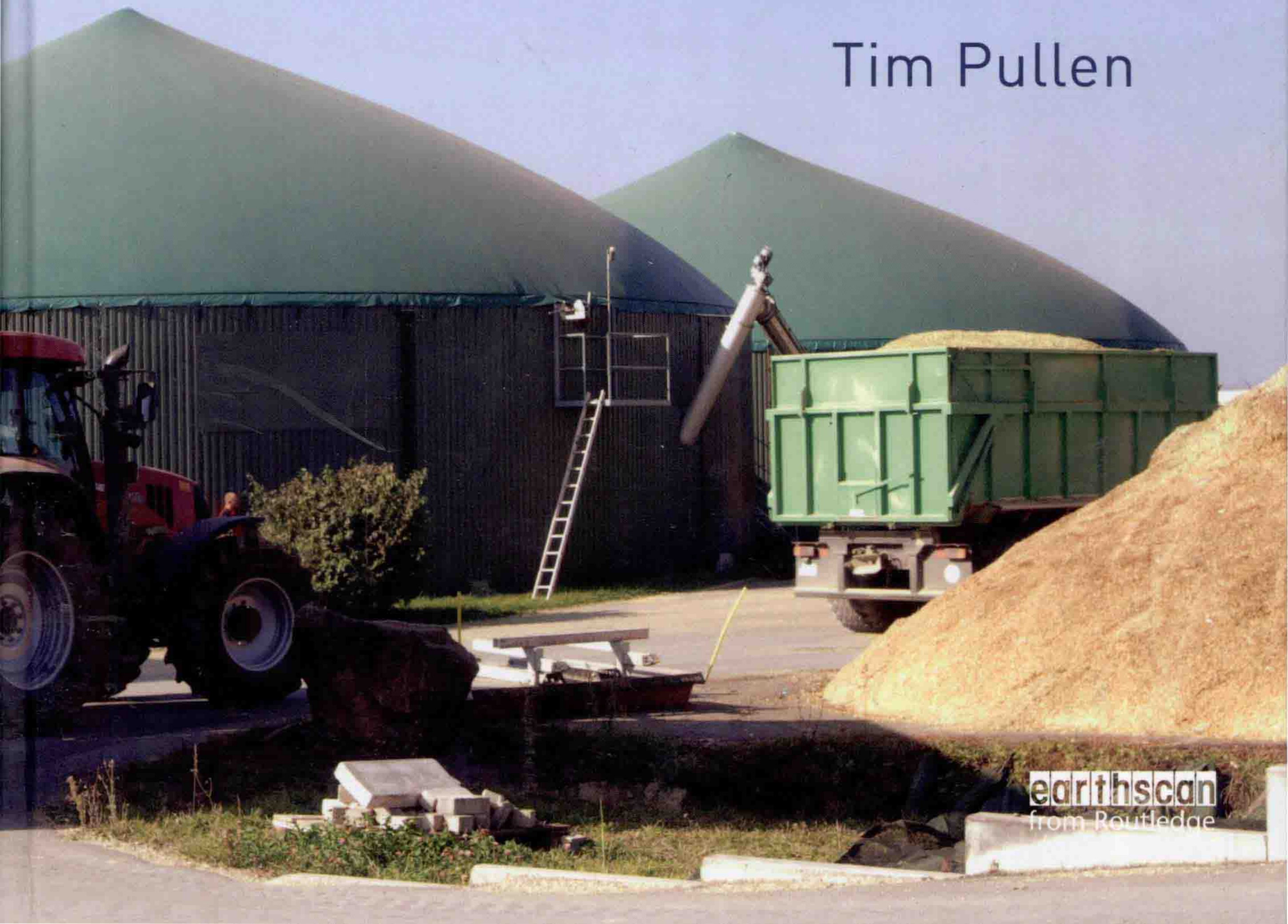
EARTHSCAN EXPERT SERIES

ANAEROBIC DIGESTION – MAKING BIOGAS – MAKING ENERGY

THE EARTHSCAN EXPERT GUIDE

Tim Pullen



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The Earthscan Expert Guide

Tim Pullen

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Anaerobic Digestion – Making Biogas – Making Energy

Hundreds of millions of tonnes of agricultural and food waste are produced each year around the world, most of which is just that, waste. Anaerobic digestion (AD), biogas and the heat and electricity that can be produced from it is still a nascent industry in many countries, yet the benefits of AD spread throughout the community:

- Gives good financial returns to farmers and eco-entrepreneurs
- Helps community leaders meet various policies and legislative targets
- Offers an environmentally sensitive waste disposal option
- Provides a local heat and power supply, and creates employment opportunities
- Reduces greenhouse gas emissions, as well as providing an organic fertiliser.

Although the process of AD itself is relatively simple there are several system options available to meet the demands of different feedstocks. This book describes, in simple, easy to read language, the five common systems of AD; how they work, the impact of scale, the basic requirements, the costs and financial implications, and how to get involved in this rapidly growing green industry.

Tim Pullen is a consultant at WeatherWorks Ltd, a company he established himself in 2004. WeatherWorks provides advice and guidance on sustainable building and renewable energy solutions to self-builders, developers and housing associations. In 1975, Tim built his own AD plant at his then home in Kent, using slurry from a neighbouring pig farm, igniting a passion that continues to this day. Tim is also an eco-expert for *Homebuilding & Renovating* magazine and has published books on sustainable building.

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Introduction to anaerobic digestion and biogas

It can be argued that two of the problems we currently face are a steady decrease in fossil fuel energy sources and a steady increase in the production of organic waste. In many countries waste management, waste reduction, waste prevention and waste recycling have become political and legislative issues as well as environmental issues. Waste dumping, landfill and incineration are highly visible aspects of the waste industry and we are increasingly viewing these 'traditional' disposal methods as unacceptable. They are seen as a blight and a major contributor to pollution and greenhouse gas emissions. But they are also a lost opportunity. There is very little waste that cannot be reused, recycled or have valuable materials extracted from it. The contents of a grease trap or the input to a sewage treatment works might not seem high on that list, yet even these highly unpleasant materials have been used in anaerobic digestion plants for decades.

The energy versus food debate

It is true that anaerobic digestion (AD) plants could use land to grow energy crops that could otherwise be used for food production. Some AD schemes already do,

Figure 1.1 Landfill site on Staten Island, New York, USA. Rubbish dumps, landfill and incineration are increasingly viewed as unacceptable. They are seen as a blight and a major contributor to pollution and greenhouse gas emissions. But they are also a lost opportunity.

Source: Shutterstock

although many do not. Something over nine million AD plants across the world operate perfectly well on waste alone, be that animal, food or human waste. There are less than 10,000 plants worldwide which grow energy crops, but this must be kept in context. There are plans to increase the number of AD plants in the UK from its current level of around 280 to 1,000. The UK National Farmers Union reports that even if all of these need to grow energy crops it would use less land than is currently used for golf courses or keeping horses used for leisure. It also states that farmers have traditionally used up to 25% of their land for energy, either to produce wood for heating or feed horses and oxen for motive power. This raises the question: is it any more desirable to have food without power than power without food? We clearly need both.

What is AD?

AD is a natural process where organic waste – plant and animal material – is broken down by micro-organisms (bacteria) in the absence of air. It occurs naturally in bogs, landfills, on the bottom of lakes or in the stomachs of animals. For the purposes of this book AD is a process that controls that natural activity in a way that allows the gases given off to be captured and made usable.

The AD process begins when organic matter – for example, manure, slurry, food waste and specifically grown energy crops – is put into a sealed tank called the digester. The mix of this organic matter, known as substrate or feedstock, is discussed in Chapter 3. Naturally occurring bacteria then break down the material, which releases a methane-rich gas (biogas). The gas can then be used as a fuel to generate heat and/or electricity or refined to be used as a road vehicle fuel or for injection into the national gas network. In its refined state it is very similar in composition to natural gas. The material left in the digester, known as digestate, is rich in nutrients (nitrogen, potassium and phosphate) and is a good-quality pathogen and odour-free fertiliser and soil conditioner.

AD is sometimes still considered as a new, exciting or even daunting technology, but in fact it has been in constant use since the late nineteenth century. The first AD plant was built in India in the 1890s and the first UK plant in 1911 but is only in the last ten years or so becoming more widely adopted. The problem has been that it was not clear what AD actually does. In its early history it was a waste management process, a way of cleaning otherwise extremely unhealthy waste. It was then seen as a nutrient extraction process, a way of turning that waste into useful fertiliser. Although the energy content of organic waste has been known since the 1930s it was not until the 1970s that the potential to extract that energy began to be exploited. As a result of this confusion AD tended to get lost in governmental policy making. Most renewable energy and bioenergy technologies do only one thing, produce energy, and are therefore simple to deal with. As AD has three distinct products it crosses government department boundaries and has been much more difficult to deal with. Until around 20 years ago, with cheap fuel readily available and climate change still not high on the agenda, it was a solution to a problem that was not perceived to exist.

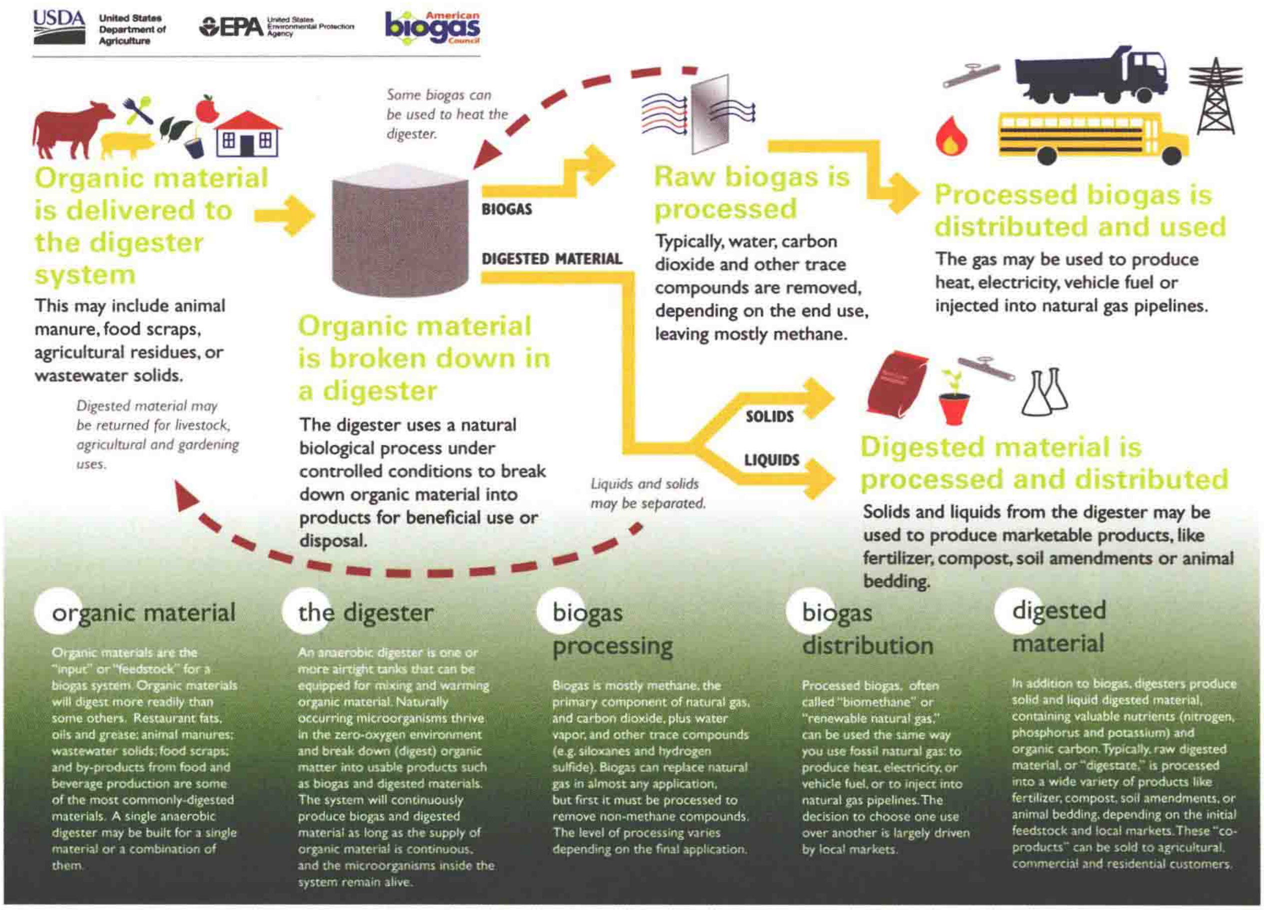

Figure 1.2 Inputs and outputs of an AD plant. The main inputs are manure, and slurries, food and agricultural waste, and energy crops. The outputs are digestate (fertiliser), heat, biogas (biomethane which can be used to power vehicles or fed into the gas grid) and electricity. The whole process is largely CO_2 neutral.

Source: American Biogas Council, www.americanbiogascouncil.org

Figure 1.3 Dry digestate from an AD plant as soil improver.

Source: Courtesy of HRS Heat Exchangers Ltd, Watford, UK

What this book is about

This book sets out to look at AD as a waste treatment and fuel source option, and therefore as a financial income stream. It considers the process from pragmatic and operational viewpoints and discusses implications for the very smallest, domestic scale projects through to the largest, industrial scale projects.

The book starts by giving a brief history of AD, essentially to provide an understanding of the development of the technology from its earliest inception as a relatively crude means of treating waste to its current, highly sophisticated means of producing renewable energy (and treating waste).

It then takes a step-by-step approach to leading the reader through the key issues – from selecting the feedstock through to how a plant works and what the basic requirements are, from the financial and regulatory issues to the practicalities of implementation, the aim being to help a potential biogas plant owner form a decision of whether AD is the right technology for them and select the solution that is most appropriate to their needs.

It is not primarily a technical 'how-to' book and nor does it deal in any unnecessary depth with the science behind the technology. It looks at the different types of plant currently available and the implications of each. It considers schemes from a financial as well as environmental viewpoint to help the potential owner decide what type of scheme is likely to be best for them.

There is a perceived wisdom that, in AD terms, big is beautiful. This book sets out to challenge that with detailed consideration of small, even micro-scale and community-owned schemes. It looks at how the technology has advanced to make these sorts of projects practically as well as financially viable.

Typical AD plant owners

That perceived wisdom leads to a precept that only big farmers with big dairy or pig herds can run a successful AD plant. This book also challenges that with the aim of making AD accessible to a far wider range of potential owners. There are issues around location, access to the organic material needed to feed a plant that mean it is not a technology that will suit everyone, but the book sets out a case for the technology being suitable to many more situations and people than may have been considered. To list a few:

- Small farmers – the idea that thousands of tonnes of manure are needed to successfully operate an AD plant is now far from the truth. The book will show that there is plant available to successfully handle the waste from just 20 or 30 cows or pigs.
- Food processors – food waste has a far higher energy content than manure or slurry and the book will show examples of highly successful schemes running solely on the waste from food processing – from bakeries to abattoirs.
- Local authorities – in many countries there is a requirement on local authorities to collect organic waste from householders and to dispose of that waste in an environmentally sensitive way. The book makes the case that AD

could be and should be the preferred means of recycling an ever-increasing quantity of waste.
- Local communities – the book will show examples of where local communities have come together to take the initiative and install their own plant. Here the motivation may tend to be different. It may be a matter of producing a secure source of cheap, accessible energy rather than of dealing with a waste stream. But ultimately we all end up with the same benefits, irrespective of why we choose to do it.

The list is not exhaustive but it illustrates that AD is not solely for the big land owner.

The environmental and ecological case for AD

Many AD schemes start with the idea of getting rid of a waste problem. In the developing world, waste is increasingly becoming a health problem. In the developed world, waste producers are beset with ever stricter regulations for disposing of waste. Across the world, waste disposal has a cost, in both financial and human terms. As will be shown, AD is a good and in many cases the only means of dealing with that waste in a clean, sustainable and productive way.

It needs to be recognised that disposing of organic waste by conventional means – typically landfill – has a direct cost to the waste producer but also leads to uncontrolled digestion. The process of digestion (or rotting) still takes place and biogas is still produced but in that case it is released to the atmosphere. Methane (being typically 50% to 70% of biogas) is 21 times[1] more potent as a greenhouse effect inducing gas than CO_2. Many local authorities now process organic waste by composting. Laudable as a step in the right direction but the methane is still given off to atmosphere and the energy content is wasted.

AD also has the effect of retaining and concentrating the nutrients in the original materials, turning them into high-quality fertiliser. That fertiliser replaces chemical fertiliser that would otherwise have to have been bought by the farmer, but it also offsets the CO_2 emissions and other by-products associated with their manufacture. The environmental case is clear. AD removes the pollutant potential from a wide range of organic waste materials, captures the methane and CO_2 that would otherwise be released to the atmosphere, and can provide a useful, renewable energy source and a clean nutrient-rich fertiliser.

The financial case – why invest in AD

One hundred kilogrammes of mixed animal waste and green feedstock can produce usable, low-CO_2 energy worth UK£5.98.[2] There is over 100 million tonnes of agricultural and food waste produced each year in the UK, most of which is just that, waste. Europe's fruit and vegetable industries produce some 30 million tonnes of waste each year. The biogas produced from UK waste could provide electricity for up to 350,000 households. An AD plant handling 5,000 tonnes of mixed waste each year would generate an income in excess of

UK£220,000 annually. The return on investment of this technology is typically 20% to 50% per year, varying with the size of the plant and the uses made of the biogas. That compares to around 7% for solar PV (photovoltaic / solar electricity generation), up to 12% for on-shore wind power and 15% to 25% for hydro power. AD, biogas and the heat and electricity that can be produced from it is still a nascent industry in most countries, yet a typical AD plant will recover its capital cost in three to seven years. These figures are based, broadly, on EU farms. Farms in the USA tend to be larger and average numbers of livestock are significantly higher. The potential there is to improve on even these figures.

The amount of waste available for processing continues to increase. The demand for clean, low-cost energy continues to increase, as does the cost of safe waste disposal. At a time when entrepreneurs are looking to invest in renewable energy and farmers are looking for the protection of diversification, AD offers a financially attractive solution. As will be seen, AD is not without its risks and there are issues around location, scale and capital cost that mean it is not for everyone. But where the right conditions exist AD can provide a return on investment at least as good, and typically better, than any other form of renewable energy.

What's so good about biogas?

An AD plant is often referred to as a biogas plant – both terms are ubiquitous across the world. Biogas is, after all, the purpose and product of AD. But biogas is actually a mixture of gases as shown in Table 1.1.

As it comes from the digester, biogas is only marginally useful. It will burn but at relatively cool temperatures as the moisture content in the gas and its low pressure act against high temperature combustion. As a personal anecdote, in the late 1970s the author and his father built a very home-made AD plant at their home, running principally on slurry from an adjacent pig-fattening unit. The process of producing biogas proved to be fairly easy. A few tweaks and refinements (over a period of a few months) largely automated the process and produced a constant supply of gas. At that time we did not know what the gas consisted of, although we understood it was largely methane, and did not know that it contained water. We knew from experimentation that it took an inordinately long time to boil a kettle and eventually surmised that it was the water content that was the problem. At that point our project came to an end as we lacked the knowledge, and will, to dry the gas. That problem is now well understood and most plants dry the gas to below 2% moisture content and remove the hydrogen sulphide as a matter of routine. This last has to be removed because when it is burnt in air it forms sulphuric acid, which does not do an engine any good at all.

Table 1.1 Typical composition of biogas

Component	Concentration
Methane – CH_4	50–75 volume – %
Carbon dioxide – CO_2	25–45 volume – %
Water vapour – H_2O	2–7 volume – %
Oxygen – O_2	<2 volume – %
Nitrogen – N_2	<2 volume – %
Ammonia – NH_3	<1 volume – %
Hydrogen – H_2	<1 volume – %
Hydrogen sulphide – H_2S	20–20,000 ppm

Source: Sustainable Energy Authority of Ireland, 2013

The methane in biogas corresponds chemically to natural gas and is the most energy-dense component