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29th September 2010

The Right Hon. Chris Huhne MP
Secretary of State for Energy and Climate Change,
House of Commons,
London,
SW1A 0AA.

Dear Mr Huhne,

RESPONSE TO DECC CONSULTATION: ENERGY PATHWAYS TO 2050

Renewable multi-fuel Synthetic Natural Gas (SNG) and biogas versus coal combustion with CCS

EXECUTIVE SUMMARY

The DECC consultation indicates that nuclear power, coal combustion with carbon capture and sequestration (CCS) and intermittent renewables will form the basis of a greatly enlarged UK electricity supply sector in 2050. No rational policy for the decarbonising of the UK's energy supplies in 2050 can omit the decarbonising of the existing large UK gas storage, grid, distribution and gas fired electricity generating infrastructure. This report argues that instead of the large scale development of coal combustion with CCS, the UK should invest in the retention and decarbonising of the UK's existing gas grid using a combination of: low carbon renewable SNG produced from indigenous biomass, waste and coal; zero carbon biogas, and Natural Gas, in order to generate indigenous renewable fuelled 'dispatchable' low carbon load following electricity. This will support zero carbon base load nuclear power, and zero carbon intermittent renewables, thereby achieving maximum carbon reduction, and optimum energy system 'resilience', at least cost and disruption to the Nation. Should further decarbonising of the gas grid be required, a much smaller CCS infrastructure than that necessary to support coal combustion can be developed on a phased basis as empty gas fields become available.

	MULTI-FUEL CO-GASIFICATION TO RENEWABLE SNG PLUS BIOGAS	COAL SPFC WITH CCS
• Existing proven technology at industrial scale	Yes	No
• Requires imported primary energy resource	No	Yes
• Requires conversion of UK electricity grid from demand led to supply led	No	Yes
• Renewable or sustainable energy supply	Yes	No
• Provides storage for primary energy resource	Yes	No
• Supports intermittent renewables	Yes	No
• Supports increasing use of biomass	Yes	No
• Carbon capture ready	Yes	No
• Retains existing UK electricity and gas grids	Yes	No
• Requires re-construction of UK electricity grid	No	Yes
• Requires construction of new UK CCS grid	No	Yes
• Affordable electricity supply to consumers	Yes	No
• Profitable commercial investment	Yes	No
• High primary energy efficiency	Yes	No
• Waste heat recovery to electricity and CHP	Yes	No
• Provides double ROC's biomass and waste	Yes	No

This report argues that:

1 Renewable gas produced either by the gasification of renewable fuels to produce SNG, or biogas produced by anaerobic digestion of 'green' biomass and wastes are not awarded with equivalent ROC's in the UK as renewable electricity. This practice is not compliant with general EC practise.

2 HMG currently has no policy for the UK gas grid in 2050. The gas grid currently provides the primary energy store to ensure the stability of the electricity grid and serves 85% of UK consumers.

3 HMG policy currently envisages a large transfer of energy supplies from the gas grid to a greatly enlarged electricity grid, and the creation of a new CCS grid. The decarbonising of the existing gas grid would reduce the need for the investment in the reconstruction of the UK grids.

4 The 'dispatchability' of nuclear, coal and intermittent renewables to the electricity grid, and their ability to support system 'resiliance' and stability vary enormously. The relationship between the 'connected' and 'dispatchable' loads also vary. DECC's consultation does recognise this fact.

5 The UK produces annually far more zero carbon renewable biomass and low carbon sustainable residual hazardous and non-hazardous wastes than it does high carbon unsustainable coal. Multi-fuel gasification of UK indigenous solid fuels to produce renewable SNG, plus biogas produced by Anaerobic Digestion, will produce a greater quantity of more 'dispatchable' clean low carbon energy more economically than the combustion of UK mined coal.

6 HMG's support for base load coal combustion technologies for export does not meet the UK energy market need for load following renewable solid fuel technologies.

7 Large scale zero emissions high efficiency slagging co-gasification of 80% biomass, hazardous and non-hazardous residual wastes, and 20% coal to produce SNG and electricity is an existing proven British technology developed in the UK and Germany during the period 1956 to 2007, and currently being developed by British and German companies in India and China.

KEY FACTS

1 The central scenarios in the above DECC consultation envisage the supply of an average of 100GW of largely decarbonised electricity in 2050. This total is reasonably consistent with the central scenarios in The Royal Academy of Engineering's recently published study "Generating the Future".

2 Recently published studies by Poyry Energy Consulting Ltd on the effect of planned intermittent wind electricity generation on the demand for intermittent gas supplies in 2030 indicate an average requirement for the supply of 50m cub.m. of Natural Gas (NG) per day in 2030.

3 DECC's central scenarios envisage UK 2050 electricity demand being supplied by:

- Base load zero carbon nuclear power.
- Base load zero carbon coal supercritical pulverised fuel combustion (SPFC) with carbon capture and sequestration (CCS).
- Intermittent zero carbon renewables and biomass.

4 The above energy mix is neither economically or technically feasible. The above scenario requires:

- The conversion of the UK electricity grid from demand led to supply led operation.
- The replacement of the UK gas grid as the primary energy store for load balancing electricity generation by other as yet undetermined means of energy storage.
- The abandonment of the UK gas grid, gas import and storage facilities and associated gas fired generating capacity for electricity generating purposes.
- The construction of a nationwide CCS grid and storage facilities in order to capture carbon produced by coal combustion for electricity generation and fossil fuel derived NG by UK industry and consumers.

5 The attached report proposes electricity supply in 2050 being generated in roughly equal parts by:

- Base load zero carbon nuclear power.
- Base load zero carbon coal SPFC with CCS with a local CCS grid located in North East England, combining CCS with 'end of well' gas and oil recovery.
- Load following low carbon electricity generation fuelled by a mixture of: low carbon Synthetic Natural Gas (SNG) produced by variable throughput high efficiency zero emissions slagging co-gasification and catalytic methanation of 80% biomass and residual hazardous and non-hazardous wastes and 20% low

quality coal; zero carbon biogas, and high carbon NG, injected into the existing UK gas grid, and fired in the UK's existing fleet of Combined Cycle Gas Turbines with additional 2 stage Organic Rankine Cycle turbine waste heat recovery to generate base load electricity and heat.

- Intermittent zero carbon renewables: wind, tide and solar.

6 The above energy mix is economically and technically feasible, uses <u>all</u> existing and well proven technologies, and does not require the replacement of a large proportion of the existing UK electricity and gas grids and associated infrastructures:

- Demand management introduced in order to reduce demand fluctuations, but the electricity grid remains primarily demand led.
- The UK gas grid remains the primary energy store for load balancing electricity generation.
- No requirement to develop a major new national CCS grid and storage infrastructure.
- Residual hazardous and non-hazardous wastes are used as a high value primary energy resource for zero emissions 'dispatchable' load following electricity generation.
- Supports biomass supply chain development by the progressive replacement of waste by biomass as a primary energy resource.

HISTORICAL BACKGROUND

Large scale high energy efficiency zero emissions slagging co-gasification of 80% biomass and liquid and solid residual hazardous and non-hazardous wastes and 20% coal to produce SNG is a fully proven technology, which was developed in the UK during the period 1956 to 1992. Subsequently the technology was developed by associated British and German companies in East Germany, India and China during the period 1990 to the present. Large scale financial support for the necessary R. and D. effort was provided by the UK, US and German governments and the EC. This technology is recognised by the EC, United Nations Environment Programme and the International Energy Agency.

Unfortunately, the existence of this very successful British technology has not been recognised by H.M.Government since 2003. The current ongoing development by British companies, and their associates, of solid lignite (very low grade coal) slagging gasification technology in India and China is not supported by HMG, despite it being avowed HMG policy to support the export of British 'clean coal' technology to India and China. Some of the somewhat unusual historical reasons for this apparently irrational state of affairs are explored in the accompanying report.

Coal gasification for electricity generating purposes has not generally been able to compete with Natural Gas except in situations where R. and D. subsidies have been offered, or political or economic considerations outweigh normal international energy and commodity market considerations. The same applies to coal gasification with CCS.

The economics of multi-fuel gasification using coal as a minority fuel are, however, very different from the economics of gasification using coal as the principle fuel. Multi-fuel gasification is based on:

- Sustainably resourced biomass is a zero carbon renewable energy resource.
- Residual hazardous and non-hazardous waste is a negative cost low carbon sustainable energy resource.
- Coal is a reliable internationally traded energy commodity with the least price per unit energy content of any fossil fuel.

The combination of the above benefits, plus the financial benefits accruing from the sale of double ROC's for the sustainable biomass fuel and biomass element of waste processed by Advanced Thermal Technologies, was recognised by DTI in its reports on multi-fuel gasification published in 2002/3, but very unfortunately the information published by DTI at that time was misleading. Based on DTI's own figures, the Levelised Cost of Electricity (LOE) for a 400MW 75% waste and 25% coal fuelled IGCC (Integrated Gasification Combined Cycle) power station was 1.0p/kWhr. DTI did not publish this information, and instead published the LOE for a 20MW 33% biomass fuelled gasification plant of 10p/kWhr; the LOE for a 400MW coal fired IGCC of 3.4p/kWhr, and the LOE for a 400MW NG CCGT of 2.5p/kWhr. The wholesale cost of electricity in the UK in 2002 was around 2.0p/kWhr. The implication of the published information was that multi-fuel gasification could not compete economically with fossil fuel combustion, whereas in fact the opposite was true. The above engineering and costing information was provided to DTI by UK Coal plc, Mitsui Babcock Technology Ltd. and Innogy plc. These businesses were not disinterested parties.

At the time when H.M.G. recognition of slagging co-gasification of biomass, waste and coal was withdrawn in 2002/3, UK energy and waste policies and economics were somewhat different from now. The accompanying report argues that the information published by DTI in 2002/3 was incorrect, and that correct information, based on both DTI's 2002/3 reports, and the report on future electricity generation costs published by Mott MacDonald and DECC earlier this year, indicate that the zero emissions slagging co-gasification of biomass, waste and coal to produce low carbon content load following 'dispatchable' electricity is a commercially viable and profitable investment, which is carbon capture ready, and wholly compliant with a wide range of over-arching economic, energy, waste and Sustainable Development policy objectives. Please see attachments.

An outline design, cost benefit analysis and Return on Capital Employed (ROCE) analysis carried out by the author for a proposed 275MW load following multi-fuel IGCC at the combined sites of Sutton Courtenay landfill and Didcot Power Station reached similarly financially attractive conclusions. Please see attachments.

This report is particularly concerned with the macro-economic and political objective of achieving the maximum reasonable decarbonisation of UK energy supplies, at least overall Capital and Operational cost to the UK energy industry, which is compatible with delivering energy supplies to UK consumers and business which are: sustainable, secure and affordable, all in accordance with H.M.G. policy objectives for 2050.

This report notes The Royal Academy of Engineering's report "Generating the Future" published earlier this year which stated that current plans to enlarge and convert the UK electricity grid in 2050 from demand led to intermittent supply led operation, plus the development of new nuclear, intermittent renewables, coal and CCS infrastructures, will require a "wartime" scale of transfer of the Nation's wealth to the energy sector. In contrast, in 2003 DTI reported that the decarbonisation of the UK's energy supplies could largely be achieved at zero net cost to the Nation due to a combination of: technology cost reduction; economies of scale, and costs being absorbed by growth in GDP. Both these positions are somewhat extreme. Nonetheless, more weight should in my opinion on balance be given to the RAE's views than to DTI's views.

There is a risk that the macro-economic effects of the planned combination of: the withdrawal of liquidity from the economy to reduce the National Debt to a sustainable proportion of the UK tax base; the reduction in employment and the velocity of money due to the down-sizing of the Public sector to a sustainable proportion of UK GDP; the increasing cost to consumers of UK energy supplies, and the transfer of liquidity from UK consumers and businesses to the energy sector, could lead to a loss of international economic competitiveness, and the re-emergence of 'stagflation'. Were 'stagflation' to re-occur, it could be both politically and economically extremely difficult for the current coalition government to manage.

I am an independent consultant, and have no commercial, or other financial interest, in any of the businesses named in the attached documents. Please let me know if you require any additional information.

Yours faithfully,

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Attachments:

1 History of the development of the British Gas Lurgi slagging gasifier.
2 Extract from 2002 DTI/UK Coal plc report on multi-fuel co-gasification.
3 Extract from 2003 DTI "cleaner coal technology programme" newsletter.
4 Proposal for a 275MW multi-fuel waste to energy IGCC at Sutton Courtenay landfill and Didcot Power Station.
5 Photo of recently relocated 3.6m diameter BGL from SVZ to India.
6 Photo of recently delivered 4.0m diameter BGL in China.
7 Extract from Poyry Energy Consulting Ltd. report on Intermittent Gas in 2030.

THE DEVELOPMENT OF CLEAN MULTI-FUEL RENEWABLE GAS AND LOAD FOLLOWING ELECTRICITY USING THE BRITISH GAS LURGI SLAGGING GASIFIER

Facts

The British Gas Lurgi (BGL) slagging gasifier, developed in the UK from 1956 onwards, is the World's only fully proven industrial scale high efficiency solid and liquid multi-fuel slagging gasifier. The BGL is available in a range of standard sizes capable of gasifying between 100,000 and 300,000 tonnes pa of 80% low calorific value liquid and solid biomass; hazardous and non-hazardous wastes, and 20% coal or lignite to produce high grade Synthesis Gas (Syngas) suitable for: either electricity generation direct, or catalytic methanation to produce renewable UK grid quality low carbon content Synthetic Natural Gas (SNG). The heavy metals and minerals in the fuel stream are captured in the form of an inert vitrified recyclable aggregate. The UK produces around 10 times more biomass and waste than coal. Waste is a negative cost sustainable low carbon fuel and sustainably resourced biomass is zero carbon renewable fuel. Multi-fuel co-gasification of UK indigenous solid fuels will support the operation of the existing UK gas and electricity grids, and produce more energy, more cleanly and at lower cost than the combustion of UK coal with carbon capture and sequestration. Since 2003, H.M.Government has not recognised the existence of this successful technology.

Executive Summary

1. Industrial scale high temperature and efficiency zero emissions slagging co-gasification of waste, biomass and coal to produce low carbon content renewable Synthetic Natural Gas (SNG) is a fully proven and available British technology, developed during the period 1956 to 2007, and currently being developed in India and China by British and German companies. Between 2003 and 2005 H.M.Government withdrew acknowledgement of the existence of this technology in favour of coal combustion technology.
2. H.M.Government has no policy to use the UK gas grid to supply energy for electricity generation in 2050.
3. The UK gas grid provides the primary energy store to support load following electricity generation to ensure the stability and resilience of the UK electricity grid.
4. Gas import, interconnection and storage facilities to support the UK gas grid are being enlarged. Nearly 30GW of Natural Gas (NG) fired generators (CCGT's) are currently 'queuing' in the UK Planning system.
5. Supercritical pulverised fuel combustion of coal with carbon capture and sequestration is primarily a base load electricity generating technology, which will not be able to support the large scale deployment of intermittent renewable energy resources.
6. UK indigenous production of renewable biomass and sustainable hazardous and non-hazardous wastes is an order of magnitude greater than UK production of coal.
7. The co-gasification of 75 to 80% zero carbon content sustainably resourced biomass and low carbon content wastes, and 20 to 25% coal, will support the economic de-carbonising of the existing UK electricity and gas grids and associated infrastructures, and support the development of intermittent renewables, without requiring the development of a new carbon capture and sequestration infrastructure, thereby greatly reducing the cost of delivering H.M.Government energy policy for 2050.
8. The slagging co-gasification of approximately 100m tonnes pa of biomass, wastes and coal to produce SNG will deliver an average of approximately 66% of projected 2030 UK intermittent Natural Gas consumption of 50m cub.m. per day of Natural Gas by the electricity industry in order to support intermittent renewables. The same quantity of biomass, wastes and coal will deliver an average of 25 to 30GW (or 50GW of peak load) of low carbon content electricity in order to support the projected 2050 UK requirement of an average of around 100GW of near zero carbon content electricity generation.
9. Medium sized zero emissions EfW plants co-gasifying around 450,000 to 850,000 tonnes pa of biomass, waste and coal will produce an average of 135 to 275MW of profitable dispatchable load following electricity at a net efficiency of approximately 51.5%, electricity only, or 55% with CHP.
10. By 2030 to 2050, the UK will produce around 200m tonnes pa of energy bearing biomass, waste and coal.

International developments of gasification

The extraction of gas from coal was discovered in Italy during the 16^{th} C. Commercial scale extraction of gas from coal for street lighting was developed in Britain at the end of the 18^{th} C. Modern high pressure gasification was developed during the period before and after WW1. During WW2, Germany relied on coal gasification to produce ersatz rubber and fuel. By the end of WW2, all the major Western economies relied on large scale industrial coal gasification, which formed the basis of numerous gas, coke, fuel, tar and chemical industries.

Following WW2, large scale R. and D. programmes were mounted in the USA, Russia, Germany and the UK to develop new coal gasification technologies, often based on German wartime developments. The USA Bureau of Mines ran a large R. and D. programme during the late 1940's and early 1950's to determine the ideal physical and chemical conditions for the catalytic conversion of Syngas (produce by gasifiers) to Synthetic Natural Gas (SNG), effectively chemically pure Methane. Some of these programmes were on a very large scale, but were gradually largely abandoned as a consequence of economic competition from cheap fossil fuels following the discovery of oil in the Middle East, and Natural Gas in several other locations. Due to a combination of economic sanctions and abundant coal reserves, the World's largest continuing coal gasification to liquid fuels development programme occurred at Sasol in South Africa. The World's second largest gasification development at SVZ Schwarze Pumpe produced 75% of East Germany's town gas from low grade lignite.

Despite the reduction in the continuing development of ultra large scale gasification projects, due to economic competition from fossil fuel oil and NG, numerous large scale gasification developments continued due to a combination of specific political or economic needs. Numerous petcoke (the solid residue from petroleum refineries) gasification projects were developed, most notably in Italy. Coal gasification to produce power and CO_2 for enhanced end of well oil extraction was developed on a large scale in the USA. Coal gasification to produce SNG, liquid fuels and fertilisers continued to be developed in China and India for strategic reasons. The general development of 'clean coal' technologies continued in the USA, UK, Germany, India and China.

British 'clean coal' developments during the period 1956 to 1992

The British R. and D. programme was carried out in collaboration with US and UK coal and power interests, and funded by both the UK and USA governments, at a cost of around £350m over a period of over 3 decades between 1956 and 1992. The primary objective was to produce clean high energy efficiency 'load following' electricity from coal. As a side issue at the time, it was also recognised that the same technology had the capability of supporting carbon capture. This was a major industrial research programme involving a consortium of British Gas, Central Electricity Board, National Coal Board, Rolls Royce, ICI and Lurgi GmbH. There were several major areas of development:

- The British Gas Lurgi slagging gasifier (BGL) consisting essentially of a Lurgi dry ash gasifier with a slagging hearth base.
- The HICOM or HCM (High Carbon Monoxide) catalytic methanation of Syngas to produce high purity SNG.
- Suitable methanation catalysts were developed by ICI at Billingham under the Katalco trade name.
- Controllable flexible rate of stable gasification in order to support load following electricity generation.
- The ability to gasify a wide range of different quality coals and briquetted coal fines.
- Recirculation of heavy hydrocarbons, tars and dusts for gasification to extinction.
- SNG fired aeroderivative gas turbines.

By 1985, the development programme had delivered all its essential goals, and design work was well advanced for a 500MW Integrated Gasification Combined Cycle (IGCC) 'clean coal' power station. This work was extensively reported in the UK and USA. Thereafter, the story becomes more than a little complicated.

During the 1970's, oil and Natural Gas was discovered under the UK Continental Shelf. British Gas' policy was to use Natural Gas as a premium fuel for domestic heating, and to continue to use coal and nuclear power as the basis of electricity generation. During the 1980's the Conservative government sought to de-nationalise the UK nationalised industries in order to foster economic efficiency. HM Government also sought to reduce dependence on UK coal due to difficulties in the coal industry. In 1991, the EC decided to release North Sea gas for bulk electricity generation.

The effect of the above developments was to cause: the first 'dash for gas'; the collapse of the UK deep coal, and nuclear power industries, and the cancellation of the UK coal gasification R. and D. programme. Experiments using large 2.3m diameter BGL gasifier at Westfield, prior to its shutdown in 1992, demonstrated that the BGL's tolerance to widely varying quality coals included the ability to co-gasify biomass and coal.

Development of the BGL in East Germany during the period 1990 to 2007

SVZ Schwarze Pumpe, in the heart of the East German lignite belt had been developed during mid 1950's by the Communist government as a major lignite gasification plant producing 75% of East Germany's town gas. Following the introduction of Natural Gas and German reunification, this extremely large industrial complex, the second largest gasification plant in the World after Sasol, with associated employment of 20,000, and supporting business infrastructure, had by 1996 become redundant. SVZ was transferred in 1996 from the Treuhand (the State privatisation agency) to the Berlin Water Authority. The conversion of number of the existing lignite to town gas gasifiers to co-gasify waste, biomass, coal and lignite in order to produce primarily synthetic methanol as an industrial base stock (largely for the production of formaldehyde for adhesives for the East German furniture manufacturing industry), plus an IGCC, was put in hand.

Very little information is available on the economic basis of this conversion, but clearly while it was not intended to be a pure economic loss maker, the need to maintain employment, and political stability, in East Germany was of considerable importance. Large State financial subsidies were provided (approx 0.5bn Euro's). There is evidence that higher waste 'gate fees' than were available at that time, and high methanol prices, were required in order to achieve 'break even' conditions for the very large plant, and that the existing plant when converted to gasify wastes, while having low, largely sunk, capital costs, had high operating costs. On the other hand, the ability of the plant to treat hazardous wastes meant that high 'gate fee' wastes could be attracted.

In 1990, early discussions commenced between SVZ and Lurgi GmbH to develop a 3.6m diameter industrial size scale up of the Westfield BGL capable of handling up to 240,000 tonnes pa of wastes, or 300,000 tonnes pa of coal. These negotiations were reinstated in 19944, and full agreement was reached in 1996. Funding was obtained from the EU and German government to the tune of around 0.6bn Euros. Full scale design work was put in hand in 1996. Dresden State Environmental Consent was granted in 1998 to co-gasify several hundred classified liquid and solid hazardous and non-hazardous wastes. Construction was completed during 1999, and commissioning was successfully completed in 2000. In 1999, the SVZ site was sold by the Berlin Water Board to a consortium of RWE, Allianz and Vivendi, and subsequently sold in 2000 to Global Energy Inc (the owner of the Westfield site) and its subsidiary Envirotherm GmbH. These transactions involved the liquidating of SVZ Schwarze Pumpe's debts and subsidies, and the transfer of SVZ for the sum of 1 Euro.

During the period 2000 to 2005 ongoing development work on the BGL at SVZ continued with funding from the EU Thermie programme. The engineering development work consisted primarily of production engineering developments to improve fuel feed, slag drainage, cooling system and tuyere (the steam and Oxygen injection tubes) linings. It should be noted that refractory lining reliability issues, which have commonly affected pulverised coal slagging gasifiers, have not occurred in the BGL due to the much lower gasifier wall temperature.

Development work also continued on varying the types of waste feedstock, and increasing the proportion of waste to coal which could be successfully co-gasified while maintaining stable gasification. Consent was granted to reduce the proportion of coal to 15%. A higher proportion of waste to coal would greatly improve the economics. The ability to gasify 'difficult' wastes would both improve the economics, and provide a useful service to the wider economy. Of particular interest was the gasification of plastic residues, including plastic shredded waste and vehicle plastics. Many of these plastics have high Chlorine and Bromine content. This work was funded by the EC and the European Plastics industry via Tecpol. This work successfully demonstrated the ability of the BGL to co-gasify up to 80% mixed wastes, plastics and biomass and 20% coal.

By the end of 2004 this development work had largely been successfully completed. Global Energy declared the SVZ site to be bankrupt. Global Energy had by then acquired, via its parent company Allied Resource Corp's 70% interest in Envirotherm GmbH of Essen, Lurgi GmbH's interest in the BGL intellectual property (IP) at SVZ, in addition to the BGL IP it had acquired via its acquisition of the Westfield site. Global Energy Inc. is a subsidiary of Allied Resource Corp. Allied Resource Corp, and is directed by the ex CEO and Finance Director of Metallgesellschaft GmbH. Metallgesellschaft had previously owned the gasification IP's of Lurgi and Lentjes AG (the two major gasification developers in Germany and Holland), but these IP's had been divested following Metallgesellschaft's notorious financial debacle due to trading in oil futures. There is strong evidence (confirmed by information published by Envirotherm on its website) that there had been a planned programme of a four-phase re-assembly of the Lurgi and Lentjes gasification IP's, which had been previously owned by Metallgesellschaft and then divested, and is now owned by Allied Resource Corp. and its various subsidiaries.

In 2005 Sustec AG purchased SVZ from the German State Receiver. Sustec announced an expansion programme, including additional BGL's, despite its being a relatively small company, which had acquired a very large bankrupt previously state owned industrial complex. During 2005 and 2006 the EC, under the then German presidency, promoted the granting by UNEP of R3 Recovery status for the irreversible destruction of Persistant Organic Pollutants, using the SVZ process owned by Sustec. This was achieved at the UNEP conference in Nairobi in December 2006. Shortly afterwards Sustec declared the SVZ site bankrupt, and ceased the production of methanol. The IP in another pulverised fuel gasification process, which had been developed at SVZ, was sold to Babcock Wilson Borsig, and then to Siemens; the ex-SVZ BGL gasifier was sold to India to be re-installed by Envirotherm, plus a second identical BGL to be designed by Envirotherm, and the SVZ site was sold to Vatenfall, which is currently using it for the development of CCS. The French government sought to have the UNEP recognition of the SVZ process annulled, and Friends of the Earth refused to recognise the UNEP decision. Sustec moved on to invest in wind power.

Following German re-unification, and the inter-connection of the East German and European electricity and gas grids, there was a large unplanned contraction in the East German economy. This led to a glut in East Germany of low cost base load nuclear and lignite combustion generated electricity being sold onto the European grid. The conversion of the SVZ site in the 1990's to co-gasify waste and coal in order to produce primarily methanol, with a relatively small proportion of electricity via an IGCC, was, therefore, probably a reasonably sound economic decision, albeit it is impossible to tell whether it would have been truly economically competitive. Further unplanned contractions in the East German economy occurred in 2000 and 2004, with large waves of bankruptcies. In the mid-2000's the World price of methanol halved due to the bringing on stream Worldwide of a number of very large Natural Gas based methanol synthesis plants serving the international methanol market. The East German chemical industry was unable to compete with the more modern West German chemical industry.

One of the 2000 bankruptcies was Mannesmann Sieffert GmbH of Berlin, which had supplied the waste and plastics pelletising equipment for SVZ. Mannesmann had been purchased by British Telecomms, and then by Vodaphone. Part of the Mannesmann business specialising in gas pipe manufacture was sold on again. What happened to the pelletising plant manufacturing capability is unclear. Siemens is currently operating a waste pelletising plant in Berlin. Engineering information on the operation of the SVZ pelletising plant can be found on the Internet.

It is difficult to determine exactly what happened politically and economically at SVZ, but there is strong circumstantial evidence that the plant was not developed for the primary purpose of being able to compete in the liberalised international energy and commodity markets, and that the plant never financially solvent. There is also strong circumstantial evidence that from 1999 onwards the plant was acquired by businesses which functioned at least in part as asset strippers. On the other hand, the plant was undoubtedly technically successful, and the SVZ technology is now being re-used in India and China. The price of residual waste disposal in the UK has now risen to the level which was stated in 2000 was required to achieve profitable operations at SVZ. In 2005, the CEO of the SVZ plant stated that he wished to convert the whole gasification plant to operate on modern BGL's.

Development of the BGL in Britain and by British companies in India and China during the period 1992 to 2010

Since the break-up of the UK nationalised energy industries, BGL development has continued via two routes:

- Development of the ex-Lurgi GmbH IP. Several proposals have emerged to re-open the Westfield gasification plant owned by Global Energy Inc, based on either the co-gasification of biomass and coal, or the co-gasification of 66% sewage sludge: 33% coal. To date these proposals have not borne fruit. The current re-construction of the ex-SVZ BGL, plus an additional identical new 3.6m diameter BGL, at Haldia in West Bengal to gasify coal to produce synthetic Ammonia, is due for completion in 2011. This joint project by Envirotherm GmbH, which is co-owned by Global Energy's parent company, Allied Resource Corp, and Shriram EPC Ltd. on behalf of Haldia Chemicals Ltd. has ensured the continuation of the BGL engineering expertise within that group of companies. An extremely large BGL based gasification scheme is also progressing at South Heart in Dakota, albeit currently delayed by litigation over land matters.

- Development of the ex-British Gas IP by its successor companies Advantica PLC and GL Noble Denton Ltd. An attempt to develop a BGL based waste gasification plant in Yorkshire around 2002 failed due to concerns over the reliability of waste supplies. Since 2002, GL Noble Denton has largely concentrated its efforts on developing the BGL in China for low grade lignite to SNG, liquid fuels and fertiliser plants. These efforts have been successful, leading to the development of a range of standard size BGL's: 2.3m diameter (as at Westfield), 3.6m diameter (as at SVZ) and 4.0m diameter (the largest size that can be readily transported); operating at up to 75 atmospheres pressure, and capable of handling between 100,000 and 300,000 tonnes pa each of mixed biomass, waste and coal. The throughput of the different size BGL's is proportional to their cross-sectional areas. Fabrication of the BGL in Taiwan has been established.

A technology sharing agreement is in force between GL Noble Denton and Envirotherm. GL Noble Denton has access to the design, operational and engineering data at Westfield and SVZ; employs personnel with experience of operating and designing both those plants, and is able to offer a full range of design and engineering services. The HICOM methanation IP is owned by GL Noble Denton and is licensed to Davy Process Technology Ltd, which is a subsidiary of Johnson Matthey plc, which in turn now owns the ex-ICI catalyst plant at Billingham and continues to develop the Katalco range of catalysts.

There has recently been a change in these arrangements. Part of GL Noble Denton's interest in the BGL IP has been acquired by a Chinese investor. That IP has been vested in ZEMAG Clean Coal Technology GmbH of Leipzig, which was the company which supplied lignite briquetting machinery for the East German lignite industry, SVZ and the recent developments of the BGL in China. Other companies in the same group are Shanghai Zemag Mindac Machinery Equipment Co. Ltd. and Zemag Hongkong Ltd. Associated companies are: IFE Aufbereitungstechnic GmbH, Austria; Franz Ludgwig GmbH, Mainz, and Lodige Industries Group, Warburg. This group of businesses can supply a wide range of materials handling, preparation and monitoring equipment. A separate company Zemag India Pvt Ltd. also exists. The various Indian companies involved in gasification are based around Calcutta. There is also a group of gasification and boiler business interests based in Taiwan.

It can be seen from the above, that the essential elements of British multi-fuel to SNG capability, which had been dispersed following the break-up of the British nationalised industries, have largely been re-assembled, following the successful development of the BGL at SVZ, and by GL Denton Noble in China. The development of the BGL in China and India has unfortunately received no support from H.M.Government, despite HMG's long-running policy to assist British companies to sell advanced 'clean coal' technology to China and India.

H.M.Government policy on the development of 'clean fossil fuels' technology

There two fundamental technology routes to high energy efficiency 'clean fossil fuels':

- Supercritical pulverised fuel combustion (SPFC) with carbon capture and sequestration (CCS).
- Slagging gasification either with, or without, CCS

Within each of the above fundamental technologies there exist further sub-divisions:

SPFC with CCS:

- 'Oxybustion' (Oxygen fed combustion) SPFC with post-combustion CCS.
- Air fed SPFC with post-combustion CCS.

Slagging gasification:

- Pulverised coal/lignite slagging gasification with pre-combustion CCS to provide zero carbon content electricity.
- Lump coal/briquetted lignite slagging gasification with pre-combustion CCS to provide zero carbon content electricity.
- Low carbon multi-fuel slagging gasification to provide low carbon content SNG and electricity.
- Low carbon multi-fuel slagging gasification with pre-combustion CCS to provide negative carbon content electricity.

Of the above primary technology routes, all were supported by HMG, via various DTI programmes, until around 2002/3. Since then HMG has supported Oxybustion, SPFC and pulverised coal gasification. These three technologies all have a number of things in common – they are all:

- Coal based technologies, which will require large scale coal imports.
- Unable to support the large scale deployment of biomass and waste as primary energy resources.
- Base load power generators which cannot support the development of large scale intermittent wind.
- Unable to support the operation of the UK gas grid. The UK gas grid provides the primary energy store for intermittent gas fired generation to support intermittent wind.
- Require large scale investment in the UK electricity infrastructure in order to replace displaced gas consumption.
- Require large scale investment in a new UK wide CCS grid and storage facilities. The only suitable grid for CCS purposes currently in existence is the UK gas grid.

In order to justify the above illogical proposition, whereby coal SPFC with CCS will effectively be unable to support the decarbonising of the gas grid, which is the only current means of supporting intermittent wind power, it is necessary to demonstrate that Oxybustion SPFC with CCS can be developed into a load following electricity generating technology. This is a very dubious proposition due to the high mass and thermal inertia of the process, and there being no means of storing energy on a large scale between the combustion and generation stages of the process. Gasification on the other hand has been proven to have a flexible throughput, and produces a storable primary energy resource between the gasification and generation stages. Modern 'fast start' geared CCGT's can synchronise onto the grid within 5 minutes of start up, and generate a significant proportion of their rated load within 10 minutes of start up. No coal combustion based technology can match this flexible response to intermittent wind and tide power, and demand fluctuations. (I exclude the current use of 'hot spinning' reserves, which are energy inefficient, environmentally unsound and uneconomic.)

The Energy Technologies Institute is currently calling for proposals for a 800MW IGCC with CCS to be located on the coast of North East England. The call for proposals: names the Shell gasifier, which is a pulverised coal gasifier, which cannot support multi-fuel use; does not include Syngas storage; does not include multiple geared turbines and secondary Syngas duct burn in order to support fast start varying load electricity generation, and requires the gasifier to be sized to the "full appetite" of the gas turbine. In short, it will be a base load generator running on imported coal. The proposed North East coal IGCC with CCS, and the planned offshore wind farm developments in the North Sea, will thus compete with, and not complement, each other.

The UK has recently completed large investments to increase UK gas import capacity, and the electricity industry is currently planning a large expansion in CCGT capacity. Only the gas grid can support the development of large scale intermittent renewable, and electricity grid 'resilience'. The DECC consultation on energy pathways to 2050 proposes the large scale development of intermittent renewable, but proposes no use for the UK gas grid and associated infrastructure in 2050. For the reasons behind this apparently contradictory position, it is necessary to look back to recent UK energy politics and history.

Following the break-up of the UK nationalised energy industries, and the introduction of the RPI- formula for electricity pricing by OFGEM, UK expenditure on energy R. and D. dropped dramatically. Since the early 2000's, expenditure on energy R. and D. has gradually expanded again, largely to fund wind and tidal energy.

In the late 1990's a policy debate occurred in which it was argued that the UK could not afford to continue R. and D. in all fields of energy research, and that the UK should concentrate on the development of exportable technology. A number of HMG programmes have run over the years: "The Clean Coal Technology Programme"; "The Cleaner Coal Technology Programme"; "The Cleaner Fossil Fuels Programme", and "The Carbon Abatement Technologies Programme". Despite the changes in name, these were all one and the same programme, largely run by the same HMG Departments and the same UK companies, with a view to promoting the sale of British coal technology to India and China. Until 2002/3, the above programmes promoted both SPFC with CCS, and multi-fuel co-gasification using the BGL.

During 2002 and 2003, DTI, UK coal plc, Babcock Wilcox and Innogy plc issued four inter-related reports on multi-fuel co-gasification, all of which mentioned the BGL's at Westfield and SVZ as the leading developments in multi-fuel co-gasification, and clearly recognised the fundamental advantages of the BGL for co-gasification:

- Sustainably resourced biomass is a zero carbon content fuel.
- Waste is a negative cost reduced carbon content fuel (the processor receives a 'gate fee' for the waste).
- Coal is a reliable readily available energy source which can be used to stabilise the gasification reaction when co-gasified with biomass and waste.
- The BGL is the only slagging gasifier with proven capability to handle a wide range of difficult to prepare liquid and solid fuels.
- Slagging gasification is an inherently energy efficient, clean carbon capture ready technology.

The above parties published a comparative cost table for the Levelised Cost of Electricity (LOE) for 7 different proposed multi-fuel technologies at the IChemE Conference in April 2002. The table from the report is appended. There were, however, two concealed misleading statements in the comparative cost table:

- The cost analysis omitted the known capability of the BGL at SVZ to co-gasify lump, pelletised and liquid 75 to 80% waste and biomass:20 to 25% coal.
- The cost analyses for 100 and 400MW IGCC's based on 100% coal; or 90% coal:10% biomass or RDF, are all typically for pulverised coal gasifiers, not for solid and liquid multi-fuel gasifiers.

If the fuel costs for a solid 75% waste: 25% coal fuel mix are substituted for pulverised 90% coal: 10% RDF in a 400MW IGCC, the comparative costs are:

Extract from 2002 DTI/UK Coal plc report on the co-gasification of waste, biomass and coal

	400MW CCGT Natural Gas	400MW IGCC 100% coal	**400MW multi-fuel IGCC** **75% waste:25% coal**
Capex p/kWhr	0.75	1.89	**1.92**
Fuel	1.37	0.96	**-1.56 Note (1)**
Staffing	0.08	0.13	**0.15**
O & M	0.26	0.45	**0.48**
Cost of electricity	2.5p/kWhr	3.4p/kW/hr	**0.99p/kWhr**

Note (1)	Cost of coal	120p/GJ (All at DTI 2002 costs)
	Cost of waste	-300p/GJ
	Cost of RDF	0p/GJ
	Cost of 75% waste:10% coal	-195p/GJ

Cost of 90% coal:10% RDF 108p/GJ
Fuel cost of 75% waste:25% coal @ 45% net efficiency -1.56p/kwhr

Please note that the above analysis is based on 2002 prices as reported by DTI and UK Coal plc. Very shortly before the publication of the above analysis, DTI had published a technology status report on the co-gasification of waste, biomass and coal, which reported favourably on the development the BGL's at Westfield and SVZ, but reported the LOE for a 20MW biomass gasifier to be 10p/kWhr; the LOE for a 400MW NGCCGT at 2.5p/kWhr and the wholesale price of electricity at 2.0p/kWhr. DTI did not report the LOE for a 400MW multi-fuel IGCC of 1.0p/kWhr. Based on its own information, therefore, DTI mis-reported the basic economics of multi-fuel gasification by a factor of around 1000%; and reversed the economic relationship between non-renewable fossil fuel coal gasification and NG, and multi-fuel gasification of largely renewable non-fossil solid fuels.

It should be noted that: the British coal mining and coal combustion technology industries are powerful political and industrial lobbies, particularly under a Labour government; UK Coal plc had an interest in selling more coal, and Babcock Wilcox had commercial interests in both pulverised coal combustion, and via Babcock Wilcox Volund had interests in competing pulverised coal gasification, having acquired the DTI supported British Coal Corporation Air Blown Gasification Cycle (ABGC) electricity generation technology. The ABGC technology was not a success, nor was the DTI supported Arbre biomass gasification technology. Subsequent support by Defra of small scale dry ash waste gasification technologies has also run into technical difficulties.

By 2005, co-gasification had disappeared from the technologies supported by the DTI 'clean coal' programme, which now only supported pulverised coal combustion technologies. The lack of any industrial base in the UK for the manufacture of large industrial gas turbines was stated by DTI in 2005 to be a consideration when determining which technologies to support. The constraint that it was only possible to co-combust 10% biomass with 90% coal was embedded in DTI's MARKAL macro-economic World energy market model.

In 2007 the Advisory Committee on Carbon Abatement Technologies was set up. The terms of reference favoured the development of coal SPFC with CCS, and gasification was only mentioned in the context of a technology to support the future "Hydrogen economy". Only UK coal and combustion industries are represented on ACCAT.

In 2010 DECC and Mott MacDonald published an up to date survey of the cost of generating electricity by various different technologies. Again, this recent survey omitted any analysis of the cost of generating electricity using multi-fuel resources. Based on best current cost projections, the analysis below indicates the LOE for multi-fuel co-gasification based on 2010 prices projected forwards to 2013.

Extract from Mott Macdonald/DECC 2010 survey of projected electricity generation costs with added multi-fuel IGCC

	Gas CCGT	Gas CCGT with CCS	Coal IGCC	Coal IGCC with CCS	**Multi-fuel IGCC**	**Multi-fuel IGCC with CCS**
Capital costs	11.2	27.7	55.5	73.6	**55.5**	**73.6**
Fixed operating costs	3.7	7.7	9.7	17.7	**9.7**	**17.7**
Variable operating costs	2.3	3.6	3.4	4.6	**3.4**	**4.6**
Fuel costs	48.5	67.2	20.3	28.3	**-40.5** (Note 9)	**-55.8** (Note 10)
Carbon costs	21.0	3.0	56.9	7.9	**56.9**	**7.9**
CO2 transport & storage	-	4.3	-	9.6	**-**	**9.6**
Levelised Cost of Electricity	86.7	113.5	145.8	141.7	**85.0** (Note 11)	**77.6** (Note 11)

Notes
1 Discount rate 10% pa.
2 Projected 2013 start date EPC prices.
3 All technologies first of a kind (FOAK) except gas CCGT which is nth of a kind (NOAK).
4 Assumed price of coal £2/GJ.
5 Assumed waste 'gate fee' £100/tonne, based on Landfill Tax 'escalator' to £72/tonne.
6 Assumed calorific value of mixed municipal, commercial and industrial wastes 11 MK/kg.
7 Assumed cost of waste as a fuel £-9/GJ.
8 Net cost of 75% waste:25% coal approx £-6.25/GJ.
9 Fuel cost @ 56% net efficiency for multi-fuel IGCC approx. £-40.5/MWhr.
10 Fuel cost @ 40% net efficiency for multi-fuel IGCC with CCS approx. £-55.8/MWhr.
11 The carbon cost for a multi-fuel IGGC is an overestimate, as it is the same as for 100% coal. If 0% carbon content sustainable resourced biomass, and deemed 65% carbon content waste, is used, the carbon cost is lower than for coal IGCC. If CCS is added, a: negative carbon footprint; negative carbon cost, and a total LOE in the order of £60 to 70/MWhr can be achieved.

Some clear conclusions can be drawn from the above analyses and the history of the two 'dashes for gas' by the UK electricity industry since North Sea gas was released for power generation purposes in 1991:

1 Coal IGCC is not economically competitive with NG CCGT in an open competitive market.
2 The addition of CCS reduces the gap in economic competitiveness between coal IGCC and NG CCGT.
3 Multi-fuel IGCC is economically competitive with NG CCGT.
4 The addition of CCS makes multi-fuel IGCC the most economic of all options.

FUTURE DEVELOPMENT OF THE BGL IN THE UK

The international market for the gasification of solid hydrocarbon bearing fuels is dominated by coal, which is the World's largest economic energy resource. The position in the UK is, however, very different. In the UK, the annual production of biomass and energy bearing wastes greatly exceeds the annual production of coal, by a factor of around 10 times. The total amount of useable energy which can be produced by using UK coal as a secondary fuel to support the co-gasification of biomass and waste as the primary fuels is several times greater than can be produced by burning UK coal as the primary fuel, with the addition of a small proportion of biomass. The negative cost per unit of energy of waste greatly exceeds the positive cost per unit of energy of coal. By using waste as the primary fuel, a net negative cost fuel supply can be assured. Coal gasification, or combustion, on its own cannot compete economically with either Natural Gas, or multi-fuel gasification.

The UK already possesses a large and well developed gas supply infrastructure, with associated gas fired electricity generation. In essence the gas grid provides the primary energy store for load following electricity generation in order to ensure the stability of the electricity grid. In essence the electricity and gas grids are wholly inter-independent. Only gas can provide the intermittent back up generation required to support the growing development of intermittent renewable energy resources.

Recently published studies by The Royal Academy of Engineering, DECC and Poyry Energy Consulting Ltd. indicate a developing consensus that total UK average electricity demand in 2050 will be around 85 to 100MW. (Note. The 'connected' electricity generating capacity will be greater than average demand.) In 2030 an average of 50m cub.m. per day of Natural Gas will be required to provide intermittent gas fired generation to support intermittent wind generation.

Some reasonable engineering assumptions and 'broad brush' calculations for different energy and waste policy scenarios can be made:

First scenario

In order to support the engineering 'resilience' of the electricity grid in 2050, between 25 and 33% of total electricity demand will be met by low carbon content gas fired load following electricity generation, an average of around 25 to 30GW.

	ENERGY SUPPLIES		ELECTRICITY SUPPLIES		
	Connected	Average	Base	Peak (min wind/sun/tide)	Peak (max wind/sun/tide)
Base load nuclear fission	20GW	20GW	20GW	20GW	20GW
Wind, wave and solar	100GW	20GW	20GW	-	45GW
Multi-fuel IGCC with CCS	50GW	30GW	20GW	45GW	15GW
Coal SPFC with CCS	15GW	15GW	15GW	15GW	15GW
Unabated NG CCGT	15GW	-	-	15GW	-
Other fossil fuels	50GW	45GW	-	-	-
Total energy supply	250GW	130GW			
Total electricity supply		85GW	75GW	95GW	95GW

Notes:

1 Assume base to peak demand fluctuations reduced from +/- 40% in 2010 to +/- 12.5% in 2050 by a combination of energy storage, microgeneration and demand management.

2 Grid engineers currently plan 'resilience' of intermittent electricity supplies at the square root of 'nameplate' generating capacity, i.e. 100GW of connected intermittent renewable equates to 10GW of 'dispatchable' load. Assume that by 2050, developments in supply and demand controls and energy storage will double the 'dispatchable' load to 20GW.

3 Assuming multi-fuel IGCC fuel is approx. 50% carbon content SNG, 93.5% of average electricity supplies in 2050 will be zero carbon.
4 Total IGCC plus unabated CCGT capacity equates approximately to UK's existing and currently planned CCGT fleet as at 2010.

Second scenario

Assume that 66% of gas demand in 2030 will be provided by low carbon content Synthetic Natural Gas (SNG), with the balance being provided by a mixture of zero carbon biogas and NG/LNG. Based on SNG produced from 33% sustainably resourced biomass; 50% wastes (with a deemed carbon content of 65%) and 18% coal, the above energy mix would have a carbon content of around 50% without requiring CCS. Based on 25% of UK electricity being generated from gas, this would equate, when combined with zero carbon nuclear and zero carbon intermittent renewables in an 88% zero carbon electricity supply.

1 Projected total average UK Natural Gas (NG) demand in 2030 approx. 250m cub.m./day.
2 Projected average UK NG demand for power generation in 2030 approx. 50m. cub.m./day.
3 Assume NG calorific value (cv) of 40MJ/cub.m.
4 Total NG power generation requirement approx. 725m GJ pa.
5 Assume approx. 66% Synthetic Natural Gas (SNG):33% NG = approx. 485m GJ of SNG pa. (Some NG will be required in order to ensure flexibility and security of a storable primary energy resource)
6 1 tonne of solid multi-fuel mix with an average cv of 18.075MJ/kg produces approx. 1.12 tonnes of Syngas with an average cv of approx. 16.4 MJ/kg. (This is a gross energy conversion figure. The net energy energy efficiency is somewhat lower in order to take account of process steam, Oxygen and electricity inputs, etc.)
7 Assume conversion of Syngas to SNG occurs at a net energy efficiency of 65 to 75% depending primarily on the gasification pressure (Catalytic methanation is strongly exothermic, and generally occurs at around 500 deg.C. The net efficiency can also be increased by capturing some of the waste heat as electricity, etc, but this would not appear as an increase in SNG output).
8 The production of 485m GJ pa of SNG requires an input of approx. 90 to 100m tonnes pa of solid fuel with an average cv of 18MJ/kg. (Studies have been done on the co-gasification of a number of biomass, waste and coal fuel mixes with average cv's between 17.5 and 20.0 MJ/kg)
9 Total UK waste production exceeds 300m tonnes pa. Total UK production of energy bearing wastes, biomass and coal is in the order of 200m tonnes pa.
10 A large proportion of the UK low carbon content 'dispatchable' load following electricity generation required to support intermittent renewables, base load nuclear, demand fluctuations and the operation and stability of the existing gas and electricity grids and generating infrastructure could be economically provided by the slagging co-gasification of approximately 50% of UK's useable annual supply of sustainably resourced biomass, wastes and coal without requiring the wholesale reconstruction of the UK electricity and gas grids, and with a only a small requirement to deploy CCS.

Third scenario

Biomass, residual low and intermediate level nuclear hazardous and non-hazardous wastes, Persistant Organic Pollutants, landfill mined materials and coal are transported to regional carbon capture ready energy zero emissions energy from waste IGCC's, and used to produce: low carbon content load following 'dispatchable' electricity; recycled wastes; non leaching inert vitrified aggregate; recovered industrial feed stocks; soil conditioner; recovered waste energy for district heating and cooling; restore previously landfill land; support the growth of biomass supply chains, and sell double Renewables Obligation Certificates for the biological content of the input fuels. Projected net energy efficiency approximately 55% including: diurnal plant load cycling; Syngas storage; Oxygen, Nitrogen and Argon storage; 'fast start' geared 2-into-1 CCGT; energy recovery via 2 stage Organic Rankine Cycle turbine, and CHP.

Please see the attached proposal for a 750,000 tonne pa of mixed biomass and wastes, and 90,000 tonne pa coal zero emissions to average 275MW zero emissions energy from waste plant at Sutton Courtenay landfill and Didcot Power Station. An outline cost benefit analysis indicates a LOE of £40/MWhr, including 5% profit contribution; Weighted Aggregate Cost of Capital of 9% and an average Return on Capital Employed of 34%

over 25 years, based on a waste gate fee of £72/tonne for local residual MSW; an average gate fee of £100/tonne for other wastes and RDF, and an average wholesale electricity price of £58.68p/MWhr (based on current 12 month 'futures'), excluding income from all other sources. This is not a wholly representative cost comparison as LOE calculations are usually done on a 'green field' site basis, whereas the chosen site has the benefit of existing infrastructure. Nonetheless, the basis for a commercially profitable investment clearly exists.

GL Noble Denton Ltd. has provided various gas analyses for the BGL based on a number of biomass, waste and coal fuel mixes with average calorific values in the range 17.5 to 20.0MJ/kg, these being similar to the cv's of the fuels used at SVZ and in China. These analyses indicate that the above scenarios could be justified by the slagging co-gasification of around 100m tonnes pa of biomass, waste and coal. The UK currently produces something in excess of 200m tonnes pa of energy bearing wastes, biomass and coal.

CONCLUSIONS

1. HMG and USA DOE supported the development of the BGL slagging gasifier, and associated methanation technology to produce SNG, during the period 1956 to 1992. This technology is still available.
2. The EC authorised the release of North Sea gas for electricity generation purposes in 1991 thereby rendering investment in the UK in all other forms of electricity generation uneconomic at that time.
3. Development of the BGL for multi-fuel slagging co-gasification at industrial scale was supported by the EC and German government during the period 1990 to 2007.
4. HMG withdrew support for UK development of BGL multi-fuel slagging co-gasification around 2002/3.
5. British companies have successfully developed the BGL in China, with no support from HMG, during the period 2002 to present.
6. Only the BGL can support economically competitive solid and liquid multi-fuel slagging gasification.
7. Multi-fuel slagging gasification can be used EITHER to generate electricity directly from Syngas; OR to produce low carbon content SNG for injection into the existing UK gas grid in order to support the associated existing gas fired electricity generating infrastructure and intermittent renewable.
8. HMG currently has no policy for the UK gas grid in 2050.
9. The UK gas grid is the only existing infrastructure available to support the development of CCS.
10. CCS is only necessary if coal SPFC is deployed.
11. Coal SPFC with CCS cannot support intermittent wind.
12. The co-gasification of 50% of total UK production of useable biomass, waste and coal will support the economical de-carbonising of the existing UK electricity and gas grids, and existing infrastructure, and support intermittent renewable, without requiring the wholesale reconstruction of the UK electricity and gas infrastructure.

EXTRACT FROM APRIL 2002 DTI/UK COAL REPORT ON MULTI-FUEL CO-GASIFICATION p1 of 3

more correctly referred to as thermolysis). Fast pyrolysis or thermal gasification maximises the production of syngas, whereas slow pyrolysis or carbonisation maximises the production of char, tars and oils.

Table 1 - Typical analyses of coal, biomass and waste fuels by decreasing oxygen content (Davidson, 1999; Hein and Scheurer, 2000; Optimat Ltd, 2001)

ar - as received daf - dry ash free	straw	wood	dried sewage sludge	MSW (UK av)	RDF	brown coal	hard coal	TDF
Proximate analysis, wt% (ar)								
moisture	10.6	7.2	3.0	31.4	4.1	50.4	5.1	0.4
ash	5.5	2.9	45.1	27.8	11.7	2.5	7.8	5.8
volatile matter	66.5	74.6	49.5	36.8	79.2	25.8	32.9	68.2
fixed carbon	17.4	15.3	2.4	4.1	5.0	21.2	54.2	25.6
Ultimate analysis, wt% (daf)								
carbon	50.7	49.3	48.1	54.2	64.7	69.4	79.2	84.7
hydrogen	4.8	6.3	9.4	7.8	9.0	5.2	6.2	8.0
oxygen	43.2	43.2	34.0	34.8	24.3	24.2	12.1	4.8
nitrogen	0.64	0.44	6.16	1.50	0.84	0.73	1.40	0.42
sulphur	0.08	0.11	2.12	0.29	0.28	0.41	1.03	1.59
chlorine	0.59	0.60	0.19	1.35	0.93	0.11	0.14	0.51
Ash fusion temperature, °C	850	1200	1200		1120	1050	1250	
Calorific value, MJ/kg (ar)								
higher heating value	17.1	15.6	11.6	9.4	23.5	10.6	29.2	36.8
lower heating value	16.0	14.3	10.6	8.0	21.9	9.0	28.0	35.2

Capital cost The normalised cost of a power generation plant is expressed in terms of £/kW. The cost of a waste to energy plant is expressed as £/tonne of annual capacity which can easily be converted to a £/kW basis. The capital cost must include land, permitting, infrastructure, equipment, project management, interest during construction and contingencies. To calculate an annual capital charge, we have assumed a real rate of return of 12% over 15 years - numerically equivalent to a simple, straight line depreciation over 7 years.

Fuel cost Coal is assumed to cost 120 p/GJ (net); gas 20 p/therm (gross) or 210 p/GJ (net); biomass £40/odt (oven dried tonne) or approximately 300 p/GJ; MSW -300 p/GJ, equivalent to a gate fee of around £30/tonne; RDF is available at no cost; and, tyres at -150 p/GJ, a gate fee of £50/tonne.

Staff cost A staff cost of £50,000 per man per annum is assumed. This includes all employment and training costs. To safely man a plant 24 hours per day, 7 days per week requires 5 shifts of 2-3 men, implying a minimum of 12 men for even the smallest plant, unless it is automated or operates as a batch process.

O&M cost It is extremely difficult to estimate operation and maintenance (O&M) costs without detailed information from suppliers. Those quoted are best estimates and include for all consumables and maintenance costs.

The most startling fact to emerge from this analysis is that none of the technology options is currently viable. With market prices in the UK for electricity hovering around 2 p/kWh, no type of power plant, whatever the fuel, is competitive; this might explain the absence of new build. Coal-fired IGCC is more expensive because of the high capital cost, but could become competitive if governments chose to reward its environmental benefits in a similar manner to renewables. Also apparent, is the rising COE at the smaller size as scale economies are lost. For example, the 8 MWe p3of3

subsidy proposed under the Renewables Obligation, and raises a big question mark over such small-scale biomass gasification projects.

Table 4 - Cost of electricity (COE) from different technologies and fuels

		CCGT	IGCC	IGCC	IGCC	W2E	IGCC	adv.W2E
capacity	MW	400	400	400	100	20	10	5
efficiency	%	55%	45%	45%	36%	23%	31%	25%
load factor	%	89%	89%	89%	89%	89%	89%	89%
capex	£/kWh	400	1,000	1,020	1,400	2,000	3,000	2,500
	£/tpa					160		780
	£m	160	400	408	140	40	30	12.5
fuel		nat. gas	coal	coal/RDF	coal/biomass	MSW	biomass	tyres
ratio				9:1	9:1			
CV	MJ/kg	50	25	24.5	24	10	14	35
consumption	kt/yr	408	998	1,018	326	244	65	16
cost	p/GJ	210	120	108	138	-300	300	-150
staffing	no.	50	84	86	30	32	15	12
	£k/man	50	50	50	50	50	50	50
	£m	2.5	4.2	4.3	1.5	1.6	0.75	0.6
O&M	£m	8	14	15	5	4.5	0.7	0.35
capex	p/kWh	0.75	1.89	1.92	2.64	3.77	5.66	4.71
fuel	p/kWh	1.37	0.96	0.86	1.38	-4.70	3.48	-2.16
staffing	p/kWh	0.08	0.13	0.14	0.19	1.03	0.96	1.54
O&M	p/kWh	0.26	0.45	0.48	0.64	2.89	0.90	0.90
COE	p/kWh	2.5	3.4	3.4	4.9	3.0	11.0	5.0

It is only co-gasification at the larger scales where the marginal economics have any attraction. If co-gasification can be arranged at an existing plant, then the COE might be competitive. Section 9

Waste/Biomass Co-Gasification with Coal

Gasification has been considered for many years as an alternative to combustion of fossil fuels, biomass materials and wastes. It is easier to clean gaseous mixtures than it is to clean solid or high-viscosity liquid fuels. Combining coal and biomass or waste in gasification has many advantages over single-fuel gasification and can result in clean power plants using a range of fuels. Potential benefits are:

- Combines use of a reliable coal supply with gate-fee waste and biomass qualifying for renewables certificates and greenhouse gas benefits.
- Allows economies of scale from a larger plant than would be the case with waste and biomass only.
- Capable of achieving high environmental standards on all fuel sources.
- Flexible in choice of gas-to-electricity technology: reciprocating engine, gas turbine, boiler or, in the future, fuel cell.
- Better public image than incineration processes.
- Potential for petrochemical plant feedstock products in addition to electricity.
- Potential for efficient conversion of solid fuel to electricity.
- Potential for siting at collieries.

For large-scale power generation (>50MW$_e$), gasification plant is dominated by pressurised, oxygen-blown, entrained-flow and fixed-bed gasification of fossil fuels. Operational experience to date with entrained-flow gasifiers has largely been with well-controlled fuels, short-term trial work, low co-gasification ratios and easily handled fuels. The British Gas Lurgi (BGL) gasifier, a fixed-bed technology, is better suited to difficult-to-mill feedstocks than are entrained-flow gasifiers and has the most operational experience with fuels of widely differing mechanical properties. The former British Gas interests in this technology are now owned by Advantica Technologies, which is widely believed to be the clear leader in the larger-scale gasification of variable property feedstocks. Global Energy, backed by El Paso, leads in both implementation and project proposals for co-gasification. The BGL technology appears to be their preference for projects with the potential for gate-fee fuels. They have ambitious additional plans in Europe and the USA for using BGL technology with coal, municipal refuse and sewage sludge feedstocks in co-gasification modes. One of Global Energy's co-gasification projects is in Scotland alongside their natural gas-fired power plant. Their SVZ plant in Germany is currently operating a BGL gasifier in co-gasification mode.

Fife Power 120MW$_e$ GE 6FA power plant at Westfield, Scotland. Gasifier under development. Courtesy of Global Energy.

British Gas Lurgi gasifier at the Schwarze Pumpe Secondary Raw Materials Value Enhancement Centre in Germany. Courtesy of Advantica and SVZ.

Gasification plant designed for waste and biomass fuels, as opposed to those initially designed for coal or heavy oil, are usually well below $50MW_e$ capacity. Waste materials attract significant disposal credits. As a renewable fuel, biomass may attract premium prices for electricity generated. Availability of sufficient fuel locally for an economic plant size is often a major issue, as is the reliability of the fuel supply. Use of coal, which is readily available on the open market, alongside these fuels may overcome these risks. Coal may be regarded as the 'flywheel' that keeps the plant running when the fuels producing the better revenue streams are not available in sufficient quantities.

A number of large co-gasification plant are operating worldwide. These are listed in the Table below.

Coal characteristics are very different to younger hydrocarbon fuels such as biomass and wastes. Hydrogen-to-carbon ratios are higher for younger fuels, as is the oxygen content. This means that their reactivities are very different under gasification conditions. Gas cleaning issues can also be very different, with sulphur a major concern for coal gasification but chlorine compounds and tars more important for waste and biomass gasification.

Most small to medium size biomass/waste gasifiers are air-blown, and operate at atmospheric pressure and at temperatures in the range 800-1200°C, which restrict the use of larger and more efficient gas turbines. Their specific capital costs are higher. Operational labour costs are a major proportion of total costs.

Despite these challenges, there are many enthusiastic UK developers of gasifiers or gasification systems. British companies are well known for having the know-how and capabilities for project development, overall engineering, component supply (particularly materials handling) and consultancy. British suppliers are also competing in the market for reciprocating engines and small to medium size gas turbines using the gas from gasifiers. Biomass fuel producers, coal producers and, to a lesser extent, waste companies are also enthusiastic about supplying to co-gasification power plant and realise the benefits of co-gasification.

More information is available from Technology Status Report TSR017 and Report R216, available from the Web site or from the Helpline.

PLANT	Output / Gasifier output	Comments
Amercentrale 9 (Netherlands):	$600MW_e$/ $85MW_{th}$	Lurgi CFB gasifier using demolition wood which supplies gas to the main boiler.
Kymijarvi CHP Plant (Lahti, Finland):	$350MW_e$ / $70MW_{th}$	Foster Wheeler gasifier using a range of biomass. Again the gas is co-fired.
Zeltweg Power Plant (Austria):	$137MW_e$ / $10MW_{th}$	Austrian Energy CFB biomass gasifier. Again the gas is co-fired in the main boiler.
SVZ GCC/Methanol Plant at Schwarze Pumpe (Germany). Global Energy ownership.	1 new BGL gasifier 7 old Lurgi fixed-bed gasifiers 2 entrained gasifiers	True co-gasification including lignite, plastics and sewage sludge.
Elcogas (Spain):	$300MW_e$	70% pet coke, 30% coal.
Berrenrath (Germany):	Methanol from MSW and lignite (tests only)	High temperature Winkler.

A 750,000 TONNES PA MIXED HAZARDOUS AND NON-HAZARDOUS WASTES, LANDFILL MINING AND BIOMASS

AND 90,000 TONNES PA COAL

TO 275MW ZERO EMISSIONS CARBON CAPTURE READY MULTI-FUEL IGCC WITH CHP

AT

DIDCOT POWER STATION AND SUTTON COURTENAY LANDFILL

[redacted]

INTRODUCTION

H.M. Government is committed to: achieving a 80% reduction in UK carbon emissions by 2050; delivering sustainable, secure and affordable energy supplies to UK industry and consumers, and developing an economically and operationally balanced portfolio of diversified energy supplies: nuclear, gas, 'clean coal', sustainably resourced biomass and intermittent renewables. H.M.Government is also committed to achieving a progressive reduction in residual wastes, and their final disposal to landfill, and the development of commercially viable sustainable biomass supply chains.

Didcot 'A' Power Station is due to close at the end of 2015. RWE npower has ruled out the possibility of developing a technically logical, but locally unpopular, nuclear power station at Didcot. RWE npower has also ruled out the disposal of the site. The combined sites of the power station and landfill are uniquely well suited to the development of a profitable zero emissions carbon capture ready hazardous and non-hazardous wastes, biomass, coal and Natural Gas fuelled Integrated Gasification Combined Cycle (IGCC) power station. The design, economics and scientific rationales behind this proposal are set in the attached brochure. The technologies on which this proposal is based are all fully proven.

Planning consent has recently been refused for a municipal waste incinerator at Sutton Courtenay landfill. These two adjoining sites comprise nearly 10 sq. kilometres of previously developed land with a full range of existing strategic infrastructure services and transport connections, already paid for by the taxpayer, and with existing Planning consents to import, or export, around 4.5m tonnes of solid material per annum. Didcot 'A' and 'B' Power Station combined supply 6% of total peak UK electricity demand and is the only major power station equidistant from the major conurbations of London, Bristol, Southampton and Birmingham. The landfill site receives both locally produced wastes, and wastes by rail from London, Bristol and Bath. The Power Station receives coal via Avonmouth Coal Dock and biomass from various sources. Consideration is being given elsewhere to developing an Anaerobic Digestor (AD) and Solid Refuse Derived Fuel (SRF) facility at the landfill site. The scheme will provide a guaranteed 'off take' for the Methane produced by AD, and for the final disposal of SRF by means other than combustion. In addition the scheme will provide for the processing of both residual Municipal Solid Waste (MSW), and Commercial and Industrial Wastes (C and I) produced within Oxfordshire. The combination of AD, SRF and plasma gasification fulfils the waste disposal policy objectives of Defra and the Greater London Authority. The development can be phased.

EXECUTIVE SUMMARY

The scheme has been designed to deliver the following:

- A profitable average Return on Capital Employed (ROCE) of 34% over 25 years, based on waste 'gate fees' and the sale of electricity, excluding all other potential revenue streams: sales of double ROC's, heat, recyclates, biogas and land value enhancement.
- Flexible and profitable operation, with secure diversified primary energy resources, under different future UK energy market scenarios.
- Combined base and peak electricity output from Didcot 'A' and 'B' of 1.7GW, approximately 3% of total peak UK electricity demand.
- Zero emissions to air, soil or water. Carbon Capture ready.
- Reuse previously developed land, and reuse existing strategic infrastructure facilities.
- Restoration of the topology and hydrology of the floodplain of the River Thames, and its development for biomass energy crops.

- Provide a useful outlet for a substantial quantity of hazardous and non-hazardous wastes, with 100% diversion from landfill.

The scheme is based on integrating a unique combination of the following proprietary technologies with standard process engineering technologies:

- The solid and liquid multi-fuel high temperature and pressure British Gas Lurgi slagging co-gasifier, owned by GLI Ltd and Envirotherm GmbH, as previously developed at British Gas Development Centre Westfield, Fife and SVZ Schwarze Pumpe, East Germany, and currently being developed in India and China.
- The plasma torch solid hazardous waste conversion process developed and owned by Tetronics Ltd.
- The flexible dual fuel Syngas, Natural Gas or Hydrogen fired CCGT developed and owned by GE Energy.

ENGINEERING DESIGN CONCEPT

- Zero emissions to air, soil or water. Carbon Capture ready.
- Maximise overall energy efficiency by use of slagging gasification with high cold gas efficiency; minimise quantity of solid APC residues to be processed by plasma waste conversion; high efficiency CCGT, and waste thermal energy recovery via high temperature thermal store and CGGT pre-heat, and low temperature ground mass thermal store and Organic Rankine Cycle turbine. Target overall energy efficiency of 55%.
- Use multi-fuel capability of BGL gasifier in order to develop IGCC concept to maximise the use of renewable energy sourced fuel stocks. Design scheme uses approx. 82% hazardous and non-hazardous wastes, including Refuse and Tyre Derived Fuels, biomass and landfill mined material.
- Use broadly balanced multi-fuel portfolio in order to maintain diversity and security of fuel supplies, and enhance opportunities for the profitable arbitrage of input fuel costs. Stable Syngas output with solid fuel inputs with average calorific values in the range 17.5 to 20.0 MJ/kg.
- Balance proportions of wastes, biomass and coal in order to maximise income from waste 'gate fees' and achieve negative overall fuel cost.
- Balance the size of the gasification plant and 'two into one' CCGT plant in order to maximise Syngas to Natural Gas fuel proportion. Use two gas turbine into one steam turbine geared CCGT with self shifting and synchronising clutches, steam saturation of Syngas, Nitrogen dilution, dry Low-Nox combustors, water fog bar and in duct Syngas burning to maximise flexibility of power output, optimise energy efficiency and minimise NO_x. Provide storage for 12hours Syngas production in order to balance contra-cyclical gasification plant and peak load CCGT operations. Maximise heat recovery via: CCGT boiler water pre-heater; steam turbine exhaust economiser; BGL and Syngas quench heat recovery; 2 stage Organic Rankine Cycle turbine; high temperature and underground thermal mass stores, and Combined Heat and Power.

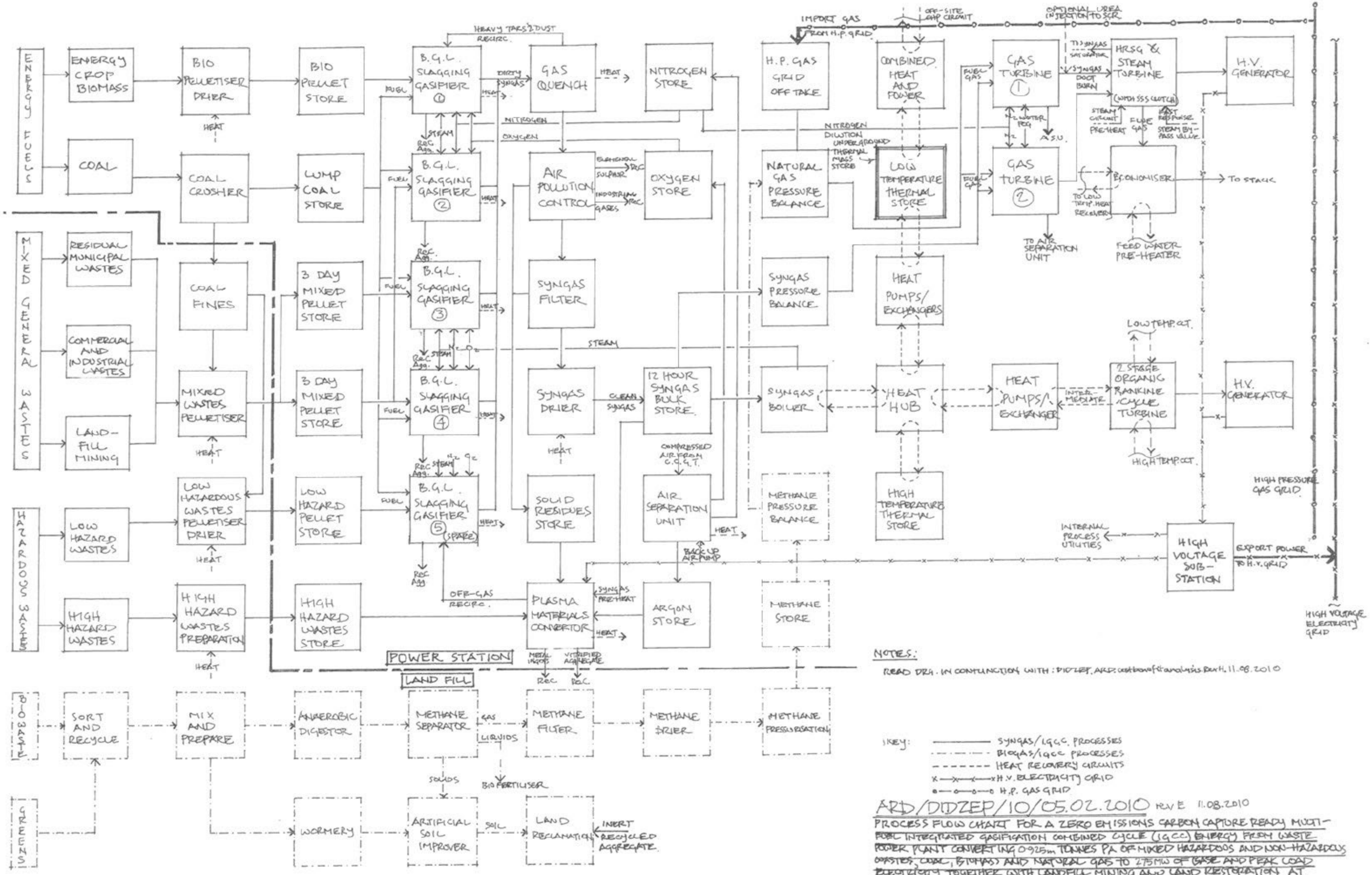
LAND USE PLANNING DESIGN CONCEPT

- Maximise reuse of existing 'brownfield' land and existing fully 'written down' strategic infrastructure investment.
- Balance rate of landfill mining with rate of refilling of the landfill void with certified inert vitrified aggregate in order to restore the original ground levels of the flood plain of the River Thames. Replace existing landfill materials and enclosures with a certified non-leaching man made aggregate in order to provide a permeable sub-surface drainage stratum in order to replace the previously worked out natural sand and gravel stratum in order to restore the sub-surface hydrology of the flood plain of the River Thames.

- Total material movements at combined Power Station and landfill sites equals around 20% of existing Planning consents.
- Total waste imports into, and exports from, landfill site equals 100% of existing Planning consents.
- Minimise long-term (60 year) liability for the management of the environmental impact of the landfill site after the completion of landfill operations.
- Maximise opportunities for the future use and re-development of the landfill site after the restoration of the topology and hydrology of the flood plain of the River Thames.
- Maximise opportunities for the Sustainable Development of biomass energy crops and hydroponics plant reusing waste heat and CO_2.
- Use low temperature ground mass thermal store as an interface for a Combined Heat and Power system serving local commercial properties, thereby allowing for the balancing of year round waste heat production with seasonal heat demand.

ENVIRONMENTAL DESIGN CONCEPT

- Zero emissions to be the driver of design: zero emissions is a design opportunity not a constraint. Scheme to be Carbon Capture ready.
- All possible clean biological materials to be separated from the front end of the fuel stream and processed by Anaerobic Digestion.
- All possible reyclates to be separated from the front end of the fuel stream and re-cycled as useable products, etc.
- Remove maximum proportion of pollutants from fuel stream as early as possible in process. Minimise 'tail pipe' clean up requirement.
- Thermal processes cannot operate between the thermoplastic slag formation threshold temperature of around 900^0 C, and the fully liquid slag temperature around 1200^0 C. High temperature and pressure slagging gasification maximises energy efficiency and minimises emissions.
- Oxygen and blown slagging gasification process. At gasification phase change temperature of approximately 1420 deg. C., total dissociation of co-valent molecular bonds in Persistant Organic Pollutants occurs. Minerals and heavy metals captured as inert vitrified aggregate.
- Use rapid water quench of Syngas from 516 deg. C to approx. 165 deg. C. in order to avoid the main temperature range where the de novo metal catalysed synthesis of Dioxins and Furans occurs.
- Recycle heavy tars captured in quench to gasifier train for gasification to extinction.
- Heavy metals and minerals in fuel stream are captured within a certified inert non-leaching vitrified aggregate produced as a by-product of slagging gasification and plasma waste conversion. Reuse the aggregate as a substitute for previously worked out sand and gravel in order to restore the sub-surface drainage stratum in flood plain of River Thames.
- Use Rectisol cooled methanol solvent loop and Claus process, or similar, standard chemical engineering gas clean up processes to capture and recycle elemental Sulphur and acid gases, etc. Solid Air Pollution Control residues to be treated in plasma waste convertor in order to produce further vitrified aggregate and metal alloy ingots. Gaseous residues to be recycled into the gasifier train.
- The use of steam saturated Syngas, Nitrogen dilution and dry Low-NOx combustors in the CCGT will achieve a NOx emission level of 10 ppm. This exceeds current draft EU BAT requirements. Should further reductions in NOx levels be required, this will be achieved by deploying dry urea or ammonia Selective Catalytic Reduction (SCR).
- Full Environmental Consent already granted within the EU and by UNEP for the slagging co-gasification waste disposal process and the destruction of Persistant Organic Pollutants (POP's) at SVZ Schwarze pumpe. Vitrified residues are certified inert under EU and UK regulations.



NOTES:

READ DRG. IN CONJUNCTION WITH: DIDZEP. ARD. carbonofftanalysis.Rev H. 11.08.2010

KEY:
- ———— SYNGAS/IGCC PROCESSES
- —·—·— BIOGAS/IGCC PROCESSES
- - - - - HEAT RECOVERY CIRCUITS
- x—x—x H.V. ELECTRICITY GRID
- o—o—o H.P. GAS GRID

ARD/DIDZEP/10/05.02.2010 REV E 11.08.2010

PROCESS FLOW CHART FOR A ZERO EMISSIONS CARBON CAPTURE READY MULTI-FUEL INTEGRATED GASIFICATION COMBINED CYCLE (IGCC) ENERGY FROM WASTE POWER PLANT CONVERTING 0.925m TONNES PA OF MIXED HAZARDOUS AND NON-HAZARDOUS WASTES, COAL, BIOMASS AND NATURAL GAS TO 275MW OF BASE AND PEAK LOAD ELECTRICITY TOGETHER WITH LANDFILL MINING AND LAND RESTORATION AT DIDCOT POWER STATION AND SUTTON COURTNEY LANDFILL

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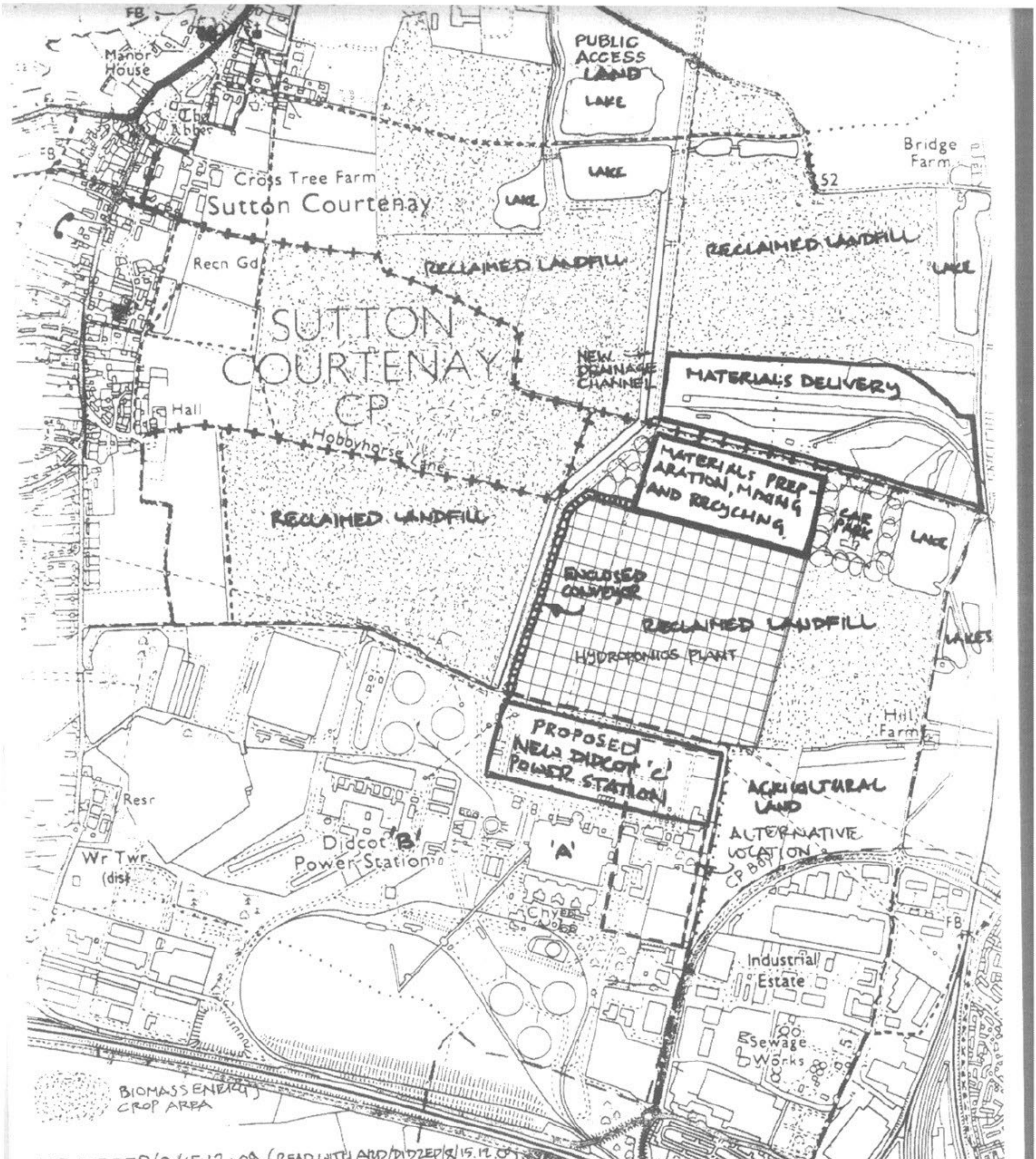


ARD/DIDZEP/9/15.12.09 (READ WITH ARD/DIDZEP/8/15.12.09)
DIDCOT POWER STATION AND SUTTON COURTNEY LANDFILL
PROPOSED 1.125m TONNE p.a. TO 1.1GW PEAK POWER AND 200MW BASE POWER NEAR ZERO EMISSIONS ENERGY FROM WASTE CARBON CAPTURE READY WITH ZERO NET LANDFILL
SCALE: APPROX 1:12500

[redacted]

B) HYDROPONICS & BIOMASS ENERGY CROP ADDED 01.03.2010
A) ALTERNATIVE LOCATION ADDED 06.01.2010

COST BENEFIT ANALYSIS - DIDCOT ZERO EMISSIONS MULTI-FUEL IGCC

SUMMARY OF KEY FACTS

Carbon capture (CCS) ready EU Zero Emissions Platform compliant 0.840m tonne pa hazardous and non-hazardous wastes, biomass and coal slagging co-gasification to average 275MW Integrated Gasification Combined Cycle Energy from Waste plant with heat recovery. Interchangeable inputs and flexible operating strategies to meet changing market conditions and regulatory uncertainty while ensuring consistency of Return on Capital Employed (ROCE). Load following generation supports: UK Carbon reduction targets; energy affordability, security and sustainability; intermittent renewables; existing energy intrastructure; land restoration and Sustainable Development. Commercially 'bankable' investment not dependent on unknown carbon costs.Approx. 75% carbon content sustainable fuels. Potential CO_2 capture during gas clean and catalytic methanation to SNG. All technologies available and proven.

ROCE	Average 34% over 25 years. (Excludes income from double ROC's, heat, recyclates, land development and biogas plant, etc.)
WACC	ROCE exceeds assumed 9% Weighted Aggregate Cost of Capital in operational year zero.
CAPEX	£0.925 bn (Includes 12% contingency on CAPEX costs)
Revenue	£188.8m pa (Based on RWE March 2010 12 month electricity 'futures' and commercial waste 'gate fees')
EBITDA	£120m pa (Includes contingencies: 10.5% on OPEX costs; 5.75% on CCGT energy input, and 10% on parasitic loads)
Upside	Profit enhancement by fuel and energy price arbitrage and multiple operational strategies in volatile energy markets.
Downside risk cover	Flex-fuel strategy to cover price movement risk. Dual fuel CCGT's can operate on any combination of Syngas, Natural Gas and Hydrogen. Investment appraisal does not depend on future technology upgrade to suit unknown future price of carbon. Use waste 'gate fees' under-written by Landfill Tax escalator until 2028 in lieu of financially uncertain carbon trading.
CCGT operation	'Fast start' load following capability with steam circuit pre-heat, Self Shifting and Synchronising clutches, dry low Nox burners, Nitrogen dilution, Syngas saturation, water fog and fast response steam by-pass valves. Multiple geared shafts, in duct Syngas burn and flue gas heat recovery. CCGT output can vary between approx. 100 and 295 MW depending on CCGT operational configuration. Optional urea SRC to reduce Nox levels if required. 250MW Base and peak load: 100.0% Syngas (0% storage required. 87% of max.daily Syngas production) 250MW Base and 295MW peak load: 98.5% Syngas:1.5% NG (12.5% storage @ 98% max. daily Syngas production.)
2 stage ORC	Approx. 30MW steady state load. Operate as a 'slow response' base to peak load cycling generator, approx 20 - 40MW.
Load cycling	225MW Base and 310MW peak load with CCGT, ORC and gasification plant load cycling.
Parasitic load	13.75% of gross electricity output (Includes 10% contingency)
Energy Mix	16.4% coal:82.0% opportunity fuels: 1.6% Natural Gas (By energy content)
Total input energy	Approx. 15.433m GJ pa. (inc. 5.75% Syngas contingency)
Energy efficiency	Ave. 55% overall: 50.5 to 51.75% net electricity generation (inc. 1.25% parasitic load contingency) plus estimated 2.5 to 5% CHP
CHP	Heat recovery approximately 10 to 20MW based on year round demand from commercial premises. (8 to 16% of ORC heat flow)
Solid fuel cost	Approx. £5.25m pa, mixture of coal, biomass and landfill mined materials.
Natural Gas cost	Approx. £0.625m pa (Initial cold start only)
Current energy costs	Coal £1.80/GJ (March 2010 RWE report) Natural Gas £6.25/GJ " " Base power £13.50/GJ " " Peak power £16.50/GJ " "
Biogas	Biogas installation using 'green' fuels, biological wastes and site grown energy crops,etc, shown on drawings, but excluded from cost benefit, and ROCE, analyses. Use biogas for CCGT start up and for injection into gas grid. Sell or reuse soil conditioner.

TECHNOLOGY VENDORS

GL Noble Denton Ltd	**Successor to British Gas. UK licensor of BGL slagging gasifier, the only slagging gasifier which can handle multiple solid and liquid fuel feeds, and, therefore, zero emissions multi-fuel co-gasification of wastes, coal and biomass. Competing pulverised fuel entrained flow slagging gasifiers cannot gasify wastes. BGL certified by UNEP and EU for the safe destruction of Persistant Organic Pollutants. Heavy metals and minerals bound into inert vitrified aggregate. The only proven high efficiency technology basis for delivering 'clean coal', 'clean waste' and and zero emissions 'multi-fuel' biomass, wastes and coal. Co-gasification can support production of: Syngas for use on site; or Synthetic Natural Gas (SNG) for injection into gas grid.**
ZEMAG GmbH	**Fuel processing, pelletising and feed systems.**
Tetronics Ltd.	**Gloucestershire based DTI supported developer of plasma materials convertor. Ultra-high temperature dissociation of molecular and crystalline bonds. Proven for the destruction and vitrification of all known wastes except high level nuclear.**
GE Energy Inc	**Current technology dual fuel CCGT's can burn Syngas, Natural Gas or Hydrogen. No exotic materials required.**
Aker Solutions Ltd.	**Process engineering integration.**

DESIGN CONCEPTS AND CRITERIA

1.0 ENGINEERING DESIGN CONCEPT

Carbon capture ready zero emissions multi-fuel IGCC using pelletised or lump solid fuel; BGL oxygen and steam blown slagging gasifier operating at 1420 deg. C. and 40 - 45 bar pressure; Syngas quench and clean up train producing elemental Sulphur and industrial gases; plasma conversion at of APC residues and residual hazardous wastes at 5000 - 10,000 deg. C.; Syngas storage and mixing with Natural Gas back up; dual fuel fast start load following CCGT's; waste heat recovery; underground thermal mass store, and 2 stage Organic Rankine Cycle turbine, and Combined Heat and Power. Target overall energy efficiency approx. 60%, actual efficiency achieved approx. 55% inc CHP.

2.0 STRATEGIC ENERGY CONCEPT

Develop in parallel with the rundown of Didcot 'A' in order to maintain balance of supplies to UK grid; maintain power station operator's cash flow, and meet OCC's requirement to minimise MSW disposal to landfill. Minimise requirement to import Natural Gas for power generation purposes. Support UK energy diversity and security; intermittent renewables, and existing gas and electricity grids. Minimise strengthening of electricity grid to North, East and West of Didcot. Support growth of UK biomass industries.

3.0 PLANNING DESIGN CONCEPT

Replace proposed Oxfordshire CC 300,00 tonne pa waste incinerator at Ardley, and proposed GLA 225,000 tonne pa Refuse Derived Fuel (RDF) at Sutton Courtenay with a single 0.925m tonne pa EfW plant to provide 'off take' for RDF; disposal of Tyre Derived Fuel (TDF), and disposal of hazardous wastes (both of which are lacking in Southern England) and replacement 'off take' for developing biomass supply chain at Didcot 'A'. Future planned increase in biomass production to progressively displace planned reduction in wastes. Zero emissions; Sustainable Development; converts hazardous wastes to non-hazardous recyclate; landfill mining of previously discarded materials and energy; void re-filling with recycled aggregate; restoration of topology and hydrology of Thames flood plain; materials deliveries within existing road and rail transport infrastructure capacity and consents. Low profile waste processing plant on landfill site; high profile gasification plant on power station site. Demolish cooling towers. Use existing coal handling facilities.

4.0 FINANCIAL ENGINEERING CONCEPT

Bankable investment strategy to maximise hazardous and non-hazardous waste gate fees; maximise sales of electricity and to minimise risk of fuel price and regulatory uncertainty. Profit maximisation and risk minimisation via multi-fuel strategy; stockpiling of raw materials, and on site generation and storage of Syngas. Commercial funding not dependent on unknown future price of Carbon. Income from sales of double ROC's, recyclates, biogas and land development a bonus. Zero hazardous waste disposal costs. Zero Landfill Tax. Opportunities for LATS trading. Maximise long-term return on investment in land. Minimise long-term costs of environmental management and remediation.

5.0 POWER GENERATING CONCEPT

UK CCGT capacity expected to double between 2010 and 2020 as only economically rational response to: regulatory and carbon price uncertainty; closure of obsolete coal and nuclear power fleet, and planned substantial increase in intermittent wind power connected to UK grid. Maximise plant utilisation by maximising base and peak load despatchability' by optimising CCGT fast start and peak load following capabilities, and optimising marginal cost bidding strategies by minimising dependency on NG prices.

6.0 PLANT OPERATIONAL STRATEGIES

Flexible plant design to suit two different operational strategies according to market conditions, and required cash flow:

A. Single cycle 250MW 24 hours per day operating on 100% Syngas. (87% nominal max. Syngas throughput)

B. Dual cycle: 295MW for 14 hours, and 250MW for 10 hours per day, operating on 100% Syngas (98% nominal max. Syngas throughput)

C. Operate 2 stage ORC on dual cycle basis to increase peak load generation by approx 10-15MW. Use base power for grid for part plant utilities. Increase high temp. heat store.

Further alternative operational strategies could be:

D. Increase biogas production. Store biogas for peaking operation and sell excess to gas grid. Double ROC's for biogas sales to grid.

E. Add second 250MW CCGT. Increase consumption of coal to increase Syngas production. Use all biogas on site. Import additional NG from grid for peak load generation.

7.0 SOLID FUEL ANALYSIS

Fuel	Tonnes pa	Calorific Value MJ/kg	Cost per tonne	Cost per GJ	Total cost pa	
Coal	90,000	28	£50	£1.8/GJ	£4.5m	(-ve cost = 'Gate fee' for waste disposal)
Oxfordshire CC MSW	150,000	10	-72	£-7.2/GJ	-10.8	
Oxfordshire C and I	150,000	15	-100	£-6.6/GJ	-15	(Cost to OCC rate payers)
GLA RDF	225,000	18	-100	£-5.5/GJ	-22.5	(Commercial & Industrial)
Biomass	25,000	15	25	£1.7/GJ	0.625	(Cost to GLA, London C & I waste producers)
Tyre Derived Fuel	50,000	36	-50	£-1.4/GJ	-2.5	
Hazardous industrial	125,000	20	-100	£-5/GJ	-12.5	
landfill mined material	25,000	7.5	5	£0.67/GJ	0.125	
TOTALS	0.840m tonnes pa	Ave. approx 18.075MJ/kg	Ave. approx -£69.1/tonne	Ave. Approx. £-3.823/GJ	Approx. -£ 58.05m pa	

Several different fuel and waste mixes have been analysed with average solid fuel input calorific value in the range 17.5 - 20.0 MJ/kg. Syngas output cv in the range 14.4 - 17.5 MJ/kg. Mass output varies: 1.085 and 1.115 tonnes of Syngas per tonne of solid fuel input, including 1.9% by weight of heavy hydrocarbons regasified to extinction. Energy balance and output depends largely on the proportion of coal and moisture. BGL gasifier requires min 20% high carbon solid fuel for optimum operation. Large range of substitute fuels available.

With appropriate buying strategies, it should be possible to minimise exposure to fluctuations in international energy commodity prices and international currency movements.

8.0 TOWN PLANNING AND SUSTAINABLE DEVELOPMENT

Development designed to achieve zero emissions to air, soil and water in order to comply fully with the EU Waste Directive and the Precautionary Principle in EU Law.

Combine two small waste processing schemes at Ardley and Sutton Courtenay into single economic scheme. Provide long-term 'off take' for proposed RDF scheme at Sutton Courtenay.

Maximise sustainable re-use of existing developed land, and existing strategic infrastructure assets, at Didcot.

Restore topology and hydrology of Thames floodplain. Mine landfill. Refill void with non-leachable aggregate thereby restoring permeable sub-surface drainage stratum.

Convert hazardous wastes into non-hazardous recyclate. Provide solution to current severe shortage of hazardous waste disposal capability in Southern Central England.

Achieve high energy efficiencies; reduce use of new primary materials and energy, and reduce Carbon emissions. Support development of biomass supply chain by progressively substituting biomass and biological wastes for coal and non-biological wastes. Convert carbon capture readiness to Carbon Capture and Sequestration (CCS) when UK regulatory, financial and physical infrastructure is in place. Develop the gasification of energy crops and biogas as low Carbon substitute for Natural Gas.

Total material import and export movements of 0.9m tonnes pa = approx. 20% of existing consented total materials movements at Power Station and landfill sites.

Total of 775,000 tonnes pa of materials to be imported and exported from the landfill site not to exceed existing consent of 775,000 tonnes pa.

Total of 0.125m tonnes pa imported fuels into Power Station = approx 3.33% of existing total of 3.75m tonnes pa.

Capacity exists to import over 4.0m tonnes pa of materials and fuels by rail into the combined Power Station and landfill sites. If the Power Station and landfill sites, complete with two main line rail heads and existing rail connections to London and Avonmouth Docks, were to be treated as a single entity, a much larger quantity of solid waste and fuel could be satisfactorily converted into useful electricity and gas at Didcot than proposed in this scheme.

AMENDMENTS: Cost benefit analysis rev. F. 24.04.2010

1 Redesign scheme to be primarily financially 'waste led', not primarily 'electricity led' as previous scheme. Maximise cash flow from waste gate fees. Minimise purchases of coal and NG.

2 Redesign scheme to combine currently proposed separate schemes: 300,000tpa at Ardley and 225,000tpa at Sutton Courtenay, and provide additional commercial hazardous waste disposal.

3 Total solid materials imports into, and exports from, landfill site to be contained within existing consented total of 775,000 tonnes pa.

4 Size electricity generation scheme around commercially available GE Energy 206FA dual fuel CCGT. Output to vary between 110MW and 310MW depending on turbine firing and connection configurations, and plant operational strategies.

Current material and energy price assumptions

Peak power:	**£60/MWhr**	**(March 2010 RWE report 12 month futures £59.50 /MWhr)**
Base power:	**£50/MWhr**	**(March 2010 RWE report 12 month futures £48.50/MWhr)**
Natural Gas	**£6.25/GJ**	**(March 2010 RWE report 12 months futures 65p per therm)**
Coal	**£50/tonne**	
Biomass	**£25/tonne**	
Mixed MSW, C & I, mixed hazardous and non-hazardous wastes.	**Average 'gate fee' approx. £100 per tonne. £72 per tonne for OCC residual MSW**	

CAPEX assumptions:

Gasification plant		\$3.5bn/GW	(Aker Solutions Ltd)	
CCGT		\$1.0bn/GW	Trade source/IEA	
2 stage ORC		\$1.5bn/GW	CCGT + 50%	ARD estimate
Pelletising plant	Item	£0.125bn	ARD estimate	

OPEX O and M assumptions

Gasification plant		\$100/kW pa	(IEA/ETSAP)	
CCGT plant		\$45/kW pa	(IEA/ETSAP)	
ORC		\$15/kW pa	ARD estimate	(33% of CCGT)
Pelletising plant	Item	£10m pa	ARD estimate	(See breakdown below)

Parasitic loads

Total IGCC parasitic load	10-12.5% of IGCC output	(GE advise 10 - 12.5% of total IGCC throughput. GLI advise gasifier and quench require 1.5% of IGCC output)
Plasma vitrification of APC residues	0.25% of IGCC output	(Tetronics advise 1200 kWhr/tonne. GLI advise APC residues approx 1.5 - 2% of mass throughput)
Add Contingency	1.25% of IGCC output	(10% contingency ARD estimate)
Total parasitic load	13.75% of IGCC output	

COST BENEFIT ANALYSIS

1.0 ENERGY OF SYNGAS OUTPUT FROM GASIFIER TRAIN

Total mass input of solid fuel	0.840m tonnes pa	(See breakdown above)
Mass ratio Syngas output to solid fuel input	1.12:1	(Average GLI estimate including regasified heavy hydrocarbons)
Calorific value of Syngas	16.4 MJ/kg	(Average GLI estimate including regasified heavy hydrocarbons)
Total Syngas energy output pa	**15.429m GJ pa**	(Average at design gasifier load. Gasifiers can be ramped down to 20% of throughput, or throughput can be increased by increasing coal or Tyre Derived Fuel proportion)

2.0 ENERGY REQUIREMENT INTO CCGT TRAIN

Nominal CCGT output		Approx. 250MW	(GE Energy CCGT Model 206FA)
Nominal CCGT efficiency		Approx. 55%	
CCGT output with duct burn of additional Syngas		Approx. 295MW	
CCGT efficiency with in duct Syngas burn		Approx. 53.5%	
Total base load energy requirement		0.250GW x 365 days/year x 10 hours x 0.92% utilisation x 1/0.56% efficiency = 1499 GWhrs = 5.397m GJ pa	
Total peak load energy requirement		0.295GW x 365 days/year x 14 hours x 0.92% utilisation x 1/0.5275% efficiency = 2629 GWhrs = 9.464m GJ pa	
Total energy requirement		5.397 + 9.464 = 14.862m GJ pa	
Syngas energy supply into CCGT train		14.862m GJ pa	(All normal running operations and 'warm start')
Add contingency for cold starts, load	Syngas	0.567m GJ pa)	
trimming and other losses.	Natural Gas	0.250m GJ pa)	(Contingency 5.5% total CCGT energy input requirement)
Total gas energy supply to CCGT train		**15.679m GJ pa**	

3.0 TOTAL ENERGY SUPPLY INTO PLANT

Coal: 0.09m tonnes pa @ 28MJ/kg	2.52m GJ pa	(16.3% of total)
Biomass: 0.025m tonnes pa @ 15MJ/kg	0.375m GJ pa	(Combined
Wastes: 0.700m tonnes pa @ ave. 17.30MJ/kg	12.108m GJ pa	(82.1%
Landfill mining: 0.025m tonnes pa @ 7.5MJ/kg	0.187m GJ pa	(of total
Natural Gas	0.250m GJ pa	(1.6% of total)
Total energy supply into plant	**15.433m GJ pa**	(Exc approx. 1m GJ pa gross energy inputs which are deducted from the net electricity output as parasitic loads, see below)

4.0 SPLIT OF GENERATING CAPACITY

Steady state operation	Average	
IGCC capacity running on 100% Syngas	Approx. 0.250GW	
ORC capacity: 25% recovery of 45% total waste energy	Approx. 0.030 GW	
less parasitic and plasma loads	Approx. (0.0345) GW	(Approx. 12.5% of 0.25GW + 10% contingency)
Sub-total Average net electricity output	Approx. 0.2455GW	

Load cycling operation	Base	Peak	
Steady state net CCGT generation	0.2455GW	0.2455GW	
Syngas Plant load cycling	Increase load	Reduce load	(Syngas plant runs antiphase to daily generating cycle)
Variation to 0.0345GW parasitic load	(0.010GW)	0.010GW	(Syngas plant parasitic load cycle from 0.0475GW base to 0.0275GW peak)
CCGT plant Syngas duct burn	zero	0.045GW	
2 stage ORC load cycling	(0.010GW)	0.010GW	(ORC cycle same phase as daily cycle from 0.020GW base to 0.040GW peak)
Total net electricity output	0.2255GW	0.3105GW	
Average total power output of plant	**Approx. 0.275 GW**		(Excludes CHP @ approx. 10% of waste heat throughput assuming 12 month pa commercial heating and cooling demand via adsorption chillers, or similar)

5.0 REVENUE FROM SALES OF ELECTRICITY AND WASTE 'GATE FEES'

Sales of peak power:	0.3105 GW x 365 days x 14 hours x 92% utilisation x £60/MWhr = £87.6m pa	
Sales of base power:	0.2255 GW x 365 days x 10 hours x 92%utilisation x £50MW/hr = £37.9m pa	
Waste 'gate fees'	See breakdown above	Approx. £63.3m pa

Total revenue from electricity and waste excluding all other sources **Approx. £188.8m pa**

6.0 OPEX

Fuel costs

Waste	Accounted for under revenue, not costs.	Net zero	(See Above)
NG	Approx. 0.25m GJ @ £6.25/GJ	£1.625m pa	(Nominal quantity for cold starts only, use Syngas for warm starts)
Coal	0.09m tonnes pa @ £50/tonne	£4.5m pa	
Biomass	0.025m tonnes pa @ £25/tonne	£0.625m pa	
Landfill mine	0.025m tonnes pa @ £5/tonne	£0.125m pa	

Total fuel costs Approx. £6.875m pa

O and M costs

Gasification plant: 0.55GW @ $100/kW pa	£33m pa	
CCGT: 0.275 GW @ $45/kW pa	£7m pa	
ORC: 0.025 GW @ $15/kW pa	£0.5m pa	(ARD estimate. 33% of CCGT O and M)
Pelletising plant and landscaping operations	£10m pa	(ARD estimate: 40 personnel x £40k pa x 250% variable overhead + 100% fixed overhead, plus head, plus £5m pa landfill restoration costs, excluding landfill mining costs above. No cash value ascribed to potential future landfill property development, or saving on costs of 60 year maintenance costs after landfill op's cease.)
Add Contingency	£5.0m pa	(O and M contingency 10%)
Total O and M costs	Approx. £55.5m pa	
Total OPEX pa	**Approx. £62.4m pa**	

7.0 FREE CASH FLOW

Total revenue	Approx £188.8m pa	
less total OPEX	Approx. £(62.4)m pa	
Net revenue	Approx £126.4m pa	
less contingency	Approx £(6.4)m pa	(Total OPEX + O & M contingency £10.6m pa = 10.5%)
Total free cash flow	**Approx. £120m pa**	

8.0 CAPEX

Off site infrastructure costs.		Zero	(All infrastructure exists, costs all fully written down)
Gasification plant: 0.55GW @ $2.25 bn/GW		£0.5 bn	(Aker Solutions Ltd. advise approx. £1.0 bn for 2.25m tonne pa gasifier, APC and ASU plant)
CCGT plant: 0.025 GW at $1.0 bn/GW		£0.15 bn	(Well established trade figure)
ORC plant: 0.0.025 GW @ $1.5 bn/GW		£0.025 bn	(ARD estimate CCGT £/W + 50%)
Pelletising plant	Item	£0.15 bn	(ARD estimate)
add contingency		£0.1 bn	(Total CAPEX contingency 12%)
Total CAPEX		**Approx. £0.925 bn**	

9. Return on Capital Employed

NPV of capital investment	£0.925 bn	(includes 12% contingency)
Free Cash Flow	£120m pa	(Includes 10.5% contingency)
Investment life time	25 years	
ROCE average over 25 years	34%	
ROCE exceeds 9%	Year 0	

REW standards: WACC = 9%; and ROCE = 14%. Scheme ROCE exceeds 9% from year 0 and average ROCE = 34%. Scheme outperforms RWE standard investment criteria

INVESTMENT OUTPERFORMS RWE STANDARD INVESTMENT CRITERIA WITH GOOD POTENTIAL FOR PROFITABLE 'UPSIDE' AND COVER FOR 'DOWNSIDE' RISKS

Investment appraisal based solely on material input and energy output costs. Other financial 'add ons' have been excluded. Sales of: Double ROC's; heat; recyclates; biogas; processing of 'green' and food wastes, and growth of on site biomass crops excluded. Land value enhancement excluded.

Double ROC's available for approx. 25% of total fuel input which is effectively zero carbon (25ktpa of biomass @ 0% carbon content, and 550ktpa of MSW, C and I and landfill mined materials which are deemed to be 65% carbon content). Further reductions in carbon content may be achieved if required via CO_2 capture at the Rectisol gas clean up process, and subsequently during catalytic methanation of Syngas to Synthetic Natural gas (SNG)

DIDCOT POWER STATION AND SUTTON COURTENAY LANDFILL AVERAGE 275MW LOAD FOLLOWING MULTI-FUEL IGCC - RETURN ON CAPITAL EMPLOYED

Profit & Loss *(in GBP m)*	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Revenue	189.00	189	189	189	189	189	189	189	189	189	189	189	189	189	189	189	189	189	189	189	189	189	189	189	189
Fuel input costs	7.00	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
Operating & Maintenance Costs	62.00	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62
EBITDA	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120
Depn & Amort	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37
EBIT	83	83	83	83	83	83	83	83	83	83	83	83	83	83	83	83	83	83	83	83	83	83	83	83	83
Capital employed	925	888	851	814	777	740	703	666	629	592	555	518	481	444	407	370	333	296	259	222	185	148	111	74	37
ROCE	9%	9%	10%	10%	11%	11%	12%	12%	13%	14%	15%	16%	17%	19%	20%	22%	25%	28%	32%	37%	45%	56%	75%	112%	224%
AVERAGE	34%																								
Capex	925.00																								
Project life	25.00 years																								

Overall fuel mix approx. 16.4% coal : 82% mixed wastes and biomass : 1.6% Natural Gas
Solid fuel mix approx. 700,000 tonnes mixed wastes; 25,000 tonnes biomass; 90,000 tonnes coal, and 25,000 tonnes of landfill mined wastes pa.
Gas mix varies 98% Syngas:2% NG when peak to base load cycling, ramping down to 87% of full load Syngas throughput at continuous base load.
Revenue: Wastes @ £100 per tonne, peak power @ £60/MWhr and base power @ £50/MWhr.
Electricity output: Base load 225MW for 10 hours per day; peak load 310MW for 14 hours per day. Average 275MW.
CAPEX includes 12% contingency
OPEX includes 10% contingency
Plant design parasitic load includes 10% contingency
CCGT input energy requirement included 5.5% gas energy contingency.
ROCE exceeds 9% from Year 0.
Average ROCE of 34% pa over 25 years.

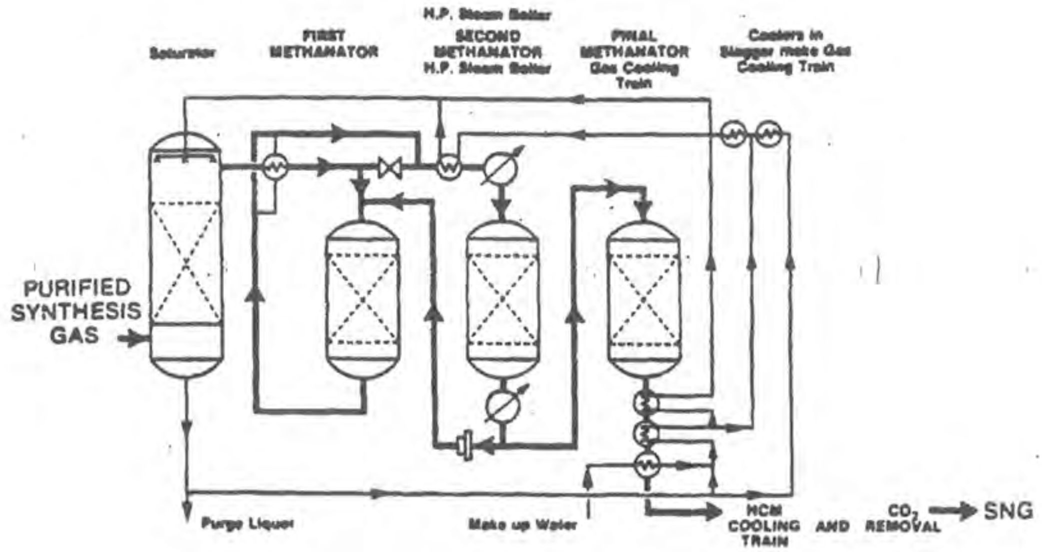
Preliminary Results Summary

Company	**Didcot Sutton Courtney EfW v8.0**
Feedstock	**840 ktpy mix as per 11082010**
Proximate analysis (wt%)- As fed to gasifier	
Moisture	8.61
Volatiles	56.54
Ash	17.81
Fixed Carbon	17.04
Total	100.00
Ultimate Analysis (wt%, daf):	
Carbon	66.83
Hydrogen	7.23
Oxygen	22.79
Nitrogen	1.32
Sulphur	0.91
Chlorine	0.92
Total	100.00
CV (HHV, kJ/kg(daf))	29152
Parameters	
Number of Gasifiers	1
Gasifier internal diameter (m)	3.6
Gasifier pressure (bara)	41
Oxygen purity (mol%)	95
Steam/oxygen ratio (molar)	1.00
Coal throughput (t/day ar)	630
Coal throughput (t/day as fed to gasifier)	630
Flux rate (t/day)	1
Oxygen rate (Nm3/hr)	5189
Oxygen usage (kg/kg daf coal)	0.3607
Steam rate (kg/hr)	3924
Steam usage (kg/kg daf coal)	0.2031
Outlet gas temp (°C) (see note 1)	349
Crude Gas Production Rate (Nm3/hr, dry) (see note 2)	30451
H2+CO Prodn, rate (Nm3/hr, dry)	20989
CH4 Prodn, rate (Nm3/hr, dry)	4714
Slag production (t/hr)	4.64
Cold Gas Efficiency (%) (see notes 3 & 4)	87.5
Crude Gas Composition (mol%, dry):	
Nitrogen	4.27
Carbon dioxide	9.31
Carbon monoxide	45.15
Hydrogen	23.54
Methane	15.48
H2S, COS and CS2	0.38
CxHy	1.82
NH3, HCl and HCN	0.04
Total	100.00

Crude Syngas cv: ~ 16.4 MJ/kg
Mass ratio ~ 1.12:1

Notes

1. Gas temperature at gasifier outlet . This will be dropped to 160°C at outlet of Waste Heat Boiler
2. Normal conditions used are 1.013 bara and 0°C
3. Based on (Cooled gas product)/(Coal and fuel gas inputs)
4. Partial recycle of by-products has been assumed



Typical Gas Compositions from a HICOM Pilot Test

Component	Feed to HICOM Reactor % mol	Product from HICOM reactor % mol
CO	12.6	1.1
CO_2	43.0	53.1
H_2	11.7	5.5
CH_4	31.7	39.3
N_2	1.0	1.1

Range of Operating Conditions

Inlet Temperature, °C	230 - 320
Pressure, bar	25 - 70
Maximum Temperature, °C	460 - 640
Total Test Time, h	15,000

FIG. 3-2 HICOM PROCESS Source: Ref. 4 & 5

GL Noble Denton

[redacted]

[redacted]

26 July 2010

Dear Tony

Thank you for your letter dated 11 July 2010, drawing our attention to statements at the Ardley Incinerator Planning Public Inquiry where it was claimed by witnesses present that the BGL gasification technology was not available for commercial use and thus not BATNEEC for conversion on waste to power.

This claim is incorrect as I hope will be shown by this letter which takes the form of a brief history of the development of the BGL Gasification Technology development, a statement of its current status and a further statement of our capabilities in supporting and delivering the technology to potential clients.

BGL Background

Investigations into gasification originally began at the Gas Council's Midlands Research station in 1958 using a 3ft gasifier. In 1974 development moved to Westfield Development Centre where a series of BGL gasifiers were constructed, initially by conversion of existing Lurgi Dry Ash Gasifiers.

Over 180000 tonnes of US and UK coals were gasified at Westfield representing 14,300 hours operating experience. This experience included a 90 day run to demonstrate that the gasifier components were capable of meeting life expectancy and reliability requirements and operation with US and UK power station fuels demonstrating the load following capabilities necessary for power generation.

This work was funded by British Gas and Lurgi with significant additional funding from government bodies such as the Department of Trade and Industry (DTI) and the US Department of Energy (DOE). Funding also came from industry consortia such as the Electrical Power Research Institute (EPRI). Overall spend during the development of the technology is estimated to have been in excess of £350 million.

The BGL gasification concept was thus proven on commercial scale gasifiers but at the conclusion of the programme in 1992 the need for SNG had not materialised in the UK and further development by British Gas was limited to feasibility studies.

Scale up of the Technology at SVZ

The first commercial application of the BGL was in the form of a 3.6m internal diameter unit built at the Schwarze Pumpe site for SVZ. Design and construction of this plant began in 1996 and it was commissioned in 2000. The plant was in operation until late 2007. The gasifier was used to gasify a combination of coal (20%) and waste feedstocks (80%) and produced a syngas used for power generation and methanol production. When operating on coal the plant met or exceeded all its design parameters and has shown increases in gasification efficiency compared to the smaller diameter gasifiers operated at Westfield.

In 2007 the BGL gasifier ceased operation. This was due to Sustec, the site owner, ceasing waste gasification activities at the site after a halving of the price of methanol and difficulty in sourcing supplies of waste to gasifiy. The gasifier at SVZ (and all associated documentation and records) was however bought by Envirotherm GmbH. This gasifier is currently being transported to India where it will be joined by a second, newly constructed BGL, in a plant to be located near Calcutta. Currently completion of this new plant is expected to be in late 2011. Envirotherm have also recruited several gasification engineers from the SVZ site to strengthen their BGL team

Continued Development of the Technology

In 2004 Advantica (now GL Noble Denton) reached agreement with the Yunnan Coal Chemical Group (YCCG) to construct a 2.3m slagging gasifier at a site in Kaiyuan, Yunnan P.R. China. The process design of this plant was carried out by Advantica Engineers at Loughborough and the plant was successfully commissioned in 2006. YCCG have since constructed a further commercial scale plant.

The YCCG project and other enquiries led Advantica to re-establish a gasification team to actively market the BGL technology, primarily in China, but also in the US and Europe. At the same time Envirotherm GmbH (successor to Lurgi's rights to the BGL technology) started to actively market the BGL technology in North America through a sister company, Allied Syngas. Unfortunately the majority of gasification projects in the USA have however been put on hold due to changing economic conditions.

Marketing efforts in China brought fruit in the form of a contract for the license and design of a second commercial BGL gasification plant which was signed with Hulunbeier New Gold Chemical Co. Ltd. in May 2008. This plant is currently under construction near Hailar, Inner Mongolia, P.R. China. Employing two 3.6m diameter gasifiers, the gasifiers will provide gas to a chemical complex producing 800,000 t/year of urea. The majority of the major vessels and items for this plant have been fabricated in China by local engineering companies whilst proprietary internal components were supplied by Western companies through a GL subsidiary. Preliminary commissioning of the gasifiers is expected to begin in September 2010.

A further commercial BGL plant has since been designed for China Yituo Group to provide fuel gas for an Industrial Complex in Henan Province P.R. China. The process design for this plant has been completed by GL Noble Denton and the Detail Design is currently being undertaken by the clients Engineers. Commissioning of this plant is expected to take plant in 2011.

Summary

1. GL is the direct successor to British Gas Research and Development and as such owns the British Gas Intellectual Property Rights to the BGL Technology. The Lurgi Intellectual Property rights are owned by

Environtherm GmbH. A cooperation agreement is in place between GL and Envirotherm regarding the BGL technology.

2. GL is actively marketing the BGL technology worldwide and has a team of engineers who, with support from Envirotherm have delivered process designs for 3 such plants since 2004.

3. The technology operated gasifying waste and coal mixtures in Germany from 2000-2007 meeting all state environmental requirements. Envirotherm have since bought the BGL gasifier from SVZ and have ownership of all the documentation and direct access to experience from that site.

4. GL can currently offer clients BGL gasifiers of 2.3m or 3.6m internal diameters. When operated on waste-coal mixtures these units would be capable of producing approximately 75 and 185 MW fuel gas equivalent respectively. We are also currently basing a bid for a project in China on a 4.0m gasifier operating at 40 barg pressure – this would have a throughput of approximately 230 MW when operating on a suitable coal-water mixture.

5. Chinese engineering companies have proved capable of constructing the process vessels required for the 3.6m gasifiers. With the exception of proprietary internal components for the gasifier, all other equipment items have been successfully sourced by the Chinese Engineering company building this plant. We have no doubt that a competent UK or European contractor could do the same. The proprietary components for the gasifiers were sourced by a GL subsidiary and the companies who manufactured them have confirmed to us that they would welcome the opportunity to respond to further orders.

I hope this letter is sufficient to convince you of the commercial viability of the BGL gasification technology as a means of converting waste to energy.

Yours faithfully

[redacted]

Managing Director UK   Head of Gasification

[redacted]

Coal Gasification Technologies

In the early 1990s, British Gas plc completed a coal gasification research, development and demonstration programme.

The programme began in 1975 in collaboration with Lurgi Energie und Umwelt GmbH. The programme's focus was the British Gas/Lurgi (BGL) gasifier, a slagging version of the long-established Lurgi dry-ash gasifier. Conversion to slagging operation gives the BGL gasifier several advantages over the original Lurgi design, including:

- Higher coal to product-gas conversion efficiency
- Significantly lower steam usage
- Significantly higher plant throughput
- Ash replacement with a non-leachable glassy solid

Between 1975 and 1981, a 1.8m-diameter gasifier was operated with a throughput of 300t/day at an operating pressure of 25 bar. In tests, the gasifier, the process gasified over 100,000 tonnes of coal with ash contents up to 21%, sulphur levels up to 4.5% and a wide range of ash fusion temperatures. After 1981, a 2.3m-diameter gasifier was operated for over 5,000 hours gasifying over 75,000 tonnes of coal. The programme demonstrated three methods of handling fine particles in the coal: briquetting for addition via the lock-hopper, dry injection via tuyeres and water slurry injection via tuyeres.

In 1990, the BGL gasifier's electricity generation performance was demonstrated with support from the Department of Trade and Industry (DTI). Electricity was generated from cleaned raw product-gas produced in the gasifier using a Rolls-Royce Olympus gas turbine.

The demonstration proved that the technology could produce electricity efficiently from coal and that the BGL gasifier could rapidly ramp from 30% to 110% of design throughput at rates of 5% of throughput per minute and down at rates of 20% a minute, easily meeting typical utility flexibility requirements. The data generated allowed commercial guarantees to be given for the gasifier - whether used for integrated gasification combined cycle (IGCC) power plants or synthesis gas production.

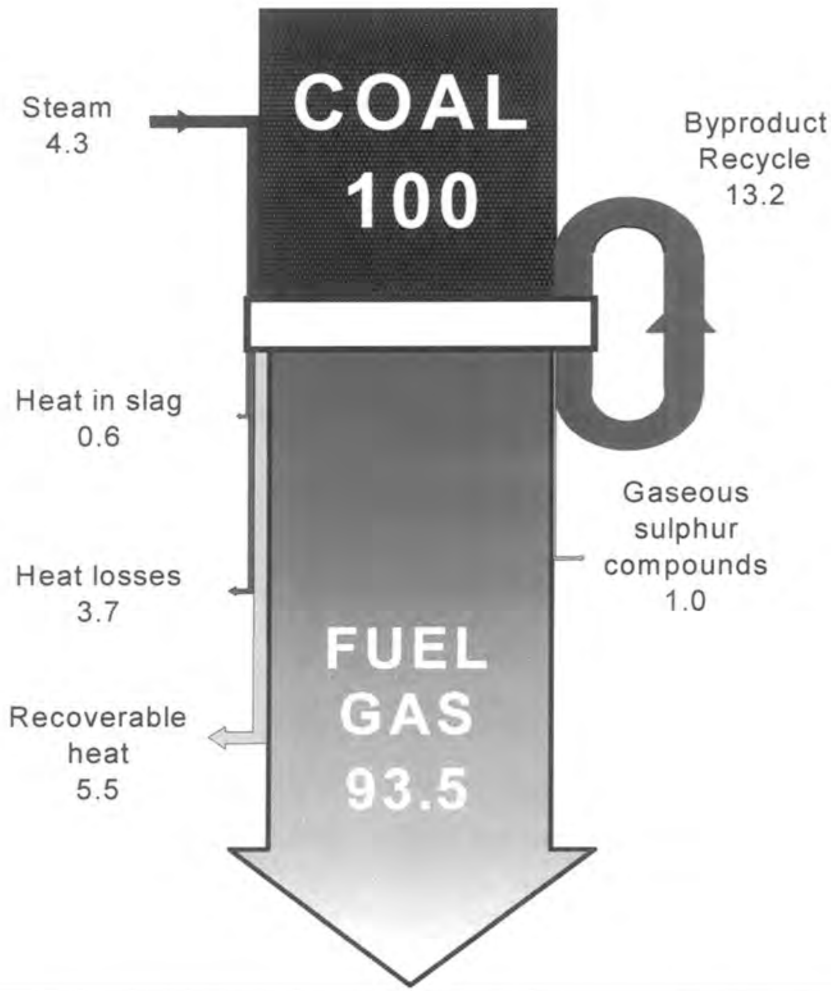
A concluding study commissioned by the DTI showed that a BGL IGCC plant would be an efficient and economic process to generate electricity and that it was more environmentally acceptable than conventional coal-fired power stations.

The final phase demonstrated the performance of the BGL gasifier at pressures up to 70 bar in a newly built 200t/day gasifier with a 1.2m internal diameter. Tests were carried out using a rank 802 coal with a 5% ash content. Gasifier operation was excellent over the entire pressure range from 25 to 70 bar and demonstrated that increasing methane concentration in the product gas and increasing throughput was achievable at higher pressures.

Subsequently the gasifier scale up has been demonstrated by construction and operation of a 3.6m diameter gasifier at the commercial SVZ plant in Germany. This gasifier also demonstrated the handling of a wide range of waste feedstocks and the co-production of methanol, syngas and power.

Fixed Bed Gasifier Advantages

BGL Gasifier



- Heat recovery from product gas by contact with coal bed
- Low oxygen consumption – 50-60% of that for entrained flow gasifiers
- High cold gas efficiency
- High carbon conversion
- Low gasifier outlet temperature
- Inexpensive and well proven conventional gas cooling train
- Low CO_2 content in Syngas

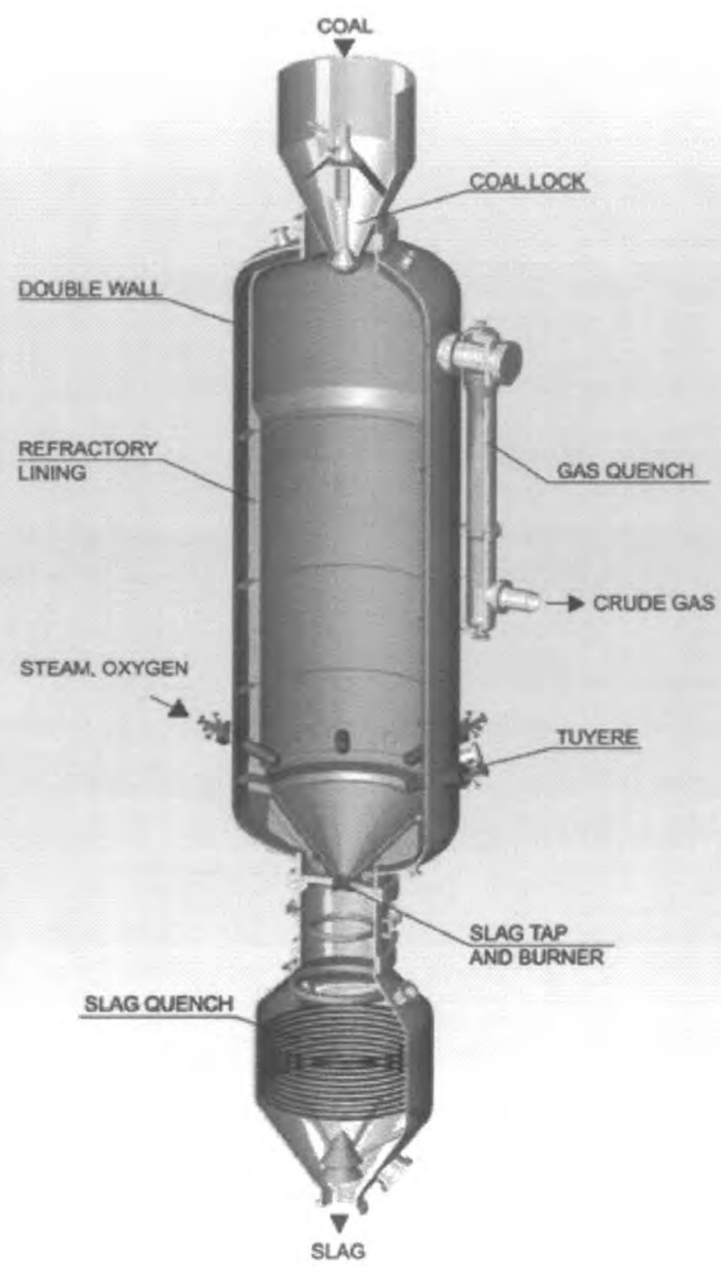
Germanischer Lloyd

Operational

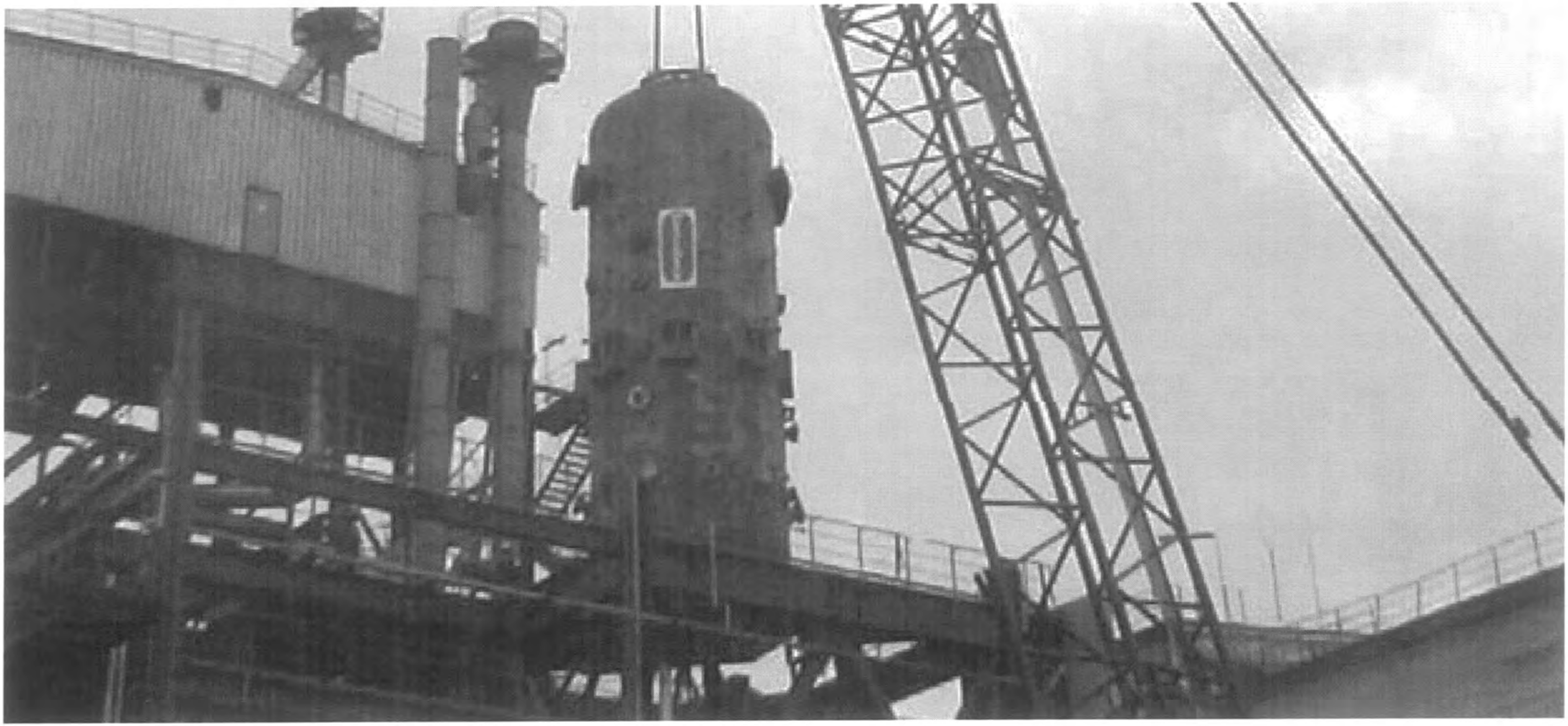
- Extensive development history (Lurgi: 75% of worldwide coal gasification experience)
- High cold gas efficiency between 82% and 93% / high specific throughput
- Low oxygen consumption (ca. 0.5-0.6 kg / kg Coal)
- Low steam consumption (ca. 0.3-0.4 kg / kg Coal)
- Lower aqueous liquor production
- Fuel flexibility (nearly all coal types and other types of fuels (e.g. waste) can be processed)
- Excellent load following capabilities
- Modularity (spare/reliability)
- Slag as by-product is non-leachable (vitrified) and can be utilized (road work)

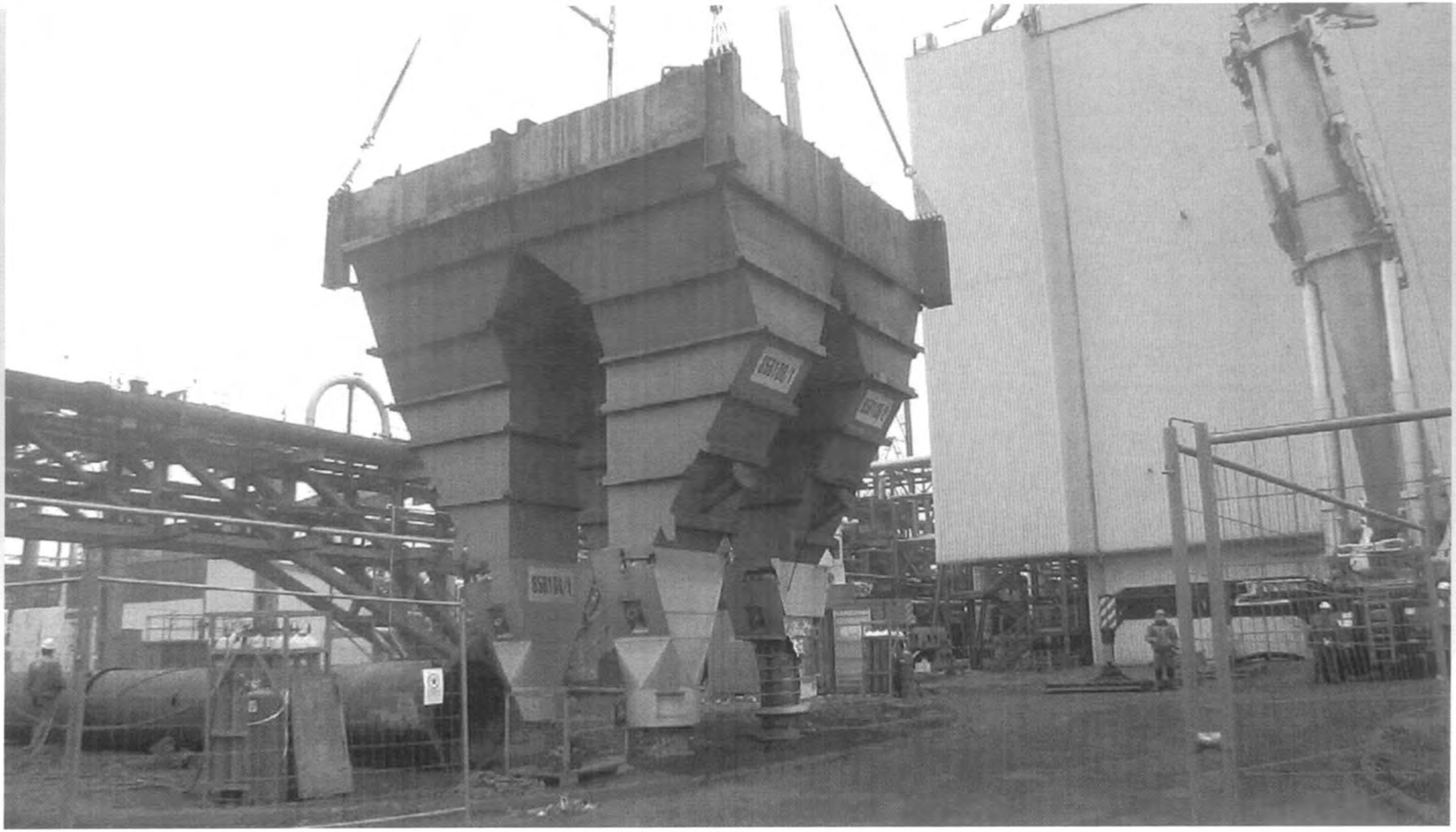
Capital/Investment

- Simple gasifier design (no exotic materials, no sophisticated heat exchangers)
- Smaller air separation unit (ASU) due to low oxygen requirements



EX SVZ 3.6m DIA BGL BEING REMOVED TO CALCUTTA





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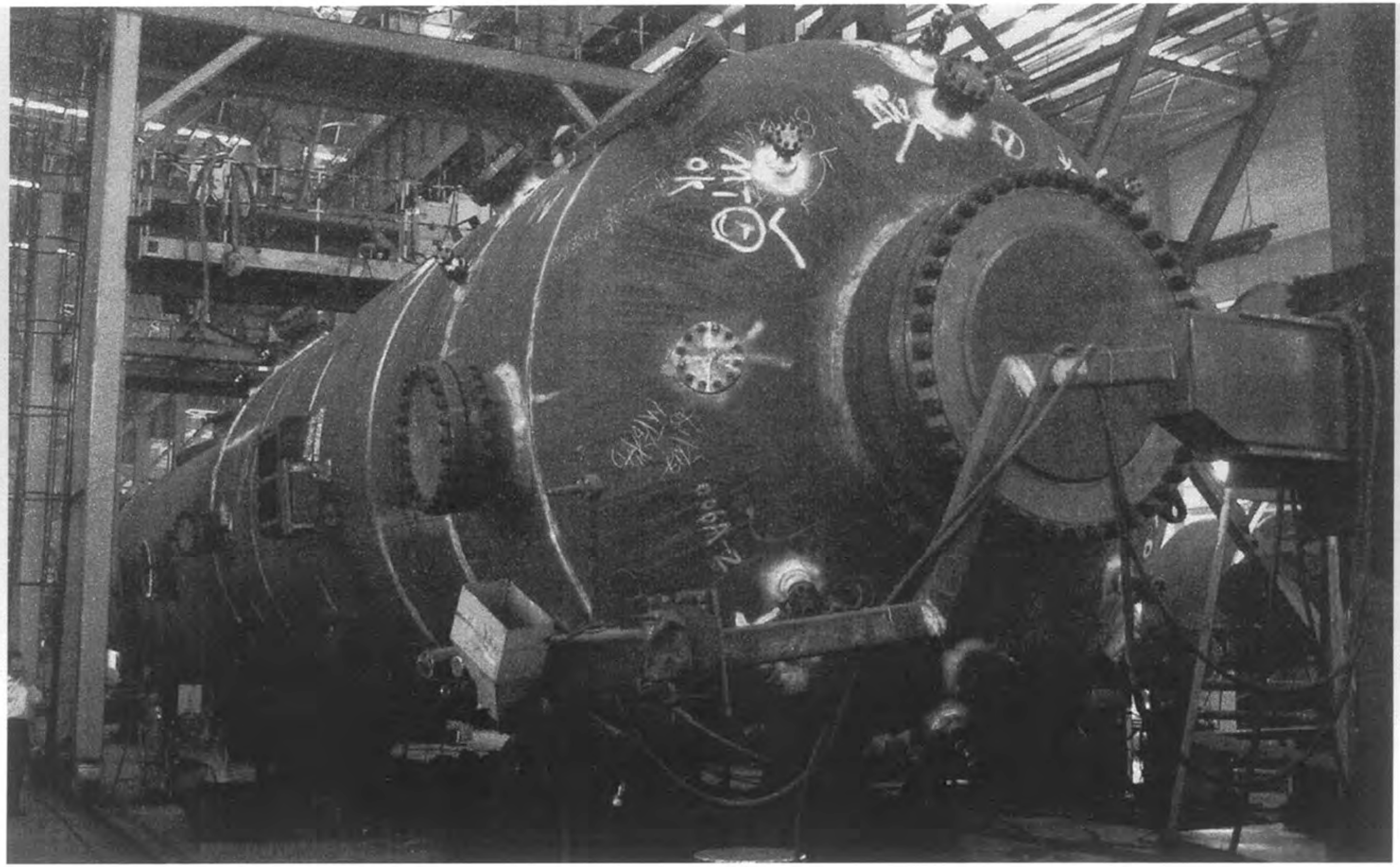
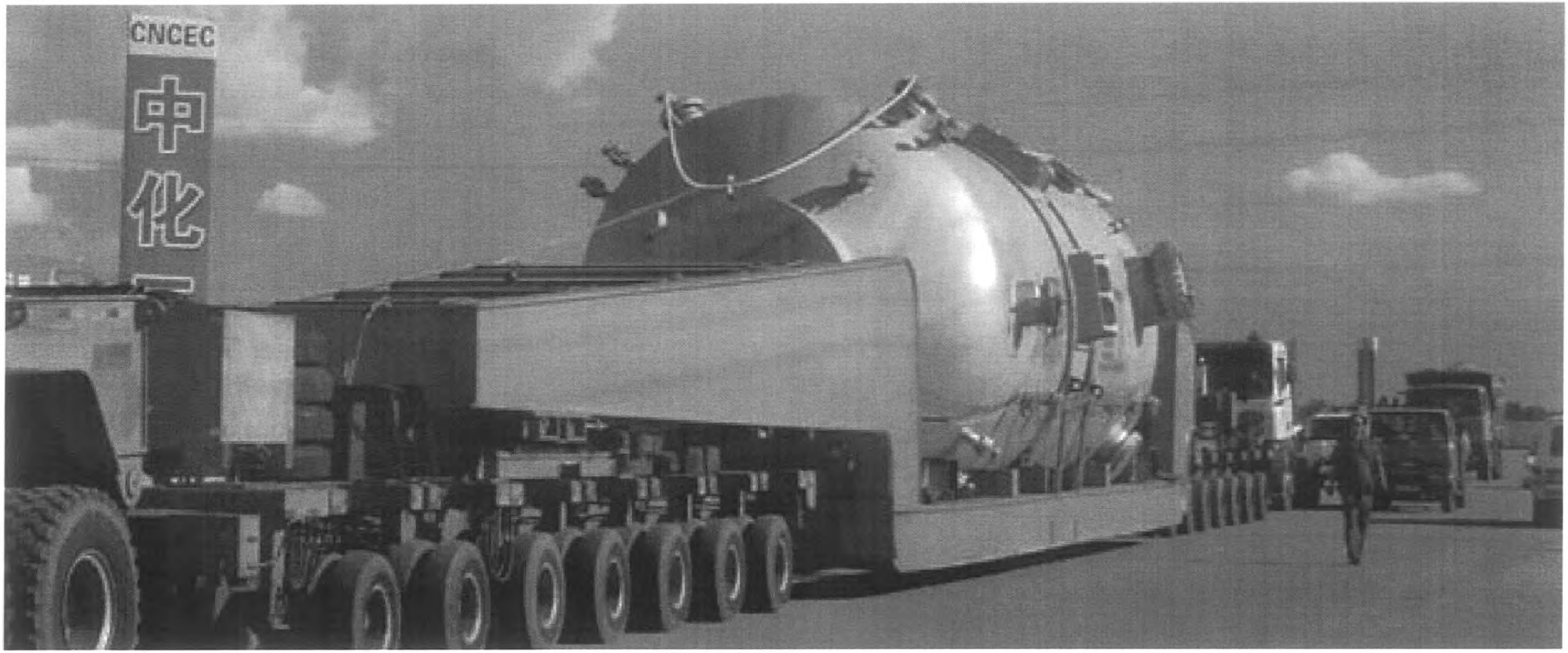
NEW 4.0m BYL BEING FABRICATED IN CHINA

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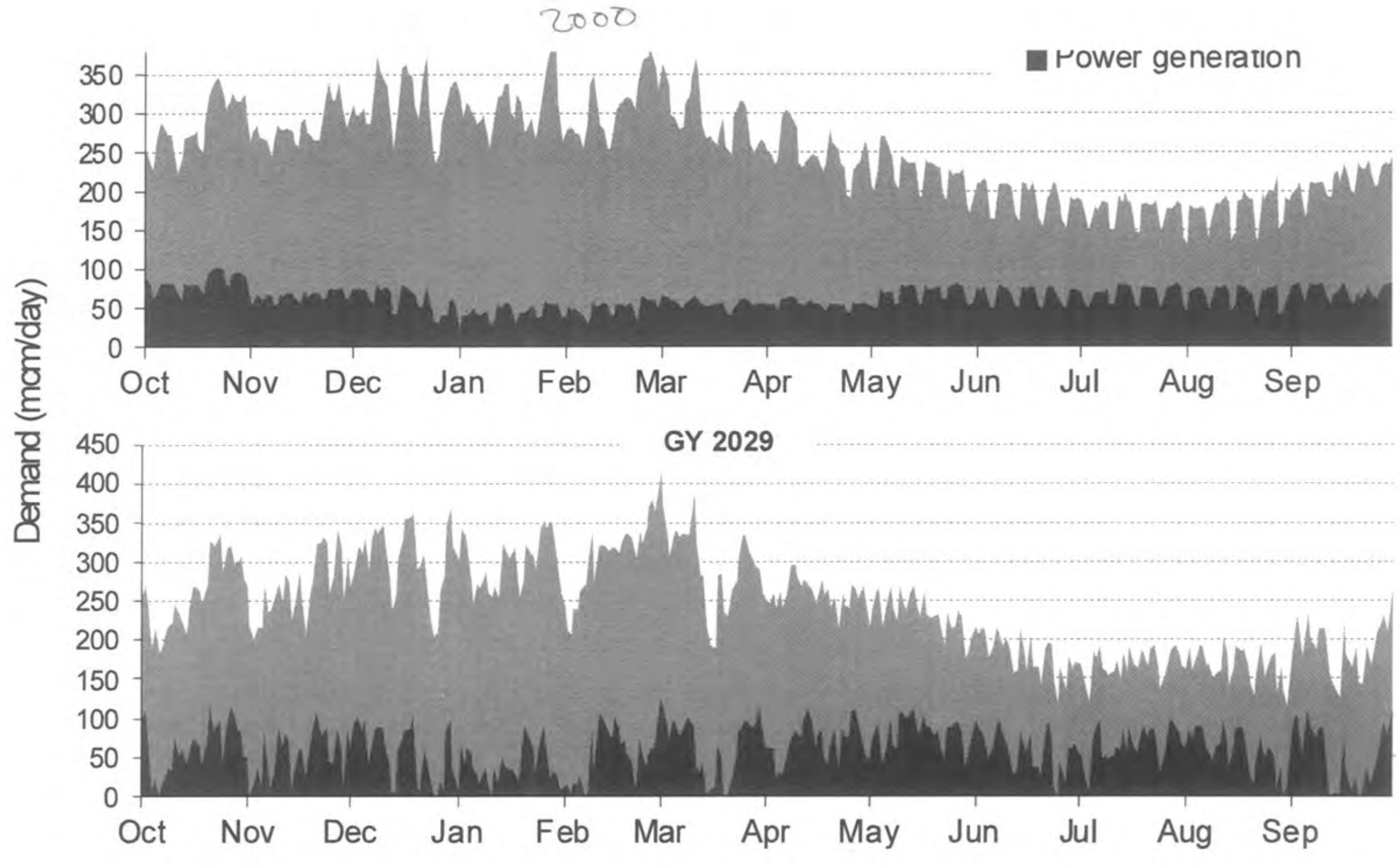

EXTRACT FROM POYRY ENERGY CONSULTING LTD REPORT ON INTERMITTENT GAS TO SUPPORT INTERMITTENT WIND IN 2029/30.