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# DELIVERING NET ZERO

## 21ST CENTURY AD COMES IN ALL SHAPES AND SIZES

THE WORLD BIOGAS SUMMIT · THE WORLD BIOGAS EXPO · AD AND BIOGAS INDUSTRY AWARDS


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# HORSES FOR COURSES - THE GUIDE TO AD

**Angela Bywater**, formerly the co-manager of AD-Net and now EB-Net, considers the primary types of AD and how they can meet not only the government's aspiration to deliver net zero but also that of farming and business, if the right enabling conditions are put in place.

All life forms on Earth are carbon based. The planet's natural systems are continuously capturing carbon, such as when growing plants photosynthesise carbon dioxide, or releasing carbon, such as when microbes degrade dead plants and animals, turning them into 'soil' and carbon dioxide. Whilst carbon dioxide levels in nature are not static when viewed over millennia, the natural carbon cycle has become highly unbalanced in the last short 170 years or so, primarily due to human activity pulling sequestered fossil fuel carbon out of the ground and combusting it, releasing carbon dioxide to the atmosphere. This has created climate change.

In the carbon cycle, two very different complex communities of microbes break down organic materials, creating different by-products. In **aerobic decomposition or composting**, the community requires oxygen to degrade these materials, creating heat, releasing carbon dioxide back to the atmosphere and producing 'compost', a soil amendment that contains recalcitrant carbon. Such microbes are particularly good at recycling woody (lignocellulosic) materials, such as trees, branches, wood chip and dead leaves.

In **anaerobic digestion (AD)**, microbes living in the absence of oxygen turn the recalcitrant carbon from organic materials into fertiliser, with the volatile carbon being produced as biogas, a mixture of carbon dioxide and methane. The fertiliser, known as digestate, differs from compost in that it contains nitrogen in a form readily available to plants. It also contains other nutrients, trace elements and other compounds that can be lost during some forms of composting.

AD systems are highly flexible and scalable. The purpose of an AD plant - as well as the feedstocks, engineering, equipment, operating parameters, biogas use, digestate use and digester location - can vary widely. AD can operate at sizes from that of a test tube to tanks of many thousands of cubic meters.

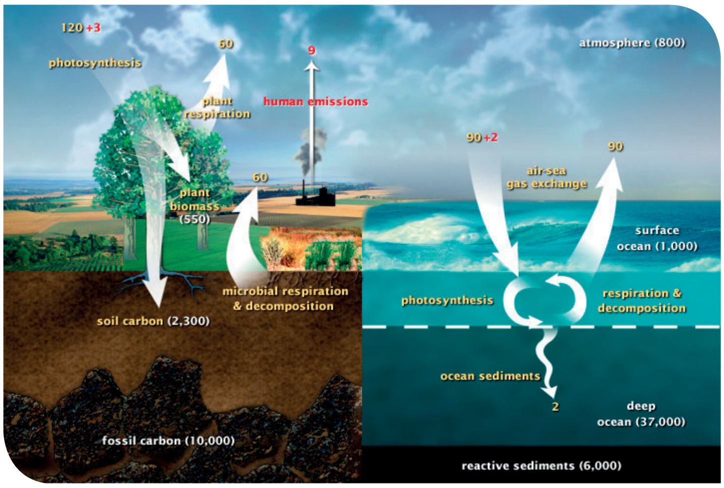
The flexibility of AD is both its strength and its Achilles heel: it can do many things, but does not fit comfortably into any single government or regulatory department, budget or policy/incentive framework.

Is it an essential agricultural technology for the farming community? A slurry management system? An on-site low carbon technology for food and beverage manufacturers? A circular food growing system for organic growers? A waste recycling system? An integral part of wastewater treatment? Electricity production? Renewable energy? Community energy? A technology to produce a 'transition' fuel? Renewable transport fuel production? Renewable heating? Fertiliser production? A way to return carbon to depleted soils? Part of a bio-refinery?

AD can be all these things and more, ranging from simple plants through to complex systems, where size is not necessarily a measure of complexity. It is particularly suited to on-site applications, where it can be used to extract clean energy and stabilise wastes and process residues on farms or factory sites.

This very flexibility means that AD and its by-products can be deployed in many forms across a tremendous range of geographical locations. It also means that 'one size' definitely does NOT fit all situations.

Thus, no 'one size' of digester technology, incentives or regulation will work comfortably for most situations where the technology may be deployed; indeed,

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This diagram of the fast carbon cycle shows the movement of carbon between land, atmosphere, and oceans. Yellow numbers are natural fluxes, and red are human contributions in gigatons of carbon per year. White numbers indicate stored carbon. (Diagram adapted from U.S. DOE, Biological and Environmental Research Information System.)

history has shown us that it does not and may even be positively detrimental to some AD sectors. Here, we take a look at a number of different implementations of the technology, the situations they might fit into, some of the regulations and incentives that apply (at least in the UK) and the pros and cons of such systems.

## The very smallest systems

Researchers and labs often require a large number of small digesters in order to analyse a system under varying conditions. Such operating variation may include the use of different microbial communities, feedstock(s) added in varying proportions and perhaps with different pre-treatments, temperature variations, different mixing regimes, different system loading rates, the addition of other materials such as trace elements, chars or gases (e.g. hydrogen) or any other conceivable variation that a digester system might operate under. Under these circumstances, it is helpful to have a large number of digesters, so that each parameter variation can be run in triplicate and compared against a control system which is run with no parameter variation.

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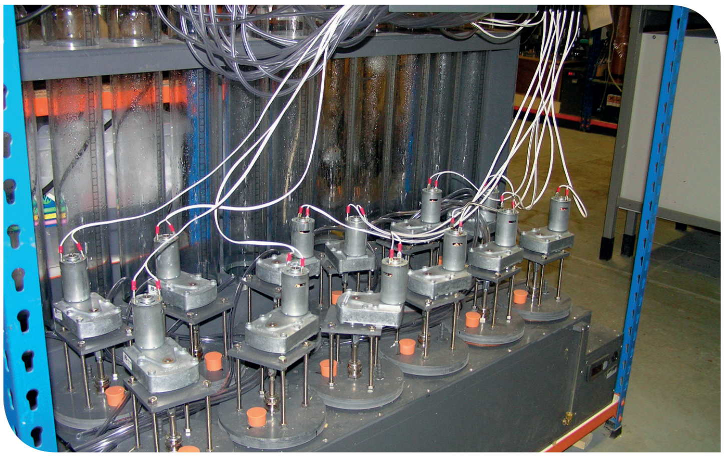

© Southampton University

(Above and previous page bottom right) Lab-based AD: multiple, small scale digesters analyse systems under variable conditions.

Such systems may range in size from that of a large syringe to several cubic meters, but are typically in the region of about 500 ml – 5 litres. The challenge in these systems is to keep costs down in order to have a sufficient number of digesters to vary the necessary parameters whilst maintaining sufficient accuracy for robust results. Systems range from tens of pounds for the simplest to many thousands of pounds for sophisticated lab systems which can also be used for 'clean' fermentations.

These lab-based systems are used for research and therefore are not generally subject to EA permitting. However, there are strict health and safety procedures and risk assessments in these facilities.

It should be noted that care should be taken when extrapolating such lab data to full sized systems and a good dose of common sense should be applied. However, a number of larger on-site trial units have been built for specific applications, such as the one designed by Derek Rodman for the Blackmore Vale Dairy ambient-temperature AD trial. With a larger capacity of up to 10m$^3$, such units have been shown to replicate the performance of larger commercial units with considerable accuracy.

Many of these small systems and trial units will be true CSTR's (continuously stirred tank reactors) – that is, they are continuously mechanically mixed. Thus, data on, for example, trace element supplementation is likely to extrapolate better to full-sized systems than that of a computational fluid dynamics study which is more dependent upon digester size and engineering. Nevertheless, the capability of such systems to expand our knowledge and to push operational boundaries is invaluable – just pity the poor researcher who pushed the boundaries too far and found their digester contents on the lab ceiling.

## Home scale anaerobic digesters

This comprises a small, but growing sector of the industry, particularly for users in remote areas, where organic waste disposal is difficult/expensive or where the cost of fossil fuels is prohibitively expensive.

## HOME BIOGAS OUTPUTS

The following 'rules of thumb' on the heated/mixed digesters Vs ambient temperature unmixed systems are just that: digester engineering, feedstock quality, operator competence and loading rate, will all cause variations – as with any digester.

The retention time for a system running on food/garden waste may vary from 60 days for mixed and heated (~35C-40C) digesters, to more than 250 days for an unmixed digester running at ambient (~25C+) temperatures.

The more productive of these can produce from 1 to 3 volumes of biogas per day, depending upon loading rate and the quality of the feedstock, i.e. a 200-litre digester could produce 200-600 litres of biogas per day. On 'normal' food waste, 1.5 volumes could be expected, running at a gentle loading rate of 1.6 kg VS/m$^3$/day (see here): unheated/mixed digesters are likely to produce less than 1 volume of biogas per day – possibly as little as .3-.4 volumes.

Suppliers in the USA, India, China, Israel and the UK sell systems which are suitable for home ownership and use. Systems manufactured in China and India are arguably the cheapest, as their potential home consumer market is large and their manufacturing costs are low. These systems may be made out of hard plastic, flexible (bag) plastic, fibreglass or stainless steel.

Newcomers to AD who are interested in 'home' systems should be aware that many are not designed for a temperate UK climate and may not be heated or insulated. Biogas production significantly diminishes at lower temperatures (below about 20C-25C), so a small unheated and/or poorly insulated digester fed on ambient temperature feedstocks struggles to produce much biogas in the UK's cooler climate. In these small systems, the heating energy required to maintain a constant temperature generally exceeds mixing energy, so it makes sense to mix a heated digester which increases biogas production (see above, Home Biogas Outputs).

This sector would also include the 'DIY digesters' of YouTube fame which are a fun introduction to the technology – although it is important that any prospective DIY'er should familiarise themselves with the basic health and safety.

The biogas produced by such systems is generally used for cooking, although biogas lights, showers and water heaters (boilers) exist in the marketplace.

Off grid: backyard biogas production is increasingly deployed as a 'lifestyle' choice by some, and an alternative to fossil fuels for those off-grid in the UK, but predominantly as a necessity, meeting sustainable development goals, in remote locations, such as in Bangalore, India

© Homebiogas/Synod Bioscience

Household AD: The author's anaerobic digester, which powers her gas cooker and provides natural fertiliser.

Some suppliers offer the option to add a toilet and generate biogas from humanure, as well – however the biogas yield solely from such sources is limited, except at very large volumes. Users find the technology helpful, usually as part of a range of sustainability measures.

As with most other attempts to categorise digesters, the size of a home digester is difficult to define. Depending upon the technology design and whether the digester is heated/mixed, reasonable gas production for cooking can be achieved from a digester at sizes from about 200 litres. By the time the digester size increases to 6000 litres (6m$^3$), the size of the 'standard' fixed dome Chinese style digester, it is likely too large to fit into most homes, so it is starting to stray into the territory of community or small agricultural systems.



Regulation of this very small and relatively low-risk sector is unclear. In England and Wales, for example, a T25 exemption, where 'you can store or treat up to 50 m$^3$ of waste at any one time', allows 'a business or organisation…[to use] a small AD plant for their kitchen waste…'.

A 'home' anaerobic plant is likely to be run by an individual in much the same way as a 'home' aerobic plant, i.e. a compost heap. In both cases, the products will almost certainly be used at the individual's premises. In neither case is any form of 'end of waste' possible or practical, due to the costs associated with obtaining PAS100 (for compost) or PAS110 (for digestate).

## Micro-scale community digesters

Starting more than a decade ago, with the advent of wide-ranging UK incentives for the deployment of renewable energy, a number of community energy groups investigated the possibility of investing in anaerobic digestion. The majority of these initiatives, reports and feasibility studies came to nought, often due to the more attractive and less risky investment in alternative renewable energy technologies such as solar, as well as the normal pressures of putting an AD project together.

The main challenges included finding and securing sufficient feedstocks, the larger capital cost per m$^3$ for smaller systems and the lack of incentives specific to (generally) smaller installations which might provide wider community or other benefits. Some encountered problems specific to their region: one community found that the local council was happy for organic waste from their village to be transported for miles to a facility outside the county, but objected to the 'road movements' of transporting these materials to a local community digester.

A few micro-scale community digesters have been built, with the capital cost being met through a combination of their own funds, fundraising and external funding. The WRAP-funded Camley Street project in London operated by LEAP (now MADLEAP www.madleap.co.uk) ran for five years, collecting local food waste on cargo bikes and using the digestate for local food growing until the site was re-developed and the digester re-located to another community. Analysis showed that the plant could result in carbon reduction of 0.741 kg $CO_2$eq per kg of waste treated mainly through on-site energy production and by reducing food waste to landfill.

A DIY digester at the Calthorpe project just down the road was replaced by a more automated system and is used as part of a range of activities, including a Living Lab, growing food both in raised beds and hydroponically using digestate, as well as running courses on wider aspects of sustainability and the circular economy.

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Circular economy in action: The Calthorpe Project AD uses feedstock from the café to create biogas and separated digestate, with the fibre used to grow food in raised beds and liquid used for hydroponic growing. The food is then sold in the café, which is powered by biogas (in the warmer months). The digester is housed in the greenhouse.

In spring 2012, Community Energy Warwickshire commissioned a study of the potential for generating energy from food waste in south Warwickshire.

These micro-AD systems generated significant interest from the local organic food growing community, but the energetic cost of pasteurising digestate from these small systems, as well as the impossibility of meeting the costs of end of waste for such projects meant that many felt that the risk to their businesses of using digestate was too great, even where the digester was vegetarian or vegan.

A detailed risk assessment and systematic study of best practice use of digestate in small-scale horticulture would be invaluable to such producers, particularly as the Camley Street project showed that the digestate was excellent: plastic free and easily meeting PAS110 quality limits. There is no low-risk, low-cost, small-scale regulatory position for achieving end of waste by such small producers, so this limits their ability to adopt AD and monetise/utilise digestate, except perhaps by operating within a cooperative.

## Farm Digesters

The concept of a cooperative around an AD plant is an idea that fifth-generation organic farmer Richard Tomlinson and a small group of local residents turned into reality when they established the Lower Park Farm Co-operative Ltd to raise £1.25M to fund the construction of a 240 kWeq farm digester (http://lowerparkfarmcoop.co.uk/).

Richard had experience of co-operatives having been involved in the formation of Calon Wen, a farming co-operative of 25 Welsh farmers who pooled resources to supply 15 million litres of organic milk to market annually. Their aspiration was to use the digester to supply all of the farm's on-site heating and electricity requirements. Feedstock to the digester includes the slurry from the farm's circa 700+ dairy and beef cattle, as well as local chicken muck and waste silage.

A reduced minimum number of Co-op shares were first offered to local investors. Co-operative members are encouraged to participate in the co-operative and can also have free digestate, as well as 10% off Calon Wen products. Such an approach has numerous benefits: local people learn about and benefit from local agriculture and its products, members get to realise the benefits of using digestate as an excellent peat-free gardening alternative and the farm lowers its carbon footprint, returns carbon to its soils and improves its sustainability. The co-operative receives income from feed-in tariffs for electricity production, as well as the renewable heat incentive.


Small-scale biogas upgrading for on-farm AD, producing transport fuel.

Lower Park Farm Co-op.

The digester is well able to deal with the sand and grit in slurries, as it utilises a patented novel de-gritting system, assigned by digester engineer James Murcott to Fre-Energy, a successful local firm who have built a number of on-farm digesters. The Co-op's original objective of possibly adding more digesters to the co-operative are unlikely to come to fruition under current economic conditions, as support is non-existent for these relatively small farm systems using primarily low-energy waste products such as slurry.

This approach could be replicated on multiple farm sites as part of efforts to decarbonise production, but we need to see the development of modular designs. With agriculture being a particularly hard sector to decarbonise and soil carbon at critically low levels, Government would do well to incentivise and encourage such multiple-benefit AD projects in a post-Brexit agricultural world. This is particularly important, as many farms are off the gas-grid and rely on higher carbon heating oil, as well as often having significant electricity requirements.

Also, biogas if upgraded to biomethane (at a smaller scale) can provide clean fuel for agricultural vehicles without the need for grid injection, as demonstrated by the small Metener compressed biomethane upgrading and vehicle fuelling system, which ran for a number of years and was funded by WRAP and operated by Evergreen Gas.

Where sustainability criteria now encourages 'waste' feedstocks and limits the amount of purpose-grown crop that can go into a digester, livestock farming should have an excellent opportunity to utilise the volatile carbon energy in their slurries, manures and local waste feedstocks, including otherwise uneconomic break crops which support soil improvement. Professor Charles Banks of the University of Southampton estimates that, if the UK's slurries are not digested, 3M tonnes $CO_2$ equivalent would be produced, based on DECC 2009 GHG emissions data.

It should be noted that these digesters are, however, small in terms of energy output by today's standards – certainly below 250 kWeq. For example, running on slurry alone, it requires 1,000 good-sized dairy cows to provide sufficient slurry for a 100 kWeq 1,000m$^3$ 'small-scale' digester. With an estimated 100 million tonnes of slurries and manures in the UK and only a very small percentage of these being valorised through AD, this market has huge potential, but will need specific policy incentives to grow.

Apsley Farm, Hampshire, which has taken to social media to market its digestate.


The businesses behind these are quite different, the drivers are different, the challenges are different, yet AD can be utilised in both situations. However, if policymakers deem it desirable to develop a given AD sector, the policy must align with the economic characteristics of that sector: with no Environment Agency regulation on PGC (purpose grown crop) digesters and incentives solely for energy production, it was not surprising when AD projects eschewed any significant inclusion of slurry feedstocks at a production of 23 $m^3$ biogas per tonne in favour of maize at 220 $m^3$ of biogas per tonne.

During the late 80's/early 90's, a number of UK livestock farmers with AD plants created a nascent market for digestate through sales of Heritage compost, a clean, balanced multi-purpose compost mixture of coir and digestate fibre for domestic and horticultural use. There is certainly an opportunity to explore a regulatory approach whereby small farmers who wish to create a paying market for such products can do so, thereby relying less on outright subsidies.

Even within the 'farm digester' sector, all digesters are not the same: systems range from very small, such as St Davids' farmer Wyn Evans' 70$m^3$ 40+ year-old digester which takes slurry from 65 dairy cows and heats the house, to the Hampshire arable farm's 16 MW system described below.



Nevertheless, AD has an important place in arable farming where crop feedstocks have a much higher energetic potential than mainly slurry-based livestock digesters. A recent Environment Agency report noted that intensive agriculture has caused arable soils to lose 40 to 60% of their organic carbon. Replacing this carbon in a world with a changing climate not only helps to reduce flood risk by absorbing water, it also helps to sequester a significant amount of carbon. Whilst practices such as no-till, cover crops and so on help soil carbon levels, AD is also a vital way to provide income from break crops and to reduce the carbon emissions of arable farming, whilst improving soil health.

The 1,150-acre Apsley Farms site in Hampshire not only use their digestate on-site, but they also sell it as a fibre and liquid, marketing it in innovative ways, including via social media outlets. It is impressive to see the word 'digestate' come up in, for example, a mainstream Instagram feed. Their 16 MW crop-based digester, in addition to providing biomethane-to-grid, also provides food grade $CO_2$.

With increasing numbers of biomethane plants built under the Renewable Heat Incentive, UK policy needs to encourage the utilisation of this $CO_2$ as an important by-product, increasing the UK's rather fragile supply chain resilience, as evidenced by the events of the summer of 2018 which affected various food sectors including the meat, bakery, soft drinks and alcohol industries.

Beeswax Dyson (plan to compress biomethane in order to power tractors and lorries, cutting diesel consumption. At their 3MW Carrington site, digestate, heat and $CO_2$ from the upgrading process will be used in their six hectare state-of-the-art glasshouse growing strawberries and other soft fruit.

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Beeswax Dyson's Carrington AD plant.

Beeswax Dyson are not alone in using AD as part of their drive to manage natural capital and work to a 'triple bottom line' (profit, people and the planet). MD Richard Williamson expresses the company's determination to 'be a good business that operates for the long term and carbon management is fundamental to these ambitions', adding that 'respect for the environment can also be profitable'.

Such large wholly or mainly crop-based AD installations can provide a host of benefits, including significant carbon reductions. However, particularly with the introduction of sustainability criteria, flexible policy including a timely and streamlined FMS (fuel measurement and sampling) system which allows rapid changes in AD feedstocks is hugely important in a world of increasing climatic and economic uncertainty.

With 2020 UK cereal yields set to hit a 30-year low due to extreme weather events, how can crop-based digesters utilise waste feedstocks in a timely and safe way? With Covid-19 meaning that some reliable long-term waste streams dried up overnight in some areas, whilst other areas saw spoilt food dumping, flexible policy to ensure that re-direction of good food and re-cycling of spoilt food through AD is imperative. On-site bioenergy should be part of plans for a post-Covid green recovery.

## On-site AD for agri-food businesses

Agricultural businesses are not alone in their drive to reduce their carbon footprint. The agri-food sector is too. Yet the potential of AD has barely been tapped.

Turning rejected chocolate into energy is a catchy headline, but Nestle's 2015 AD installation at Fawdon is only part of a range of initiatives to reduce the company's carbon footprint. The site piloted a smaller version of the digester technology before building the full-sized plant. The electricity and heat produced by the AD plant was designed to meet about 10% of the site's energy needs, improving the quality of the discharge water and with a potential payback in the region of five years, although subsequent industrial projects have demonstrated a payback of under five years.

BREWDOG

Brewdog Brewery, based in Aberdeenshire, is aiming for carbon neutrality at their Ellon site by 2022. As part of a £14M investment phase, they have already installed 2.4 MW of wind turbines and submitted a planning application for an AD plant. The AD plant will use residues from the brewing process to create energy for the site, cutting their annual residue disposal costs by 50%, improving the resource use on the site and helping the company to meet their 2022 aspiration of becoming 'the world's most sustainable drinks company'.

The relatively significant investment in utilising AD to process on-site organic residues needs to make economic sense, although some businesses will take a longer view and accept lower IRRs (internal rate of return), depending upon a number of factors, including their business ethos and investment aims.

While many multi-national agri-food businesses have plans in place to lower their carbon footprint through a range of initiatives, including utilising their residues through AD, this is a sector which could also use solid policy encouragement, particularly at the SME (small and medium enterprise) end. Such sites can potentially use the biogas energy in many ways: heat, electricity or, in some cases, vehicle fuel.

Given the flexible uses of biogas/biomethane, there are viable options which don't force the producer down the expensive grid injection route suitable only for very large AD systems. Ongoing support for smaller bioenergy projects on SME and farm sites is a key policy ask under the planned Green Gas Support Scheme.

As with farm AD systems which, after all, are a particular type of on-site AD, industrial on-site systems can vary in size from relatively small to very large. Unlike merchant food waste plants that take in a wide range of organic materials, including kerbside collections, on-site AD has much greater control over the feedstocks (often from a single source) and thus the corresponding digestate.

Because of the types of feedstocks that agri-food biogas plants can deal with, there are also much greater potential opportunities for extraction/utilisation of products both before and after the AD process, effectively turning the system into a biorefinery, as there is more likely to be sufficient concentrations of a given organic material to make extraction cost effective. AD can be applied to treat the residues from the biorefinery process.

## The biorefinery and product production

Imagine a world where fossil fuel-based products are largely replaced by bio-based, recyclable products, with AD at the heart of this refinery recycling nutrients from the final residues back to land after extracting the volatile carbon as energy.

Swansea's ALG project is growing single cell proteins on digestate.

Sweet: Nestlé's Fawdon biogas plant.

Food waste to fertiliser: InsPro is to trial its black soldier fly project at Malaby Biogas' Bore Hill Farm facility.

Although admittedly a rather simplified and idealised notion, this is nevertheless a sector with exciting wide-ranging potential and its gains to date have been quietly increasing. A couple of niche examples illustrate the challenges of bringing such innovative technologies and products to the marketplace.

In a world where protein demand is increasing and elements of protein production at current levels are increasingly unsustainable (e.g. certain meat and soya production), there are many innovative ideas for low carbon protein production. The ALG-AD project, for example, aims to take digestate and grow single cell protein (SCP) using algae. The SCP could then be used to feed farmed fish instead of importing soya protein or utilising wild fish to make fish meal.

The use of insects for protein supply into different levels of the food chain is also a growing area. Companies such as InsPro utilise black soldier fly larvae to recycle food waste, with the larvae providing protein for fish food. Frass (larvae dung) can be used as a soil re-conditioner and fertiliser product. Such a process could be integrated with AD by using heat from the AD to provide an optimal growing environment, shared permits and transport - and by putting any residues and waste materials from the process into the AD and vice versa (digestate). Malaby Biogas are working with InsPro on an integrated Black Soldier Fly (BSF) trial at Bore Hill Farm Digester.

Scaling biorefinery projects from the lab to a size commensurate with commercial production requires a range of technical and business expertise, and a rigorous realistic assessment of the greenhouse gas (GHG) savings and environmental credentials. Ensuring that the process works on a commercial basis is imperative for entrepreneurial businesses in this sector, necessitating a keen eye to sort the wheat from the chaff, the bio-winners from the bio-bollocks.

But of course, innovative processes will only get us so far – we also need a level playing field when it comes to regulations. While considering the area of digestate derivatives, Dr David Tompkins of Aqua Enviro recently raised questions about 'when is a digestate not digestate'. These are important when AD operators are asked to cover digestate stores and use expensive digestate application techniques – both of which become irrelevant when digestate has been turned into something else.

At the same time, turning food waste or manure-derived digestates into something else – such as ammonium sulphate – would attract regulatory costs that wouldn't be applied to crop-only digestates. It isn't possible to know whether this approach is proportionate unless AD operators in different sectors start to collaborate and share data on their derived materials. Providing guidance on when digestate is no longer digestate would also help to ensure that operators don't accidentally invest in an inappropriate process.

In a commercially competitive world, how can the cost be met of demonstrating equivalence between waste-derived products and those of non-waste origin where there is no value attached to the GHG savings that AD delivers? Currently, if an operator of a 50:50 crop and slurry digester extracts something from digestate, such as struvite, ammonium sulphate, phosphorus, while it is no longer digestate it is still considered a waste. However, if the same materials are extracted from a non-waste, they can be both extracted and sold.

This reflects the fact that PAS110 (ADQP) covers digestates but not products derived from digestates. It makes no sense for 'AD Plant A' to go through the pain and cost of proving their digestate-derived product is safe and equivalent to a non-waste product, and then require 'AD Plant B', with a slightly (or very) different feedstock mix, to then go through the same costly process.

So that each company is not footing the entire cost of 're-inventing the wheel' for their own product, is there an opportunity for like-minded companies with similar products to share the benefits, as well as the costs of data analysis and risk assessment, potentially with technical input from trade bodies and academia?

With an increasing focus on valorising waste materials through AD, with the extraction and creation of valuable products both upstream and downstream, a cooperative approach and relatively small investment into the development of end of waste positions for digestate use in other markets would be a significant step towards adding value and creating a market for such products. Also there is a need for policy makers to work with the agri-food sector to encourage investment on SME sites that proliferate in the sector and lack the resources to match investment by larger multinationals.

## AD for sewage treatment

Anaerobic digestion has long been deployed in the wastewater sector as a means of removing dry matter from sewage sludge, but the role of the technology in reducing the parasitic load of wastewater treatment plants has become increasingly important over the past few decades, particularly with successive UK government renewable energy incentives, beginning with the Non-Fossil Fuel Obligation of 1990. With 2019's ambitious water industry commitment to reach net zero carbon by 2030, the sector has long realised the benefits of renewable energy and knows the impact of climate change events such as flooding and drought on water supply and demand.

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"Anaerobic digestion is a real priority for us". Severn Trent when it announced the launch of an integrated thermal-hydrolysis AD project.

Minworth Wastewater Treatment biogas upgrading facility.

A £60 million investment at Severn Trent's largest sewage treatment works at Minworth aims to produce 30% more green energy by using Cambi's thermal hydrolysis process as part of the company's bid to reach a target of 50% renewable energy by 2020.

In addition to reducing parasitic energy use, driving down carbon emissions in the supply chain, introducing low-carbon transport options within the business and other initiatives common to many business, the industry has the unique requirement to reduce process GHG emissions which delivers triple bottom line value. This is a particularly challenging task and will require a range of approaches.

The Environment Agency reviewed the current regime for septic tank and sewage sludge and plan to bring these into their Environmental Permitting Regulations for England and Wales in 2023, replacing the Sludge (Use in Agriculture) Regulations 1989. One of the of objectives of the change is to create consistency across the waste and water industries, partially due to changes to the treatment of such organic materials, including AD which focuses on the energy value of the sludge.

Several UK water companies have set up arms which own and operate food waste digesters. Geneco, part of Wessex Water, inject 1900m$^3$ of biomethane every hour from their Avonmouth food waste digester. And with the 2018 acquisition of Agrivert's AD and composting facilities, Severn Trent Green Power is now the UK's largest food waste recycler and composting business.

With water company aspirations for net zero carbon and their investments in innovative technologies to get there, coupled with the projected EA changes in permitting, this will be an interesting space to watch.

## Merchant food waste AD plants

Merchant food waste AD plants provide an important role in keeping waste food out of landfill, producing renewable energy and recycling nutrients back to land. With government aspirations to reduce GHG emissions from food waste, the Resources and Waste Strategy seeks to ensure that, subject to consultation, every 'householder and appropriate business has a weekly separate food waste collection' in England. This is good news for AD which can reduce the GHG emissions associated with food waste.


Avonmmouth food waste digester. Every tonne of food waste diverted from landfill will displace 0.6 tonnes of $CO_2$eq. Every year the UK wastes an estimated 10 million tonnes of food with a value of over £17 billion. It is associated with around 20 million tonnes of greenhouse gas (GHG) emissions.

A recent University of Bath study of Malaby Biogas' Bore Hill Farm AD plant concluded that the plant had an emissions intensity of -102g $CO_2e$/MJ electricity generated – significantly carbon negative due to its renewable energy generation, diversion of food waste and production of fertiliser. The plant, which yearly processes almost 30,000 tonnes of food and organic waste into over 7,000MWh of renewable electricity and more than 25,000 tonnes of biofertiliser, is relatively small-scale for plants of this type.

The study estimated that there are 100 plants similar to Malaby's which together reduce GHG emissions equivalent to taking 400,000 new cars off the road, a further indication of the necessity for government to put policies in place that provide support to AD. The University of Bath is undertaking a follow up study to improve the accuracy of methane slip, which could further improve the GHG emissions position by up to 20%.

## And so...

It could be said that the categories above are rather arbitrary, but they do illustrate the wide applicability and variation within the technology of anaerobic digestion. The increasing tendency to lump anaerobic digestion technology under the banners 'Energy from Waste' or 'Biomass energy', or even as a 'transition fuel', does not fully explain the benefits of the industry. Doing this ignores and demeans the role of AD and its myriad and flexible applications at all sizes in agriculture, horticulture, research, agri-food industries, waste

Continued>>

Carbon negative, as revealed in a lifecycle assessment of Malaby Biogas, Bore Hill Farm.

## SMALL AND MICRO-AD DEFINED

The identification of scale is arbitrary since tank size/gas use are dependent on other factors, particularly feedstock and loading rate. However, the notes below provide a basic guide to the scale and potential of small and mirco-AD.

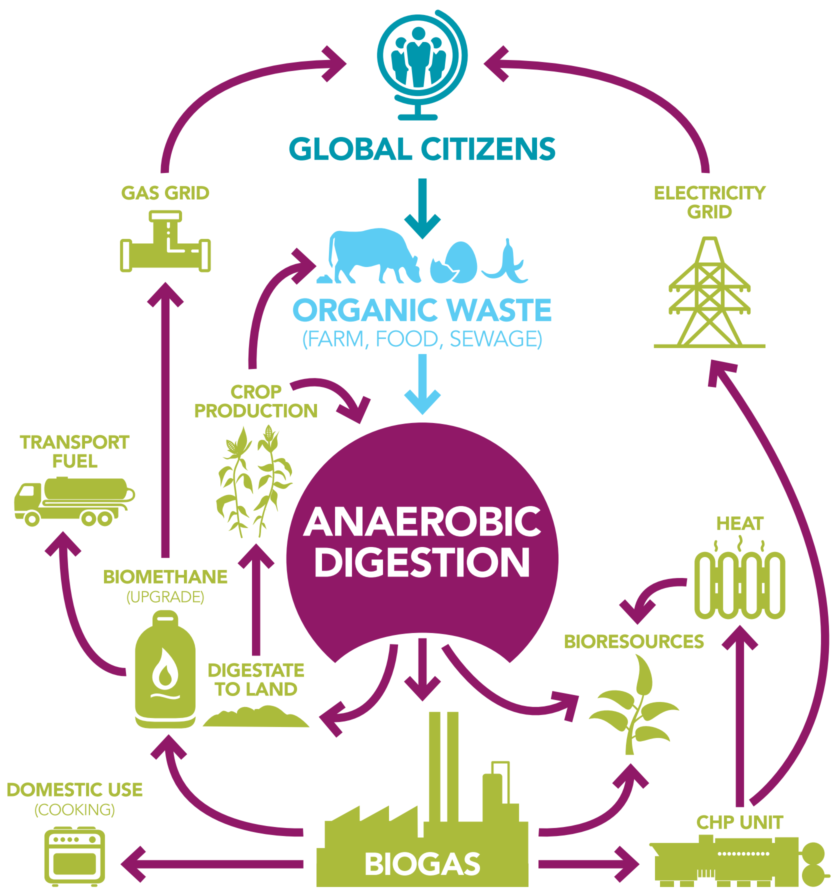
| Scale | Tank Size | Gas Use | Reasoning/Notes |
|---|---|---|---|
| **Micro** | $0.2m^3$-$100m^3$ | ~ <$20m^3$: heating and cooking. ~ >=$20m^3$: heating or CHP 3-25kWe, depending upon feedstock and loading rate. | $0.2m^3$ is practical enough to provide cooking gas for a small household, although it is also used at lab scale; a $20m^3$ digester on for example food waste can run a small CHP. Up to about $100m^3$ is possible on modular/'portable' systems (eg 5 x$20m^3$ tanks). After about 80-$100m^3$, it is usually more economic to build a single fixed tank. |
| **Small** | $100m^3$- ~$1,000m^3$ | CHP ~ 10kWe-200kWe, depending upon feedstock and loading rate. Gas heating possible, as well, particularly at lower end. | After $100m^3$, fixed tank(s) likely to make more economic sense. $100m^3$ tank on slurry would produce ~10kWe (100 cows). $1,000m^3$ tank would produce ~100kWe on slurry (1,000 cows) or potentially ~230kWe on food waste. |
| **Medium** | ~$1,000m^3$+ | CHP ~100kWe – 1MWe. | The lower range of 'medium' is where the slurry-only digester becomes almost impossible (1,000+ dairy herds are still relatively rare in UK) and up to the point where biomethane becomes economic. Early UK biomethane plants were in excess of 1MWe equivalent. |
| **Large** | ~$4,000m^3$+ | Biomethane upgrading & CHP. | Biomethane upgrading is economic at this scale, policy dependant. |



management, recycling, wastewater treatment and for communities. There are many upsides and very few downsides.

The International Energy Agency says AD sits at the heart of the circular economy. It is the nexus of waste management and nutrient recycling, renewable energy and transport fuel production, reducing GHG emissions throughout every step of the way.

There will always be wasted organics to be recycled back to land in an environmentally sound way and for the foreseeable future the best technology for this is AD, so it must feature in our future energy mix, alongside electricity and hydrogen. The technology works now. And research digesters are working on ways to turbocharge these systems in both the short- and long-term.




AD at the heart of the circular economy.

The sector has proven itself to be hugely successful at responding to market conditions and creating capacity across a range of scenarios. If AD is to fulfil its longer-term potential and realise its vital role of recycling nutrients and creating energy in a future low-carbon circular economy, industry, academia and government departments must work together to create the framework for the future development of AD. AD has a clear place in a low-carbon future that includes healthy soils, healthy environments and renewable energy.

In particular, tapping the largely unexploited potential for smaller and on-site AD to support the 'difficult to decarbonise' agricultural and on-site agri-food sectors will contribute to local economies and jobs, while meeting the proximity principle and supplying decentralised bio-energy, both on and off-grid. This reduces 'waste miles' and works hand-in-hand with other renewable technologies to deliver flexible distributed heat, electricity and/or transport fuel that can be tailored to site needs.

Many people involved in this industry are aware that sweeping statements of what AD is (or isn't) just do not apply to all the varied situations that the technology is used in. Things are far more nuanced than that. The term AD describes a stable of technologies that are carefully designed to serve a particular purpose across a wide variety of sectors. To achieve net zero all must be deployed.