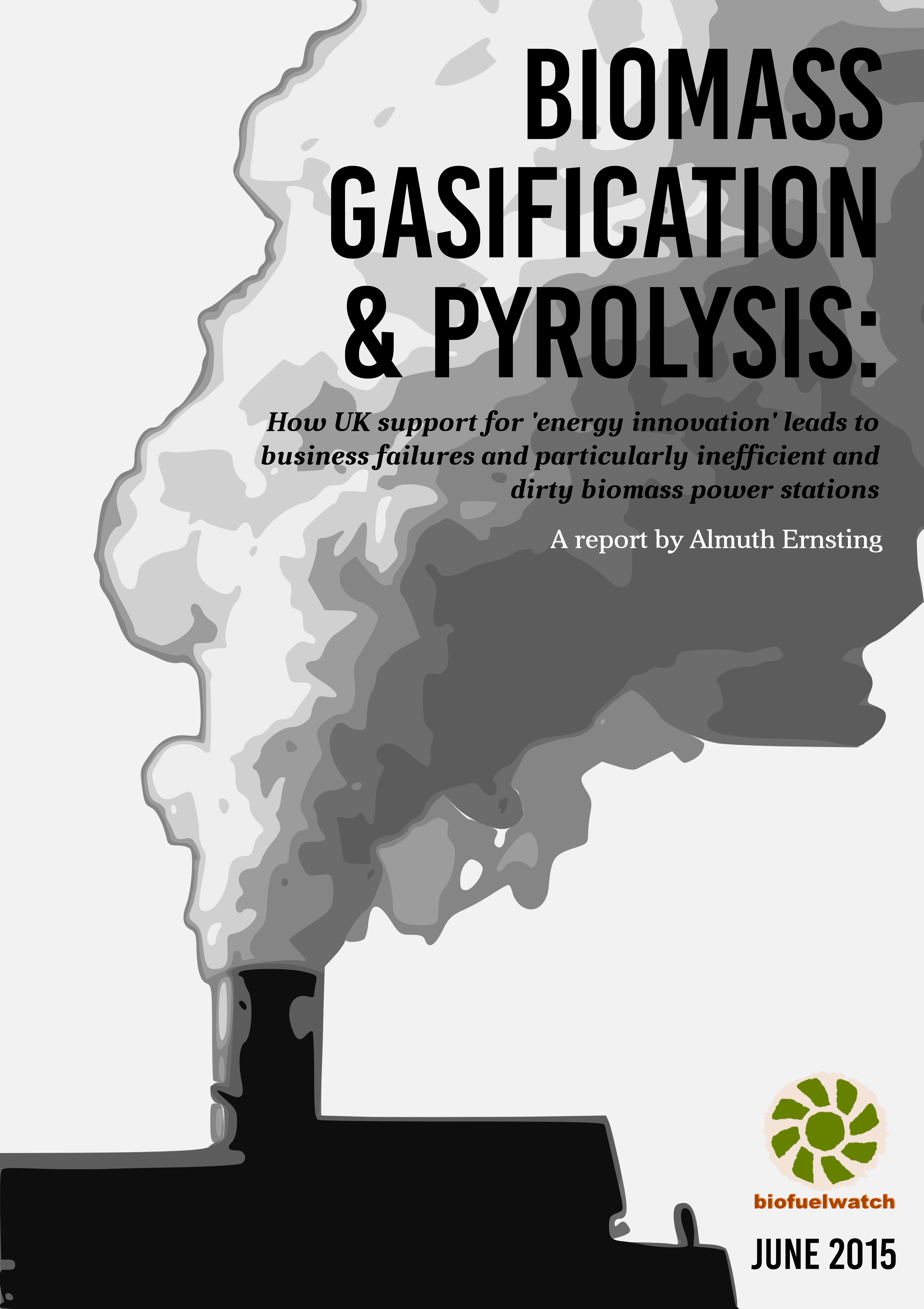

BIOMASS GASIFICATION & PYROLYSIS:

How UK support for 'energy innovation' leads to business failures and particularly inefficient and dirty biomass power stations

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biofuelwatch

JUNE 2015

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EXECUTIVE SUMMARY

Biomass and waste gasification and pyrolysis are being heavily promoted by the UK government. According to the UK Bioenergy Strategy 2012, developing advanced gasification technologies, especially biomass gasification, is vital to achieving low-carbon targets in different sectors. The government has made particularly generous subsidies available for electricity from biomass and waste gasification and pyrolysis.

This Biofuelwatch report focuses on biomass (including waste wood) rather than non-biomass waste gasifiers and pyrolysis plants. However, the policy framework and subsidies are largely identical for both, and the technologies – and therefore the technical challenges – are very similar. The findings in the report will therefore be relevant to Municipal Solid Waste gasifiers and pyrolysis reactors, too.

Biofuelwatch has identified 40 biomass and pyrolysis plants with a capacity of at least 1 MW which have been proposed across the UK in recent years. At least 9 such plants have been built, though some of them may never have been fired up. 8 of these gasifiers have failed and been shut down. Two have been redesigned and re-opened. One of them (supposedly a pyrolysis plant rather than a gasifier) appears to have generated no energy as yet and the other one, according to the most recent published evidence, was operating at less than one-tenth of its capacity for the first five months, indicating technical problems. One company claims to have built another biomass gasifier but Biofuelwatch could find no planning consent for that one and there are contradictory statements from two other companies that also claim to be behind this plant. By comparison, Biofuelwatch is aware of 13 conventional biomass power stations built in the UK with at least 15 MW capacity, none of which have been shut down.

Despite the failure of eight biomass gasifiers, at least 14 biomass gasification and pyrolysis plants hold planning consent as of May 2015 (including those reportedly built) and at least two of them are under construction. Clearly, biomass gasification and pyrolysis has attracted significant interest from companies – but the technologies have been beset with serious problems.

Biomass pyrolysis linked to electricity generation is a new and entirely unproven technology – so far it has not been done successfully anywhere in the world.

Biomass gasification, on the other hand, is not a new technology. It was discovered in the 18th century and there were attempts to develop it for 'town gas' in the 19th century. It was used to drive hundreds of thousands of cars in Europe during World War 2 (although not without technical and health and safety problems) and it has been promoted for heat and electricity in many countries since the 1970s. Despite this long history, biomass gasification technologies remain beset with technical difficulties and a very high failure rate. This is particularly the case for biomass gasifiers designed to supply electricity rather than steam for heating or cooling only. Some biomass gasifiers have been generating electricity for several years but these tend to be ones involving either collaborations between companies and research institutes or collaborations between companies with different types of expertise. Success appears to depend on companies being able and willing to invest in overcoming technical problems and upgrading plants over long periods. Such plants are expensive to build, expensive to operate and prone to far greater problems than conventional biomass plants. At best they offer just minor efficiency gains, with the worst being less efficient than most conventional plants.

Globally, interest in biomass gasification revolves around the potential for producing clean syngas, which is chemically similar to natural gas (though less energy dense). Syngas can be burned in gas engines and gas turbines, which are more efficient than the steam turbines used by conventional power stations burning solid fuels. Burning clean syngas would in theory also emit less pollution than burning biomass, but only where gasifiers operate without technical problems. Furthermore, research and development is underway in various countries to refine syngas into transport fuels and to use it for various industrial purposes.

In the UK, however, the recently built gasifiers and two new ones which have received sufficient investment to be built, as well as most of the currently proposed gasifiers, do not involve producing and using any clean syngas at all. They involve burning dirty gas to power a steam turbine, in particularly inefficient plants. These developments consequently make no meaningful contribution to any technology developments worldwide and, like other biomass gasifiers, are beset with key technical challenges. These challenges are mostly due to the highly explosive gases involved and the fouling and corrosion of key plant components.

This report examines individual biomass gasifier developments and most of the companies involved. The first biomass gasifier ever built in the UK remains the most ambitious project yet. The company set up to build it went into liquidation in 2002. A peer-reviewed study was subsequently conducted about the project. The authors found that a lack of effective scrutiny and oversight contributed to the failure of it and that the offer of deployment-related subsidies (i.e. renewable electricity subsidies paid per unit of electricity generated) may have led to poor technology choices. The lessons from this project's failure have not been learned. Subsidies for electricity generation coupled with deregulation or 'barrier removal' are cornerstones of the UK government's strategy for supporting 'energy innovation' in general. The experience with biomass gasification and pyrolysis plants suggests that this policy approach has had entirely unintended consequences:

Rather than driving 'technology innovation', it has driven a proliferation of small companies, many of them sharing the same directors and none of them with any track record in designing and operating such complex and challenging technologies. Failed gasifier schemes have led to tens of millions of pounds of investors' money being lost. For example, two company directors, David Pike and David Nairn, have been directors of companies directly responsible for two failed biomass gasification schemes, which lost investors a total of £50 million. They were also behind another ultimately unsuccessful biomass gasifier venture which was taken over by another company that subsequently went into liquidation.

Remarkably, the companies associated with these same directors, despite the disastrous track records of their gasifier ventures, have been greatly boosted by the Green Investment Bank, which recently joined a consortium building a waste wood gasifier in Tyeseley, Birmingham. The consortium has chosen a main developer with directors linked to three failed biomass gasifiers, and on top of this has chosen a Canadian company, Nexterra, to deliver the key technology. Nexterra has built three biomass gasification power plants to date, and not a singel one has been successful. One was closed after three accidents described as 'potentially lethal' by a spokesperson of the university where it was installed, another failed soon after it opened, and commissioning of the third has so far been delayed by over a year. Furthermore, if this new gasifier is to succeed, it will be less than 21% efficient – far below what many conventional biomass plants achieve.

The key losers of the government's unsuccessful policy of promoting biomass gasification and pyrolysis have primarily been investors, including investors participating in the government's subsidised Enterprise Investment Scheme. Health and safety and air emissions risks associated with both technologies have also put local residents at a particularly high risk, one even greater than living close to conventional biomass plants. Fires, explosions and excessive pollution have been associated with biomass gasifiers and pyrolysis pilot plants outside the UK and, in Scotland, a waste gasifier was responsible for hundreds of air quality permit breaches, a fire and an explosion.

INTRODUCTION

In December 2013 the Green Investment Bank (GIB) announced funding for "the first gasification plant of its kind in the UK" i.e. the first 'advanced conversion' biomass plant that would generate electricity. The hope, according to the GIB's Chief Executive, was that it would "offer a positive demonstration effect that others will follow"[i] [i].This GIB-funded gasifier is now being built in Tyseley, in Birmingham. If it successfully operates then it will indeed be the first UK biomass plant of this type to do so. But it is by no means the first such plant to have been built in the UK

At least 24 biomass gasification and pyrolysis plants with at least 1 MW capacity have received planning consent across the UK[1] [1]. 9 biomass gasifiers have been built[ii] [ii], although some of those may never once have been fired up. Out of those 9 plants, 8 have failed and been shut down. Two of those have been redesigned and reopened: One of them operated at less than 10% of its capacity and no more recent information has been published. The other does not appear to have generated any energy as yet. One other plant was reported by a company to have been commissioned but contradictory information has been published by two other companies and Biofuelwatch could find no planning consent for it. Thus, out of 9 biomass gasification plants reportedly opened, not one appears to have operated successfully so far.

By comparison, Biofuelwatch is unaware of any dedicated biomass power station using conventional technology that has been commissioned and then closed down in the UK – 13 such conventional plants with at least 15 MW capacity are in operation at present[2]. Clearly, operating a biomass gasifier is beset with far greater technical difficulties and challenges than operating a conventional biomass plant.

Nonetheless, at the time of writing this report, at least 14 biomass gasification or pyrolysis plants have planning permission (excluding those with planning consents that have been abandoned by the developers but including two already built) 'advanced conversion' biomass plants have planning permission in the UK, five planning decision are pending, and two others have been publicly proposed, although full planning applications have not yet been published. This does not include the even larger number of similar plants proposed and being developed that would use Municipal Solid Waste rather than biomass.

Thus, despite major technical problems, companies' interest in 'advanced conversion' of biomass is growing. The reason for this is simple: A successfully operated 'advanced conversion' plant (whether it uses biomass or Municipal Solid Waste) attracts more subsidies per unit of electricity than any other power plant[3]. The Government's Bioenergy Strategy[iii] highlights the "crucial role" which it sees

1 This includes ones for which planning consent has expired and developments not pursued any further by the developer.

2 This does not include coal power stations converted to biomass: Tilbury B was operated on 100% biomass for about two years and then closed down and Ironbridge Power Station, currently operated on 100% biomass, is scheduled to close at the end of 2015. However, these have been amongst the largest biomass users worldwide and economic considerations related to such large-scale wood pellet sourcing appear to have played a role in the operators' decisions to close these plants – rather than technical barriers.

3 Such 'Advanced Conversion' plants attract 2 Renewable Obligation Certificates per megawatt hour which is higher than the rate available for conventional biomass power plants. The only renewable electricity technologies that attract a higher rate of subsidies are tidal stream and wave power (https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/211292/ro_banding_levels_2013_17.pdf).

for advanced biomass conversion in "delivering low carbon energy going forward" and high subsidies have been chosen as the main way of incentivising the development of such technologies.

This report will start with an overview of the two technologies classed as 'advanced biomass conversion': biomass gasification and biomass pyrolysis. It will then give a brief global and historical overview of the development of both and look at whether such plants have been operated successfully in other countries. This is followed by a discussion of how efficient and clean – or otherwise - biomass gasifiers and pyrolysis plants can be expected to be and what determines their efficiency levels and air emissions. This general overview is then followed by an in-depth discussion of the experience of failed and proposed biomass gasification and pyrolysis plants in the UK. Have the lessons from the failed projects been learned? What are the chances of the planned new developments overcoming the problems encountered in the past? Would the plants that are being built or proposed produce more efficient and cleaner energy from biomass than conventional power stations? And finally, what lessons can be drawn from the UK's policy to incentivise 'advanced biomass conversion' plants?

SCOPE OF THIS REPORT

This report focuses on two technologies for converting biomass to electricity[4] (including combined heat and power plants): gasification and pyrolysis. Both are classed as 'advanced biomass conversion' under UK subsidy rules. The report does not discuss the impacts of large-scale biomass use for electricity and heat generation in general i.e. the impacts on forests and climate change. Biofuelwatch has documented and discussed those in detail elsewhere[iv]. Air quality impacts are considered only in so far as emissions from gasification and pyrolysis plants are compared to those from standard combustion biomass plants.

We attempt to answer the following questions:

1. Are biomass gasification and pyrolysis proven technologies?

2. Are there technical problems associated with these technologies and, if so, what are they and could they negatively affect nearby communities or workers (e.g. through health and safety risks or pollution)?

3. Are biomass gasifiers and pyrolysis plants more or less efficient than standard biomass power plants? What makes individual plants more or less efficient?

4. Do biomass gasifiers and pyrolysis plants cause more or less air pollution than standard biomass power plants?

5. Does the UK government's support for biomass gasification and pyrolysis – especially their rules for subsidising both technologies – promote the most efficient and least polluting types of 'advanced conversion plants'?

The report does not look at gasification and pyrolysis plants which rely on Municipal Solid Waste or other non-biomass waste. However, gasification and pyrolysis uses the same technologies regardless of which type of solid fuel is used[5]. Furthermore, UK subsidy rules and rates are identical for biomass and for energy from waste 'advanced conversion'. This means that the conclusions drawn will be relevant to those concerned about energy from waste gasifiers and pyrolysis plants.

The main focus of the report is on proposed, operating, and abandoned biomass gasification and pyrolysis projects with a minimum capacity of 1 MW in the UK. We have identified 40 such schemes[v] for which planning applications (including scoping requests) have been submitted[6] in the UK. This figure includes developments for which planning applications were submitted but later rejected or withdrawn, ones where planning consent was granted but has expired without any plant being built, and plants which were built but subsequently closed down. In 31 cases we were able to access planning documents[7], from which we obtained key information about the schemes and in the 2 cases

4 Biomass gasification and pyrolysis can be used to supply heat only, but we have found no proposals for heat-only plants in the UK and therefore we focus on electricity generation only, with and without cogeneration of heat.

5 The only exception is plasma arc gasification which appears to have only been proposed and used for non-biomass waste gasification to date.

6 This includes Scoping Requests to Planning Authorities.

7 The plants for which we could not access planning documents were: A plant built and closed down in Wick, about which Audit Scotland has published a detailed report; a plant in Usk which a company claims to have

where full planning applications are still pending, we accessed consultation documents published by the developers. We also searched for and used information published by the developer(s) and any additional information publicly available. For those plants said to be operational, we consulted Ofgem data to see whether any renewable electricity subsidies have been received – a proxy for evidence of electricity generation. Our list may not be exhaustive as far as advanced conversion plants not yet built and commissioned are concerned. For example, one company, Aggregate Micropower Holdings, states that they are raising investment for five biomass gasifiers[vi], but we have only been able to find details of one of these.

However, before discussing these 40 UK schemes, we present an overview of how the technologies work, a historical overview, and a global overview of the current state of the technologies and of the main motives behind investments in them. We draw on a wide range of literature, including publications by the International Energy Agency, studies commissioned by the UK government, and peer-reviewed studies.

There is significant international interest in using biomass gasification and pyrolysis as the first stages for producing liquid transport biofuels from solid biomass. Biofuel production would involve complex further refining of either the gas obtained from biomass gasification or pyrolysis, or the bio-oil obtained from pyrolysis. Biofuel production of this type is not commercially viable so far and no refinery of this type has been proposed in the UK. The report therefore does not look at this potential application, nor does it look in detail at the potential uses for char, which may be a by-product of gasification and is either a by-product or a primary product of pyrolysis. This report only focuses on heat and power generation from the two technologies.

commissioned but for which we could find no planning records – even though our planning search revealed unrelated planning applications for the same site; the Tyseley gasifier currently under construction(about which the Green Investment Bank has published details); a gasifier built and shut down in Newry biomass gasifier(about which company and media reports), and the ARBRE gasifier built and shut down in Eggborough (about which a peer-reviewed study has been published.)

HOW DOES BIOMASS GASIFICATION AND PYROLYSIS WORK?

There are three possible ways of converting biomass (or for that matter any solid fuel) into electricity and/or heat: Conventional combustion, gasification, and pyrolysis. Here we shall focus on plants that generate electricity (although they may also make use of heat):

In a conventional ***biomass – or coal – power station***, the fuel is combusted in the presence of air[8]. As the biomass or coal burns, it reacts with the oxygen in the air and most of it turns into a hot mix of gases (except for the unburnable residue which remains as ash). The hot gases from the burning biomass or coal, heat water to produce super-heated steam. That steam then passes through a steam turbine which generates electricity.

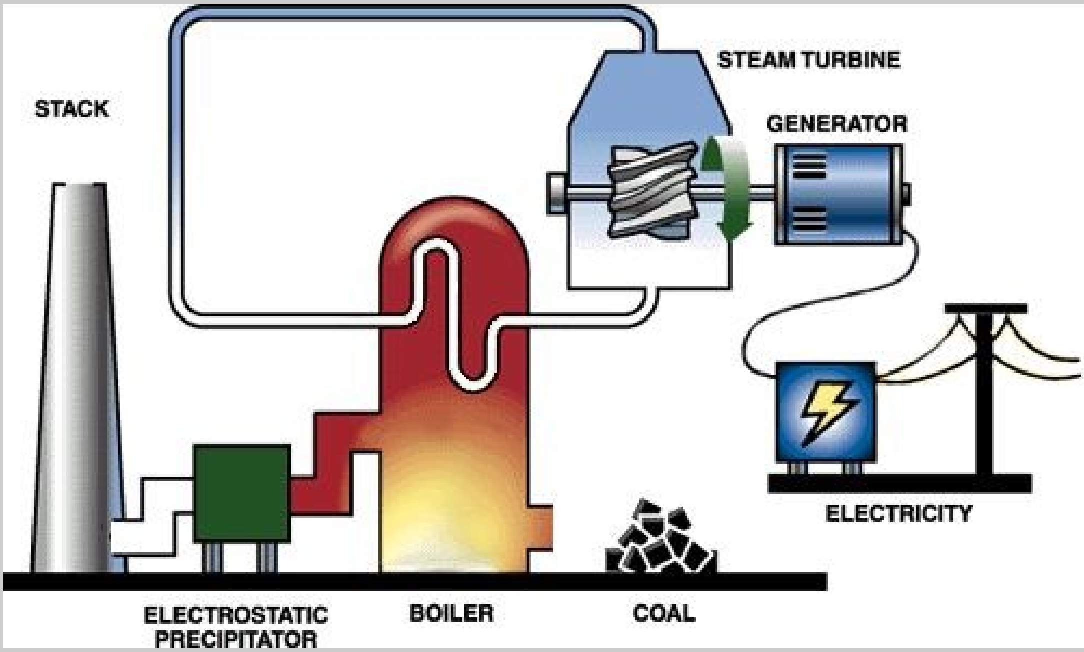
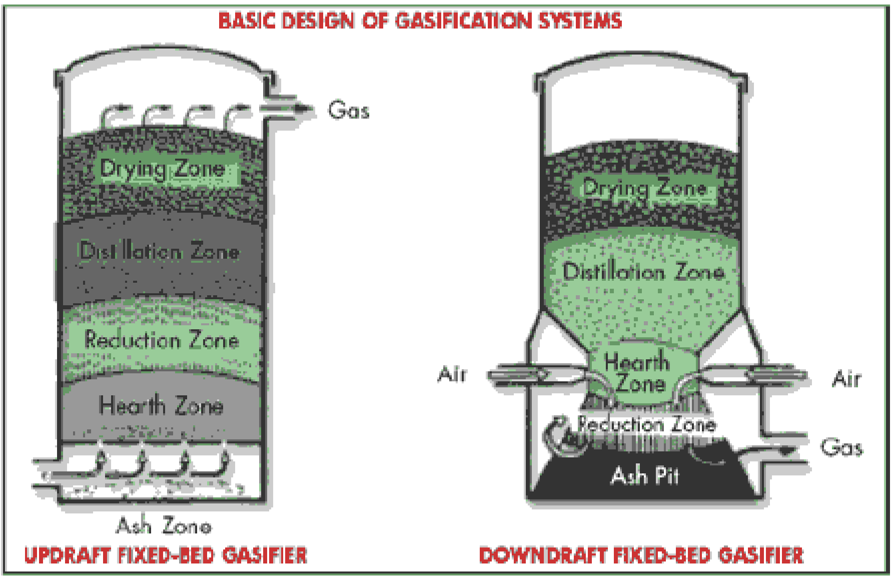


Diagram of a solid-fuel steam power plant; Source: http://1.bp.blogspot.com/-zNeQnbEhvfo/Ucl0g-OcyjI/AAAAAAAAAEI/v3aOpC1pLYk/s1600/steam+turbine+by+coal.jpg

8 To be precise, effective biomass or coal combustion requires the entry of air to be carefully staged.

The idea behind ***biomass gasification*** is that biomass is heated not in normal air, but with limited oxygen. This produces a different composition of hot gases, which the International Energy Agency[vii] and many others call 'producer gas'[9] and which can then be cleaned of different pollutants and tars. The cleaned up gas is called 'syngas'. Syngas, unlike the dirtier producer gas, can be burned to power not just steam turbines, but also gas turbines, Combined Cycle power plants (i.e. ones combining a gas turbine and a steam turbine to increase efficiency), or gas engines. However, if the producer gas is not cleaned then it can only be used as fuel for a boiler that provides steam for a turbine or, otherwise, for providing heat only. This is the least efficient form of generating electricity through biomass gasification. Either ash or a small amount of char is left behind as a waste or by-product, but the maximum amount of char derived from gasification is much smaller than what can be produced with pyrolysis.

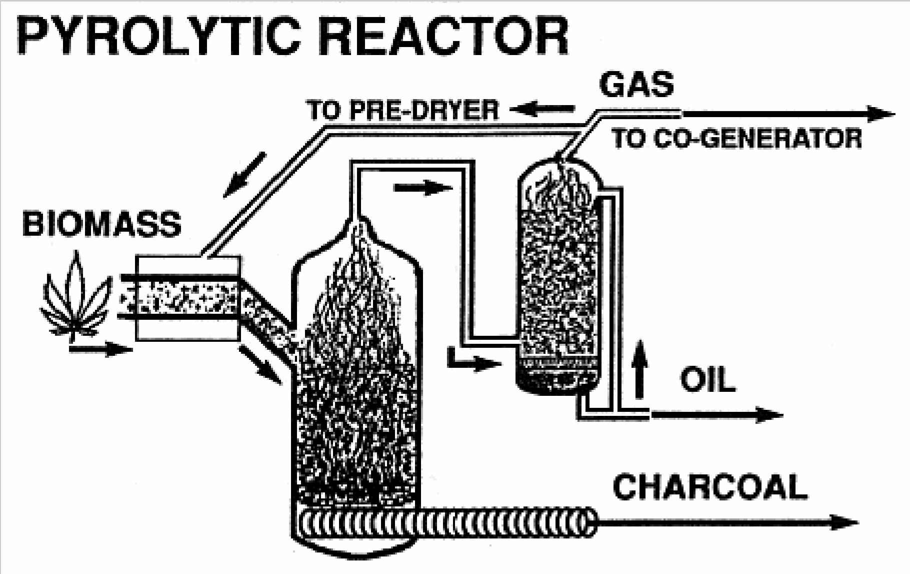


Two biomass gasifier designs; Source: http://www.sankalpacmfs.org/src/02ene/image/gasifier_app.gif

Biomass pyrolysis involves exposing biomass to high temperatures in the absence of oxygen for a short period of time. Pyrolysis produces different quantities of pyrolysis oil ('bio-oil'), producer gas (which can be transformed into syngas through gas cleaning), and char - depending on the specific pyrolysis technology used.

A range of different technologies and designs can be used in biomass combustion plants, biomass gasifiers, and biomass pyrolysis plants. For example, conventional biomass and also biomass gasifier plants can use different boiler technologies, some of which are more efficient, some of which are suitable for larger or smaller plants only, and some of which are only suitable for certain types of biomass. Different pyrolysis processes are distinguished by the temperatures and the length of time for which biomass is exposed to heat. A range of different types of pyrolysis plant technologies are being developed. An overview of different biomass gasifier technologies can be found at: www.ieatask33.org/app/webroot/files/file/publications/Fact_sheets/IEA_What_is_gasification.pdf and a description of all of the different biomass pyrolysis technologies being developed can be found at: www.mdpi.com/1996-1073/5/12/4952 .

9 Note that the term 'producer gas' is used in different ways. Some use the term as interchangeable with (cleaned) syngas, others use it to describe a particular industrial fuel. In this report, we will use this term to describe un-cleaned gases resulting from biomass gasification. And we will use the term syngas to describe producer gas which has been cleaned sufficiently so as to be suitable for gas engines and turbines.



Overview of a pyrolysis plant (not including the actual combustion of gas and/or oil)
Source: www.ratical.org/renewables/pyrolytic.gif

A SHORT HISTORY OF BIOMASS GASIFICATION

Biomass gasification to produce 'wood gas' is not a new technology. Its discovery and early development dates back to the 18th century. In 1789, a French engineer, Philippe Le Bon, wrote about distilling wood to produce gas. He later obtained a patent for this, although there is no record of him having turned such a process into practice[viii]. In 1785, another French inventor, Jean Pierre Minckelen, reported using the first gas lights[ix]. Gas lighting became commonplace in cities such as London during the early 19th century. Some of that gas would have been produced from wood and peat but most of it was coal gas, which came to be known as 'town gas,' and was widely used until it was replaced by natural gas after World War 2.

From the early 1920s there was renewed interest in wood gas, this time as a transport fuel. The British inventor Thomas Hugh Parker is said to have built the first car to run on wood gas in 1901[x] though his invention of an oil-burning steam powered car and a very first electric vehicle are better documented[xi]. During the early 1920s, George Imbert developed the first wood gasifier suitable for a vehicle[xii] and commercial wood gas vehicles began to be built, especially in France. By 1929, around 1,880 vehicles in France ran on wood gas and the number increased to around 7,800 in 1938. Both Nazi Germany and fascist Italy heavily promoted the development and use of wood gas as a transport fuel[xiii].Wood gas use in transport peaked during the Second World War when access to oil became difficult in Europe. It was most widespread in Germany but also widely used in Sweden, France, Finland, Denmark, Switzerland, Austria and the Netherlands[xiv].But although Germany reportedly built up to half a million wood gas cars, wood gas cars were never without problems – which is why petrol supplies were reserved for the armies.

Car running on wood gas, Germany, 1944

A study of World War 2 wood gas vehicles in Finland[xv], wood gas vehicles details these problems:

- Cars driven with wood gas were slower and less efficient than those run on petrol – they had to be pushed up even small hills;
- The wood gas generators had to be cleaned and maintained regularly. Wood needed to be loaded more often than petrol tanks would be filled and engines took up to 15 minutes longer to start up;
- Large quantities of polluting soot were emitted;
- Drivers had to be careful to avoid a risk of explosion from flames or hot charcoal;
- Constant supplies of chopped wood o f the right type were required and those were difficult to come by, especially in cities;
- The most serious problem of all was carbon monoxide (CO) poisoning: At least 5-15 people a year were killed from CO poisoning but around half of all drivers using wood gas – including bus drivers - suffered some level of CO poisoning and, over a two year period, 6,000 car drivers using wood gas were reported to have fallen unconscious as a result. CO poisoning became so widespread that a specialist clinic had to be opened in Helsinki.

Not surprisingly, wood gas use for cars, trucks, and buses fell out of favour once petrol supplies resumed after the war.

Interest in biomass gasification resumed again after the 1973 'oil crisis'. This time it focussed on converting biomass to heat and electricity in order to reduce diesel use in developing countries. By the early 1980s, there were over 15 manufacturers of small scale biomass gasifiers and international development funds, as well as the governments of Brazil, China, India, Indonesia, Philippines and Thailand were supporting such investments[xvi]. In 1983, the World Bank and the UN Development Programme initiated a monitoring programme for such gasifiers. Their final report – published in 1995[xvii] – made for rather sobering reading, especially where electricity generation from biomass gasification was concerned. It included:

"*Almost none of the projects identified became fully commercial, and most proved unsustainable for technical, financial/economic, and institutional reasons*". Even the successful projects had been plagued by technical problems for a year or longer and had relied on ongoing technical support and supply of spare parts. Heat gasifiers posed less technical problems but several closed for economic reasons.

'Success' however was measured purely in terms of a plant continuing to operate. Replacement of diesel, rather than clean and efficient energy production, was the main motivation for installing biomass gasifiers at the time.Pollution – especially with liquid effluents – was identified as a significant concern. In one case, 15kg of highly toxic phenols were discharged every hour.

15 years later, a similar survey of small-scale biomass gasifiers, this time commissioned by the German government, was published[xviii]. From the 1990s, investment in biomass gasifiers was no longer confined to developing countries and the 2010 report looked at experiences in Germany as well as in India, Sri Lanka, and various African countries. By 2010, so the study suggested, small-scale biomass gasification had become no more reliable or successful than it had been during the 1980s and similar difficulties were being experienced everywhere, not just in poor countries, but also in Germany. There, 50 biomass gasifiers had been installed between 2000 and 2010:

However, "*many have been taken out of operation after some months of trial. Some plants went up in flames and developers went bankrupt. The few plants that achieved more or less continuous operation were operating under special circumstances: They were part of university research* *programmes or were operated by the developers themselves. Moreover, in almost all cases about one to two years of adaptation were necessary*".

Lack of reliable technology, high costs for technology support and repairs, and dangerous threats to the environment and to health and safety, were seen as the main obstacles to the technology. The authors suggested that these problems may have been overcome by operators of large biomass gasifiers in Scandinavia, though they did not in fact study such plants.

Biomass gasification is thus a relatively 'old' technology but one which, for the past century, has remained beset with technical problems.

A VERY SHORT HISTORY OF BIOMASS PYROLYSIS

Humans have used biomass pyrolysis for thousands of years – to produce charcoal. Charcoal was used in cave paintings older than 30,000 years and was being produced in significant quantities by the time the Bronze Age started over 5,000 years ago[xix]. However, the idea of using pyrolysis to produce bio-oil and gas to generate energy is a very recent one. The first 'commercial' (or at least larger than laboratory-scale) pyrolysis plants to have been built, appear to have been ones built by Dynamotive plants in West Lorne and Guelph in Ontario. These were opened in 2007/08 but only operated for a short period.

BIOMASS GASIFICATION AROUND THE WORLD TODAY

Today, interest in biomass gasification worldwide is motivated by four main objectives:

- The development of 'drop in' transport biofuels made from solid biomass, based on the refining of syngas derived from biomass gasification: This type of biofuel production remains in the early Research and Development stage;
- The use of clean syngas derived from biomass gasification for a variety of chemicals and other materials currently produced from fossil fuels: These uses also remain in the early Research and Development stages;
- Mainly small-scale biomass gasifiers promoted in developing countries to increase overall energy supply and access and in the hope of reducing dependence on diesel;
- Biomass gasification for heat and/or electricity generation as a contribution towards renewable energy targets and, potentially, a way of generating energy from biomass more efficiently and with less air pollution than would be possible in a conventional biomass plant.

All commercial investments in biomass gasification in the UK are for electricity generation (with and without cogeneration of heat).

The International Energy Agency (IEA) has published a map of biomass gasifiers worldwide: www.ieatask33.org/content/thermal_gasification_facilities . Although this map/list is far from complete it shows a significant number of investments and it also confirms that some biomass gasifiers have now been operating for several years, some for over a decade, although 17 cancelled, stopped, or suspended projects are listed. Unfortunately, no independent information about the status, operation, or potential problems of any of the gasifiers listed is available and at least one of the companies listed by the IEA as operating four such plants (Stirling DK) has gone out of business[xx]. Those projects which appear to have been successful – i.e. which have been operating for several years – have tended to either involve collaborations between companies and research institutes or long-term company commitments to continually invest in adjusting upgrading and optimising plants in order to resolve technical problems. Subsidies appear to be essential in all cases – although conventional biomass power plants also generally rely on subsidies.

For example, an 8 MW combined heat and power gasifier in Guessing has been operational since 2002. This is a steam-blown gasifier using dry wood as fuel. According to the company, "*Renet-Austria, a competence network on energy from biomass, consisting of experts from universities and industry started to develop this process further to a commercial stage. During the last years a lot of improvements could be reached*"[xxi]. Continuous development and the involvement of many experts has allowed this plant to be operated relatively successfully. Also, a smaller biomass gasification combined heat and power plant in Oberdorf, Switzerland, has been operational since 2007. It is run by a cooperative enterprise but has involved collaboration with 10 companies, a regional authority, and three not-for-profit organisations[xxii].

MAIN TECHNICAL CHALLENGES ASSOCIATED WITH BIOMASS GASIFICATION

- Efficient energy generation through biomass gasification depends on clean syngas, i.e. gas of a quality similar to natural gas and therefore capable of being burned in gas turbines and engines. This is discussed further below. **Effective gas cleaning** is one of the main difficulties associated with this technology;

- Biomass gasification at temperatures below 1,300°C produces gas with a range of heavy hydrocarbons. These are collectively known as **tars**. If tars build up, they cause 'fouling', which means they clog up vital equipment and prevent it from working properly. This could include clogging up of air emissions mitigation systems, and create greater air pollution as a result[xxiii]. It can also require plants to be shut down. Avoiding and/or breaking down tars is a major challenge. Using dry wood can reduce but not eliminate problems. Higher combustion temperatures can also reduce problems but may not be practicable. Plasma arc gasification has been proposed as one solution, however we have been unable to find any examples of operating plasma arc biomass gasifiers in Europe and none of the biomass gasifiers ever proposed in the UK would have used that technology;

- There are **health and safety risks** associated with any plant that involves handling large quantities of woodchips and pellets, since wood dust is highly explosive and wood can self-ignite. However, biomass gasification carries additional risks because producer gas and syngas are highly explosive. To prevent an explosion when pressure builds up inside a gasifier, operators may be forced to vent dirty producer gas straight into the atmosphere, bypassing the various mitigation systems designed to clean it. These risks were exemplified by a Municipal Waste gasifier in Scotland: Between 2009 and 2013 (when the plant's permit was finally removed[10]), there were at least 88 bypass stack activations resulting in unlawfully high air emissions. Nonetheless, an explosion eventually did occur, as did a major fire[xxiv].

10 Note that another company has since applied for a new permit to reopen the accident-struck plant.

BIOMASS PYROLYSIS: A GLOBAL OVERVIEW

The US Department of Energy, the European Union, and various other governments support Research and Development into biomass pyrolysis. The International Energy Agency has set up a platform to facilitate cross-country collaboration to develop this technology[xxv]. The technical challenges associated with bio-oil and syngas production through pyrolysis are significantly greater than those associated with biomass gasification. It is widely accepted that more Research and Development are required before this technology can become commercially viable[xxvi].

Interest in advancing this technology, despite the significant technical obstacles, is primarily motivated by the quest for second-generation biofuels: Although pyrolysis or bio-oil itself is not of high enough quality to be burned in car engines, it could, at least in theory, be refined into transport biofuels. Pyrolysis is thus one of several pathways for turning solid biomass into liquid biofuels which is being researched.

Entrepreneurs, researchers, and others promoting the use of biochar also have an interest in biomass pyrolysis. Biochar is being promoted as a soil amendment which is claimed to make soils more fertile, to help sequester carbon long-term, and to have various other benefits. In reality, the scientific evidence so far shows that these claims are highly questionable and that biochar use cannot be relied on to have such desired impacts. Biochar has been discussed by Biofuelwatch elsewhere[xxvii]. Pyrolysis char of the right quality can also be used as 'activated carbon'. Activated carbon is char with very fine pores which can be used to filter different contaminants from water or from flue gases (e.g. mercury from coal power plants).

However, optimising pyrolysis for char production means using 'slow pyrolysis', i.e. exposing biomass to temperatures averaging 400°C for a relatively long period. Slow pyrolysis yields around 30% bio-oil, 35% char, and 35% gas – with lower temperatures resulting in more char production. By varying the temperature and length of time that the biomass is exposed to heat, different qualities of chars can be produced. However, slow pyrolysis – with lower temperatures – produces less bio-oil and bio-oil that is of lower quality and thus even more difficult to refine into transport fuels. Furthermore, exposing biomass to heat for longer periods requires more energy[xxviii].

Exposing biomass to higher temperatures for much shorter periods – called fast and flash pyrolysis – results in 50-75% production of bio-oil, which is of a higher quality than that produced through slow pyrolysis. However, it produces far less char. Moreover, char produced at high temperature appears less likely to improve crop yields than char produced through slow pyrolysis because it is less alkaline and has other chemical properties which make it less easy for plants to absorb nutrients[xxix][11]. Slow pyrolysis is also used to produce activated carbon - though the pyrolysis is then followed by further treatment of the carbon[xxx]

In short, pyrolysis can either be optimised to produce char for use as biochar or for conversion to activated carbon, or to produce bio-oil as a fuel, but not both. As for syngas production, gas yields also drop with higher temperatures and companies interested primarily in producing and using syngas will always opt for gasification (which yields 90% gas, rather than a mere 10-30% from fast and flash pyrolysis).

11 Note that this is appears to be a general trend – but the interaction between different biochars with different soils and crops is highly complex and so far impossible to predict with any accuracy.

The prospect of a highly-efficient pyrolysis plant which produces bio-oil as a useful fuel, clean syngas to produce energy and commercially useful char, is thus a very remote prospect indeed.

In fact, just one company – Dynamotive – appears to ever have built pyrolysis plants (two in Ontario) with the purpose of selling biochar and bio-oil. Both closed down after a short period.

The largest existing commercial biomass pyrolysis projects we identified, were developed by Fortum and Ensyn and are both heavily subsidised. A third such plant, called the 'Empyro Project' is currently under construction in Hengelo in the Netherlands. The aim is that this flash pyrolysis plant will produce steam, electricity, pyrolysis oil and organic acid. This project, too has been subsidised (through the 7th Framework Programme of the European Commission[xxxi].

The Finnish company Fortum, together with other corporate partners, started commissioning a pyrolysis plant capable of producing up to 50,000 tonnes of bio-oil in November 2013. They were still carrying out test-runs when a major explosion occurred in March 2014, injuring three workers[xxxii]. Commissioning restarted in September 2014 but Fortum do not expect the plant to be fully operational until autumn 2015. Bio-oil is burned in Fortum's existing combined heat and power plant in Joensuu in Finland, which is adjacent to the new pyrolysis plant and which otherwise burns wood and peat.

Ensyn, a Delaware-registered company working in 'strategic alliance' with Honeywell subsidiary UOP LLC, claims to have built a fast pyrolysis plant with a capacity for producing 3 million gallons of "renewable fuel oil" (i.e. bio-oil) a year in Renfrew, Ontario, as well as 15 smaller fast pyrolysis plants in the US, five of them commercial ones in Wisconsin, with new developments underway in Malaysia and Brazil. They started in April 2014 and have produced 37 million gallons of bio-oil over 25 years[xxxiii]. Ensynhas received substantial subsidies for their investments. If the figures they cite are correct, then Ensyn would appear to have achieved commercialisation of larger-scale biomass pyrolysis – contradicting the International Energy Agency Task Force on pyrolysis, who believe that several challenges will have to be overcome before this could happen[xxxiv]. They would have achieved what no other company in the world has managed and Fortum's claims about having built the world's first commercial bio-oil combined heat and power plant would be incorrect. Independent research into and analysis of Ensyn's experience, as well as into evidence of actual quantities of bio-oil produced and any technical obstacles encountered, would seem highly valuable.

MAIN TECHNICAL CHALLENGES ASSOCIATED WITH BIOMASS PYROLYSIS

A 2012 peer-reviewed technological review of biomass pyrolysis[xxxv] concluded:

"*Conversion of biomass to bio-fuel has to overcome challenges such as understanding the trade-off between the size of the pyrolysis plant and feedstock, improvement of the reliability of pyrolysis reactors and processes to become viable for commercial applications… Bio-oil production through pyrolysis is still an immature technology and is not commercially feasible yet. Pyrolysis bio-oil needs to overcome many technical, economic and social barriers to compete with tradition fossil fuels*".

- One of the challenges consists of producing bio-oil of a high enough quality to be used as a heating fuel and modifying engines, turbines, and boiler combustion systems so that bio-oil can be efficiently burned without damaging the plant's components through slagging and corrosion.

- Different pyrolysis technologies have been developed but there are challenges associated with each of them[xxxvi]. For example, one technology offers reliable pyrolysis reactors which can be scaled up – but heat-transfer and thus efficiency remains unproven at larger scales. Another technology overcomes the problems with heat-transfer, but it has not yet been possible to scale it up and there are problems with 'char attrition', i.e. with char particles breaking up and contaminating the bio-oil, making it less usable.

- There are particular health and safety problems associated with pyrolysis[xxxvii]. Like gasification, pyrolysis produces highly explosive and flammable gases. Furthermore, pyrolysis gases are toxic and one accident in a municipal solid waste pyrolyser in Germany, led to an entire neighbourhood being evacuated and several workers and residents being admitted to hospital for observation[xxxviii].

HOW EFFICIENT ARE ADVANCED CONVERSION BIOMASS PLANTS?

CONVENTIONAL BIOMASS COMBUSTION

Burning biomass to generate electricity is an inefficient process: Most biomass power stations operate at 20-30% efficiencies, i.e. they lose 70-80% of the energy contained in the feedstock[xxxix]. Smaller plants tend to be less efficient than larger ones, but even the very largest and most efficient plants that burn wood to generate electricity only, still waste over 60% of the energy contained in the biomass.

Overall efficiency levels of biomass power stations can be raised by capturing waste heat and supplying it to customers i.e. by designing such plants as combined heat and power plants. The greater the proportion of heat supplied compared to electricity, the more efficient a combined heat and power plant will be. However, in the UK, the vast majority of biomass is burned in electricity-only rather than combined heat and power of heat only plants. According to a 2013 DECC forecast, 14.3 million tonnes of biomass are expected to be burned in electricity-only power stations in 2016/17, compared to 900,000 tonnes in combined heat and power plants[xl]

GASIFICATION

The efficiency of a biomass gasifier depends on:

- How electricity is generated: Gas turbines and gas engines are significantly more efficient than steam turbines on their own. Combined cycle plants – which combine a gas turbine and a steam turbine – are more efficient still. Integrated gasification combined cycle (IGCC) plants have been proposed as (in theory) the most efficient form of biomass gasification, but we have found no evidence that any biomass IGCC plant exists anywhere in the world[12] and none is planned in the UK. Furthermore, experience with coal IGCC plants shows that actual energy returns can be far worse than predicted ones (and worse than for conventional coal power plants[13]).[xli]

- The biomass feedstock: Different types of biomass with different moisture content produce

12 A demonstration biomass IGCC combined heat and power plant started being commissioned in Värnamo in Sweden in 1993, took a further three years to become operational, and was closed in 2000. Although the project was later resumed, this was to try and produce biofuels, not heat and power. Another biomass IGCC demonstration plant started being commissioned in Xinghua in China in 2005 but by 2008, the project wasn't fully running (http://pubs.acs.org/doi/abs/10.1021/ef8004042?journalCode=enfuem). We have not been able to find any evidence to suggest it is currently operating.

13 We note that most conventional biomass power stations achieve lower peak steam temperatures and thus lower efficiency than conventional coal power stations. In theory, the 'efficiency gain' achieved by biomass IGCC plants could therefore be greater than that achieved by coal IGCC plants. However, in the absence of any experience with biomass IGCC plants, it is impossible to know whether this would indeed be the case.

syngas with a different energy content;

- The size of the gasifier: As is the case with biomass combustion plants, smaller units tend to be less efficient than larger ones. It is not the overall size of the project that matters in this context – it is the size of the individual units. Some medium-sized biomass gasifiers proposed would consist of several very small units or 'modules'.

In a biomass gasifier which produces and combusts cleaned syngas, it is always necessary to first cool down the dirty producer gas in order to clean it. During this cooling process, a proportion of the original energy contained in the biomass will be lost. According to the International Energy Agency's Task Force on biomass gasification, during gasification "*70-80% of the energy contained in the initial solid fuel is transferred to the chemical energy of producer gas (remaining 20-30% accounts for heat and losses*)"[xlii]. The greater efficiency of a gas engine or gas turbine – compared to a steam turbine, on which a conventional biomass plant relies, – can more than compensate for this energy loss. Burning clean syngas to power a steam turbine, on the other hand would result in a significant energy loss compared to what a conventional biomass plant would achieve.

As one peer-reviewed study about biomass gasification published in 2014 states:

"*The challenge of this system [biomass gasification reliant on a steam turbine] is related to the net electrical efficiency, which is extremely low (10–20%). The high capital cost and the limitation of boiler and steam turbines lead [companies] to avoiding this technology for power generation from biomass gasification gas.*"[xliii]

However, none of the biomass gasifier proposals that have been made in the UK which rely on powering a steam turbine involve any cleaning of the producer gas. This means that their efficiency will simply be comparable (i.e. comparably low) to that of a comparable conventional biomass plant. In reality, though, the efficiency of those proposed gasifiers tends is particularly low[14]. This is largely due to the very small size of the proposed individual units or modules. This also applies to the Tyseley development which is supported by the Green Investment Bank: Based on published figures, the expected efficiency would be a mere 20%. This seemingly illogical technology choice, as we shall see below, is a perverse result of the UK government's subsidy rules for bioenergy.

What about gasifiers which power a gas turbine or engine with cleaned syngas? These can achieve slightly greater efficiencies than conventional biomass of the same size despite the loss of energy during gas cooling. This is due to the fact that gas engines and gas turbines are more efficient than steam turbines. The Guessing biomass gasifier in Austria, mentioned above, achieves 20-25% electric efficiency, but 80% overall efficiency due to a high level of heat use – though it is not clear from the citation whether this is gross or net efficiency, i.e. whether use of energy to run the plant is included in the figure [xliv]. This is a high efficiency level for a combined heat and power plant, but it is one that can be achieved by a well-designed combined heat and power biomass combustion plant too. Another company planning to build a 5 MW biomass gasifier with a gas engine in Bulgaria, states that they will achieve 70% overall efficiency and 26% electric efficiency[xlv] . Those figures are relatively high for a biomass plant of this size but could be easily exceeded by larger conventional biomass power plants.

14 Our calculations suggest electrical efficiency rates of just 19-23.5% for several currently or recently proposed biomass gasifiers in the UK.

PYROLYSIS

Pyrolysis, as we have seen above, yields bio-oil, producer gas (which can be cleaned to become syngas) and char in varying proportions. In theory, optimum efficiency would rely on cleaning the producer gas and burning it in a gas engine or turbine and also burning the bio-oil as efficiently as possible, while keeping non-fuel char yields as low as possible. But no plant in the world has ever been built which makes use of all three products – and world's only pyrolysis plant designed to produce bio-oil and combined heat and power is not yet fully commissioned. In the absence of any real experience with pyrolysis plants for energy generation, we cannot credibly predict how efficient those might be.

ARE BIOMASS GASIFIERS CLEANER OR MORE POLLUTING THAN BIOMASS COMBUSTION PLANTS?

As we have discussed elsewhere[xlvi], burning virgin wood in power stations emits approximately as many pollutants as burning coal in similar plants, but more of some pollutants and less of others. Burning chemically treated waste wood emits a greater range of pollutants and many of them in greater quantities.

If the producer gas from biomass gasification is cleaned to such a high standard that it can be burned in gas engines or turbines, then the emissions will be significantly lower than those from biomass combustion plants – as long as the plant operates smoothly. As we have seen above, technical problems with such plants are almost universal and they can include dirty producer gas being vented straight into the atmosphere to prevent pressure build-up and an explosion.

Yet cleaning of the producer gas is costly and not necessary in order to run an inefficient steam turbine – although burning dirty producer gas will increase boiler corrosion and make boiler maintenance more costly. Thus, a biomass gasifier that powers a steam turbine can be expected to emit similar types and levels of pollutants as a comparable biomass combustion plant. But again, this would only apply if such a gasifier was to operate smoothly. Which, as we have seen, is unlikely to be the case - at least for the first year or two of operation. Even without any incidents requiring venting of dirty producer gas, frequent shutdowns and start-ups of such a plant will result in significant peaks in the emission of dioxin and furans and other air pollutants[xlvii]. Technical problems thus translate into very real pollution and public health concerns.

THE UK'S EXPERIENCE WITH BIOMASS GASIFICATION AND PYROLYSIS SCHEMES

LESSONS NOT HEEDED: ARBRE – THE UK'S FIRST FAILED BIOMASS GASIFIER

In February 1997, Selby District Council granted planning consent for the UK's first biomass gasification project, and arguably for the most ambitious such project yet proposed in this country. The ARBRE ("Arable Biomass Renewable Energy") project was developed by a consortium of four companies in response to a European Commission call for biomass gasification demonstration projects. The European Commission grant was to cover 40% of the cost, although costs escalated and it therefore only covered 28%. In addition, the developers were guaranteed UK subsidies for electricity generation. The ARBRE plant, located in Eggborough, was built as an Integrated Gasification Combined Cycle (IGCC) power plant – in theory a particularly efficient, low-pollution type of biomass plant which, however, has never been technically proven. In 2001, the plant was finally fired up. But it never operated successfully and in 2002, the project went into liquidation. A peer-reviewed study has since looked at the obstacles faced by the projects and the reasons it did not succeed[xlviii] , due to a combination of technical, organisational, and financial problems. Gas cooling and cleaning was described as the project's 'Achilles heel'. The authors concluded: "

> "*Arguably, there was insufficient control and monitoring by the organisations and companies involved in Project ARBRE. This lack of control seems to have exacerbated the degree of technical errors and the failure to address these errors in sufficient time. Perhaps the key policy message to emerge from the case is that effective scrutiny and oversight of publicly funded demonstration projects is required throughout their development, especially when bodies that might usually be performing this function in a commercial setting (e.g. banks) are not involved in this capacity*".

These lessons, as we shall see, have not been heeded: The government has since increased subsidy rates for biomass gasification and pyrolysis but exercises virtually no oversight or control over projects. Planning policy requires planning authorities to ignore any questions about the technical feasibility of projects. Planners must assume that any plant will operate in full accordance with its Environmental Permit and that the conditions in the permit will be fully enforced by the Environment Agency[xlix].This is despite the fact that the literature about biomass gasifiers shows that they cannot be expected to operate smoothly for at least the first one or two years, and even though the Environment Agency (or their Scottish equivalent, SEPA) will only revoke permits in the most extreme circumstances. And, as we shall see below, the Green Investment Bank's support for the Tyseley biomass gasification project raises questions about their level of diligence.

BADLY ADVISED: HOW HIGHLAND COUNCIL BOUGHT INTO BIOMASS GASIFICATION TECHNOLOGY AND LOST £11.5 MILLION

From 2002, Highland Council embarked on a biomass project in Wick: They would build a combined heat and power plant which would use residues from nearby tree plantations to heat local housing and sell electricity to the grid. Few would fault the idea. The plant was to meet local heating needs with local wood, it could be run on local tree plantation residues, it was to involve one of the very few local heating networks built in the UK, and it was to be highly efficient. Unfortunately, as it turned out, the arms-length company set up by Highland Council, Caithness Heat and Power, became convinced that a biomass gasifier– using gas engines which relied on effective gas cleaning - provided them with a credible and efficient choice. 247 houses were linked up to the new district heating network. When technical problems became apparent, Highland Council took full control of the scheme. Trials were started in October 2008 but by December that year, an expert report advised that the plant would never work. The Council had to provide heat and hot water to the 247 homes with an oil boiler – a polluting, high carbon source of heating. Eventually, a private company agreed to replace the defunct gasifier with a conventional biomass combustion plant to supply and expand the heating network. And this combined heat and power plant is reportedly working well.

The Scottish public sector auditor, Audit Scotland, decided to carry out a full investigation into how Highland Council had lost £11.5 million and issued a highly critical report[l]. Much of their criticism related to the way in which the Council had dealt with the arms-length company responsible for choosing the gasification system – including the lack of scrutiny. Audit Scotland was unequivocal about the reason why the scheme failed:

> *"Ultimately, the project failed because the company procured 'experimental' and high risk gasification technology which could not be commissioned successfully"*.

It seems unfortunate that no similar level of scrutiny has ever been paid to the UK and that the Scottish government supports measures for biomass gasification and pyrolysis, mainly through renewable electricity subsidy rules.

THREE UK BIOMASS GASIFIERS IN OPERATION?

Two companies claim to be operating biomass gasifiers in the UK and another company claims to have built one, though it is not clear whether they have tried to commission it yet[15].

One of these is a small 1 MW plant at a poultry farm near Calthwaite, north of Penrith. In 2006, the owners of the farm obtained planning permission to install a gasifier provided by a company called Biomass Engineering, which promised an efficient and low-pollution gasifier with gas cleaning before combustion and with two spark ignition gas engines. The gasifier was installed the following year but it clearly did not work since it was mothballed soon after[li] without having received any renewable energy subsidies. In 2014, a UK startup company called **Aggregated Micropower Holdings (AMPH)** decided to reopen the plant, announcing plans to either increase the size to 1.5 MW or to build a new 1.5 MW gasifier next to the existing one. In fact, AMP did not re-start the old gasifier, they replaced it with their own design, about which few details are available[lii]. This new gasifier has indeed received renewable electricity subsidies, which means that AMP has succeeded in generating electricity from it; at least during the months May to October 2014 (no more recent data is available)[liii]. However, throughout that time, the gasifier only operated at 10% of its capacity, indicating likely technical

15 Note that Biofuelwatch has not looked at any projects smaller than 1 MW capacity.

problems[16]. Whether AMP will overcome those problems and succeed in running the gasifier longer-term remains to be seen.

Another gasifier was supposedly commissioned in Monmouthshire in June 2014, by a company called **Green Power Plant Ltd**, with a capacity of 5.99 MW. The company has obtained accreditation for renewable electricity subsidies[17] from the UK's electricity and gas market regulator Ofgem, though we have found no record of them having been awarded any actual subsidies. We have not been able to find any record of planning consent for such a plant having been granted either. Furthermore, a different new startup company, **Ecocycle**, claims to be building the same plant[liv] while a third firm, called **Dortech** claims to have already built it for Ecocycle[lv].

And finally, a company called **Clean Energy Generation** claims to have built a 2.2 MW demonstration plant in Sinfin, Derby, though they have not announced the commissioning of this plant[lvi]. On the same site, a biomass gasifier had previously been built and had failed. According to Clean Energy Generation's website, the technology involves the use of engines, pre-cleaning of syngas and, furthermore, the production of torrefied wood pellets – something that appears not to have been attempted in the UK so far. Producing torrefied pellets – and, as we have seen above – generating electricity from a gasifier that powers gas engines are both highly complex, immature and technologically challenging processes. Yet Clean Energy Generation appears to have no record of operating any other plants in the UK (and thus no prior experience) and they list no commercial partners or collaboration with any research institutes.

GREEN INVESTMENT BANK BOOSTS CANADIAN GASIFIER COMPANY NEXTERRA'S BUSINESS

In December 2013, the Green Investment Bank helped set up and joined a consortium to finance a "first of its kind" biomass gasifier in ***Tyseley, Birmingham***[lvii]. As we have seen, it won't be the first biomass gasifier to be built in the UK, though it will be a first if it operates successfully. The company chosen to provide the gasifier technology is a Canadian firm, Nexterra. According to the joint press release issued by the Green Investment Bank (GIB), "Nexterra has successfully delivered seven similar gasification facilities in the USA and Canada". But have they?

Nexterra's own website lists eight, not seven, gasifier projects in North America. Out of the eight gasifiers built, only three were designed to supply electricity as well as heat. The others were built to provide heat or process steam for industrial use only, which, as a World Bank report about biomass gasification already pointed out twenty years ago[lviii], is technically much more straightforward than building a gasifier designed to generate electricity.[lix]

Nexterra's first electricity-generating gasifier, built at the University of South Carolina, was ill-fated: Between December 2007, when the developers first tried to operate the plant, and June 2009, there were three incidents which a senior staff member of the University of South Carolina described at 'potentially lethal', the third of third of which blew a metal plate 60 feet towards the control room[lx]. Over a period of two years, the plant provided steam on just 98 days. Nexterra blamed a supplier for this plant's failure. But this wasn't the end of the problems with Nexterra gasifiers.

16 When a plant is first commissioned, it can be expected to initially run at a very low capacity, with the amount of fuel burned gradually being increased. However, in this case, the amount of electricity generated dropped by about 50% from September to October 2014, which is a red flag for technical problems.

17 Accreditation is granted before any renewable electricity subsidies can be claimed. It is based on an application by the developer. Actual subsidy awards then depend on the amount of electricity generated.

In October 2012, the second Nexterra gasifier designed to provide electricity and heat was commissioned at the University of British Columbia. In 2013, the plant's gas-cleaning system failed so that the gas could no longer be burned in the plant's engines.
The university decided to continue with this 'demonstration project' in the hope that the problems could eventually be overcome. Meantime, however, they have been purchasing 'upgraded' biogas (from anaerobic digestion) from another company, and burning that in the engines[lxi]. This means that the biomass gasifier has not successfully operated beyond a short initial period.

The third such Nexterra plant was set to be commissioned at a health centre in Michigan in March 2014 but no announcement of it actually being commissioned has been released. The University of Montana, meantime, cancelled a similar Nexterra contract on which they had already spent over half a million dollars, amidst public concerns about air quality impacts[lxii].

Thus, contrary to the Green Investment Bank's claims, Nexterra has never delivered a successful plant similar to the one being built in Birmingham (i.e. a biomass gasifier that successfully generates electricity).

On top of this, although biomass gasifiers that only supply steam for heat are technically less challenging, one of Nexterra 'heat only' gasifiers also failed. This was a gasifier commissioned at Oak Ridge National Laboratory in 2012 which had to be permanently closed the following year after a systems check found that vital parts were already failing due to corrosion caused by weak acids[lxiii].

Nonetheless, the Green Investment Bank's support for the Tyseley biomass gasifier appears to have inspired other banks and companies to have confidence in Nexterra's technology:

- In March 2015, a company partnership involving Nexterra announced that they had obtained sufficient loan finance to build a 10.4 MW waste wood gasifier in ***Theddingworth*** in Leicestershire[lxiv]. Nexterra is to design and supply the gasification-to-steam generation system. The plant will be built on a site for which another company, Pure Power Holdings Ltd, had obtained planning permission for another biomass 'advanced conversion' plant in 2008. That company did not succeed in building the plant and is now in liquidation.

- In ***Grays, West Thurrock***, Procter & Gamble have decided to partner with Nexterra and to seek to build a biomass gasifier to provide heat and electricity for their factory as well as electricity to sell to the grid[lxv]. A full planning application is currently pending.

A fourth Nexterra biomass gasifier was granted planning permission in ***Avonmouth*** near Bristol in April 2015: There, the Planning Inspectorate overturned a decision by Bristol City Council to refuse the development due to concerns over its air quality impacts.

If Nexterra's UK gasifiers were to operate successfully (which, judging by their North American record, appears doubtful) they would become the UK's least efficient biomass power plants. Based on published figures, these plants would achieve particularly low efficiency levels, as low as 20.4%. This is largely due to the fact that all four gasifiers are relatively small units which would power steam turbines. Such a process, as we have seen, is cheaper to install but significantly less efficient than a gasifier powering gas engines or gas turbines. Of the four proposed Nexterra plants, only one (in Grays) is expected to supply heat as well as electricity. This would make it more efficient than the other three plants – but its projected overall efficiency will still only be 33%, whereas efficient biomass combined heat and power plants can achieve over 70% efficiency.

Furthermore, Nexterra's plants would do little to advance the research and development of biomass gasification worldwide. This is because the greatest challenge associated with gasification is to produce clean syngas which can be burned relatively efficiently in gas engines or gas turbines. Yet there would be no gas cleaning before combustion in the Tyseley plant.

DAVID PIKE, HIS 30 (OR MORE) ADVANCED CONVERSION COMPANIES AND £50 MILLION LOSSES TO INVESTORS

Nexterra wasn't the only winner from the Green Investment Bank's support for the Tyseley gasifier. Another big winner was a small company called Carbonarius, who were appointed as the developers of the plant. But who are Carbonarius?

According to industry media reports of the Green Investment Bank loan, Carbonarius are "a joint venture between Stoke-on-Trent technology developer O-Gen and property firm The Una Group[lxvi]". According to information available on www.companycheck.co.uk, there is indeed a company called ***Carbonarius Ltd*** – but their only subsidiary (***O-Gen Plymtrek Ltd***) is a company that was set up with the sole purpose of developing a biomass gasifier in Plymouth. We will look at the failure of that plant below. Three out of Carbonarius Ltd's five directors, however, are also directors of two similarly named companies: There is ***Carbonarius2 Ltd***, set up in July 2012, who own £4.40 (sic) of shares in a company called ***Tyseley Bio-Power Ltd***. Tyseley Bio-Power Ltd was set up two months before the Green Investment Bank loan for the plant was announced. And there is ***Carbonarius3 Ltd***, set up just three weeks before the Green Investment Bank loan, who describe themselves at Tyseley Bio Power-Power's parent company (though the latter was set up first). Finally, there is a company called ***Birmingham Bio-Power Ltd***, set up in July 2012, who own £10 of Tyeseley Bio Power's shares. Four of these companies – all but ***Una Group*** – share three of the same directors: David Pike, David Nairn and Ian Brooking. Ian Brooking is also a director of Una Group, as is another of the Carbonarius Ltd directors, David Young.

Indeed, the five companies mentioned above are five out of at least 30 companies of which David Pike and his associates have been directors since 2005, all of them in the field of advanced conversion in the UK. Five of the companies have been dissolved. For simplification, we shall call them the 'O-Gen Companies', since the first 11 of them had 'O-Gen' (or 'Ogen') in their title. Altogether, the record of the O-Gen Companies has been a highly unsuccessful one:

- Their first gasifier was built in ***Stoke-on-Trent***. This particular company involved (***O-Gen Acme Trek Ltd***) tried to commission it from April 2009 to October 2011, but without success. Throughout that time, it operated at just 0.6% of the plant's capacity[lxvii]. No electricity appears to have been generated since. The auditors' report of the company's latest account, published March 2015, state: "[They] incurred a net loss of £1,691,821 during the year ending 30 June 2014, and at that date, the company's current liabilities exceeded its total assets by £13,214,994, and it had net current liabilities of £14,909,434". These figures, according to the auditors, "may cast significant doubt about the company's ability to continue as a going concern". The O-Gen Companies' first gasification venture, it seems, is on course to going into receivership or being dissolved with a loss of almost £15 million of investors' money. Company House records[lxviii] do not reveal who those investors are – other than that 99% of shares are owned by a dormant, non-trading company called "Share Nominees Ltd". Some of the remaining shares have been owned by three companies belonging to the Foresight Group – the Green Investment Bank's first external fund manager[lxix]. But this is not the biggest loss incurred by one of the O-Gen Companies' gasifier ventures.

- In December 2009, ***Plymouth*** City Council granted planning consent for a waste wood gasifier which two of the O-Gen Companies (***O-Gen Plymtrek Ltd*** and their parent company, Carbonarius Ltd) planned to build. Construction started but the plant was never commissioned. O-Gen Plymtrek's audited accounts, published April 2015, state: "In December 2014, the company was advised by the design and build contractor that it was ceasing construction. In addition, the main project funder to the project exercised its right under a Sales Agency Agreement...and required that the Company's main asset, the energy centre, was marketed for sale. On 27th March 2015 the energy centre was sold and proceeds paid to the external project funder...The Company has no further significant assets. The directors intend to wind the Company up...The Company made a loss after tax for the year of £35,334,000." Just whose £35.33 million were lost is difficult to ascertain. Bizarrely, audited accounts for Carbonarius Ltd, published at the same time and signed by the same auditor, report net liabilities of just £243,709 for the same period – even though their subsidiary had lost over £35 million. Also for the same period, Una Group[18], one of the two companies that hold 50% each of Carbonarius Ltd's shares, recorded a profit of £7,465 from that same company (i.e. Carbonarius Ltd) for the same period. Carbonarius Ltd's other shareholder, O-Gen UK Ltd, has not yet published their accounts for 2014. Perhaps their shareholders are amongst the main losers? 99.98 of them are investors through the Enterprise Investment Scheme. This is a scheme set up by the government which provides tax relief for buying shares in new high-risk companies – effectively a subsidy.

- In July 2008, O-Gen UK Ltd obtained planning permission for a waste wood gasifier in Derby, which opened in 2012 or January 2013 and was closed after several months of unsuccessful attempts to operate it. In this case, however, none of the O-Gen Companies incurred a loss. This is because they had succeeded in selling the development on to an unrelated startup company, ***Withion Power (formerly Clarke-Power Ltd) and their subsidiary, Boyle Electrical Generation Ltd.*** During the summer of 2013, both Withion Power Ltd and Boyle Electrical Generation Ltd filed for bankruptcy. Withion's main shareholders had belonged to the Foresight Group (i.e. the Green Investment Bank's first external fund manager). We could not find information as to how great the losses incurred by Withion Power were.

David Pike and David Nairn, directors of the O-Gen Companies associated with the Tyseley gasifier, have been directors of all of the O-Gen Companies mentioned above and associated with the gasifiers in Stoke-on-Trent, Plymouth and Derby (though not with the companies that acquired the Derby scheme in 2010). ***They have therefore been directors of two biomass gasifier ventures which have lost investors a total of £50 million, and behind a third biomass gasifier scheme which ultimately led to the bankruptcy of another company and its subsidiary***.

Nonetheless, the Green Investment Bank's support for Carbonarius, has been used by O-Gen companies and their directors to attract support for yet more ventures:

- A relatively new O-Gen Company, ***Cogen*** (also with Pike, Nairn and Brooking amongst the directors) has partnered with Balfour Beatty. Loan funding has been obtained for the £52 million gasifier in ***Theddingworth*** mentioned above (which uses Nexterra's technology), and Cogen will be the developer.

- Peel Energy, part of the larger Peel Group, have partnered with two O-Gen Companies, called ***Houghton Bio Power Ltd*** and ***Northern Bio Power Ltd*** (again, with Pike, Nairn and Brooking amongst the directors). Together, they have applied for planning consent for a waste wood gasifier in ***Little Houghton***, near Barnsley.

David Pike and his associates seem hopeful of further contracts with Peel Group. Since the beginning of 2015, they have set up:

18 Una Group shares one director, Ian Brooking, with all the O-Gen Companies mentioned in this section.

- ***Ince Bio-Power Ltd***: Peel Group holds planning permission for a biomass plant in ***Ince Marshes***, Cheshire;
- ***Bilsthorpe Bio Power Ltd***: Peel Group is currently seeking planning consent[19] for a Municipal Solid Waste gasifier in ***Bilsthorpe***, although Peel Group has so far announced Harwoth Estate Property Group Ltd and Wast2Tricity, rather than this new company, as their corporate partnersl
- ***Southmoor Bio Power Ltd***: Peel Group holds planning permission for a Muncipal Solid Waste gasifier called Southmoor Energy Centre near ***Knottingley*** in North Yorkshire.

Also in 2015, they have founded:

- ***Hooton Bio-Power Ltd***: Biossence holds planning permission for a Muncipal Solid Waste gasifier in ***Hooton Park, Eastham***;
- ***Dartmoor Bio-Power*** and ***Dartmoor Operations Ltd*** (we could find no existing project to link this to);
- ***Riverside Bio-Power Ltd***: Riverside ReSource Recovery Ltd and Cory hold planning consent for a Municipal Solid Waste gasifier called Riverside Resource Recovery Facility in ***Bexley, London***.

Finally, an O-Gen Company, ***Almondbank Power Ltd***, is currently proposing a biomass pyrolysis plant in ***Perth***. The particular technology they want to use is called 'steam thermolysis', to be provided by a US company called Concord Blue. Concord Blue promises on its website that their technology is 'commercially proven, nearly any scale' and that they have five plants in operation and two under construction worldwide[lxx]. An investigative journalist in the US found that two of the supposedly operating plants have not actually been built, a third had broken down every 10-15 days before being finally shut in 2013, and a fourth had been experimental and was also closed down due to technical problems. A fifth (in India) has, according to the journalist's findings, been operated without any electricity being generated – but has raised serious complaints over air and water pollution, the discharge of untreated waste, and foul odours. A plant supposedly under construction in Germany had in fact been abandoned and the only operational Concorde Blue plant, based in India, has failed to generate any electricity at all[lxxi].

Tens of millions of pounds in losses to investors clearly haven't deterred the O-Gen Companies and their directors from seeking to greatly expand their advanced conversion activities.

A CLOSER LOOK AT OTHER COMPANIES INVOLVED IN UK BIOMASS GASIFICATION

As we have seen, a successful biomass gasification scheme requires a high level of technical expertise and experience and a company with sufficient funds to keep upgrading the technology and solve problems over a long period of time. It may also require close collaboration between companies with different types of expertise and with researchers.

So who, apart from Nexterra and the O-Gen Group Companies are the main players in UK biomass gasification?

One of them is ***REACT Energy Ltd/Kedco***, who announced in September 2012[lxxii] that they had started exporting electricity from a 2 MW biomass gasifier in Newry, County Down, and that they were

19 The application has gone to Public Inquiry and a decision is not expected until 2016.

planning to double its capacity by the end of 2013. The plant itself belongs to a subsidiary of Kedco/REACT and their main shareholder, Farmer Business Developments Plc, called *Newry Biomass Ltd*. Loans for the plant had been provided by Ulster Bank and Royal Bank of Scotland[lxxiii] and, in January 2014, Ulster Bank made a further loan available to finally increase the plant's capacity to 4 MW.

In fact, the Newry gasifier has been a failure. It never received any Renewable Obligation Certificates[lxxiv], subsidies of around £87 per MWh generated to which the operators would have been entitled[20]. In June 2014, REACT announced that they were looking for an "alternative technology provider" to "take full responsibility for the construction, commissioning and operation of the project"[lxxv]. REACT's own Kedco subsidiaries, which had been responsible for building and operating the plant were put into voluntary liquidation with a debt of €3.5 million (around £2.5 million) for which REACT accepted no liability[lxxvi]. In December 2014, REACT suspended trading on London's stock market (Alternative Investment Market[lxxvii]). And in May 2015, they applied for 'examinership', i.e. court-supervised restructuring, in the High Court of Dublin[lxxviii]. The Newry plant remains mothballed.

The failed Newry plant hasn't been REACT's only problem. In August 2010, they had obtained planning permission for a larger waste wood gasifier in Enfield, North London, and they had eventually succeeded in signing a Collaboration Agreement with the Foresight Group. Since then, planning consent has expired, Foresight Group has withdrawn from the agreement and REACT has withdrawn a new planning application.

However, a company's financial troubles and previous development failures are not matters deemed relevant in planning cases. Nor, for that matter, are their legal status and claim on sites -. Until 1st December 2014, REACT was seeking planning consent for another gasifier, in Plymouth. They withdrew the application only after the planning officer had recommended that the Planning Committee should reject the application, following a significant number of local objections. REACT continues to seek planning consent for a waste wood gasifier in Clay Cross Derbyshire.

Another company with great ambitions in the biomass advanced conversion sector is ***Sunrise Renewables Ltd***. Incidentally, one of the two directors of each of their five local subsidiaries, Howard Davies, had previously been a director of Withion Power Ltd and their subsidiary, Boyle Electrical Generation Ltd., the two companies that went into liquidation after the failed biomass gasification project in Derby (the project first initiated by one of the O-Gen Companies). Between December 2008 and July 2010, Sunrise Renewables obtained planning consent for four biomass pyrolysis plants in Barrow-in-Furness, Barry, Hull and Sunderland. However, the company has not become the world's first successful electricity generator from biomass pyrolysis. Instead, they have changed their plans and have started getting their planning consents changed to biomass gasifiers (which, according to the planning applications, would use significantly more wood for a relatively small increase in projected electricity output). At the time of finalising this report, at least two such planning consents have been changed, although Hull City Council has since rejected a further application to allow non-biomass waste to be gasified there, too. A similar application is pending in Barry.

A company called ***Alternative Use Group PLC*** claimed in its latest annual accounts that they started building a 12 MW biomass gasifier in ***Boston, Lincolnshire*** during the year up to May 2014 and that the plant would be finished in 2016. They had obtained planning permission together with a company called ***Alchemy Farms Ltd***. But neither of the companies' financial statements suggests that either of them has the funds to commence construction, or that any significant external funding, including any loans, have been obtained, even though the plant would be slightly bigger than the £47.8 million Tyseley biomass gasifier. And neither company appears to have any previous

20 This is based on each biomass advanced conversion plant attracting 2 ROCs per MWh and on the average price per ROC over the past 12 months at the time of finalising this report.

experience in this sector.

A particularly active company in the UK's gasification sector was ***Bioflame Ltd***. According to a media report in December 2010, they had secured planning permission for 17 biomass gasifiers, two of which had been built and two of which were in the late stages of construction[lxxix]. The vast majority of Bioflame's projects were smaller than 1 MW and have thus not been included in the mapping exercise accompanying this report. One, however, was a 2.6 MW waste wood gasifier in ***Cobham***, Surrey, for which SAS Waste Ltd was seeking planning permission and which Bioflame was to build. The local authority rejected the application[21], based on a planning officer's report which exposed Bioflame's record[lxxx]: Designers of key components of their plants lacked experience, and no Engineering, Procurement and Construction contract had taken overall responsibility for their projects. Four plants were constructed simultaneously, before experience with operating a single one had been gained. At the time of the planning officer's report (February 2014), a Bioflame gasifier in ***Doncaster*** had failed to operate successfully since attempts to commission it were first made in 2009. Another one, in ***Claythorpe***, had been started up in mid-2009, failed to operate successfully and was shut down in mid 2011. A third one, in ***Brandesburton, East Yorkshire***, was first started up in spring 2010, but could not be operated successfully and was shut in 2011. And the fourth, in ***Thurleigh, Bedfordshire***, was constructed with serious delays but never commissioned. In fact, at that time the Planning Officer's report was written, Bioflame was already in liquidation[lxxxi].

Another company that sought to build biomass advanced conversion plants and is also now in liquidation was ***Pure Power Group Ltd***. They had tried to obtain planning consent for a waste wood gasifier in ***Hungerford*** and they had been granted planning consent for two other biomass advanced conversion plants: One was in Theddingworth, on the same site that Cogen and Balfour Beatty later obtained a new planning consent for the biomass gasifier which has now attracted funding and is being built (see above). The other consented Pure Power plant was to have been built in ***Huntingdon***. In January 2013, a different company, ***Energy 10***, obtained planning consent for a waste wood pyrolysis plant on the same site, one that is to generate electricity. Energy 10 plans to produce syngas to supply to the national grid from 100,000 tonnes of mainly waste wood, but with some virgin wood and plastics mixed in. No company in the world has so far succeeded in operating a pyrolysis plant comparable to either of those planned by Energy 10.

In ***Wellingborough, Northamptonshire***, a company called ***Larner Recycling Ltd***, in partnership with a consultancy firm called ***Oaktree Environmental Ltd***, obtained planning consent for a biomass gasifier in 2008, with several changes to the planning conditions approved subsequently. Larner Recycling has been collecting and chipping waste wood but their director is currently serving a suspended prison sentence over persistent breaches of Environment Agency permitting conditions and pollution control regulations. His related business on the same site, Larner Timber Recycling Ltd, went into liquidation in 2013[lxxxii]. The planning consent appears to have been taken over by a new company called ***Green Plan Energy Ltd***. Green Plan Energy, according to their website "aim to become Europe's largest developer of biomass gasification plants – they do not appear to have any experience in this field so far and we have found no indication of them having raised funds for the Wellingborough plant either.

Two larger companies - ***Invictus Capital*** in ***Georgemas, Caithness*** and ***Honda*** in ***Swindon*** have obtained planning consents for biomass gasifiers but the former has abandoned their plans and the latter appears to not have pursued them further as yet[22].

21 There had been an active local campaign against this plant. The developer appealed against planning refusal but later withdrew the appeal.

22 Honda's planning consent was granted in March 2014 and they are still well within the time period for starting construction.

WHEN A GASIFIER IS NOT A GASIFIER – THE CURIOUS CASE OF THE PROPOSED "ENERGY PARK SUTTON BRIDGE"

Had it not been for 74-year old Mrs Shirley Giles risking thousands of pounds of her own savings on a Judicial Review, then ***Sutton Bridge*** would now be the site of the largest approved biomass gasifier in the country and the developer would be looking for investors. In May 2013, South Holland Council had granted planning consent for a large 43-48 MW biomass gasifier. To the delight of large numbers of local residents, Mrs Giles won the legal case – the local authority decided not to contest it. Less than a year later, the plant was finally refused consent. The company behind the development was a US firm called ***Pacific Green Technologies Inc***. The Non-Technical Summary for the application[lxxxiii] described the proposed plant as follows:

> "*Biomass fuel will be combusted within the main process building to produce radiant heat, which in turn will heat hot water to produce superheated steam. This high pressure and high temperature steam will be passed through a steam turbine and drive a generator to produce electricity.*"

This is a description of a standard combustion plant. If there was any obvious difference between the proposed plant and existing conventional biomass plants it was the far lower efficiency of the former: A mere 19.4%, according to Biofuelwatch's calculations[lxxxiv]. This extremely low efficiency was due to the plant's design: It was to consist of at least 10 units, each with their own steam turbine and stack. The smaller the unit that powers a steam turbine is, the less efficient the power plant will be.

However, the same planning application nonetheless described the plant as an "*advanced conversion facility (gasification)*", strongly suggesting that they were hoping convince Ofgem to accredit the plant for the higher subsidy rate, for which gasification plants are eligible. Since planning permission was refused, we will never know whether Ofgem would have agreed with the developers.

Ofgem relies entirely on companies' own reports about the nature of their plants and on companies' own fuel sampling to determine whether the 'advanced conversion' criteria are met[23]. Setting aside the risk of fraud, it is quite possible that a plant such as that proposed in Sutton Bridge might have been accredited as an 'advanced conversion' plant. This is because the Government's definition of 'gasification' and 'pyrolysis', adopted for the purpose of determining eligibility for subsidies[lxxxv], is so vague that standard combustion plants might 'slip through the net'.

There are just two requirements for a plant to qualify as a 'gasifier' for subsidy purposes:

a) It needs to meet the Government's definition of gasification, which says: *""Gasification" means the substoichiometric [i.e. partial' oxidation or steam reformation of a substance to produce a gaseous mixture containing two or all of the following: oxides of carbon, methane and hydrogen*";
b) The gas needs to have a gross calorific value of at least 2 MJ/m^3. Gross calorific value is also called 'higher heating value' and it is a measurement for the amount of energy contained in a cubic metre of gas (or other fuel).

Unfortunately, in terms of the chemistry involved, this offers no clear dividing line between gasification and pyrolysis on the one hand and combustion on the other hand. Power station operators will almost always stage the inflow of air into the combustion chamber which means that, for a very short period of time, wood (or for that matter any solid fuel) will be gasified. Furthermore,

23 This is a general comment not intended to reflect in any way on Pacific Green Technologies Inc or anybody else involved with the Sutton Bridge biomass plant proposal.

in chemical terms, burning wood always involves a 'pyrolysis' stage. When wood starts to burn, its chemical structures decompose into a mix of gases which contain mainly carbon and hydrogen atoms[lxxxvi]. Even a bonfire involves elements of pyrolysis and gasification – hence the charred remains left behind – and the production of gases including oxides of carbon, methane and hydrogen[lxxxvii].

Furthermore, the 'gross calorific value' requirement is very weak. For example, US researchers measured the gross calorific value of syngas taken from four biomass gasifiers and found it to be between 4.3 and 17.2 MJ/m^3[lxxxviii]. It does not seem inconceivable that gases measured during standard biomass combustion might meet the "2 MJ/m^3" requirement set out in the legislation.

Clearly the Government would not have intended ordinary biomass combustion to be creatively re-defined as 'gasification' or 'pyrolysis' – but the wording of their legislation may nonetheless allow this to happen. Ultimately, what Pacific Green Technologies tried to do would have gone just one step further from what Nexterra, O-Gen and other are currently trying to do. The 'single stage' gasifiers proposed by those companies - which involve no cooling or cleaning of gas and which are to power steam turbines - are already a very long way removed from the idea of 'high-tech' gasifiers, i.e. from gasifiers that produce clean syngas to burn in a gas turbine or engine.

CONCLUSIONS FROM THE UK GOVERNMENT'S SUPPORT FOR BIOMASS GASIFICATION AND PYROLYSIS

The Government's approach to supporting 'low carbon technologies' and 'energy innovation' has been outlined by DECC as follows:

> "· *Technology push is direct funding for demonstration and pre-commercial deployment.*
> *· Market pull is indirect funding, through mechanisms such as the Renewables Obligation, Feed-in Tariffs and Emissions Trading,*
> *· Barrier removal aims to address the areas which slow development down, such as planning and grid issues."*[lxxxix]

In short, the Government seeks to support technological 'innovations' through a combination of public subsidies[24] and de-regulation.

Biomass gasification and pyrolysis are two of the technologies which the Government regards as both innovative and low-carbon and which, over many years, have been receiving support according to the DECC's 'blueprint' outlined above:

- "Direct funding for demonstration and pre-commercial deployment": Significant funding for research into biomass (and waste) gasification and pyrolysis technologies and has been made available through government-funded Research Councils[xc] and other publicly funded programmes, such as the private-public partnership Energy Technologies Institute[xci];
- "Indirect funding": Biomass (and waste) gasification and pyrolysis attract particularly generous support through renewable electricity subsidies:
    - They are eligible for a higher rate of Renewable Obligation Certificates (ROCs) than conventional biomass plants. ROCs are subsidies for electricity classed as renewable. The scheme closes to new applicants in March 2017 but plants accredited for ROCs by then will continue to receive them;
    - Developers of biomass or waste gasifiers can apply for Contracts for Difference (CfD). This is the UK's new scheme for subsidising electricity classed as renewable. Between 2014 and March 2017, developers can choose to apply for ROCs or for a CfD; after that, they must apply for a CfD for eligible new developments. CfDs are more generous than ROCs but are allocated through competition (whereas entitlement to ROCs is automatic). New conventional biomass power plants can only receive a CfD if they are classed as 'combined heat and power' which means that they must make use of some heat and generally achieve at least 35% efficiency. Yet a biomass or waste gasification and pyrolysis plants can attract CfDs, even if they make no use of heat and even if

24 Note that all of 'indirect funding' mechanisms referred to by DECC (except for Emissions Trading) are classed as subsidies by the OECD and World Trade Organisation and are classed as 'State Aid' by the EU.

their efficiency is as low as 20% or possibly even lower;

- "Barrier removal": Deregulation and the removal of 'red tape' has been at the heart of the Government's policy in relation to planning since at least 2012. As part of the recent Coalition Government's 'Red Tape' challenge, 129 out of 182 planning regulations were identified as ones that would be scrapped or 'improved'[xcii]. English planning guidance and policy documents were slashed with the introduction of the National Planning Policy Framework 2012. Similarly, reducing the supposed 'burden' of Environment Agency guidance and reporting requirement has been a focus of the 'Red Tape' challenge[xciii]. Furthermore, the Environment Agency's budget has been cut by 25% in real terms since 2009/10[xciv].

  Here are a few examples of how planning and permitting policies work for developers of gasifiers and pyrolysis plants[25]:

  - Planning authorities must determine applications on the assumption that all environmental permitting conditions will be fully enforced and complied with – regardless of any evidence that a particular technology cannot be reasonably expected to work smoothly from the outset;

  - Planning authorities are not allowed to take any account of the credibility of a proposal and of the background of the developer proposing it;

  - Although planning authorities must assume full enforcement of permitting conditions, the Environment Agency's own guidance makes it clear that enforcement action is the last, not the first resort taken in response to permit breaches. That guidance states: "*If an operator or individual is not complying, we normally provide advice and guidance to help them do so. Where appropriate, we agree solutions and timescales for making any improvements*"[xcv].

And finally, we have looked at some questionable practices by companies and directors such as David Pike, founder of at least 30 gasification-related companies without any successful project so far. Biofuelwatch has no information to suggest that any of those practices are unlawful. However, even if any companies were acting unlawfully, the chances of them being investigated and prosecuted are small and diminishing. The Serious Fraud Office's budget has been severely cut. In 2013/14, only 12 out of 2,508 reports of suspected fraud or corruption resulted in new investigations[xcvi].

This report can thus be read as a case study about the effectiveness of the Government's approach to supporting 'energy innovation'. It shows how, in relation to biomass gasification and pyrolysis, this policy approach has led to entirely negative outcomes:

Rather than leading to 'innovation', deregulation coupled with generous subsidy promises has led to a spate of development proposals none of which have so far been successful. It has led to a proliferation of small companies without any experience of successfully operating the technology they seek to use. It has led developers to back the simplest, dirtiest and least efficient gasifier power plant designs, ones which contribute nothing to the development of gasification technology worldwide. Ultimately, it led to investors, some of them investors through the Government's own subsidised Enterprise Investment Scheme, having lost tens of millions of pounds on failed projects.

25 Note that those examples do not necessarily arise from policy changes introduced since 2010. Many would argue that the planning system has been heavily weighted in favour of developers for a far longer period and that this remains the case in Wales and Scotland, too, where planning is devolved (partially devolved in Wales, fully devolved in Scotland). For example, it is common practice for both communities and developers to have the right to appeal against planning decisions in many countries – but throughout the UK, only developers enjoy such a right.

At the same time, communities are being exposed to planning blight and to well-founded fears about dirty and dangerous plant proposals. And so far, biomass gasifiers have generated virtually no electricity – and far less energy than would have gone into building unsuccessful plants.

So far, the failed biomass gasifiers in the UK have all simply been failed projects – none of them has exploded or caught fire and none appears to have operated long enough to cause significant air quality impacts. But this does not make residents' concerns unfounded: As we have seen in the report, fires, explosions and high levels of air and sometimes water pollution have been associated with biomass gasification and pyrolysis plants elsewhere, and the failed waste gasifier in Dargavel in Scotland was linked to hundreds of air emission permit breaches, an explosion and a fire. With so many more gasifiers and pyrolysis plants in the pipeline, the consequences of the UK government's misguided policies could become worse still.

i http://www.greeninvestmentbank.com/news-and-insight/2013/gib-and-foresight-group-forge-consortium-to-construct-478m-renewable-energy-plant-in-birmingham/
ii Unless otherwise stated, please see.....for details of all ‘advanced conversion’ biomass plants that have been proposed in the UK. All references in this report relate to plants with a minimum size of 1 MWe.
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vi Document provided by Aggregate Micropower Holdings for Admission to AIM – London Stock Exchange, July 2014
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