associated with grid connection and these are being addressed by Government and the regulator.

The Enhanced Capital Allowance scheme is currently operated for water and energy technologies. The Chancellor has previously announced the UK Government's commitment to support cleanest biofuels plants to stimulate the development of alterative fuels and has extended[5] it for companies not in taxable profit to ensure both profit- and loss-making firms have an incentive to invest in projects

[5] The budget statement on 21 March 2007 by the Chancellor, Gordon Brown MP.

such as centralised anaerobic digestion. Anaerobic digestion fits this category and some of the suppliers of AD plant equipments and systems are working to enlist their products on the Technology Lists. It is also the case that all ‘high quality CHP’ (i.e. those where a high proportion of the heat is used) is also eligible for the ECA.

Additional income can be generated where there is a local use for the heat from the electricity generation process. This is one of the key feature around which the CAD schemes are proposed here – by making the dairy processing sites the beneficiary in the use of heat. This will provide the dairies with several environmental benefits that will also help them to secure their market place. For instance, a significant proportion of (if not full) carbon footprint could be reduced –which will help those dairies to link up favourably with C-labelling schemes which the Carbon Trust as well as many of the retail chains are actively considering.

In addition, the waste heat will also help to pasteurise the digestate, compost or liquor produced by the process. Wider use of heat from CAD would depend on the development of infrastructure to deliver the heat to where it is needed. The availability of such infrastructure in Denmark has made CAD successful there. In the UK, the Community Energy programme offers grants to develop district heating schemes.

3 Potential CAD schemes

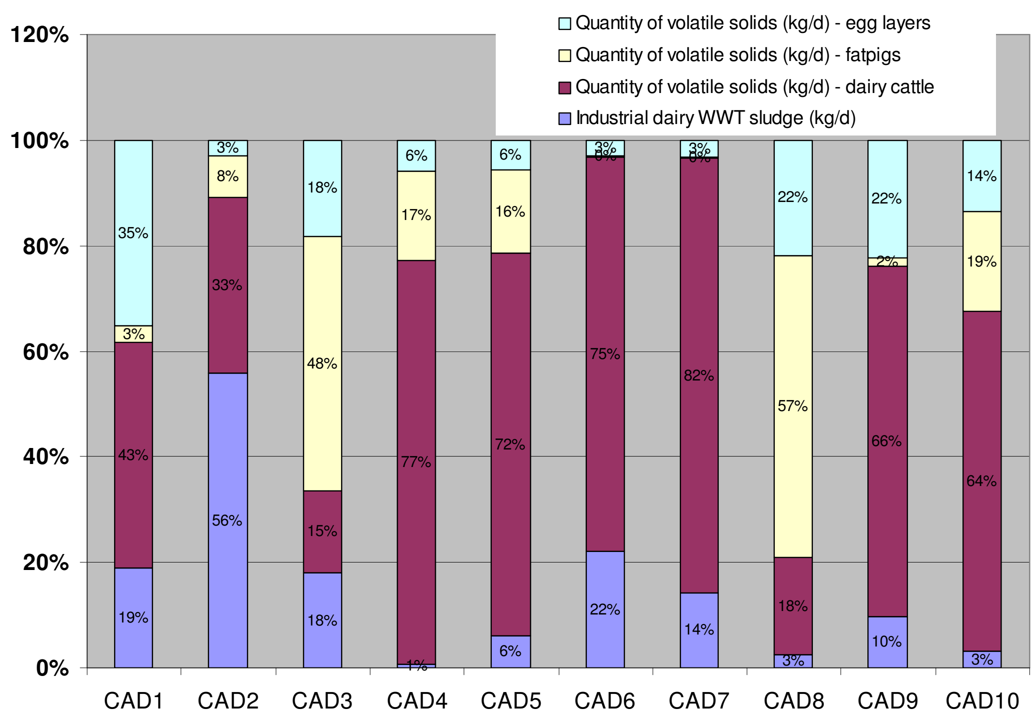
Operation of a typical centralised anaerobic digestion scheme was described in Section 2.2. This section presents the outcome of the technical and economic analysis associated with the 10 potential CAD plants and examines their economic potential and presents some sensitivity analysis of the key parameters.

3.1 Technical assessment

Table 2-1 listed likely quantity of wastes related to each of the CAD sites. The assumptions used to undertake the technical and economic analysis are along the lines of those from the Defra study AC0402, and some of the key assumptions are also given in Appendix 2.

Composition of the wastes in terms of volatile solids is an important parameter that determines biogas yields. Figure 3-1 illustrates the contribution of volatile solids in the feedstocks.

Figure 3-1 Volatile solids loading and methane generation associated with the CAD plants



3.2 Economic assessment

The assumptions used in the derivation of economic data are listed in Appendix 2. Figure 3-2 shows the breakdown of the capital costs, in terms of AD plant and CHP scheme, associated with the 10 CAD plants. The capital costs of the AD plants are between £750k and £5700k and those of the CHP plants are between £135k and £830k.

Figure 3-2 Estimated components of capital cost associated with the 10 potential CAD plants

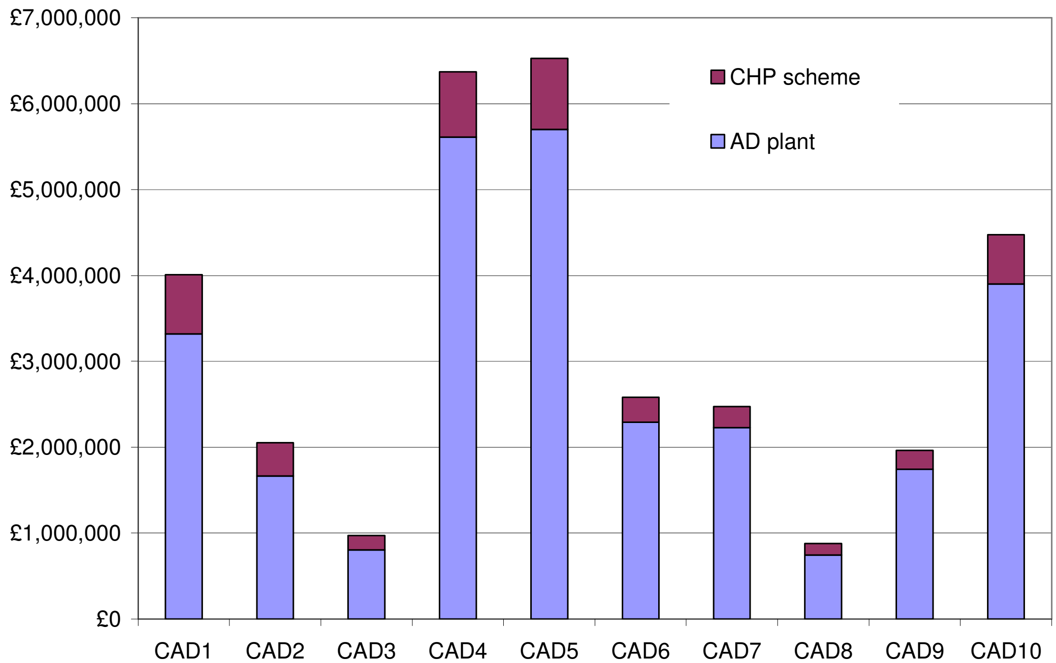


Table 3-1 Components of annual operating cost associated with the potential CAD plants

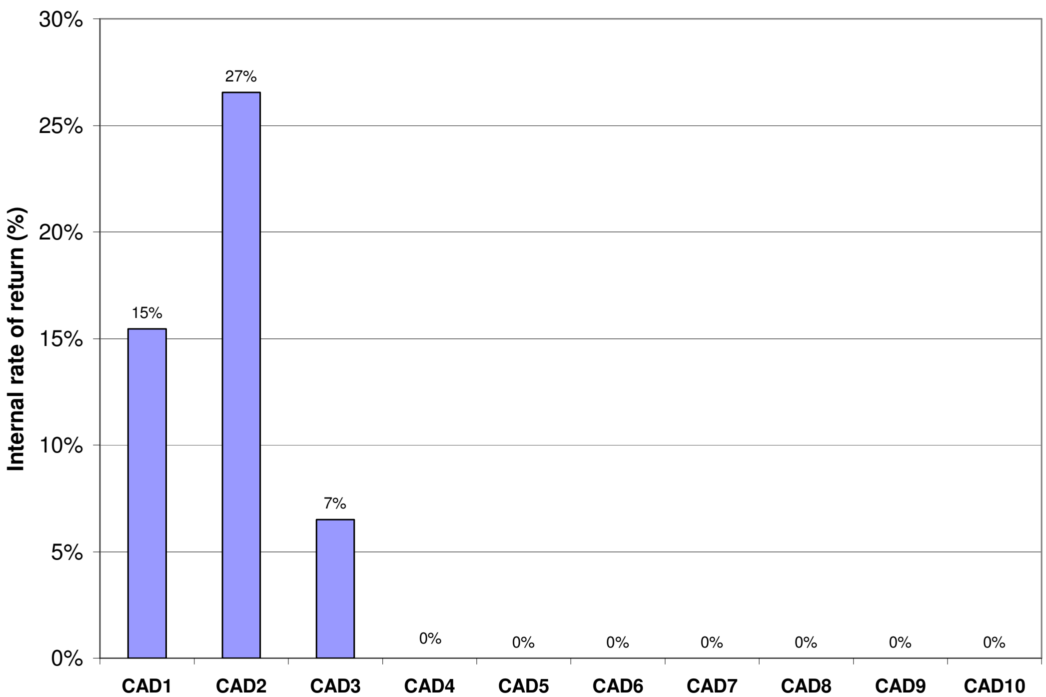
	CAD1	CAD2	CAD3	CAD4	CAD5	CAD6	CAD7	CAD8	CAD9	CAD10
O&M cost	£200,550	£102,671	£48,548	£318,442	£326,407	£129,188	£123,748	£43,935	£98,180	£223,592
Slurry transport	£182,471	£186,990	£91,370	£1,235,669	£1,235,669	£372,959	£372,959	£91,370	£261,044	£758,544
Poultry waste transport	£79,387	£8,127	£20,825	£46,878	£46,878	£7,900	£7,900	£20,825	£47,680	£75,257
Electricity - base price	-£292,106	-£159,330	-£66,481	-£322,807	-£354,883	-£119,965	-£101,455	-£53,280	-£89,328	-£239,934
Electricity - ROC	-£292,106	-£159,330	-£66,481	-£322,807	-£354,883	-£119,965	-£101,455	-£53,280	-£89,328	-£239,934
Electricity - CCL Exe	-£31,401	-£17,128	-£7,147	-£34,702	-£38,150	-£12,896	-£10,906	-£5,728	-£9,603	-£25,793
Heat income	-£153,417	-£83,682	-£34,916	-£169,542	-£186,388	-£63,007	-£53,285	-£27,983	-£46,916	-£126,016
Industrial waste	-£457,029	-£587,351	-£79,821	-£22,271	-£193,477	-£235,089	-£136,287	-£9,360	-£81,360	-£65,700
Digestate liquor	£0	£0	£0	£0	£0	£0	£0	£0	£0	£0
Digestate fibre	£0	£0	£0	£0	£0	£0	£0	£0	£0	£0
Net operating cost	-£763,651	-£709,033	-£94,101	£728,861	£481,173	-£40,877	£101,219	£6,501	£90,368	£360,018

Table 3-2 Economic and energy parameters associated with the potential CAD plants

Economic & energy parameters	**CAD1**	**CAD2**	**CAD3**	**CAD4**	**CAD5**	**CAD6**	**CAD7**	**CAD8**	**CAD9**	**CAD10**
Plant throughput (te/y)	227,073	95,961	38,703	437,394	446,080	142,742	137,729	35,128	101,502	277,555
CHP generator size (kW)	1,050	575	250	1,150	1,250	450	375	200	325	850
Capital cost of CHP scheme	£3,320,656	£1,667,116	£806,285	£5,610,349	£5,699,307	£2,290,513	£2,225,933	£746,134	£1,743,702	£3,899,160
Capital cost of AD plant	£690,352	£386,302	£164,680	£758,499	£828,832	£293,247	£249,029	£132,569	£219,902	£572,686
Total capital cost (£)	£4,011,008	£2,053,419	£970,965	£6,368,848	£6,528,139	£2,583,760	£2,474,962	£878,703	£1,963,604	£4,471,846
Net operating cost (£)	-£763,651	-£709,033	-£94,101	£728,861	£481,173	-£40,877	£101,219	£6,501	£90,368	£360,018
Pay back time (years)	5.3	2.9	10.3	N/A	N/A	N/A	N/A	N/A	N/A	N/A
IRR	15.5%	26.5%	6.5%	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Energy security[6]	21%	23%	17%	52%	34%	11%	7%	6%	6%	49%
Net carbon saving (teCO2/y)	3,632	1,955	806	3,619	4,028	1,381	1,145	638	1,025	2,743

[6] This is a measure of the primary energy recovery compared to that used on the dairy site

Figure 3-3 Internal rate of return associated with the likely investment at potential CAD sites



3.3 Economic Sensitivity

In this section the economic sensitivity is analysed with respect to:

1. A higher price that may be obtained from the electricity exported from the CAD plant,
2. Impact of heat export (for up to 100% of that generated in CHP scheme), and
3. The possibility that farmers pay for the collection and transport of their livestock wastes.

The electricity generated by a CAD scheme is valuable. This is because the value of the ROC is added to the wholesale value of the electricity. Part of the power purchase agreement negotiated in association with these projects is for the electricity to be sold directly to a customer and not into the wholesale pool. This means that the value of the 'base' electricity to the project becomes the retail value of electricity, which is some £20/MWh higher than the wholesale price.

Electricity prices are currently volatile and may fall in response to falling gas prices as a result of the increasing proportion of electricity generated from gas. However, we can assume that most dairy operators will currently be paying in the order of £70/MWh for electricity, and that this is therefore the retail value of the power. At the same time the Renewables Obligation Certificates are trading at above their £32/MWh face value due to increases in renewable electricity generation lagging behind the rate of increase in the obligation on the electricity distributors. Over the last two years or more these Renewable Obligation Certificates have been trading at round £45/MWh. To this can be added another £4.50 /MWh available from the climate change levy exemption certificate gives a total value in the order of £119.50/MWh, or just under 12p/kWh. This is considered the maximum value of the power, and its effect is shown in Figure 3-4 for the 10 CAD schemes

Figure 3-4 IRR of the CAD schemes as a function of overall price of electricity

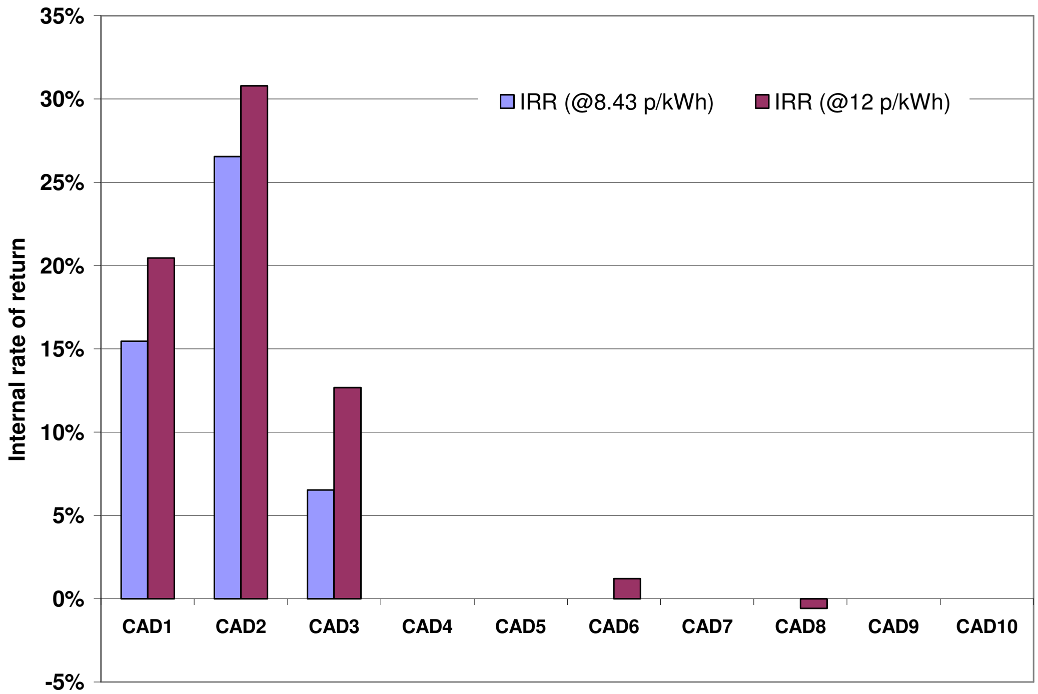


Figure 3-5 IRR as a function of heat sale

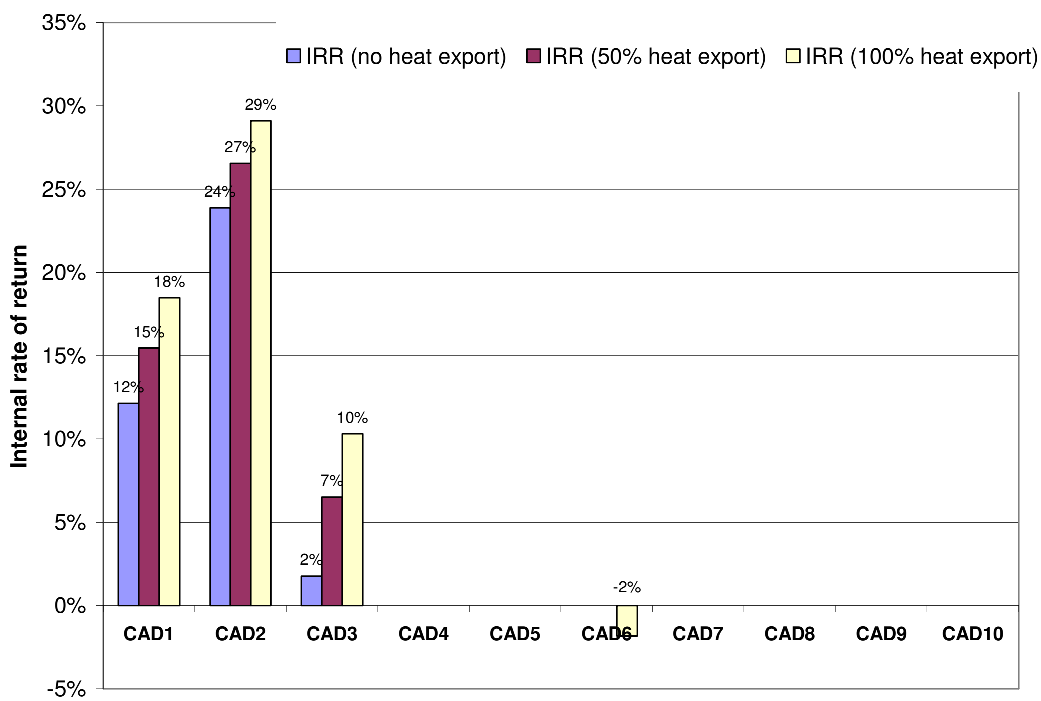
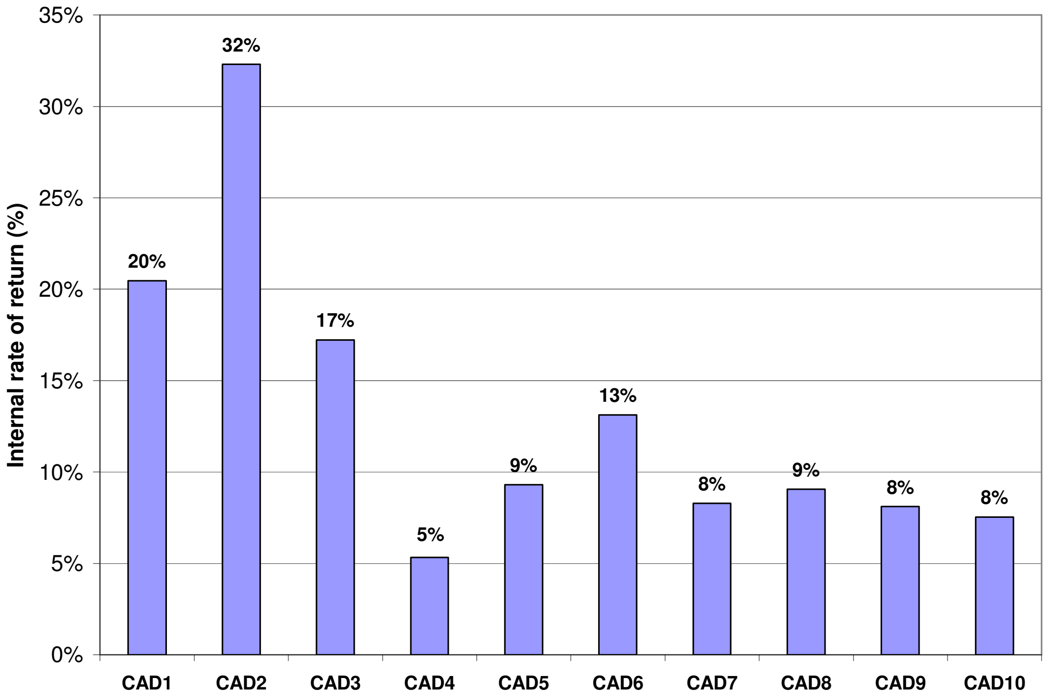


Figure 3-5 illustrates the sensitivity of the proportion of heat that could be sold at 2.5 p/kWh. The impact on the economics of the CAD schemes is significant. Another factor that would help to increase attractiveness of the schemes is if the transport of slurry and poultry waste was cost neutral.

Again it is possible that farmers would be willing to consider this charge as the CAD schemes help to manage their slurry more effectively, reduce their fertiliser cost and prevent any pollution. In such a situation all of the 10 schemes have a positive rate of return on investment. Other gate fee-earning wastes will help to make the schemes even more attractive.

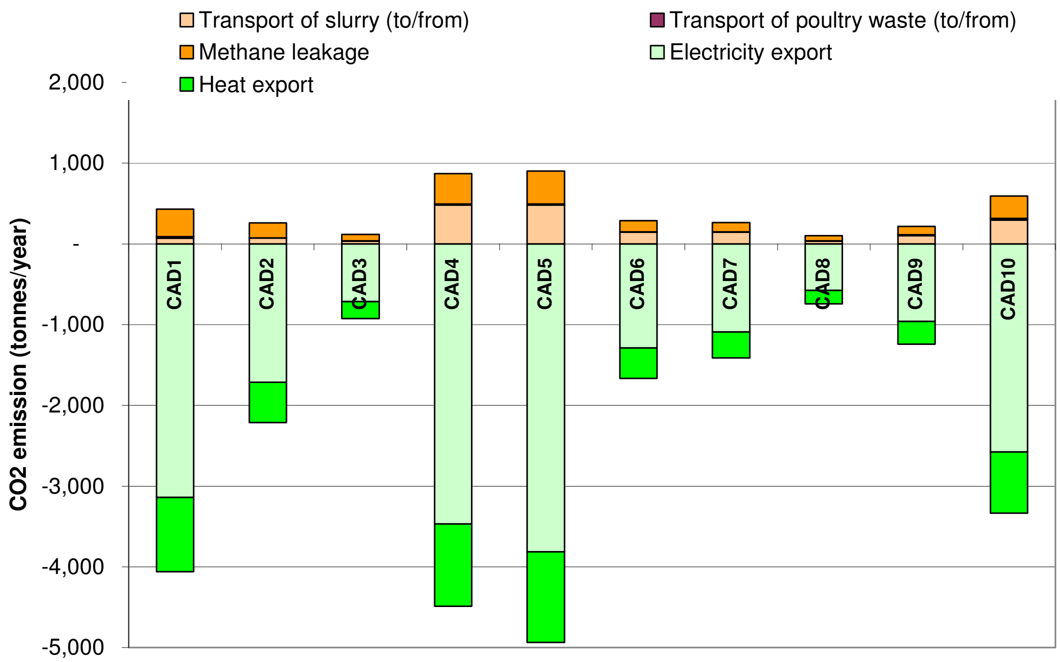
Figure 3-6 IRR of the CAD schemes if the livestock waste transport was cost-neutral



3.4 Carbon saving

Anaerobic digestion creates energy by converting polluting organic material into methane rich biogas. The energy content of this biogas or the heat and electricity produce from it is far higher than the energy spent in waste transport and operation of the CAD plant. Figure 3-7 illustrates the overall carbon balance, which also allows for possible leakage of methane during the plant operation as well as electricity and heat, which is used on the CAD plant itself. The net reductions in the CO2-emissions for the 10 schemes vary between 800 t/y and 4000 t/y; see Table 3-2.

Figure 3-7 Carbon balance associated with the potential CAD sites



4 CAD scheme development

4.1 Stakeholders in project development

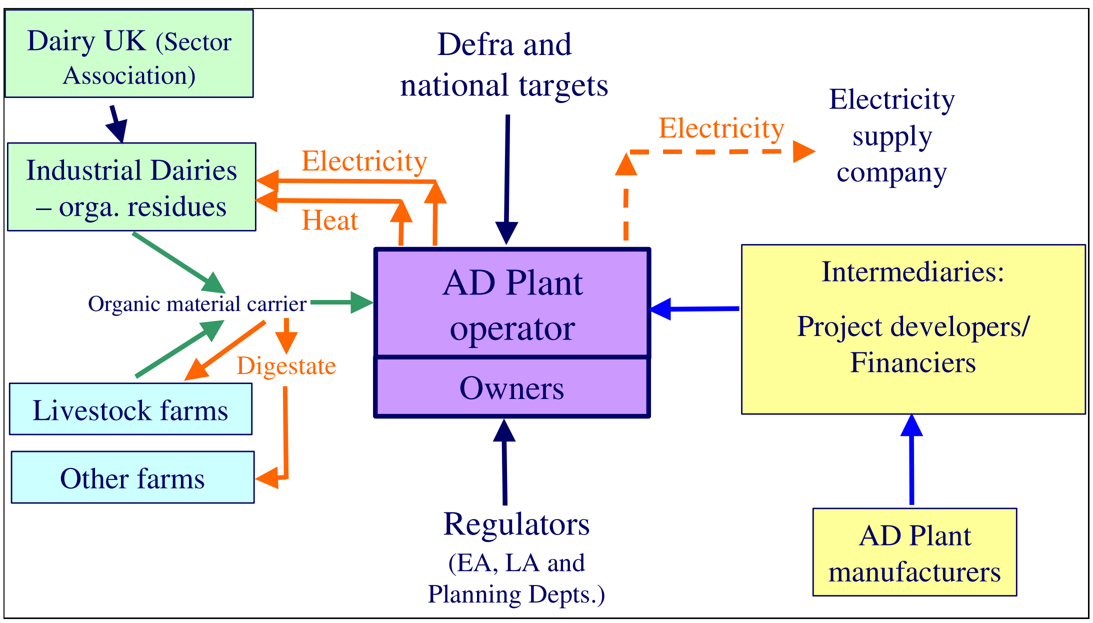
Based on the assumptions made in this study, the following three CAD schemes provide a positive rate of return on the investment:

1. Scheme CAD2 (with IRR of 27% and payback time of 3 years)
2. Scheme CAD1 (with IRR of 15% and payback time of 5 years)
3. Scheme CAD3 (with IRR of 7% and payback time of 10 years)

These may be regarded as first tier CAD plants as they are likely to be more attractive than others. By examining local factors, including availability of other fee-generating food wastes from nearby, would only help to increase the attractiveness of all of the schemes, including those CAD4 to CAD10.

Figure 4-1 below shows how the different parties could be engaged in the development of CAD projects.

Figure 4-1 Project stakeholders associated with CAD plant linked to dairy supply chain



All AD plants require relatively significant capital expenditure, as indicated in Figure 3-2. The paybacks of the chosen schemes are from 2 to 10 years and any financing scheme will need to be adapted to this type of investment. Private investors are likely to be interested in investing in CAD under the current circumstances.

This is because there are many venture capital funds that have been established to take advantage of preferential tax arrangements for 'ethical' schemes to the point where there is more money available for investment than there are projects to invest in. This means that the interested parties in a given project could be:

The waste producer. This organisation wants a secure outlet for their waste with predictable costs into the future. It cannot accept any risks around the availability of its waste outlet as this will compromise the ability of the business to operate with a short period between the failure to remove waste and the closure of the business.

The project developer/constructor. This organisation may be the supplier of the AD technology or will procure this equipment against the customers. They want to deliver the project to time and budget but may have no ongoing involvement with the project. They will look to lay all process guarantees on to the equipment supplier.

The plant owner may be the waste producer or the project developer. This organisation wants to guarantee the waste feedstock supply by charging an attractive gate fee, yet wants to maximise the income potential of the plant. To minimise business risk, the operator may chose to secure multiple waste feedstocks, even if this means over sizing the plant. As with the waste producer, it must have secure outlets for by-products for the waste produced by the process.

The plant operator. This organisation may be any of the above organisations or a specialist company providing services in this area.

The finance provider may be any of the above organisations or a specialist financier or bank. This organisation will take no risks and will expect all of the risk areas to be covered by the various suppliers to the project. Financiers usually employ consultants to undertake due diligence activities to specifically address these risk areas.

The energy customer. Electricity will be fed into the grid, with sale to an electricity distributor. The waste producer can contract to take this capacity. The heat sale is more problematic as the outlet must be close to the AD plant; however, in this project we have assumed the industry/operator will use the heat. Again, this may or may not be the waste producer.

The by-products customer. These are likely to be agricultural businesses that value the fertiliser value of the product.

4.2 Project development partners

In practice, these functions are likely to fall to one of the following businesses.

Dairy processing companies
These will be the waste producer, but can also be one or more of the following:

- Plant owner
- Plant operator
- Finance provider
- Energy customer

Farmers
Dairy farmers and other livestock producers will again be the waste producer. They can also take a share in the business making them part of the project ownership team.

Water Companies
Many water companies and their service suppliers are already completely conversant with the use of AD to treat sewage and would be ideally placed to operate AD plant in the agriculture/food sector. Indeed, there is potential benefit from the use of this industry to treat agricultural wastes as, in rural areas, many sewage treatment plants are little more than collection facilities, with sewage being tankered to larger facilities for treatment. Having more local treatment works would reduce the need for this transport. As with technology suppliers, we see the potential for government to invite the water industry to tender to operate (and even own) larger AD plant.

Waste Management Contractors

These companies have the infrastructure in place to move waste and can also act as plant operators. In some instances these organisations may also build and own plant of this kind.

4.2.1 Other project development issues

4.2.2 Local infrastructure

The success of a CAD plant will depend on a steady source of feedstock. This will require the development of local infrastructures and supply chains, with further equipment supply opportunities around issues such as vehicle cleaning, disinfection and fibre processing.

For other wastes, the supply chain is probably less of an issue and factors such as the Landfill Directive will put pressures on all organic waste although AD would need to be cost competitive with other forms of disposal. It is expected that the overall cost of landfilling will continue to rise and industrial waste as well as organic fraction of municipal waste would need outlets such as AD plants.

4.2.3 PPC Permit to operate

The centralised anaerobic digestion schemes would be subject to the Pollution Prevention and Control (PPC) Regulations. These will serve as the ‘umbrella regulations’ and will bring several other legislative and regulatory requirements into one, through the requirement of a PPC permit to operate. By way of the permit, the regulator (EA) will set a number of operational conditions. These conditions will be based on the use of Best Available Techniques. The permit condition will also require steps to ensure that energy is used efficiently, avoid or minimise waste, prevent accidents and limit their consequences. AD plants should be seen as BAT, although each plant will have to be judged individually and within the context of the local environment.

4.2.4 Planning Consent

As with any industrial plant, the CAD plants will have to acquire the site development planning consent according to the Town and Country Planning Regulations. Given the rather ‘novel’ nature of the scheme, with likely ‘emotive’ issues such as frequency of vehicle movement to and from the plant, bio-hazards and odour the developers will be required to provide detailed justification that the CAD schemes are suitable in the vicinity.

The Local Authority Planning Department will determine the application and some pro-active education and awareness aimed at planning officers would be beneficial. The Kelly Review[7] is examining the case for making the planning system more effective towards delivery expansion of the waste management facilities. Some representation to this review would be worthwhile.

4.2.5 The Animal By-Product Order

The EU Animal By-Products Regulation has tightened the regulations that govern the processing and disposal of animal by-products. These regulations favour biological treatment schemes but with stringent controls on the process, including time-temperature profile requirements, strict segregation of clean and dirty sides of the process and facilities for vehicle washing. Regulation EC 1774/2002 (the ‘EU Animal By-Products Regulation’) has been applied since 1 May 2003. It permits AD plants to treat catering waste as well as low risk animal by-products.

4.3 First tier CAD plant schemes

As was explained above, the analysis presented herein is fairly ‘conservative’ and should be regarded as provisional. For all of the 10 candidate sites, further site-specific considerations are required before any of the schemes could be taken further. These should include examination of other food and poultry wastes within ~50km radius, the type of heat the industrial dairy site can use, the vulnerability of water courses and any designation of NVZ area, as well as the likely support from the livestock and other farmers in the locality.

[7] Pre-budget report, 5 December 2005

Based on the above discussion, there are basically three options for the industrial dairy operator consider:

Option 1: To own and operate the CAD plant

Option 2: To invite companies such as water companies and waste management contractors, to compete for the plant's build, ownership and operation

Option 3: To explore possible partnership between industrial dairy operator and companies such as water companies and waste management contractors – to build, part own and operate. Share ownership with farmers is also a clear option with benefits on all sides, especially if the supply of feedstock, removal of waste, etc is in exchange for shares as opposed to requiring the farmers to raise capital.

Finally, the three schemes that look attractive with the current, rather conservative assumptions are further commented on with respect to their site-specific issues.

4.3.1 Scheme CAD2

From the sites considered in this project, this site could provide the most commercially attractive centralised anaerobic digestion plant scheme, with the IRR of 27% and investment payback time of less than three years. Additional benefits will accrue from other food wastes that could be attracted to the plant. The wastewater from the site is currently managed by a contractor, who also deals with any sludge that might be produced. For the purpose of this study, wastewater sludge was estimated to be 30 te/d by comparing with similar production site. The operator is currently examining possible changes to the management of wastewater and other wastes from the site, including investment in membrane filtration technology. The site operator has not explored the solution of AD, but is willing to invest in one. It is strongly suggested that they undertake a holistic view of wastewater and other wastes management from the site and consider centralised AD plant as part of this.

Based on the likely quantity of the site's own sludge and the estimated livestock wastes from the locality would provide up to 23% primary energy saving (i.e. by replacing some of the electricity and fossil fuel use). The plant would represent emission saving of around 1955 tCO_2/y.

4.3.2 Scheme CAD1

From the sites considered in this project, this site could provide one of the most commercially attractive centralised anaerobic digestion plant scheme, with the IRR of ~15% and investment payback time of around five years. Additional benefits will accrue from other food wastes that could be attracted to the plant. The wastewater from the site is well managed by the site operator, who is examining the options for sludge dewatering. The site is estimated to produce ~23 t/d of dewatered (i.e. 21% DM) sludge. They have not explored the solution of AD and are unlikely to invest in one. It is strongly suggested that the site operator undertakes a holistic view of wastewater and other wastes management from the site and engage in discussions with the local water or waste contracting company. Additionally, there is likely to be large quantities of other wastes in the area that could further improve the economics.

Based on the site's own sludge and the estimated livestock wastes from the locality would provide up to 21% primary energy saving (i.e. by replacing some of the electricity and fossil fuel use). The plant would represent emission saving of around 3632 tCO_2/y.

4.3.3 Scheme CAD3

From the sites considered in this project, this could provide a reasonably attractive centralised anaerobic digestion schemes, with the IRR of ~7% and investment payback time of around 10 years. Additional benefits will accrue from other food wastes that could be attracted to the plant. The site has invested in its own wastewater treatment system, which produces around 4 te/d of sludge. The operator is keen to invest in an anaerobic digestion plant if it is commercially attractive. It is strongly suggested that they undertake a holistic view of wastewater and other wastes management from the site and consider centralised AD plant as part of this.

Based on the site's own wastewater sludge and the estimated livestock wastes from the locality would provide up to 17% primary energy saving (i.e. by replacing some of the electricity and fossil fuel use). The plant would represent emission saving of around 806 tCO_2/y.

5 Conclusions and recommendations

5.1 Principal conclusions

The operators of 10 sites provided information that has been used to aid the analyses presented in this report. This work has shown that centralised anaerobic digestion plants, based at or close to industrial dairy sites, have the potential to be economically attractive for 3 of the 10 sites. This is because several positive factors would combine in their favour. Various conclusions can be drawn from this work and these are discussed below.

- Centralised anaerobic digestion (CAD) plants can be designed to co-treat organic wastes from industrial dairy sites with animal wastes from nearby livestock farms and other food manufacturing wastes. The Landfill Tax is designed to make landfilling increasingly unattractive forcing producers of industrial food waste to seek alternative outlets such as AD plants. In turn, the inclusion of these wastes at the higher gate fees being generated in the market by the Landfill Tax will help to increase the viability of the CAD. This material also provides a diverse feedstock making waste streams such as dairy derived sludges available to AD and in turn this provides an additional income stream to the CAD plant operator.

- The successful exploitation of CAD depends on gaining the full economic benefit of the heat and electricity outputs combined with full exploitation of ancillary benefits. The latter include reduced transport costs associated with waste sludge disposal and concomitant reductions in carbon emissions relative to the current situation in a retail market that is beginning to demand 'low carbon' products. The benefits at the farm level will be reduction in the use of artificial fertilisers by using the digestate more effectively. This will also reduce fossil fuel consumption further increasing the carbon benefits from AD. These more ancillary benefits have not been costed or brought into the economic analysis presented in this report.

- There is enough land available in the locality of the sites to receive all the digestate without exceeding the current Defra Code of Good Agricultural Practice to avoid land receiving more than 250 kg/ha N per year from livestock manure and excreta.

- Generation and utilisation of biogas is one of the key benefits of adopting anaerobic digestion process for treating biodegradable wastes. The Government already provides incentives that contribute to improving the economics of AD including the Renewable Obligation, CCL exemption and Enhanced Capital Allowance.

- As mentioned above, there is potential for additional energy income from the sale of heat generated from the CHP scheme. Wider use of heat from CAD would depend on the development of infrastructure to deliver the heat to where it is needed. In the UK, the Community Energy programme offers grants to develop district heating schemes.

- All CAD plants require relatively significant capital expenditure, which vary between £900k and £6,500k. Any financing scheme will need to be adapted to this type of investment but investors would be interested in investing in CAD under the current circumstances.

- The CAD schemes will provide the industrial dairies with several environmental benefits that will also help them to consolidate or secure new market outlets. For instance, a significant proportion of their carbon footprint could be reduced – which will help those dairies to link up favourably with C-labelling schemes which are being planned by retail chains and the Carbon Trust.

Based on the operating costs and income, the following three CAD schemes provide a positive rate of return on the investment:

1. Scheme CAD2 (with IRR of 27% and payback time of 3 years)
2. Scheme CAD1 (with IRR of 15% and payback time of 5 years)
3. Scheme CAD3 (with IRR of 7% and payback time of 10 years)

These may be regarded as first tier CAD plants as they are likely to be more attractive than others. It is also the case that the current economics present a worse case scenario as in the future the value of renewable energy will rise and the cost of waste disposal will increase. It is also highly likely that carbon will assume a value, providing an additional income stream into the project.

By examining local factors, including availability of other fee-generating food wastes from nearby, would further help to further increase the attractiveness of all of the schemes, including those CAD4 to CAD10. The factors that increase the attractiveness of the CAD schemes are:

- Higher proportion of volatile solids in the feedstock (e.g. through greater poultry wastes, industrial organic or food manufacturing wastes);
- CAD plant operation at thermophilic temperatures (around 53-60 ^{o}C), as they generally increase rate and yield of biogas generation;
- Higher prices on electricity and heat that are exported;
- Increase in gate fee from the controlled industrial waste;
- More efficient use of energy on the AD plant itself;
- Lower transport cost of wastes and
- Higher plant availability.

For Dairy UK, delivering the first few CAD plants identified in this study would be a pioneering way to take the dairy industry forward, delivering the benefits identified in this report. To enhance this process, it may be possible to attract grant income towards the first ‘demonstration’ plant(s), strategically placed in the country, as this would also be an excellent way to raise awareness of the technology demonstrating wider benefits locally, including:

- Generation of local wealth, through rural business creation; for instance, in local waste management systems; managing waste from local businesses to reduce waste costs in the locality.
- Sustainable method of generating local heat and electricity supply, from a renewable source, and leading towards self-sufficiency in energy supply as industrial dairy operations.
- Creation of skilled, local green jobs in commissioning, maintenance, etc.
- Transport of wastes and wider ‘waste management organisation’.
- Opportunities around the supply and demand of co-treated livestock wastes.
- Mitigation of odours from livestock slurry
- Reduced risk of pathogen transfer from slurry spreading

Given the current interest in reducing carbon emissions we are convinced that there are a number of interested parties that might be willing to consider developing AD schemes where they are economically attractive. At the same time, waste producers such as dairy companies are increasingly interested in reducing production costs and more acceptable routes to waste disposal. We can only conclude that the time is right to look seriously at AD as a technology to achieve both of these objectives.

5.2 Key recommendations

5.2.1 CAD – the next steps

Dairy UK should present the outcome of this report to all of the members.

The analysis presented herein is fairly 'conservative' and should be regarded as provisional. For all of the 10 candidate sites, further site-specific considerations are required before any of the schemes are taken further. These should include access to other food and poultry wastes within 50km radius, the type of heat the industrial dairy site can use, the vulnerability of water courses and any designation of NVZ area, as well as the likely support from the livestock and other farmers in the locality.

As part of this, financing and development pathways need to be considered, of which there are basically three options:

Option 1: Industrial dairy operator to own and operate the CAD plant

Option 2: To invite companies such as water companies and waste management contractors, to compete for the plant's build, ownership and operation

Option 3: To explore possible partnership between industrial dairy operator and companies such as water companies and waste management contractors – to build, part own and operate. Share ownership with farmers is also a clear option with benefits on all sides, especially if the supply of feedstock, removal of waste, etc is in exchange for shares as opposed to requiring the farmers to raise capital.

5.2.2 Government Support

The key to encouraging investment in AD is to reduce the perceived risks to the project either through long-term guarantees of income streams or by reducing the cost of capital through grants or loans with favourable conditions. As such the Government should consider supporting some of the initial CAD projects to reduce the financial risks associated with the early adopters.

5.2.3 General Education and Advocacy

As has been mentioned, AD can help comply with a wide variety of regulations and meet the environmental challenges. However, to guarantee that stakeholders (farmers, local authorities, environmental agencies, etc) can make an informed decision, they must be made aware of the benefits and shortcomings of AD. This awareness raising could include:

- Presentations to key stakeholders
- Workshops
- Website
- Newsletters

In addition to the general awareness-raising programme, an active campaign of advocacy of the AD plants may be required. Some targeted meetings and joint events with key players- manufacturers, buyers, specifiers and trade associations would also help.

We then consider it appropriate for the industry to seek dialogue with other interested parties with a view of developing CAD schemes along the lines described in this report.

5.3 References

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5.4 Glossary of abbreviations

ABP	Associated By-Product
AD	Anaerobic digestion
CCA	Climate Change Agreement
CCL	Climate Change Levy
CH_4	methane (gas*)
COD	Chemical oxygen demand (expressed as mg/l)
CO_2	carbon dioxide (gas*)
d	days
DF	Discount factor
DCF	Discounted cash flow
Defra	Department for Environment Food and Rural Affairs
DUK	Dairy UK (formerly, Dairy Industry Association Ltd)
ECA	Enhanced Capital Allowance scheme
ETL	Energy Technology List
EU	European Union
FYM	Farm yard manure
g	gram(s)
GJ	Giga joules
GWh	Gigawatt-hours
GV	Gross Value
kg	kilogram(s)
kJ	kilo joule(s)
KPI	Key Performance Indicator(s)
kW	kilowatt(s)
kWh	kilowatt-hour(s)
MCF	methane conversion factors for each manure management system
MWh	Megawatt-hours
m^3	cubic metres of gas*
Mesophilic	temperatures of AD between 35°C and 40°C
MJ	Mega joule(s)
NISP	National Industrial Symbiosis Programme
RDA	Regional Development Agency
RD&D	Research, Development and Demonstration
ROC	Renewables Obligation Certificate
t/y	Tonnes per year
Thermophilic	temperatures of AD above ~55°C
TWh	Terrawatt-hours
VFA	Volatile fatty acids (intermediate compounds in the breakdown of organics by AD)
VS	Volatile solids (i.e. degradable organic material in livestock manure)
WRAP	Waste & Resources Action Programme
y	year

All costs should be read as those as at 2005/6 unless otherwise stated.

Appendix 1: Questionnaire – Confidential

Feasibility of Centralised Anaerobic Digestion Plants

Dairy UK, in association with AEA Energy & Environment, are assessing the feasibility of establishing centralised anaerobic digestion plants where effluent, sludge and organic wastes from industrial dairy sites could form an integral part of the plant feedstock (along side slurry from livestock farms and other industrial waste from the vicinity). The work is funded by DEFRA[8] and the high level feasibilities will be completed by 31 March 2007. We are sending you this questionnaire if your site appears suitable for preliminary consideration or if you have expressed interest in participating in this project. At this stage we would like you to provide some information to help us to fully assess your site to select a short list of sites to undertake assessment of project feasibilities[9].

We would appreciate your answers to the questions on the next page. This is vital for including your site in the project. If some information is not accurate or requires more time, then we would appreciate your provisional set of answers or blanks where you are not able to provide (even indicative) information. We must have your ('one form for one site') information ASAP.

Dairy UK and AEA Energy & Environment, who are undertaking this high level assessment, will keep your data confidential and they will be restricted to DEFRA and the project partners – IGER and University of Exeter. If you have any questions please contact Prab Mistry (contact details are given below). Your co-operation in completing the questionnaire ASAP is greatly appreciated.

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Please return completed questionnaire to: Prabodh Mistry (details above)

[8] UK Department for Environment Food and Rural Affairs (DEFRA)
[9] Please note that providing this information does not mean that your site will be short-listed for further assessment. We are looking to identify up to five sites for CAD and which might also offer different routes to implementation. It also follows that if your site is not short-listed it does not necessarily mean that AD is not attractive at or around your site.

Site Details

Company name:	
Site name:	
Contact name and address	
Telephone(s):	Fax:
Email:	
How many other sites do you have?	
Key inputs (e.g. milk) and quantities/year	Key products and quantities per year

Note: one form for one site.

Interest and Commitment

1. Do you treat your effluent (on-site)?	If so, please state how (e.g. sedimentation, activated sludge) and the annual cost of treatment, if known.
2. Do you meet the necessary discharge consents? Is this likely to change in future?	
3. Are you considering investing in any on-site treatment of wastewater? If so, please provide brief details.	
4. Have you explored the scope for anaerobic digestion (AD) for your site?	
5. Heat use is important for the economic viability of AD. Would your facility use the heat from a biogas based CHP[10] plant?	
6. Is the senior management likely to invest in the plant (either at your site or close to your site).	If so, state any investment criteria (e.g. payback time of < 5years)
7. Are there dairy herd (or other livestock) farms in the locality*?	If so, please provide any information (no of farms, cows etc)
8. Are there other dairy processing sites in the locality*?	If so, please provide any information
9. Are there other sources of organic (biodegradable) wastes in the locality*? (e.g. other food or drink manufacturing wastes such as from brewery, vegetable processor)	If so, provide any details

*Locality = within around 10km radius

[10] Combined heat and power scheme based on biogas from anaerobic digestion of wastes

Energy and Waste information

Production	0.00	
Energy consumption	**kWh**	**Annual Cost (£/y) or unit price (p/kWh)**
Electricity		
Gas		
Liquefied petroleum gas		
Gas oil		
Fuel oil		
Other		
Other		
Energy from renewable sources?		
CHP schemes (number and total capacity?)		
Wastewater and waste disposal	**Quantity (t/y)**	**Cost (£/y)**
Wastewater (effluent) discharged		
Typical COD concentration	(mg/l)	-
Effluent sludge disposed, state destination		
Any waste to landfill		
Any waste applied to land		
Waste as animal feed		
Other waste (please specify)		
Any other waste management issues?		
Your Local Authority		
Your water supply company		
Any other information		

Appendix 2: Techno-economic assumptions

The following assumptions were used in the derivation of the material and energy balances and economic evaluation of the CAD plants. All other assumptions were similar to those in Defra Study AC0402 (Assessment of Methane Management and Recovery Options for Livestock Wastes).

Technical assumptions

- The quantity of livestock slurry is calculated using the IPCC parameters
- All dairy herds and fattening pig farms are based on slurry collection system (collected from within the 5 x 5 km grid)
- All egg layers in the area (within 15 x 15 km grid) are housed stock and collect the faeces without litter.
- Sludge from the wastewater treatment at industrial dairy sites is available at 21% DM.
- Methane generation factors (m3/kgVS) are based on IPCC values
- Methane leakage is assumed to be 1% of that generated
- Energy value of CH4 is 36.80 MJ/m3, at 20^{o}C.
- Electricity generation is via CHP (irrespective of the quantity of methane), with electrical generation efficiency of 35% and heat generation efficiency of 50% (i.e. 85% efficiency overall). 15% of electricity generation is used on plant and 85% is exported.
- 50% of the heat is used on the CAD plant, with the other 50% being exported to the neighbouring industrial dairy site.
- Size of digester (in m3) is taken as 15 times the daily volume of waste, plus 25% excess capacity.
- A continuous operation is represented by 365 days.
- CO_2 emission in the biogas or that emitted through its combustion are biogenic and therefore regarded as neutral, as they do not add to the emissions, over alternative, non-AD options; i.e. the emissions would be no more than if the waste was to decompose naturally.
- CO2 credit for electricity export is taken as 0.43 kgCO_2/kWh. However, this could be slightly higher if calculated on fuel consumption basis!
- The global warming potential of methane (CH_4) is 21 times that of CO_2 on equivalent mass basis.
- Overall plant availability is 95% (i.e. operation hours of 8322 per year).

Economic assumptions

- Capital cost of CAD plants are based on the classical 'total plant cost estimation correlation', using m^3 of digester as the key size parameter. The basis: 8000 m^3 digester capacity plant costs £5.5 million.
- Income from the sale of electricity is made up as follows:
  - Base price for the electricity exported to the grid is taken to be 4 p/kWh
  - ROC price for the electricity exported to the grid is taken to be 4 p/kWh.
  - Income from the CCL Exemption Certificates is based on 0.43 p/kWh.
- Heat sale income is based on 2.5 p/kWh. This is based on 2p/kWh equivalent gas fuel and 80% conversion efficiency. This waste heat is used at the nearby dairy processing site.
- Income from industrial waste at the plant gate is taken to be £54 per tonne. This is because the plant operator will keep a degree of parity with LF charges in the area. As such it is made up of £24/te LF tax and £30/te disposal fee.
- Income from digestate liquor is taken as zero, just as for the fibre, if any separated. This assumes that cost of fibre separation matches that which can be earned from its sale!
- Project life time assumed to be 20 years, following two years for construction and commissioning time.
- Annual operation and maintenance cost is taken to be 5% of the capital cost.
- Industrial dairy waste transport is zero – as the CAD plant is assumed to be at or nearby