eunomia

# Investment in Advanced Conversion Technologies

## Has the time finally arrived?

November 2016

*About Eunomia*

Eunomia has significant experience of assessing the need for new infrastructure development in the energy and waste sectors on behalf of both public and private sector clients. We provide market and technical due diligence services to a range of lenders and equity funds. Eunomia is also recognised as a leader in understanding the direction and trajectory of waste policy. We have advised Defra, Scottish Government, Welsh Government, Government of Ireland, the Environment Agency, OECD, UNEP, European Investment Bank and the European Commission on a range of waste-related issues since our incorporation in 2001. On behalf of our private sector clients, therefore, we have been able to second guess the trends in legislation and wider developments that drive change in the market. This enables us to identify more secure, but high-yield investment opportunities.

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# Glossary

ACT = Advanced Conversion Technology

BEIS = Department for Business, Energy and Industrial Strategy

CfD(s) = Contract(s) for Difference

CHP = combined heat and power

FiT = Feed-in Tariff

GLA = Greater London Authority

GQCHP = good quality combined heat and power

ktpa = thousand tonnes per annum

LCCC = Low Carbon Contracts Company

MWe = MegaWatts (electrical)

MWh = MegaWatt hours

NTDP = New Technologies Demonstrator Programme

PPA = power purchase agreement

RDF = refuse derived fuel

RHI = Renewable Heat Incentive

RO = Renewable Obligation

solar PV = solar photovoltaic

SRF = solid recovered fuel

tpa = tonnes per annum

# 1.0 Introduction and Market Overview

## 1.1 A Brief History

Advanced Conversion Technologies (ACTs), which include various forms of gasification and pyrolysis, are back in vogue. In the early-to-mid 2000s, when it was challenging to get planning consent for new incinerators, interest in ACTs swelled. ACTs were perceived to not only result in lower emissions of particulates and dioxins (as a result of higher process temperatures) than incinerators, but could be built to be modular at smaller scale. The enthusiasm for ACTs was fuelled by both support for the technologies under Defra's New Technologies Demonstrator Programme (NTDP), which aimed to support the development of a number of ACT facilities, and by eligibility for two Renewable Obligation Certificates (ROCs).[1] Furthermore, bodies such as the Greater London Authority (GLA), then led by Mayor Ken Livingstone, published reports that presented the potential climate change benefits of such technologies.[2]

At that time, a number of new market entrants to the UK waste sector were seeking to develop ACT facilities across the country, largely via competing in local authority procurement processes. Companies such as Brightstar Environmental, Thermoselect, Compact Power and Novera were attracting a lot of attention from early-stage investors.

However, many of the resulting projects were abandoned, never reaching financial close or construction. The reasons varied, but significant amongst them was the perceived technical risk resulting from ACTs not being fully proven in respect of treating mixed residual waste streams. The issue was seen as being of sufficient scale to make it highly challenging to bring debt into project finance deals, while many facilities that relied on less advanced technology were funded.

## 1.2 Ongoing Government Support for ACTs

The current renaissance in interest in ACTs comes as clean technology investors and developers seek alternatives to wind and solar photovoltaic (PV) projects. The early closure of the Renewable Obligation (RO) to these technologies, drastic cuts in the Feed-in Tariff (FiT) and their exclusion from the new Contract for Difference (CfD) support mechanism have made these technologies less attractive investment opportunities.

Critically, however, this last form of support is (currently) available to ACT projects. In the first CfD round, three projects (those being developed by BG Energy Gap,

[1] This equated to a payment of around £80/MWh for electricity generated from biomass. Further discussion of current eligibility for the Renewable Obligation is provided below.

[2] See http://www.letsrecycle.com/news/latest-news/greater-london-authority-backs-new-technology-waste-plants/

Enviroparks Hirwaun and Energy Works) received offers of contracts from the Government's Low Carbon Contracts Company (LCCC).

As discussed in more detail in Section 2.1, the Department for Business, Energy and Industrial Strategy (BEIS) has very recently confirmed that ACT projects are eligible for CfD support at the forthcoming April 2017 auction.[3] This support may allow ACT facilities to function profitably at lower gate fees than would otherwise be possible. This potentially gives supported facilities a competitive edge over plant that do not have a CfD – or, indeed, non-ACT thermal treatment waste treatment facilities – in attracting waste from potential suppliers.

The CfD is the only current policy mechanism to support new ACT projects, but some of those currently in-build were able to secure support under the RO. That support is depends on whether they commission either in advance of the RO closure date of 31st March 2017, or (for projects which met certain criteria in November 2014) by the end of the related 'Grace Period' on 31st March 2018. RO supported projects include Levenseat Renewable Energy's plant in Lanarkshire, Hoddesdon Energy's plant in Hoddesdon (North London) and SUEZ's plant at Charlton Lane, Surrey.

## 1.3 A Critical Time for ACTs

As presented in Section 3.0, in addition to the one project that is currently receiving municipal waste, eight ACT projects are now under construction; a considerable amount of further capacity has also received planning consent over the last five years. This new 'wave' of projects in-build is entering a critical phase in respect of interest from the wider investment community. Successful operation of one or more of these new facilities could pave the way for a cascade of further projects, based on increased comfort amongst investors (including potential lenders) regarding technical risk and the ability to secure sufficient feedstock at attractive commercial terms (potentially supported by a CfD).

At the same time, the prospect of 'Brexit' has introduced uncertainties regarding the continuing decline of UK residual waste arisings and the future role of residual waste exports. These topics are discussed in Section 2.3, and the issues relating to feedstock availability will be explored further by Eunomia in the forthcoming 11th issue of its Residual Waste Infrastructure Review, to be published in December 2016.[4]

## 1.4 Recent Market Developments

While the subsidy and feedstock considerations may be leading to increased optimism regarding investment in ACTs, investor confidence may be undermined by the recent emergence of discouraging stories.

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[3] BEIS (2016) *Draft Budget Notice for the Second CFD Allocation Round*, November 2016

[4] For the latest (10th Edition) please see http://www.eunomia.co.uk/reports-tools/residual-waste-infrastructure-review-10th-issue/

Energos was one of the 'young darlings' of the first wave of proposed ACT projects in the mid-2000s, and the only company that managed to actually build a plant in that era. That plant (in the Isle of Wight) recently ceased operating, but a new, larger replacement plant is scheduled to begin construction by 2018. The company has several UK projects nearing the final stages of construction, but recently entered administration. The company's situation is discussed in more detail in Section 4.1, but its financial difficulties do not seem to be related to problems with its technology.

There has also been extensive coverage of the difficulties experienced by Air Products' operation of a new 350 ktpa plasma gasification facility (TV1) in the Tees Valley. Technical issues at the plant have resulted in the cessation of operations, while the construction of an adjacent identical plant (TV2) has been halted. Air Products subsequently announced its exit from the UK waste market, but the business, including both TV1 and TV2, is the subject of rumoured takeover that could lead to the Tees Valley project eventually becoming operational.

There are nine ACT technologies currently being deployed in the UK waste market, each of which is profiled in Section 4.0. However, the travails of Energos and Air Products fuel a continuing perception of technical risk that currently remains a barrier for ACT projects. The Renewable Energy Association (REA)'s recent communication defending the technology appears to have been intended to counter such news, and may also have been occasioned by a critical report on the historic performance of ACT facilities published by an environmental NGO. [5, 6]

This report examines the reasons for the current revival of interest in ACTs, and the considerations that investors should take into account when deciding whether to engage in this market.

# 2.0 Key Considerations for Project Development

In this section we examine some of the key considerations that affect the viability of new ACT projects: their prospects of receiving support through the CfD scheme; the reliability of the technology; and their ability to secure the necessary feedstock at the right price.

## 2.1 Success in the CfD Auction

One of the routes to success for ACT projects will be to secure CfD support. All ACT projects are eligible to bid for CfDs; by contrast, incineration projects can only bid if they meet the criteria for good quality combined heat and power (GQCHP). Finding an

[5] http://www.r-e-a.net/news/rea-response-to-ukwin-gasification-report
[6] UKWIN (2016) *Gasification Failures in the UK: Bankruptcies and Abandonment*, November 2016

appropriate, bankable, long-term heat offtaker to meet this requirement can be highly challenging. As a result, very few incineration projects are likely to be able to bid for CfDs and thus, while subject to constraints in respect of feedstock treatment requirements (as discussed in Section 2.3), ACT projects may be able to obtain a competitive advantage by securing this additional revenue stream.

BEIS has recently confirmed that ACTs remain in the 'less established' technologies 'pot' alongside offshore wind, biomass CHP, tidal and geothermal generation. Eunomia's analysis, using our in-house CfD pricing model, suggests that some ACT projects may out-compete all of these technologies and are therefore likely to be successful at auction. The support available will be at a rate up to the 'administrative strike price' of £125/MWh of electricity generated from the biomass fraction of the feedstock (for the delivery year 2021/22). This is significantly greater than the price of power (of around £30-50/MWh) which might be received by an operator via a power purchase agreement (PPA) with a licensed energy supplier. It also represents a slight uplift on the level of support that was available to ACT projects under the RO.[7]

In the forthcoming auction, however, BEIS has capped the capacity of 'fuelled' projects (which includes ACTs and biomass combined heat and power (CHP)) at a total of 150 MW (which it states is 'equivalent to a budget maxima of £70 million'). Based on a set of very high-level assumptions (including plant availability, the 'deemed' biomass energy content of the input fuel and the 'reference' price of electricity), £70 million of annual CfD budget equates to around 2.6 million tpa of ACT capacity.[8] This is also broadly equivalent to 150 MW of electrical output from the biomass fraction of fuel input.

It is likely that some of the successful bidders will be ACTs that process waste, and which are able to charge a material gate fee. This gives them a considerable economic advantage over biomass CHP plant, which must either pay large amounts for feedstock if processing virgin wood, or charge only a relatively low gate fee if using waste wood.

Of course, to decide on a viable CfD bid price, ACT developers will need a good understanding of the gate fees they will be able to charge when operational. At the same time, to the level of gate fee they need to charge will depend on their CfD strike price. This 'chicken-and-egg' situation, combined with the fact that considerable market changes may occur in the 2–3 years that will elapse between agreeing a contract with the LCCC and the plant becoming operational, demands a careful, structured negotiation strategy with feedstock suppliers.

[7] In addition, it should be noted that under the RO, the biomass content of waste is 'deemed' at 50%, whereas under the CfD, it is deemed at 63.5%

[8] As described in Section 2.1, since biomass facilities tend to need to pay for feedstock, ACT plant are likely to outcompete them in the CfD auction

## 2.2 Form of Energy Generation

There is a debate to be had as to which form of pyrolysis or gasification process is theoretically the most efficient. Ultimately, however, for their proposed feedstock, developers need to know how many operating hours any particular process has completed at commercial, or semi-commercial, scale, with what level of downtime. To reach 'financial close' on the project, the level of technical risk must usually be sufficiently low that an engineering, procurement and construction (EPC) contractor is willing to 'wrap' these elements into a single contract with the developer and take on the risk of penalties should the plant not perform as specified in the contract.[9]

Globally, examples of successful commercial-scale operation of an ACT coupled with a gas engine (to generate energy) and processing a mixed waste feedstock appear to be restricted to Japan, and performance data is not readily available. As a consequence, whilst the use of a gas engine should not be wholly ruled out for the future, we understand that all UK-focused projects are based upon the use of less energy efficient steam turbines.

Whilst this does not bar ACTs from the forthcoming CfD auction in April 2017, alongside its recent communications regarding the timing and design of the CfD auction, BEIS recently published a consultation on the future validity of support for ACT projects via the scheme.[10] Interestingly, this document highlights that ACTs have the potential to produce synthesis gas ('syngas') which could be used in industrial heat, transport fuel, or higher value applications including the manufacture of chemicals. As a consequence, it suggests that the CfD (which incentivises electricity production) might not be the most appropriate mechanism to support further development of the technology. BEIS also acknowledges that a significant proportion of ACT capacity currently in the planning system is focused on generation of electricity only. It therefore asks for views on how the Government could use the CfD scheme to promote the development of innovative ACT projects that will help develop a 'circular economy' using waste as a fuel.

One approach towards this goal is to clean up syngas such that it can be injected into the natural gas network. This novel approach is shortly to be trialled at a commercial-scale demonstration facility in Swindon by a consortium including Advanced Plasma Power (APP), National Grid and Progressive Energy, with funding from the Department of Transport's Advanced Biofuels programme and Ofgem's Network Innovation Competition.[11] It is an approach that is currently supported by the Renewable Heat Incentive (RHI). To receive RHI support, new projects must be commissioned by 2020. This limited time window is such that it will be challenging for new ACT projects seeking

[9] In some situations, the EPC contractor might be affiliated with the technology supplier, or may seek to pass on the risk of penalties to the technology supplier

[10] BEIS (2016) Call for Evidence – Contracts for Difference: A call for evidence on fuelled and geothermal technologies in the Contracts, November 2016

[11] Injection into the gas network will be demonstrated following initial operation of the gasification process. See https://networks.online/gphsn/news/1000383/national-grid-pioneering-biosng-plant

to inject cleaned-up syngas into the gas network to get accreditation for RHI support. However, decarbonisation of the natural gas grid via renewable or low carbon gases is a priority for Government, and the 'Bio-substitute' Syngas ('BioSNG') route could represent an attractive opportunity in the future, under any successor mechanisms to the RHI.

## 2.3 Feedstock Considerations

Broadly speaking, ACT facilities are easier to operate when supplied with a consistent, homogeneous feedstock. As a result, on a global basis, ACTs have to date been far more effective, and with less downtime, when utilising virgin or waste wood as a feedstock. However, the vast majority of ACT facilities currently being developed in the UK are being designed to use fuels derived from municipal waste, which is inherently heterogeneous: hence the greater focus on these feedstocks in this report. As discussed in Section 2.1, the attraction of using MSW is related more to the high gate fee that operators can charge for treating this waste, rather than due to any particularly desirable characteristics as a fuel.

Waste derived fuels are commonly referred to as either Refuse Derived Fuel (RDF) or Solid Recovered Fuel (SRF). The former term generally refers to residual (household or commercial) waste that has undergone some (generally limited) pre-treatment. As a minimum, this usually means metals removal (for recycling), shredding and possibly baling (especially if it is to be transported). The latter refers to feedstock produced to a stringent specification, as a minimum covering calorific value, chlorine and ash content.

Ideally, ACT plant would be fuelled by SRF, which has been produced to a defined specification (though to varying levels of quality, depending upon the specific process). To produce such fuel, however, requires investment in specialist mechanical equipment. For new, unproven plant, finding a contract with a third party supplier to produce SRF to a specification will often entail accepting lower gate fees and potentially severe penalties for non-acceptance. Some developers, such as Levenseat in respect of its plant in Lanarkshire, have invested in their own pre-treatment equipment. Whilst this appears a sensible approach, there is a risk that in order to meet the fuel specification, significant volumes of reject material will arise, which must go either to landfill or to RDF, incurring payment of a gate fee by the operator, which reduces the attractiveness of the business model.

Alongside technical considerations, the availability of feedstock (specifically residual waste for RDF or SRF production) for ACT facilities is a critical piece of the project development jigsaw. The future availability of residual waste for a given ACT plant depends on a number of different factors including:

- Potential growth (or decline) in total waste arisings;
- Future recycling rates (which affect the amount of residual waste available);
- Current and future capacity at competing waste treatment facilities; and

- The ability of the facility to compete for feedstock on favourable terms (taking into account the need for pre-treatment) for waste not already committed to other facilities under existing contracts.

With around 3 million tonnes per annum (tpa) of RDF being exported from England and Wales to thermal treatment facilities in continental Europe, it is no longer sufficient to look at the UK position alone.

Eunomia's biannual RWIR provides information on all of these issues.[12] The scope of the 10th Issue, published in May 2016, extended to 11 EU Member States, whilst the forthcoming 11th Issue, to be published in December 2016, will consider in detail the likely impacts of Brexit upon feedstock availability for UK treatment facilities.

If it leaves the EU, the UK may not remain committed to higher future recycling targets resulting from the EU Circular Economy Package. The export of RDF, which has grown considerably in recent years, may also become less attractive: the weakened pound has raised the sterling equivalent gate fees at continental incinerators, while trade tariffs on RDF might also be a possibility.

Lenders need to have confidence that sufficient feedstock (at the right gate fee) is likely to be available (or even, can be depended upon) for the period over which debt is repaid, which might be 10 to 15 years. In a scenario of high feedstock availability, which might result from arisings growth, low recycling achievement and/or low levels of competing plant, the amount of waste exceeds treatment capacity, which enables operators to charge high gate fees. Conversely, if waste availability is low, facilities will have to compete for feedstock and gate fees may fall. The spectre of this latter scenario will result in challenges in attracting debt into a project finance transaction (to reduce the cost of capital).

As described in Section 2.1, the prospect of greater returns from CfDs is attracting new investors to ACT projects. Our financial modelling demonstrates, however, that some UK projects may be able to generate sufficient revenue from gate fees and electricity sales to make them attractive without any Government support. Usually, these projects are either:

- Located in areas where there is a lack of treatment infrastructure and no straightforward access to continental Europe; or
- Directly supplied with the majority of feedstock from a long-term local authority contract.

Consequently, while the forthcoming CfD auction will be critical for some projects, not all that fail in the auction will be ruled out.

[12] http://www.eunomia.co.uk/services/waste-recycling/treatment/rwir/

# 3.0 ACT Capacity Development in the UK

## 3.1 Current Market Status

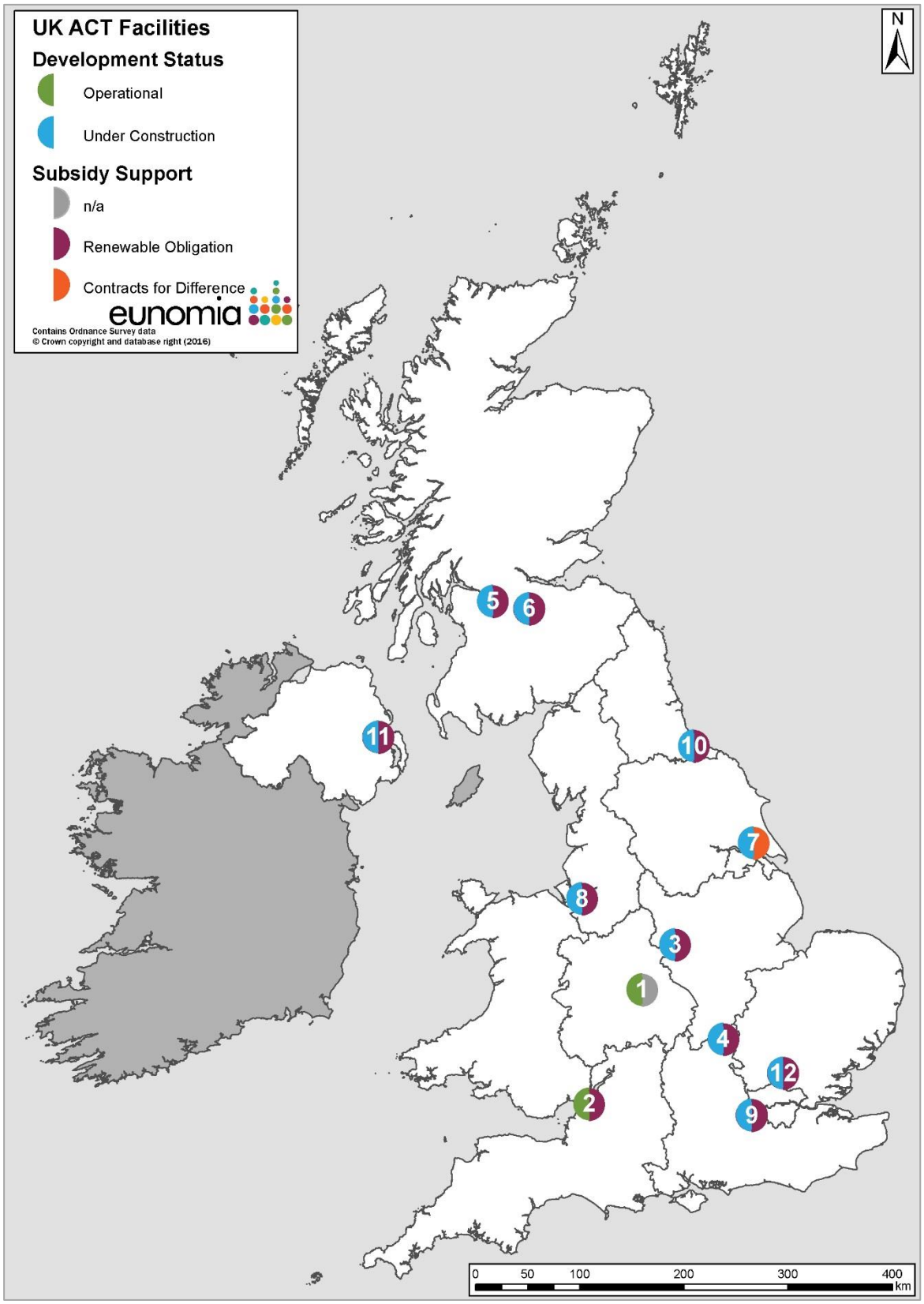
The UK's only operational ACT facility treating mixed waste is Avonmouth Biopower's plant in Avonmouth, Bristol (formerly owned by New Earth Energy). In addition, Chinook Energy is now marketing the technology used at its facility in Oldbury, West Midlands to treat MSW (although it currently only processes automotive shredder residue (ASR)) and has four further plant consented for development.

While the former Air Products' plant on Teesside recently ceased operations, it is rumoured to be the subject of a takeover that could see it become operational. Another eight ACT facilities are at various stages of construction.

There are also several facilities which claim to use ACTs but are actually designated as 'dedicated biomass' under the RO scheme; as such, they are not included within the scope of this study.

The ACTs that are currently operational, have recently operated, or are under construction are shown in Figure 1.

## Figure 1: Operational and Under Construction ACT Facilities in the UK



### Table 1: Operational and Under Construction ACT Facilities in the UK

| Map ID | Operator / Developer | Facility Name | Technology Supplier | Development Status | Design Capacity (tpa) | Support Mechanism[1] |
|---|---|---|---|---|---|---|
| **1** | IES (Chinook Energy) | Oldbury | Chinook Sciences | Operational[2] | 180,000 | n/a |
| **2** | Avonmouth BioPower[3] | Avonmouth | Syngas Products | Operational | 120,000 | RO |
| **3** | Shanks | Sinfin Lane | Energos | Under Construction | 144,400 | RO |
| **4** | AmeyCespa | Milton Keynes | Energos | Under Construction | 96,000 | RO |
| **5** | Viridor | Polmadie | Energos | Under Construction | 145,000 | RO |
| **6** | Levenseat Renewable Energy | Levenseat | Outotec | Under Construction | 110,000 | RO |
| **7** | Energy Works (Spencer Group) | Cleveland Street, Hull | Outotec | Under Construction | 187,000 | CfD |
| **8** | CoGen / Peel Environmental | Protos | Outotec | Under Construction | 170,000 | RO |
| **9** | SUEZ | Charlton Lane | Outotec | Under Construction | 60,000 | RO |
| **10** | Air Products | Tees Valley REF 1 (TV1) | Alter NRG | Under Construction[4] | 350,000 | RO |
| **11** | Full Circle Generation | Bombardier | Biomass Power | Under Construction | 180,000 | RO |
| **12** | Hoddesdon Energy (AssetGen) | Ratty's Lane | Biomass Power | Under Construction | 100,000 | RO |

Notes:

1. Two other facilities (Enviroparks Hirwaun in South Wales and BH Energy Gap in Walsall) have been awarded CfDs, but are not yet under construction.
2. The Oldbury facility is currently using automotive shredder residue as fuel, but the technology is being marketed for the treatment of residual waste.
3. Avonmouth Biopower is 42.5% owned by funds advised by Aurium Capital Markets, 42.5% by CoGen and 15% by Syngas Products Ltd
4. We understand that TV1 is soon to be reconfigured and is thus classed as 'under construction'

## 3.2 Likely Growth in UK Capacity

Table 1 shows that 10 ACT facilities are currently under construction across the UK. As a result of the closure of the RO in April 2017 and uncertainty relating to the status of

ACTs under future CfD auctions, this level of new development is unlikely to be maintained unless other forms of support are introduced.

However, were the UK's level of residual waste availability to increase beyond current expectations, it could function as a driver for new ACT plant. This scenario could be triggered by several aspects of Brexit, such as:

- A slower than anticipated increase in the recycling rate, as a result of deviating from the EU Circular Economy Package; and
- Higher prices for RDF exports, resulting from the falling pound.

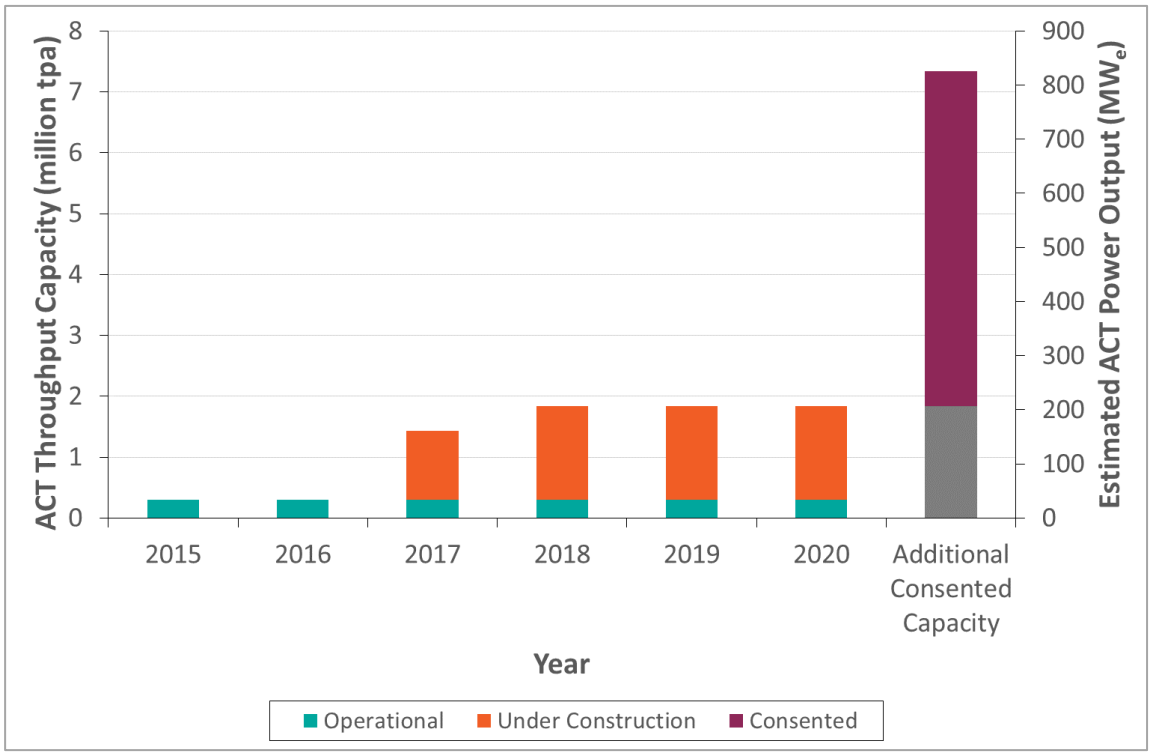
Much will depend upon how the Brexit process plays out over the coming years.

The 12 ACT facilities shown in Table 1 represent around 1.8 million tpa of treatment capacity. This is equivalent to around 200 $MW_e$ of electrical output, which can be available at peak periods of demand. In addition, 5.5 million tpa of ACT capacity has planning consent, which would deliver upwards of 600 $MW_e$ of additional power. A key question, therefore, is how likely it is that this consented capacity moves forward.

Many projects have been consented for some years, but unable to reach financial close as a result of perceived, or real, technical and/or feedstock risks. Perceptions may change if some of the plant currently under construction operate successfully, leading to increased investor interest in ACTs. That could provide an opportunity for some of the stalled projects to be resurrected, whether by the original proposer or new developers.

However, if CfD auctions beyond April 2017 are closed to projects generating electricity only, continued interest may depend upon whether investor confidence can be transferred to other forms of energy generation via ACTs that are likely to be eligible for some form of support, described in 2.2.

## Figure 2: Forecast ACT Capacity in the UK



# 4.0 Summary of Key Players

In the UK, and globally, there are a large number of companies marketing various gasification and pyrolysis technologies. In this section, we present summaries of nine key technology suppliers, selected on the basis that they meet one or more of the following criteria:

1) The company's technology has been deployed at a facility that is currently operating in the UK;[13]
2) The company's technology is currently being deployed at a facility that is under construction in the UK; or
3) The company has been selected as the technology supplier for a facility in the UK that has received an offer of a CfD from the LCCC.

Many of these suppliers also have significant levels of potential ACT capacity at consented UK sites, alongside other reference facilities overseas.

## 4.1 Energos

Energos, owned by ENER-G, is the supplier of the Energos waste gasification energy generation technology and is based in Cheshire, UK. Energos operates as a technology supplier, a project developer and a sub-contractor. ENER-G, founded in the 1980s, now operates in a number of countries around the world. It owns a network of companies specialising in energy generation from waste, including landfill gas, anaerobic digestion, and gasification.

In the UK, Energos operated a facility on the Isle of Wight, which was beset by issues relating to air emissions and breached its permit conditions on a number of occasions. The main issues suffered at the plant, however, appear to have arisen due to it being a retrofit of an existing incineration facility. In 2015, the Isle of Wight Council signed an agreement for a new, larger Energos plant to begin construction by 2018 as part of a 25-year municipal waste management contract with AmeyCespa.

Energos also has three UK facilities under construction, in Derby, Milton Keynes and Glasgow. These amount to a total electricity generation capacity of up to 23 MW, and a feedstock throughput of around 380 ktpa. The company also has a number of UK projects in the pipeline at various stages of pre and post-consent development. Energos also appears to have several operational gasification facilities in Norway and Germany, with throughput capacities ranging from 40 to 80 ktpa.

Given the contracts recently won by consortia in which Energos was the technology supplier, it came as something of a surprise to the industry when in July 2016 the

[13] NEAT Group, the technology supplier to what is now Avonmouth Biopower

company entered administration. It appears that Energos' problems are mainly attributable to cash-flow issues resulting from a number of UK projects simultaneously nearing the final stages of construction. It is, therefore, possible that a UK or overseas infrastructure fund or operator may acquire the business, inject some capital, and work with the other consortium partners (Shanks, AmeyCespa and Viridor) to move each plant into operation.

## 4.2 Chinook Energy

Chinook Sciences is the supplier of the pyrolysis technology known as RODECS®. Formed in 1998, the company soon began supplying technology and equipment to metal, gas and environmental industries. Chinook Sciences claims that the RODECS® technology has been deployed at 16 commercial-scale facilities worldwide.

In 2005, the subsidiary Chinook Energy was created, which expanded the application of its parent's gasification technology into the EfW sector. Chinook Energy's engineering and development headquarters are based in Nottingham in the UK.

Chinook Energy states that the RODECS® technology can utilise a range of feedstocks including biomass, waste derived fuels, electronic waste and scrap metal. It claims that, because RODECS® employs lower temperatures than other gasification technologies, very little initial sorting of waste is required, whilst the outputs from the process might include heat, power and liquid fuels.

In the UK, the company's facility in Oldbury became operational in 2014, and processes automotive shredder residues (ASR) as a feedstock.[14] The relatively homogenous nature of ASR makes it easier to handle and process than fuels derived from residual waste. Planning consent was granted in 2010 for a similar Chinook Energy project near Bootle. This is also intended to process ASR. It is being developed in partnership with IES, but has not yet reached financial close.

Chinook Energy has been named as the technology supplier for at least four other ACT developments that have received planning consent. Two of these appear to be led by its parent company, and two are in partnership with Shore Energy and Hills Group. At all four sites, Chinook Energy intends to process waste derived fuels from local authority or commercial and industrial (C&I) waste sources. However, development of these facilities appears to have stalled.

## 4.3 Advanced Plasma Power

Advanced Plasma Power Limited (APP) is a UK-based technology and development company that is part of Tetronics International, which is engaged in a range sectors, including precious metal refining, hazardous waste treatment and electronics recycling.

[14] At the time of writing, Eunomia has not seen any data relating to the operation of the plant.

APP uses a patented technology, Gasplasma®. This combines gasification and plasma treatment to convert waste into syngas and an inert by-product, Plasmarok®, which it aims to use as a construction material. APP states that Gasplasma can process a range of feedstocks, including municipal waste, C&I waste, waste wood, ASR, hazardous wastes, and a range of other waste derived fuels.

In partnership with Progressive Energy and National Grid (and funded by Ofgem's Network Innovation Competition (NIC)), APP now operates a 10 ktpa pilot plant in Swindon where a number of feedstocks are being tested. This plant generates bio-substitute natural gas (bioSNG) for potential injection into the natural gas network.

With the same project partners (alongside Wales & West Utilities and CNG Services), APP has also recently reached financial close for a subsequent round of funding to demonstrate the ability to sufficiently clean and upgrade the BioSNG for injection into the natural gas network and use as transport fuel. This stage of the project will be funded by the Department for Transport's Advanced Biofuels Competition and by Ofgem's NIC. It will commence operation in 2017/18.

In the UK, APP received planning consent for a 35 ktpa plant in Tyseley, Birmingham in 2013. The company has also entered into an exclusive licence arrangement with Plasma Green Energy (PGE) for it to market the Gasplasma® technology globally as well as exclusivity on construction and operation of the Gasplasma® plants that utilise industrial feedstocks. APP says that it has another eight projects at various stages of development globally, including the order of a £20 million, full-scale plant by Port Fuels & Materials Services Inc., based in Port of Hamilton, Canada.

## 4.4 Kobelco Eco-Solutions

Kobelco Eco-Solutions ('Kobelco') is a Japanese developer and supplier of environmental technologies and solutions, including water and sewage treatment plant, recycling facilities, and EfW facilities. It was created in 2003 and is part of the Kobe Steel group, which commenced operation in 1954.

Kobelco has developed a gasification technology that is aimed at using waste derived fuels as feedstocks for energy generation. The company claims to have 15 plants in operation using this technology, with another two plants under construction, mostly in Japan and South Korea.

In the UK, the technology has been selected for use at BH Energy Gap's Walsall gasification facility, which is designed to process up to 250 ktpa of waste derived fuel and generate around 20 MW of electricity for export to the grid. This project was one of the first ACT facilities to be awarded a CfD in March 2015. Kobelco also has plans to expand further into Europe and states that it is working on a number of other undisclosed projects.

## 4.5 Outotec

Outotec (formerly, Outokumpu Oyj) is headquartered in Espoo, Finland. Other than developing two pilot facilities (in North America and Germany) to test its technologies on

various fuel types, Outotec appears to operate only as a technology supplier, not a project developer. However, it does appear to provide operational and maintenance services for the lifetime of plant developed utilising its technologies.

Globally, Outotec appears to have deployed its technology at a number of operational gasification facilities in the USA. These facilities vary in throughput capacity from 70 ktpa to 500 ktpa, utilising various feedstock types, but primarily biomass and waste wood.

Outotec does not yet have its technology deployed at any operational facilities in the UK. However, four facilities are currently under construction, as shown above in Figure 1 and Table 1. Three will process waste derived fuels, while one will process waste wood. These facilities amount to over 60 MW of electricity generating capacity, with a combined throughput of over 500 ktpa. Three are due to become operational in 2017/18 and will benefit from support under the RO; one, the Spencer Group facility in Hull, was awarded a CfD in March 2015.

## 4.6 Alter NRG

Alter NRG markets a plasma gasification technology, also known as the 'Westinghouse Plasma' technology. This has been deployed at several facilities globally, including operational facilities in China, India, and Japan. In addition, the company operated a demonstration facility in Pennsylvania, USA until 2015.

Alter NRG is headquartered in Calgary, Canada, and was recently purchased by a Chinese bioenergy specialist, Sunshine Kaidi New Energy.[15] Alter NRG now operates primarily as a technology supplier, but also holds stakes in projects utilising its technology.

In the UK, Alter NRG's advanced gasification technology was deployed at Air Products' Tees Valley facility (TV1) and was in the process of being deployed at the identical TV2. Each was intended to process up to 350 ktpa of fuels from residual waste and generate up to 50 MW of electricity. However, in December 2015, construction of TV2 was halted following problems encountered with the commissioning of TV1. The root of the problem is somewhat unclear, but industry rumours point primarily to the design of the feedstock handling system. In April 2016, Air Products announced that the company will exit the EfW sector, effectively abandoning both TV1 and TV2 sites. However, it appears that work is still being undertaken on TV1 with a view to it becoming operational.

Peel Environmental intends for its Bilsthorpe Energy Centre to utilise the same technology as the Air Products' facilities. However, this will be at a smaller scale, with an intended throughput capacity of 100 ktpa and electrical output of up to 13.6 MW.

[15] See http://en.china-kaidi.com/

## 4.7 Syngas Products Group

Syngas Products Group (SPG) is a UK-based company headquartered in Dorset. It was previously named New Earth Advanced Thermal (NEAT) Group and was the technology supplier for the Avonmouth Biopower plant. This was previously known as the Avonmouth 'Energy Recovery Facility' (ERF), owned and operated by New Earth Solutions Group (NESG). SPG appears to be actively marketing its technology to developers, with its potential services including design, supply, installation and maintenance.

NESG officially entered administration in June 2016, and was purchased by PandaGreen (part of Panda Group, based in Ireland) in October 2016. This followed NESG posting a loss of around £30 million in early 2015. It appears that some of this loss can be attributed to the Avonmouth ERF. However, wider issues associated with the NESG business model relating to the operation of its three mechanical-biological treatment (MBT) facilities and two in-vessel composting (IVC) facilities also appear to have contributed significantly to the company's demise.

Prior to NESG entering administration, Avonmouth Biopower acquired the Avonmouth ERF. Data published by the Environment Agency suggests that, during the last two years, the plant has operated well below its design capacity. It has nevertheless processed significant tonnage of feedstock provided by the adjacent Avonmouth MBT plant (now owned and operated by PandaGreen).

SPG supplied its ACT technology to NESG's former Canford ERF (adjacent to the Canford MBT plant now owned and operated by PandaGreen), which appears to have operated for brief periods between 2012 and 2013. The board of SPG includes many of the former board members of NESG.

## 4.8 CHO Power

CHO Power is a French company based in Gironde, wholly owned by Europlasma Group. It was set up in 2007 to develop projects using gasification technology to process residual waste and biomass. CHO Power provides turnkey plants as a prime contractor and can also be involved in all stages of a project from design, funding, construction and commissioning, operation and maintenance.

In the UK, CHO Power's gasification technology has been selected for deployment at Enviropark's Hirwaun facility in South Wales. The facility was awarded a CfD in March 2015, and will have an electrical output capacity of 11 MW, processing around 150 ktpa of SRF from domestic and C&I wastes. The 'front-end' fuel pre-treatment facility entered construction in 2015, with construction of the gasifier expected to begin in imminently.

Elsewhere, CHO Power has one operational facility in France, the CHO Morcenx facility. The plant is designed to generate 11 MW of electricity from high calorific value C&I waste (mainly cardboard, wood, paper, tissues) and biomass from the Landes forest. In addition, CHO Power has three projects in the pipeline across France at various stages of planning and post-consent development, each of which will also generate 11 MW.

## 4.9 Biomass Power

Biomass Power, based in Stafford, England and set up in 2009, is an industrial engineering company specialising in the design, supply and commissioning of equipment for the bioenergy industry. The company aims to help develop a range of ACT facilities, whether as an owner and/or operator.

Biomass Power has developed a modular plant design to generate energy from a range of fuels including C&I and household wastes, waste wood, agricultural residues and energy crops. The company appears to have at least one operational gasification facility processing SRF in the UK, although this facility has not been accredited for support under the RO.

Biomass Power's portfolio also includes two ACT facilities currently under construction, both of which will process SRF (derived from C&I and household wastes) as the primary feedstock. These are the Full Circle Generation (Bombardier) facility in Belfast, and the AssetGen facility at Hoddesdon. The facilities will have a combined electrical generation output of 25 MW, and a feedstock throughput of around 300 ktpa.

Biomass Power also appears to have a number of other projects across the UK at various stages of development, along with an operational biomass gasification facility in Italy.