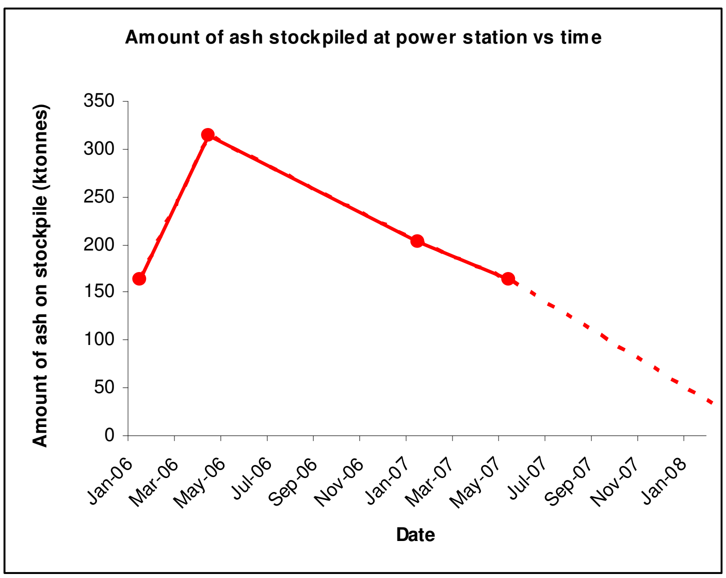
Report No. SRL/PFA/001.4d

PFA from Didcot Power Station

A Summary of Alternative Options for its Disposal

by

R Riggs, B J B Crowley and I C Kemp



SUMMARY PFA REPORT

commissioned by

Save Radley Lakes

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September 2007

LIST OF CHANGES

The following summarises the main changes to this report since version 3 (August 2007)

- Executive Summary added.
- Implications of the recent Davidson Review.
- Changes necessitated by Npower's re-publication of their ash disposal data. This has resulted in a new section on ash disposal rates (**Ash Disposal Statistics since 2005: So what has happened to all the ash?)** and major changes to Appendix 1. The new data, although substantially different to the old, do not affect the conclusions of this report.
- Additional suggested uses of PFA. The list is virtually endless. New section on **Beneficial Use** under **Alternative Options**.
- Conclusions strengthened to include more about CO_2 emissions savings (also added to summary).
- Additional general recommendations to both Government and RWE npower.
- Reference to Climate Change Regulations failing to account for offsets, and recommendation to Government on this point.
- Cumulative stockpiled amounts of ash are now shown in Table 1 (Appendix 1).
- Tables in Appendix 1 now include the 6-year averages.
- Totals corrected in Tables 4-5.
- Various other corrections and additions.

CONTENTS

PFA FROM DIDCOT POWER STATION

A summary report prepared by Richard Riggs Ph.D., Basil Crowley D.Phil. C.Phys. F.Inst.P.
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SUMMARY

This report examines the claim in the Environmental Statement, submitted by RWE npower, operators of Didcot A power station, with their January 2006 planning application, that dumping pulverised fuel ash (PFA) in Radley Lakes is the only option for their surplus PFA. We consider how much is produced, where it goes, and how much it costs, and offer some alternatives to their proposal. These include: changes in power station operation, exploiting further uses of PFA, and alternative disposal means (including storage and beneficial landfill, and noting alternative transport options). We conclude that Npower's planning with regard to their waste management has been inadequately thought out, and is based upon taking the easiest options in the short term. They have not considered all possible alternatives, and have chosen a method that will cause irreversible damage.

We argue that the perceived logistical difficulty of managing ash between winter production and summer sales is not a good enough reason to destroy Thrupp Lake, nor is the fear of not being able to sell enough of it. The EU Large Combustion Plant Directive imposes limitations on the operation of the power station after 2007, and means that, before it closes, sometime before the end of 2015, the power station can only produce a limited amount of ash, an amount that turns out to be both predictable and readily manageable, on a 24/7 basis, within that time frame. There are alternatives to dumping it into lakes that could save, not only Thrupp Lake, but also the emission of up to 1.5 million tonnes of carbon dioxide.

This report also looks at some of the background issues affecting the disposal and reuse of PFA in the UK and offers a number of recommendations to Government that could improve the situation.

EXECUTIVE SUMMARY

1. Between now and 31 December 2015, Didcot 'A' power station will close. This is a requirement of the European Large Combustion Plant Directive.
2. From 1 January 2008, it will only be allowed to operate for 20,000 hours, and, in that time, will not be able to produce more than 1.6 million tonnes of PFA.
3. The power station operators, RWE npower (henceforth Npower) propose to dump a significant proportion of this ash into Thrupp Lake at Radley. (We have calculated the capacity of Thrupp Lake to be 800,000 cubic metres which is enough to take about 800,000 tonnes of PFA. This is rather more than the nominal figure of 500,000 tonnes provided by Npower).

4. The proposal to dump the ash into a mature lake will cause environmental damage, damage that this report argues is unnecessary. It will also deprive local people of a highly valued amenity.
5. Npower seem to have given little consideration to finding alternatives to this. They appear to be driven by a mindset which dictates that an on-tap disposal facility, which is what the Radley Lakes disposal option literally amounts to, is their only way to cope with the ash on a "24/7" basis, and that without it, they cannot guarantee to be able to operate the power station when needed to.
6. PFA is a potentially valuable material with lots of uses in construction and land restoration.
7. Waste Recycling Group, the operators of the neighbouring waste site, have contracted to take 96,000 tonnes of untreated PFA per year from Didcot, on a regular monthly basis. They use it for daily capping. They will continue to need a regular supply of capping material after the power station closes, so, if a supply is not stockpiled for anticipated future use, they will need to import material, most probably by road, at additional cost.
8. Other potential uses of PFA include manufacture of cement, concrete, bricks and lightweight aggregates. PFA replaces part of the pozzolanic component in concrete and cement, which is otherwise provided by kilned limestone. Using PFA instead saves approximately 0.9 tonnes of CO_2 emissions per tonne of PFA. Potential savings are therefore as much as about 1.5 million tonnes. PFA can be used to make good quality bricks by a sintering process, and also results in CO_2 savings.
9. One effect of EU emissions regulations has been to force Didcot A to operate in a combustion regime that produces "dirty" ash, ie, ash that contains a lot of unburnt carbon, This ash is much less saleable – it is of little use for making concrete – and this has resulted in increased amounts going to landfill since the early 2000s.
10. Npower has recently commissioned ash reprocessing plant at Didcot, able to process up to 125,000 tonnes per year, to produce 'clean' ash for the concrete industry.
11. In August 2007, Npower published figures claiming that, during 2006, Didcot A disposed of over 400,000 tonnes of PFA, more than they produced in that time. However, in September 2007, they published revised figures indicating much more modest sales and total disposals of only 315,000 tonnes. Notwithstanding, it is shown that, between April 2006 and May 2007, Didcot A did dispose of 150,000 tonnes more PFA than it produced in that same time, an estimated 500,000 tonnes altogether, with only negligible amounts going to Radley.
12. They have on-site stockpiling with a capacity of somewhere between 300,000 and 400,000 tonnes, and this is how they have coped "24/7" for the past 2 years. There is no reason why this method of operation should not continue for the next few years until the power station closes.
13. Putting these facts together, not only do they not need Thrupp Lake, but they will probably need to retain ash that would otherwise be recycled in order to complete the filling process.
14. Npower's arguments regarding their need for Thrupp Lake are shown to be flawed or, at best, based upon exaggerations, such as, for example, unsustainably high rates of ash production, and the impact of road transport.

15. Npower argue that uncertainties in the ash market mean that they have no choice but to dump it. This is illogical, and is also an example of the attitude (see point 17 below) that results in it being classified as waste, which certainly does not help matters. The evidence is that there is a market out there and power generators need to put in some effort to exploit and expand that market. They certainly won't sell the stuff if they do not bother to try!
16. Government regulations and Green Taxes do little to encourage the recycling of PFA, despite the growing need to conserve landfill space, and to reduce the need to extract primary aggregates, which, in many cases, PFA could replace. There is nothing to encourage the potential CO_2 savings either.
17. The classification of PFA as waste from the moment it is produced is a hindrance to its recycling and reuse in preference to primary materials. While there have been strenuous efforts by the ash industry to get this classification lifted, it seems to be very much the result of the power generation industry's own erstwhile attitude to its disposal.
18. However other power companies are changing their policies in this respect, in recognition that "Clean Coal" power requires a sustainable approach to ash disposal, and that permanent disposal of ash to landfill is becoming increasingly unacceptable. Increasingly, power stations are investing in reprocessing plant with a throughput capability to deal with most, if not all, of the ash produced, and are making provision for above ground stockpiling to cope with demand fluctuations.
19. The report concludes with a number of specific recommendations to the power station operators and to Government as to how Thrupp Lake can be saved and future problems of a similar nature avoided.

INTRODUCTION

Producing electricity from coal produces ash, lots of it. Most of this ash is in the form of PFA, or fly ash, as it is sometimes known. Despite the fact that PFA has many beneficial uses, there is a substantial surplus, which needs to be disposed of.

Since 1983, the 2000MW coal fired power station at Didcot, known as Didcot A, has disposed of its surplus ash by mixing it with water and pumping it as a liquid slurry and tipping it into lakes, once gravel pits, at Radley, 8 km to the north, with the declared intention of restoring the original landscape. For a while, there did not seem, to many, to be a problem with this. Several large gravel pits on the Thames floodplain to the east of the mainline railway, on an area between Radley and Nuneham Courtenay, quietly disappeared as they were filled up with ash as far as the level of the surrounding land. Original trees and hedgerows were all left in place. Sometime in the late 1990s, the regulations changed and, in order to prevent pollution, the lake voids now have to be engineered so that their contents are sealed in by a layer of clay, at least a metre thick, and by surrounding clay bunds. The construction of these bunds, which are large, often rising several metres above the surrounding land, inflicts serious damage on the landscape and involves the total destruction of everything within and around the lake perimeters. This began to raise concern in the local community that the landscape and its ecology, rather than being restored, were being significantly harmed.

When, in June 2005, RWE npower (henceforth referred to as Npower) the operators of the Didcot power stations, applied for planning permission to dispose of half a million tonnes of PFA in the two oldest and most beautiful of the remaining lakes, local people protested vociferously and questioned why such severe damage to the environment should be tolerated for such a mundane purpose. Questions were also raised about risk of pollution. Why were bunds needed, when, in 1982, people had been assured that PFA was an inert substance that presented no hazard to the environment? The wide ranging objections and concern about the lack of an Environmental Impact Assessment (EIA) were strong enough to force this application into abeyance. Npower's retreat was brief, and, in late January 2006, they submitted a new planning application to fill just the larger lake, Lake E, known also as Thrupp Lake. This time, the application was supported by a voluntary EIA. Normal practice allows such an assessment to be carried out by the applicants on their own behalf, and this case was no exception.

One of the things that an EIA needs to examine is the question of need. The Environmental Statement (ES) that Npower has submitted deals with this very superficially, with many distortions of the facts and a great deal of spin, to argue that the power station has no option other than to dispose of the ash in the manner proposed.

It is in this context that this report is written. Its purpose is to determine why PFA has to be dumped in the first place and to identify alternative options for its disposal that might be available to Didcot A. The report attempts to look objectively at the beneficial uses of PFA, the factors contributing to a surplus, how the problem is being addressed nationally, and what the specific issues are for Didcot A.

THE MAGNITUDE OF THE PROBLEM

Britain has 18 coal fired power stations[1]. They all produce PFA, and have found various ways of dealing with it. Npower insists that the only option for the PFA from Didcot is to dump it in a mature lake[2,3].

When Didcot A is running at full power, it can burn up to 19,000 tonnes of coal per day[4], and it is able to handle up to 3,400 tonnes of ash per day. The higher the ash content, the cheaper the coal, so they might prefer to use coal that takes them close to the limit. PFA is the fine ash that goes up the chimney and is about 80% of the total, or 2,700 tonnes per day (the other 20% is the much coarser furnace bottom ash (FBA) all of which is sold). Technically, Didcot A could produce a million tonnes of PFA per year. To give an idea of the quantity, this would cover all of Port Meadow more than a foot (30 cm) deep. Over the 45 year projected lifetime of Didcot A, the area covered would be 100 square kilometres - more than twice the size of the city of Oxford! Fortunately this exaggerates the real situation. Nevertheless, Npower, in their Environmental Statement[3], do resort to quoting such inflated ash production rates to try to justify their pressing need for facilities for its disposal as waste on tap.

In practice, power stations do not run at full power all the time (between 2001 and 2006 Didcot A averaged about 40%). Npower has published[53] annual figures for ash production, and these are analysed in Appendix A. The annual production of PFA is about 300,000 tonnes, and their stated expectation is that, thanks to their recent investment in new ash beneficiation plant, removal of the unburnt carbon thus making the PFA more marketable they will be able to limit their surplus to 500,000 tonnes in total by the time Didcot A closes in 2015. Even if this projection is realistic, it is hard at first sight to understand why they want to spend a substantial amount on the lakes, and do irreversible damage to them, to dispose of a relatively small quantity. The answer, given in the Environmental Statement[3] (ES) accompanying their January 2006 application[2], is that they need to be able to cope with periods of peak production rather than normal operation at reduced levels, and with any circumstances under which other disposal means may not be available. In other words, Didcot needs an on-demand disposal facility capable of handling ash production at peak output levels. This is *not* the same as a disposal facility capable of handling ash production at peak output levels all of the time, ie 24/7. This distinction between a 24/7 capability and capacity to handle 24/7 ash production at peak output, is one that has become blurred in much of the debate, particularly with regard to the potential transportation demands of alternative schemes.

THE CURRENT REGULATIONS AND THE EFFECT UPON COST

We live in a world increasingly shaped by regulations. This can leave decision makers feeling that responsibility has been taken out of their hands, and they just want to settle for anything that satisfies the regulations and makes a profit. So, how do the regulations affect power station policy?

1. The Climate Change Levy[5] on the use of electricity by industry is (April 2007) 0.441 p/unit, unless it is made from renewables. The levy on gas is 0.154 p/unit and that on coal is 1.201p/unit. However power stations, which convert one form of energy (eg, oil, coal or gas) to another (electricity) are exempt altogether, so there is nothing in this policy to encourage power generation by less polluting means.
2. Emissions trading in carbon dioxide[6] emissions, which started in 2005, is one way gas is favoured over coal. It is a marketplace, so the price advantage is not fixed. and it appears to be roughly 0.65 p/unit, at present[a]. In reality, power stations receive most of their EU ETS allowances for free, but pass on their cost to their customers. This seems to be resulting in substantial windfall profits to power companies, rather than incentivising emissions reductions[7]. Whatever the market advantages of gas over coal, worries over the security of gas supplies mean that coal will remain an essential fuel for many years. Moreover, the ETS provides no incentives for offsetting CO_2 savings from related peripheral activities, from the recycling of PFA, for example.
3. The renewables obligation is to encourage burning of renewable fuels, like wood, but they can only be burnt with coal, not with gas.
4. The cost of dumping at Radley is just the landfill tax, £2/tonne for inert waste. The tax, currently at £24/tonne, is being increased steadily on non-inert waste, and will reach £48/tonne by 2011. No increases are planned on inert waste. In Germany, RWE's home country, the landfill levy applicable to PFA is around £40/tonne[8] so they have even tried to export PFA to Britain.
5. The UK Government and the Environment Agency have been over-enthusiastic in their interpretation of the European Waste Framework. For many years, PFA was used for beneficial purposes[14], but its classification as waste under the European Waste Directive has added an expensive bureaucratic load, which now discourages its use for such purposes, and which contradicts other environmental objectives, of making more use of secondary raw materials, and reducing emissions. This was taken up with a Parliamentary Select Committee by the CBI[9] and Innogy[10] but to no avail. The recent Davidson Review[11] of the Implementation of EU Legislation did not offer much help, and seemed to suggest that the classification of PFA as waste is a direct result of the propensity of the producers, ie, the power companies, to discard it. Ironically, it is the attitude of (some) power companies, including RWE npower, that the priority is to get rid of the ash by any means, rather than to dispose

[a] Based upon €19/tonne CO_2 and the 2006 emissions returns[53] from Didcot A and B power stations.

of it properly, that forces Government to classify it as waste. If these companies were to take a more responsible attitude to the problem and start to think of the ash as a resource, then the problem of its classification as waste might go away. Every business in the land is being exhorted to operate in a sustainable way, and power companies especially should not be exempt. All the same, if Npower and other power companies want to appeal against this classification, in order to promote large scale recycling of PFA instead of sending it to landfill, we should support them.

6. In 2002, Government introduced the Aggregates Levy[12], which imposes a tax on new aggregates with the aim of reducing the environmental impact of their extraction, and to help stimulate the market for recycled and secondary materials. The levy is imposed on most primary aggregates and minerals, including sand, gravel and limestone. PFA is specifically excluded from the levy. This ought to encourage the use of PFA for certain construction materials, such as lightweight aggregates, concrete and cement, but, as clay is also exempt from the levy, PFA enjoys no advantage for use in the manufacture of bricks. The levy is quite small, but will increase from £1.60 per tonne to £1.95 per tonne from 1 April 2008.
7. Local Government can also impose sustainability levies on certain environmentally damaging activities. Oxfordshire County Council imposes a sustainability levy on the landfill site next to the power station. The levy is exacted on any material over 200,000 tonnes in any year imported to the site *by road*. The purpose of the levy was to encourage the use of rail transport and to reduce the impact of the waste site on the county's roads. However, it also had the effect of discouraging the site from taking PFA from the power station, as this also came by road, albeit over a very short distance and not via public roads. Any PFA taken by the site contributed to the allowance and effectively reduced the amount of other more profitable waste that the site could take. In 2006, as a result of representations from Save Radley Lakes, and others, this was altered so as to exempt of PFA from the levy and the aggregate limit, provided that it was not imported on *public roads*. This now allows the landfill site to take any amount of PFA without incurring a financial penalty. The lesson here is that Government must scrutinise and review environmental taxation regulations to ensure that they are not having unintended consequences that may actually be contributing to environmental harm.

A tonne of low sulphur coal, costing about £30, produces about 2.7 MWh (2,700 units) of electricity worth about £135 on the wholesale market (nearer £200 to the consumer). It also produces about 110kg of PFA, of which less than 100kg will be dumped, attracting a landfill tax below 20p, which is virtually negligible. So, from Npower's point of view, if ash requires effort to sell, and if they have facilities to dump it, there is little incentive to do anything else.

We note that Npower can well afford to do better. Gas prices are continuing to rise faster than coal prices, and, as we all know, that is pushing up the cost of electricity. Further rises are likely; producing big profits for coal fired power stations, for no extra effort. Each 1p/unit rise will provide Didcot A with a windfall worth about £50 million per year.

Npower paid £3.2 million for the lake, and on top of that there is the work needed to build the bund, the processing facilities, and the later restoration. All that, plus the landfill tax, means they must be prepared to spend at least £10 per tonne of PFA disposed of.

DISPOSAL OPTIONS: WHERE DOES THE PFA END UP?

Building products

PFA has many uses[22], mostly in the construction industry: These include load bearing fill, concrete and cement manufacture, grouting, lightweight aggregate, cement-stabilised PFA eg for hard standings, building blocks, as well as many other more specialised uses. Dry PFA combines with free lime released during the hydration of Portland cement by pozzolanic reaction. This allows it to replace part of the cement component in concrete, offering both technical and economic benefits.

The UK Quality Ash Association (UKQAA)[13] publishes what proportion of PFA goes into various applications, but has not given actual amounts for several years. Much of it goes into highway construction, general fill and land restoration[14]. The value of much UK-produced PFA for other purposes, such as cement and concrete manufacture, lightweight aggregates etc, is small, because of the degraded quality, caused by a coating of unburnt carbon on the PFA particles. The carbon content of Didcot A's PFA is quite high, probably at least 10%[b], and variable[3]. Products made from such ash are not only cosmetically unattractive, but weaker and less durable, because carbon does not bind to cement. If the carbon content of Didcot's ash were reduced, it would be used more widely in building materials, resulting in less waste. PFA is an essential component of many high performance concretes, but it needs to be of suitable quality.

Didcot has investigated many technologies to remove the carbon, and has now installed new plant[15] that can process up to 125,000 tonnes per year. As well as increasing sales, the carbon can go back into the boilers as fuel. It should recover at least 5%, or 6000 tonnes, which would save at least £200,000 per year before selling any clean PFA[c].

Carbon removal is only part of the process of rendering PFA into a construction material. The German-developed Retexo–RISP "IVU-Dispersoft" process[16] is a modern process that uses plant installed on the power station site to manufacture *Dispergat*, an eluation proof, ecologically and commercially viable, cement-like, building material, directly from the raw PFA. In this way the PFA can be converted into a safe high-value product offering wider sales opportunities than even beneficiated PFA. Such an option ought to be attractive to Npower. The evidence is that they were unaware that it even existed, until, that is, their attention was drawn to it by one of us. Retexo offered to test a sample of Didcot PFA free of charge to establish its suitability for this process, but as yet Didcot have not taken them up on this offer.

The RockTron process[17], about to be installed at Scottish and Southern Electricity's[18] Fiddler's Ferry Power Station in Cheshire, takes this even further, and is able to exploit all of the economically valuable constituents of the PFA by breaking it down into a range of high-grade products, leaving no residual waste. Moreover RockTron argue that potential demand for these products is sufficient to use up all of Didcot's anticipated future ash production. Furthermore, even after allowing for capital investment, this option turns a net loss, representing the costs of disposal, into a modest net profit (See Appendix 2). The proposal, when Save Radley Lakes put it forward in 2006, made good business sense. The RockTron process is a wet process, which means that the PFA does not have to be kept dry while in storage. It also means that ash processing can continue after the power station closes, to use up any remaining stockpiles of PFA. However, any PFA pumped to

[b] Published data for Didcot PFA produced prior to 2002[4] give the carbon content (LOI) to be in the range 7-15%. Since the introduction of low NOx burning, Npower claim[3] that the carbon content has "more than doubled".
[c] In 2005, they refired 5,000 tonnes and, in 2006, 4,000 tonnes. (Ref. 53).

Radley would be rendered inaccessible and could therefore not be exploited in the future by such a process.

The use of PFA based cement products, in place of traditional Portland-cement-based materials derived from quarried limestone, saves the production of considerable amounts of CO_2 – that which would otherwise be produced by the limestone kilning used in traditional cement manufacture. Indeed, the potential savings are a measurable fraction of the total carbon emissions from the power station itself: For every tonne of PFA that is substituted for cement, approximately 0.9 tonnes of CO_2 are saved[22]. The potential savings are therefore about 4% of the total CO_2 output of the power station, or about 250,000 tonnes per year.

Unfortunately, it is difficult to see how emissions trading could benefit such an operation although it saves £2.9M worth of CO_2 per year at current prices (see footnote on p. 8).

The manufacture of bricks from PFA is now a commercial reality[19,20,21]. The process is basically the same as that used to make lightweight aggregates, ie sintering, but more controlled, and can be used to make a substitute for just about any masonry material. These bricks are superior, in virtually every respect, to conventional clay bricks: they are stronger and lighter, adhere better to ordinary mortar and require less energy (and hence produce less CO_2) for their manufacture and transportation; they possess low water absorbency, are highly resistant to frost and chemical attack; and they can be manufactured in virtually any colour, shape and surface texture. Moreover the raw material, fly ash, comes at "zero cost". The savings are even greater if the manufacturing process can use waste heat from the power station. This would mean integrating the brick manufacturing plant into the power station itself, an option worth considering as one of the new “clean coal technologies” for the next generation of power stations, including any that may eventually replace Didcot A. Moreover, unlike concrete, the main demand for which comes from large construction projects and therefore has a tendency to be sporadic, the demand for bricks is dependable and virtually inexhaustible. Government proposes to build 3,000,000 new homes in the next couple of decades. That is an awful lot of bricks, more than enough to soak up the country’s entire PFA production.[d]

It may be too late to invest in something like this for Didcot A, as it is nearing its end of life, but it is something worth considering for its successor.

Other uses

PFA has many uses in a wide variety of other industrial and construction activities[22] and a few minutes researching on the internet will expose a huge and rapidly growing literature. Here we list a few of the more important ones.

PFA can be combined with other waste materials, such as plastics, to make new types of synthetic lightweight aggregates (SLA)[23,24] offering a range of new applications, including road surfacing[22,24,25] and concrete for applications where ductility, rather than strength, is a primary requirement.

PFA is being used to make insulating floor and roof screeds. Because the particles are spherical, when PFA replaces primary materials, like sand, the resulting mixtures are easier to work.

PFA offers a surprising range of possibilities as a soil conditioner for agriculture, especially on poor soils. It can complement some organic materials as a fertiliser, and can help the

[d] A letter sent by Save Radley Lakes to Central Government on this topic is reproduced in Appendix 5.

soil to retain moisture. Care is, of course, needed with food crops because of the heavy metal content, but some are safe to grow, and the land can be used for purposes like woodland. PFA has similar properties to volcanic ash, and slowly weathers and improves soil fertility. It has been used to neutralise acid soil, clean contaminated soil, and stabilise wet or unstable soils, eg, road sub bases.

It can be used for landscaping when sufficient natural material is not locally available, eg, for raising ground levels for motorway flyovers, for example[26].

Landfill

As with all waste, landfill should be seen as a last resort, when no other use for the material can be found.

PFA is 95-98% inert. The problem with storing it is the other 2 to 5%, which dissolves in water to produce a rather strong alkaline solution. It also has a small, but unpredictable, mix of compounds that may be leached out and some of these may be toxic. The three main landfill disposal options are as follows:

1. **Lagoons**, into which PFA is pumped as a slurry, and allowed to settle. The water is decanted off into local streams and rivers. Much of the soluble component of the PFA finds its way into this water, and the only way to mitigate the contamination is by dilution and dispersal into the wider environment.
2. **Above ground storage**. PFA is perfectly safe to store in above ground mounds, in suitable locations. These may be landscaped and planted to create beneficial amenities. At Aberthaw, also operated by Npower, PFA is stored above ground on site, to make a hill that partly hides the power station from Cardiff. The PFA from the country's biggest generator, Drax, is a 40 metre high hill, which is now a prize-winning stretch of farmland[27,28].
3. **Grouting of mines**. The ability to pump PFA as fluid paste, which eventually sets hard, makes it eminently suitable for the filling of old mines for the prevention of subsidence (a notable example being the Northwich salt mines in Cheshire). However bureaucracy and concerns over potential contamination of groundwater aquifers make such applications both expensive and difficult to implement.

The third option is clearly not a satisfactory solution for Didcot A, but the first two are compared in more detail below.

Above ground or below ground?

Any form of waste disposal by landfill raises concerns about environmental pollution. When PFA is in contact with water, some pollutants will be leached out. Disposal in lagoons uses large quantities of water, and the more water that is used, the more of the soluble components will be dissolved out.

Leachate from semi-dry PFA stored above ground is much reduced, because it is only exposed to rainwater, which interacts mainly with surface layers. Compacted PFA has a very low permeability, which means that, even in heavy rain, only the surface layers within 50mm of the surface become saturated[29]. Most of the water that is absorbed by the PFA is subsequently evaporated or taken up by plants. Therefore any leachate would be produced very much more slowly than when it is dissolved out by total immersion in water. Experience has shown that properly constructed PFA mounds produce very little groundwater contamination, even when frequently disturbed by placement and removal of ash[29]. The only precautions considered necessary are to place an impermeable layer beneath the mound to prevent groundwater entering the PFA by capillary action (the so called wicking effect) and to maintain a stable upper surface to prevent airborne dust.

When PFA is pumped into lagoons as a slurry, copious amounts of water are decanted off and discharged into local streams and rivers. This water is heavily contaminated with soluble material from the PFA, and these are released in quantities equivalent to that from many decades, perhaps centuries, of exposing a mound to normal rainfall.

Because disposal in lagoons is simple and cheap, it is widely practiced in India and China. As a result, there is now serious concern about pollution and loss of land, and India has set a target of 100% beneficial use of PFA within 9 years. This was seen as important enough for the President of India to include it in an address to the nation in 2005[†]. In Britain, lagoons are now regulated to prevent contact between untreated PFA and groundwater. They must be completely sealed in order to protect groundwater. The effluent must be discharged into suitable receiving water courses which dilute and disperse it more widely. In the case of Lake E, with small and sensitive lake F right next to it, especially strict sealing would be needed to avoid the risk of contamination.

Thanks to the regulation of lagoons, most PFA in Britain is stored above ground. This is clearly preferable, as any pollutants are released at a negligible rate in comparison and are easier to contain, and so cause less harm.

Cenospheres

A small fraction of the PFA consists of hollow silica spheres, and this makes them valuable as a lightweight filler and coating material for use in specialist applications. One example is the Space Shuttle heat shield. The only practical way of efficiently separating these cenospheres is by floating them off in water. Storing PFA dry means they are lost. How does that affect the costing? Production is stated as about 400 tonnes per year[4], and a price of £400 per tonne may be obtained[30]. That would be about £160,000 total, or, as the average amount of PFA sent to Radley has been about 160,000 tonnes, about £1 per tonne. Harvesting, transporting and processing them would be fairly labour intensive. The net value is probably well below £1 per tonne of PFA, so the earnings from cenospheres would not be large enough to affect Npower's policy significantly.

THE BIGGER PICTURE

Britain has 18 coal fired power stations, of which 15 are rated above 0.5 GW, with most of the power coming from 6 companies producing about 4 GW each. In 1997, UKQAA reported 6.2 million tonnes of PFA produced, and 2.7 million tonnes dumped[13.] Since then, they have not reported actual quantities, but the country is now burning about 50 million tonnes of coal per year, which produces about 5.5 million tonnes of PFA. 55% of that is used and 45% is landfill[31] - about 2.5 million tonnes. Britain also has a large stock of landfilled PFA that could be dug up again, if needed.

For the EU, figures from ECOBA[32] are: 45 million tonnes of PFA produced in 2003, of which 47% was used[31]. However the EU seems to be better at finding a good home for the

[†] "As you are aware, the use of coal for power generation results in an increased quantum of fly ash production, which has reached about 100 million tonnes per year. All our efforts are needed to utilise this fly ash not only from environmental considerations, but also to avoid land usage for fly ash dumping. Though there has been a steady progress in fly ash utilisation from 1990, we have a long way to go to reach the target of 100 percent fly ash utilisation."
A.P.J. Abdul Kalam, 25 January 2005.

rest, as only 1.2 million tonnes of it are classified as disposal, most of the remainder being classified as reclamation and restoration. This shows the effectiveness of higher landfill taxes. It would be interesting to know how much of the 1.2 million tonnes of disposal is in Britain.

It is striking that only 4 of Britain's 15 large coal fired stations are in the South (in South Wales, Oxfordshire, and Essex) and Npower own 3 of them. With so much development in the South, these three power stations should be well placed to compete for PFA sales against the Midlands and North. Yet Npower's corporate responsibility reports for recent years[53] show the opposite - most of their PFA output goes to landfill.

One reason is the high carbon content, and they give three examples in the ES of large contracts which they lost as a result. The third one was for Aircrete blocks, which was investigated by the Competition Commission in 2002. Their report made the following comment[33] (the actual costs were edited out):

> "3.52. PFA is transported by road. Haulage costs are significant and variable depending on the distance of the PFA source from the factory. For example, MBM at Newbury quoted an average haulage cost of around £[**] a tonne whilst H+H Celcon at Borough Green told us that its haulage cost for PFA was around £[**] a tonne. The Newbury plant takes ash from the nearby Didcot power station but reduced coal burn means that Didcot no longer produces sufficient PFA for Newbury's needs. Hence MBM has to bring ash from Drax power station in North Yorkshire, resulting in higher transport costs."

Good quality PFA is valuable enough to justify bringing it by lorry from North Yorkshire. MBM are still able to compete for sales in southern England, because they save on transport costs of the finished product. But how much more competitive they could be if they could buy their PFA locally. The other two examples in the ES of lost contracts, ARC and Granulite, ended in the early 90s. It shows that Didcot A has had a PFA quality problem for a long time, well before the change to low NOx burners. As it was so easy just to dump the PFA, where was the incentive to change?

So what are other power companies doing with their PFA? Scottish Power at Longannet and Cockenzie recycle most of their ash and have won a major award recently for innovative construction materials made from PFA. EDF at Cottam and West Burton will reduce the volume of materials sent to landfill by 50% and are investing in treating ash for re-use or recycling. Drax, the UK's biggest coal fired station, sells most of its ash. The rest goes onto an on-site mound that has won awards for nature conservation. Scottish and Southern Electricity are commissioning a Rocktron Plant at Fiddler's Ferry to make cement and concrete from ash. E.ON recycled 93% in 2006 and has invested heavily at Ironbridge, Kingsnorth and Ratcliffe to ensure ash quality is consistent. Alcan are emphasising the re-use of ash in its environmental objectives statement. There is clearly a market for ash out there and Npower appears to be lagging behind in taking advantage of it. During 2001-06, they recycled less than 40%[53] (excluding any unspecified amounts that may have been sent to "beneficial landfill"[e]). Nevertheless, buried deep inside their Corporate Responsibility Report for 2006[34] can be found the words

> "We will continue to develop our ash strategy for the management of ash from coal stations, including: … minimise [sic] environmental impacts of surplus ash disposal".

Nothing is said about how this will be achieved, what might already have been achieved or what targets have been set. With all but one of their coal and oil fired power stations due to close by 2015 under the LCPD, it might seem that they are not going to bother trying.

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[e] It seems that PFA used for capping at the neighbouring municipal landfill site is deemed to be landfill[53].

CAPACITY OF THE RADLEY LAKES

First, a comment on converting between volume and mass: Published figures for the density of PFA cover a wide range, from 1.1 to 1.7 tonnes per cubic metre, depending on how much it is compacted. It is light enough so that, when it is poured as slurry, it tends to settle very loosely and leave voids, which in effect makes the density even lower. Npower's earlier experience led them to expect that they could store 1.1 tonnes per cubic metre, but they found that their sealed pits have been filling up faster than expected. They guess that this is caused by water trapped between layers of PFA. It will be interesting to see if that causes subsidence after a decade or two. They appear now to be working on a figure of 1 tonne per cubic metre. Dry storage gives a higher density, around 1.3, so that is another point in its favour.

Npower do not appear to have commissioned any research to find out why the bulk density has been lower than expected. Depending on the cause, there are well proven methods of increasing slurry concentration, compacting compressible cakes or reducing interparticle voids and liquid. These would increase bulk density and hence the mass of PFA which could be stored in any given volume. Unfortunately, now that the other lakes are largely filled, this would largely be a case of locking the stable door after the horse has bolted.

Lake E, Thrupp Lake, is approximately 360 m square, with a surveyed surface area[35] in 1981 of 110,000 square metres. The Bullfield, Lake F, which Npower now say they will preserve, is much smaller: 20,000 square metres. The lakes are quite shallow. When filled to 52m AOD, Thrupp Lake contains, according to our best estimates, approximately 265,000 cu.m of water, so the average depth, taken over the whole area of the lake, including the islands[f], is about 2.4 metres. The dimensions of the developed site are given on the approved drawings[36,37], which form part of the planning permission granted to Npower in January 2007. The effective area to be filled, after allowing for the internal sloping faces of the bunds and the 3,000sq.m cenosphere harvesting area, is approximately 83,000 square metres (Appendix 3) which is an average of the areas at the top and bottom of the PFA layer. The bottom, excavated to the Kimmeridge Clay substrate, has a mean level[37,38] of 47.7 m. Mean ground level is 52.5 m, but they plan to build up the sides and fill up to 55.5 m. That allows the maximum depth of PFA to be 7.8m, which would achieve a theoretical maximum storage capacity of 650,000 cubic metres. However this calculation ignores the lowering of the lake floor through the excavation of borrow pits in order to obtain clay for the bund construction. In Appendix 4 it is estimated that approximately 107cu.m. of clay will be needed for each metre of bund, so, with a bund perimeter of 1,350m, the total clay volume comes to about 145,000cu.m. The storage capacity of the lake is thus estimated to be about 800,000 cu.m, rather more than the nominal value of 500,000 cu.m provided by Npower in its planning application.

Another way of determining the capacity of Thrupp Lake is by an inventory of material that needs to be added and removed to achieve the final volume, exploiting the fact that the construction is virtually entirely within the existing lake boundaries and that the initial and final lake surfaces are horizontal planes. The volume of the final mound above lake surface level can be calculated quite accurately. To determine the volume of ash, one only has to add on the volume of water and solid material removed to create space below the

[f] Excluding the islands, and calculating the depth over the water filled area, yields an average depth of about 2.6 metres. However there are advantages, when doing calculations (Appendix 3) of lake capacity, to use the figure that includes the islands.

existing lake surface level. The calculation, which is given in detail in Appendix 3, also yields the Lake capacity to be roughly 800,000 cu.m.

These calculations also determine that the volume of solid material, described as “silt and gravel” but believed to be mostly gravel, that will need to be permanently removed from the lake is in excess of 100,000 cu.m.

TRANSPORT

We do not know how Npower cost their PFA, but transport to the point of use is clearly an important factor. We know from the cost of using Lake E (conveyance, landfill tax, and engineering) that they are willing to pay up to £10 per tonne to dispose of it. Transport is discussed in the ES, and the three options are considered here.

By road

Didcot A’s operators already have plenty of experience of road transport. None of us likes lorries, so planners understandably resist anything that could increase lorry traffic. But the reason why motorways have lorry loads of biscuits passing each other in opposite directions, or why MBM brings PFA here from Yorkshire, is that road transport is flexible and relatively cheap. So what are the implications of transporting say 60,000 tonnes of PFA per year?

Suppose there is a landfill site 1 hour away (Theale, perhaps?) and ash is taken there in 25 tonne lorries. The running cost is the lorry (approaching £100,000 per year), plus the drivers, plus fuel at about 50p per mile. It adds up to £6 to £8 per tonne – less than dumping in Lake E.

The number of trips needed would average just 8 per day over the 9 year period. The hours are restricted, but one per hour, during extended office hours and excluding peak hours, is negligible compared with existing traffic. Temporary stockpiling on site would maintain a 24/7 disposal capability without the need to increase this lorry traffic during times of peak production.

Npower are inconsistent in their portrayal of road transport. They say that it is an unacceptable way to remove PFA production of 100 tonnes per hour during peak periods, ignoring the storage on site and sales to the neighbouring landfill site, and yet they have up to 400,000 tonnes stockpiled for short-term large sales opportunities. It is highly likely that such sales would go by road. 400,000 tonnes is 100 tonnes per hour, 24 hours per day, continuously for 5 months. The reality that this is achievable was more than amply demonstrated in between April 2006 and May 2007 when ash sales (PFA + FBA) by road, of around 500,000 tonnes were apparently achieved.

Finally, we note that lorry traffic to move PFA would be a minor perturbation of the large amount of traffic bringing waste to the neighbouring landfill site. Oxfordshire County Council had little trouble approving that when the planning permission to extend the waste site’s operations was granted in May 2007.

By rail

A train carries 1200 tonnes of PFA and is to be preferred to road whenever possible. Didcot say they are limited to one or two trains per day, although bringing in the coal must require an average of 5 trains per day. The surplus PFA would need just one train per week. Unfortunately few potential customers have a convenient railway line next to their site.

One example of a site that could take PFA by rail is Shipton Quarry, just north of Kidlington. The site is being proposed for Britain's first eco-town[39] and is right next to the existing railway. PFA could be used for void-filling, construction and landscaping.

Whether by road or rail, the total amount of material already being transported by the power station comes to nearly 3 million tonnes per year. That is the coal, any ash that is sold, and other waste products. The extra traffic generated by transporting the remaining 60,000 tonnes per year of PFA is very small by comparison – less than 2%.

By pipeline

Ash can be transported as slurry, and as noted above, such "wet" transport washes pollutants out of the PFA and into the environment. Dry or semi-dry storage is preferable, and it means that the PFA is more accessible for recovery should it be needed in future.

Pipelines have a high capital cost and low running cost. The cost is, of course, very dependent on the route – how many road crossings, etc. However the quantity of PFA to be transported is sufficiently low that that the cost of a pipeline may not be justified. An exception might be a branch off the existing one, to somewhere like the gravel pits near Sutton Courtenay. However the underlying problem of pollution from leachate remains.

In the ES, Npower make a misleading comparison with road transport. They say that transporting as slurry is better, because the water is all recycled back to the Thames, whereas transporting by lorry in a semi-dry state means that 20% of the load has to be water, which is lost from the Thames. But they do not compare the quantities involved. If, in one year, 55,000 tonnes of conditioned PFA are taken by road, instead of by pipeline to Radley, 14,000 tonnes of water are exported. But the slurry pipe carries 17,000 tonnes of water per day! 400,000 tonnes of water are required just to convey the PFA through the pipeline. More water is needed to flush out the pipes, to maintain water levels in the lagoons, and to dilute the effluent as required. Most of this water is returned to the river. However, the proportion of water remaining trapped in the PFA when it has settled in a sealed lagoon will be significantly more than 20%. In addition, a wet rough surface, like PFA in a lagoon, evaporates water more quickly than an open lake. If the lagoon area is about 100,000 square metres, each millimetre of evaporation is another 100 tonnes. Transporting it conditioned would in fact save water. In any case, the amount of water involved is very small compared with the amount evaporated from Didcot's cooling towers.

Semi-dry pumping is a very promising development[40,41]. Advanced pumping systems are now available that are able to transport low moisture (less than 50%) fly ash over large distances[42]. This offers advantages of both road and pipeline, by enabling PFA to be deposited directly onto an above ground mound. It could also be an efficient pollution-free means of transporting PFA to an off-site reprocessing facility in the general neighbourhood of the power station.

ALTERNATIVE OPTIONS FOR DIDCOT A

In the ES, Npower discuss alternative means of disposal, and dismiss them. Their conclusion is that they have found no *economic alternative* to the lakes. That is to be expected. The whole purpose of taxes such as landfill tax is to change such attitudes, by changing the economics. Then, when taxation is not enough, legal controls are used. If it were not so, then nobody would bother with recycling, builders would be dumping their rubble down every country lane, and Npower's chimney would still be pumping out acid rain. For "economic alternative" we have to read "cheaper alternative", but decisions cannot made on economics alone. In fact, the rising cost of gas must be increasing the profit on coal, making other means of disposal more affordable. If Thrupp Lake were not available, Npower would not stop generating electricity, they would simply move on to the next cheapest solution.

It is not for us to say exactly what that solution should be; our job is to defend The Lakes. We suspect that, when this application started, Npower saw it as a mere formality before continuing to dump PFA as they had been doing. They probably did not expect any problems. It was a quick and easy solution, with no thought for the local ecology or the wishes of the local community. It is very unfortunate that they have already bought The Lakes, as they are now faced with ownership of and responsibility for land which may be of no further value to them. This must be an embarrassment, so it is in their interest that there should be no other solution.

We discuss below some alternatives to dumping the ash in Lake E.

Reduced Capacity Operation

We note (Appendix 1) that the power station was expecting to dispose of only about 25% of its total PFA production in Lake E over the period 2007-2015. We are also aware that it is not necessarily the overall quantity of ash produced that poses a problem for the station operators. It is the *rate* at which it is produced, and this is directly proportional to the rate of electricity generation. Limiting ash production by limiting electricity production is therefore one way forward We do understand that the power station's primary function is to meet the electricity demands of the grid and that managing this output figure could be difficult.

To add to this, the energy market has recently been undergoing some upheavals, and coal is now enjoying a considerable premium over gas and oil, as a result of which demand from the power station, and the wish to capitalise on it, has never been greater. Under these circumstances, deliberately limiting electricity production would not be attractive to the power station's operators.

However the power station's generation capacity *is* limited. During 2008-2015, the LCPD will effectively limit electricity production to no more than 40,000 GWh. This means that the power station is already forced into reduced capacity operation, albeit when averaged over the eight year period. It is only the operating profile within this period that will determine whether surplus ash becomes a problem. Understandably, the power station will not wish for its operating profile to be determined by ash sales, though we believe that this need not be much of a restriction if they are prepared to work hard enough to achieve the necessary sales.

Beneficial Use

In recent years, a huge amount of research across the world has gone into finding ways of using PFA beneficially, in order to obviate the harm caused to the environment by dumping it, or to conserve available landfill capacity for other uses. Many applications have been found in which the PFA-based product offers either particular advantages over, or indeed is generally superior to, traditionally sourced products. Examples include high-performance concrete, lightweight aggregates (LyTag[43] and SLAs) and bricks. Npower should actively promote these applications, if necessary, by investing directly in them.

Even PFA that has too much carbon may offer new applications, as a catalyst, or for absorbing gases or liquids. Some brick manufacturers are finding that PFA with a carbon coating has beneficial effects on the bricks. It can also be sintered into lightweight aggregates for many purposes, and the carbon helps to power the heating.

As mentioned above, PFA-based synthetic aggregates have also been tested successfully as a component of asphalt for roads[22,23,24]. Among its properties are superior skid resistance, compared with limestone chippings, and resistance to melting in extreme heat. Many of Oxfordshire's roads suffered heat damage during recent very hot summers and require replacing. PFA-based asphalt could be used for this.

Other possible local uses for large amounts of PFA include the construction of sound attenuation barriers next to the A34 to shield nearby housing estates, eg those at North Abingdon, from traffic noise.

A range of possible large scale uses of PFA is given above. The reason for listing these examples (mostly from ref[22].) is not necessarily to suggest that there are big markets out there now (though the evidence is increasingly that there are) but to point out that the need to find applications for PFA is stimulating much research, and new markets are emerging all the time. However Npower has to encourage those markets and, at the same time, conserve its stocks of ash in order to exploit them.

Storage on site

So, where can the power station operators put the ash before it finds a market?

The power station site is quite spacious, and, back in 1981, the CEGB proposed on-site stockpiling in order to accommodate fluctuations in the disparity between ash production and market demand[g]. It gave up that plan during the dash for gas. There was a triangular bund about 350 m across and 8 m high, to hold 500,000 tonnes of PFA - the same as they proposed to put into Lake E - but the space has since been taken by Didcot B.

However a sound attenuation barrier has been erected for Didcot B, containing 400,000 tonnes of PFA taken from that original stockpile. A further 315,000 tonnes was reported to be stockpiled on site[44] in mid 2006 though we think this overstates the true picture. An inventory of Didcot's ash stockpiling over the period Jan 2002 to Dec 2006 (Appendix 1) shows a surplus of production over disposals of 203,000 tonnes. The higher reported figure was the result of a mid year assessment when the stockpile would have been at its peak (a peak that occurred, whether by accident or design, within the time frame of the planning meeting in July 2006, so that power station managers were duly able to impress Councillors with the magnitude and apparent urgency of their problem). However, by the end of May 2007, the stockpile had shrunk to just 164,000 tonnes[49]. Nevertheless this shows that there is space on the site with capacity to stockpile over 300,000 tonnes, and that the existing stockpile is shrinking rapidly.

If Didcot A were to be demolished after 2015, it would leave a huge void, able to take 800,000 tonnes of PFA[3]. It is likely that a modern and more efficient coal fired power station will be built in its place, so Npower would no doubt prefer to keep their options open, but any new construction will still need at least some infill.

In the ES, Npower do not rule out on-site storage but refer to possible inconvenience to proposed nearby housing development planned for the area. A possible solution is a

[g] Inevitably, ash production peaks during the winter months, while demand from the construction industry is greatest in summer.

permanent landscaped stockpile for beneficial use as a sound-attenuation bund and sightscreen between any such development and the power station. This would be advantageous to all concerned. Similarly, bunds could be constructed alongside the railway line to reduce noise disturbance to any new development there, and perhaps allow development closer to the railway than would otherwise have been feasible. Npower give a figure of 150,000 tonnes per kilometre of sound barrier, so 500,000 tonnes would be enough for 2 miles – which is rather less than the perimeter of the power station.

From January 2008, Didcot A will be subject to a 20,000 hour limit on its operations between then and 2015, when it will have to close. Therefore, during those eight years, the maximum amount of PFA that can be produced is only 1.6 million tonnes, which is just 200,000 tonnes per year on average. Of that, about 100,000 tonnes is contracted to go to the adjacent landfill site at Sutton Courtenay, leaving just 100,000 tonnes to be disposed of elsewhere each year. We do not think that selling this amount of PFA in a year would present Didcot with a serious problem, nor would stockpiling it on site between the winter production months and the summer when it can be more readily sold. This amount of ash is also within the capacity of the new ash beneficiation plant, which is now reportedly[45] operating effectively.

However, it may be that, for commercial reasons, Npower will wish to run the power station harder and close it earlier. A closure date of 2012, rather than in 2015, has been suggested. The 1.6 million tonnes of PFA will then be produced in just 5 years, ie at an average rate of just over 300,000 tonnes per year. On the evidence of Didcot's recent ash disposals (See page 22) we do not think that even this will present them with too much of a problem. They have over 300,000 tonnes of stockpiling capacity, 100,000 tonnes of guaranteed annual sales, and half a year or more to get rid of the rest.

In order to achieve these production levels, the power station will have to attain full output at those times when it is operating. This means, the power station's operations will have to be configured to provide base load at the full 2GW capacity of the power station during the winter months when demand is greatest and most reliable. During the remainder of the year, when hopefully demand for electricity can be met by other stations, the power station will be shut down completely. In the case of Didcot A, it is Didcot B that will have to take the load during those times when the 'A' station is not operating. Work is scheduled in 2008/2009 to upgrade Didcot B[46], no doubt with a view to improving its reliability. There nevertheless may be times when Didcot A is required to operate but is unable to do so at full capacity. Because of this, the full 40,000GWh of generation may not be achieved, and consequently less ash will be produced. The 1.6 million tonnes is very much a strict upper limit to the total amount of PFA that will be produced.

In the past, Didcot has been over-reliant on the Radley Lakes. It is their fear of not being able to cope with the surplus ash by other means that has led them to go for the Lake E solution. However, since 2005, they have been learning how to manage without the Radley Lakes and have been becoming quite successful at it. Between April 2006 and May 2007, the power station reduced its on-site stockpile by 151,000 tonnes[49] despite the likelihood of having produced over 350,000 tonnes of PFA in the same period[h]. This means that, in just 13 months, they have apparently disposed of about half a million tonnes of PFA! In order to maintain a 24/7 disposal capability, to keep the power station operating, all they have to do is put ash on the stockpile as it is produced during the winter months, and clear the ash stockpile over the summer months when the power station is not operating.

[h] We do not have production figures for the period in question. However *annual* production of PFA in 2006 is estimated to be over 350,000 tonnes (Appendix 1).

Storage nearby

Immediately to the north of the power station is an enormous pit, nearly a mile across, formerly several gravel pits, which is destined to take a few million of tonnes of rubbish. Filling has already started in the north east corner. Good practice, when filling, requires that, each evening, the fresh waste is covered with a layer of earth, sand, etc, to discourage vermin. Typically the layer would be 20 cm thick over each 2 m layer of waste. Therefore, when the pit is filled it will contain about 10% of cover material. If PFA were used for this, it could account for a large part of the 500,000 tonnes. Waste classification should not be a problem because the site is already licensed. However there are regulations preventing the mixing of different types of waste. These are easily circumvented by using processed PFA, which is a recovered product, not waste. Indeed cementaceous products derived from PFA, of which Dispergat[16] mentioned above is a good example, are eminently suitable for waste site construction because of their very low hydraulic permeability and high chemical resistance.

To the west of the big pit, is another pit, similar in size to Lake E, which has been filled. It is now a low hill, covered in pipework to extract the methane, for burning in a small power station nearby. Normal practice is then to seal it by capping it with clay. However a layer of PFA, or Dispergat, could be used instead and would form an effective seal – its permeability is low, so gentle suction would catch virtually all the landfill gas. A 4 metre layer of (dry) PFA would dispose of about 500,000 tonnes.

Since planning permission was granted to them, in May 2007, to extend their operations at Sutton Courtenay, Waste Recycling Group (WRG) has been able to take PFA from Didcot without impacting on the total amounts of waste they can take from elsewhere and without attracting the sustainability levy. This has resulted in a welcome increase in amounts of PFA being taken by this operator for the purpose of daily capping and land restoration. However, after the power station closes, this supply of PFA will dry up, and WRG will then need to import, at cost, inert material from elsewhere for their daily capping until 2021. Moreover any such material imported by road will attract the sustainability levy and offset the amount of (profitable) waste that can be taken. It has been suggested that a way to tackle this problem would be to store PFA on the site in order to meet this future demand.

Unfortunately available space on this site is limited. Much of the area has already been landfilled, and, as it is still compacting, will not support the weight of hundreds of thousands of tonnes of PFA being piled on top of it. Within the remaining active cells, it is apparently not possible, or at least not desirable, to mix PFA with the ordinary waste. Still, WRG is aware of the problem, both from its, and our, points of view, and has promised to continue looking for possible solutions.

Landfill

We believe that disposal to landfill should be a last resort. However there are instances where this can be beneficial.

Oxfordshire's Structure Plan expects further sand and gravel to be extracted locally, and there are two possible sites (the Benson area or the Wallingford area). A major concern from RAF Benson, for both sites, is the risk to aircraft from bird strikes. To discourage water birds, the MOD requires that any pits near the flight paths be dry filled with PFA. The quantity of sand and gravel is very uncertain – at least a million tonnes, maybe several million – but refilling will clearly require a large quantity of PFA.

PFA can also be used at other landfill sites for daily capping. We believe that some of Didcot's PFA has been sent to Ardley Quarry in North Oxfordshire for this purpose.

Radley Lakes

The flood risk of the Radley site is examined in a separate document[47]. Suffice it to state here that, if PFA is dumped below the peak flood level of the flood plain, then it will reduce the volume available for flood water, but, if it is placed entirely above the peak flood level, it will make no difference. Lake G was filled above the flood level, with the Environment Agency's permission, to increase its capacity. It cannot go any higher, not because it is not permitted, but because, Npower say, there is not enough space by the railway line to make the bund higher. This is probably correct, but had more thought been given to this, Lake G could perhaps have been built even higher thus providing additional storage capacity so as not to have required the later destruction of further lakes.

We mention this option, not because we like it (though it would have been preferable to causing damage to Lakes E and F) but rather to demonstrate the narrowness of Npower's thinking and their lack of long-term forward planning.

It may be possible to put more PFA into Lake H/I. This lake is right on the flood plain where it is likely to remain a permanent feature. Events in January 2003 and July 2007 have demonstrated that the flood mitigation system, which allows water to flow into this lake at times of flood, has only a minimal effect on flood risk. It might therefore be better to sacrifice this altogether and replace it with a more effective flood mitigation scheme involving Lakes E and F. This would allow more PFA to be put into H/I, though, without raising the bunds, this would probably be no more than about 100,000 tonnes.

ASH DISPOSAL STATISTICS SINCE 2005: SO WHAT HAS HAPPENED TO ALL THE ASH?

The amounts of ash produced and disposed of are published annually by all coal-fired power stations. The amounts produced, sold or sent to landfill, by Didcot A Power Station, are reproduced and discussed in detail in Appendix 1, where they are used to develop scenarios for the next 8 years. The previous version of this report[48] was based on Didcot's emission data for 2006 published at the beginning of August 2007. Since then, there have been some interesting developments concerning these statistics, which have prompted this new section. It might well have formed an extension of Appendix 1, but its conclusions are far too important to be relegated to an appendix, so the discussion is presented here.

To appreciate the recent data, one should be aware of the sharp decline in ash disposals to Radley that has occurred since the end of 2004, due to diminishing space, with only 1,350 tonnes[49] being sent to Radley in 2006.

Emissions data for calendar year 2006 were published at the beginning of August 2007, and those relating to ash are reproduced in Appendix 1. These figures showed that spectacular sales had been achieved that year and indicated disposals that were apparently consistent with the decline in the size of the ash stockpile at the power station. This gave rise to congratulations being afforded to Npower in the media, congratulations that they accepted and were happy to take full credit for. The published figures also strongly supported the contention that the power station is fully capable of managing its ash disposal without having to resort to using Thrupp Lake, something which Npower nevertheless continued to refute. However, shortly after their publication, the data disappeared from Npower's website and were replaced, about a month later, by a new set of figures (also reproduced in Appendix 1). Included with the new data is the explanation that disposal amounts had originally been incorrectly apportioned between sales and landfill, and this had been corrected. It is explained that the definition of the amount of ash described as going to landfill was that amount of ash upon which landfill tax was paid, even if the disposal was for beneficial or engineering purposes. This particularly relates to ash sent to the neighbouring landfill site at Sutton Courtenay, where the PFA is used for daily capping of household waste. For our purposes, this definition of landfill is less helpful. Unlike Government, our concerns here extend beyond tax revenue, and would want to distinguish between ash that is disposed of *non-beneficially* to landfill, and any that is "sold" for beneficial purposes. We would tend to regard a "Sale" as any amount of ash that is disposed of, under contract, for any useful or beneficial purpose, which is the case for ash sent to Sutton Courtenay (but not for any sent to Radley). Unfortunately, were it not for the earlier error, we might not have noticed that the official interpretation differs from the logical one.

Unfortunately any reinterpretation of the data in this light is confounded by a significant change in the total amount of ash disposed of in 2006. The new (September) figures yield total ash disposals that are 151,000 tonnes *less* than the earlier August ones. No explanation for this is given. In one respect at least, the new data appeared odd. Whereas the old data implied that stockpiled ash at the end of 2006 amounted to *at least* 52,000 tonnes, the new data revise this upwards to *at least* 203,000 tonnes (Appendix 1). Now, Npower have told us[49] that, at the end of May 2007, the stockpile stood at 164,000 tonnes. This would indicate that the stockpile had declined in size by about 40,000 tonnes during the peak production months, which is also when sales would be expected to be at their lowest. The power station would have been expected to produce, in this time, around 200,000 tonnes of PFA, of which 40,000 tonnes would probably[i] have gone to Sutton Courtenay and a further 52,000 tonnes could have been removed from the stockpile for beneficiation[j]. This would yield an expected increase in stockpile size of about 110,000 tonnes give or take a few tens of thousands of tonnes. Therefore an increase, from 52,000 tonnes, to 164,000 tonnes, as originally indicated, would be entirely within expectations. However, a *decrease* of around 40,000 tonnes, from 203,000 tonnes to 164,000 tonnes, as indicated by the revised figures, would clearly require disposals in the region of 150,000 tonnes *in addition to any ash going to Sutton Courtenay and via reprocessing*. Moreover, we have been informed by Npower[49] that only 1,350 tonnes has been sent to Radley between 1/1/2007 and 13/08/2007. This all might suggest that they were able to achieve the bulk of their expected sales or disposals of unprocessed ash in the first five months of the year; not impossible, but not what we would have expected. Alternatively, and this is more likely, it could indicate that Didcot have access to a landfill disposal site with capacity to take around 30,000 tonnes of PFA per month.

There is more. In their Statement of Need[44], submitted to Oxfordshire County Council in May 2006, Npower stated that their stockpile stood at 315,000 tonnes at the end of April 2006. This figure is confirmed in Dr Waygood's email[49] of 13th August 2007. The same email states that the stockpile contained 164,000 tonnes at the end of May 2007, 13 months later. In that time, we would have expected them to have produced in the region of 380,000 tonnes of PFA (See Appendix 1, Table 2) which would mean that about 530,000 tonnes of PFA had been disposed of in the intervening 13 months – an average of around 40,000 tonnes per month. If we assume 8,000 tonnes of that went to Sutton Courtenay, and 10,000 tonnes was reprocessed, in line with the maximum capacity of their plant, this leaves 22,000 tonnes per month of unprocessed ash unaccounted for.

These revised ash disposal figures do not change our conclusion that they have a demonstrated capability to dispose of large amounts of ash, in excess of 400,000 tonnes

[i] The contract to supply Sutton Courtenay with 8,000 tonnes of ash per month runs from April 2007[49], but they are known to have been supplying ash before this time, probably at a similar rate.

[j] This is reprocessing to remove unburnt carbon making the ash suitable for concrete manufacture. The newly installed plant at Didcot has a maximum processing capacity of 125,000 tonnes per year, or 52,000 tonnes in 5 months.

per year, when they need to. If anything, they reinforce it. The reason for this is quite simple: We know the state of their stockpile at the end of May 2007. This is the net result of all ash production and disposals up to that date. In the light of the original sales data, this did not appear remarkable and could readily be explained by an excess of production over disposals, in the region of 100,000 tonnes or so, over the winter months. In the light of the new figures, a 164,000 tonne stockpile *is* remarkable, but it remains what it is. In simple terms, *whatever they did not dispose of in 2006, they disposed of in 2007*. The end result is exactly the same, except that, if anything, the revised figures point to a higher rate of disposal in 2007.

Npower's revised ash disposal figures are consistent with the rapid steady decline of the stockpile between April 2006 and May 2007 (Figure 1).

These are interesting and, once seen, very striking observations, and they are the clearest indication yet that they have, as we believe they must have, alternatives to the Radley Lakes for on-demand disposal. We are however unable to say exactly what these alternatives are, or for how long they will remain available. The fact remains that a considerable amount of ash has been, and, in all probability, is still being disposed of, thus effectively clearing the stockpile (Figure 1) for the final years of operation of the power station under the regime imposed by the LCPD. This reveals two things: (1) that Npower are resourceful and can get rid of PFA when they need to and (2) their operations are not under threat from an overflowing stockpile. The critical state of "urgent need" that, in July 2006, they persuaded County councillors they were in was, it now appears, an instance of being economical with the truth. In fact, the power station operators are in an excellent position to dispense with Thrupp Lake, and instead to rely on the stockpile to meet their "24/7" disposal needs and on their own, adequately demonstrated, resourcefulness to keep it from overflowing.

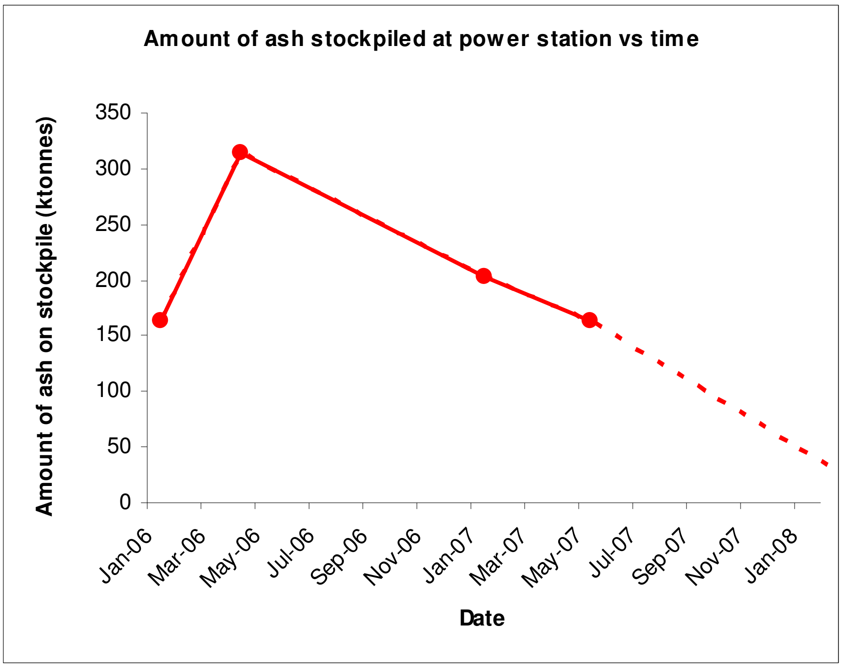

Figure 1: The vanishing stockpile
This graph shows the amount of ash stockpiled at the power station based upon the emissions returns data, as given in Appendix 1, Table 1, and additional data provided by Npower[49]. The data points (red circles) are known values. The solid line is simply to guide the eye and the dashed line is a projection.

CONCLUSIONS

Npower have spent £3 million on a plant to process 125,000 tonnes of PFA per year, and over £3.2 million on a thriving lake in which to dump about 60,000 tonnes per year (the average over the nine year remaining life of the power station at January 2007). We suspect that they have not thought out their waste management, but simply went for the easy option of continuing what they had been doing, and assumed that permission would be granted. They are now trying to justify that choice.

If Npower operate Didcot A within the LCPD limit, for the next 8 years, and if they remove the carbon from some of the PFA produced, selling the product and also selling some of the raw untreated PFA to the neighbouring landfill site for daily capping, they would have no ash left to dispose of at all (Appendix 1, table 5). This assumes a roughly level profile for their operations, ie each year they produce, and sell, 200,000 tonnes of PFA. The problem arises if the operating profile deviates significantly from this. We suspect that they will be looking to bring the closure date forward to 2012, which gives them only 5 years of operations, during which PFA production will average 320,000 tonnes per year, leading to a potential surplus of 600,000 tonnes, *if no further ash is sold,* plus any surplus on the stockpile at the end of 2007. In this very unlikely worst case scenario, they could have as much as 800,000 tonnes (Appendix 1, table 4) left over. Their proposal is to dump all of this in a beautiful lake, Thrupp Lake, known to them as 'Lake E', at Radley.

However there are alternatives. These are:

Through changes in power station operation

Operate at a lower capacity for longer (eg for the full 8 years) so reducing the rate of ash production to the point where sales match production, hence no waste.

Provide for greater recovery of PFA by installing further processing capacity and the silo capacity to stockpile reprocessed PFA.

Use some of the space used to stockpile coal for storing or stockpiling PFA. The coal stockpile capacity is 1.5 million tonnes[4]. We think this could safely be reduced by a few hundred thousand tonnes, and this space expanded as the power station nears its end of life.

By exploiting further uses of PFA

Examples include the installation of on-site facilities for the manufacture of cement products, or other building products such as concrete blocks, lightweight aggregates and bricks; and selling high quality ash to the cement and concrete industry. This would require installing suitable plant (eg Retexo, RockTron or Flash Bricks) close to the power station (or somewhere along the pipeline).

Recycling PFA saves on CO_2 as well. The substitution of the PFA produced by Didcot A power station for limestone-based cement potentially saves up to 1.5 million tonnes of CO_2 over the remaining life of the power station. The manufacture of bricks from PFA also produces CO_2 savings in both their manufacture and transportation.

At the time of writing, Didcot has not shown any inclination to invest in any of these technologies. However they have already invested in an STI ash beneficiation plant[50] on the site. This processes up to 125,000 tonnes of ash per year and came fully on line in 2006 (sales of this ash are already included in our projections).

Didcot have said that they would consider investing in additional capacity if there was sufficient market demand for the product.

Didcot need to be much more proactive in seeking beneficial methods of disposing of their PFA. They have relied on their pipeline for too long.

By alternative disposal means

Above-ground stockpiling as a beneficial landscape bund on or near the power station site is one option, thus retaining a supply of PFA to fill the void under the power station when it is eventually demolished post 2015.

Transport to other disposal sites where infilling is regarded as beneficial and where the PFA causes less harm to the environment. The construction of sound attenuation barriers alongside the A34 is one possible use.

The Government could be more helpful

Regulations influence cost and hence power station policy. These regulations include the climate change levy, CO_2 emissions trading, renewables obligation, landfill tax, the aggregates levy and the European Waste Framework. All of these are examined. The landfill tax in the UK is too low to influence a power station operator significantly, but it is much larger in Germany where it has contributed to higher recycling rates. The aggregates levy is also too low to have much effect on markets.

There are other means of transport than by pipeline to Radley.

Road and rail transport are shown to be practical and economic. Npower's arguments to the contrary are shown to be unwarranted exaggeration. Use of a pipeline to Radley is by no means the only solution.

Transportation as wet slurry to lagoons, sealed or otherwise, causes much more pollution compared to other methods of transportation and disposal. In future, semi-dry pumping, through suitable pipelines, should be considered in preference to liquid slurry pumping. This leaves the PFA in a workable state, allowing above-ground storage, and pollutes far less water.

It may be that no single alternative will provide a complete solution. A surplus of 120,000 – 160,000 tonnes per year, which is roughly the capacity of the lake, over 5 years, is not an enormous quantity to have to deal with, if there is the will to do so, and the resources to back it up. RWE certainly have the resources, but not it seems the will.

Changes in the energy market during 2006 resulted in an upward revision of Didcot's projected ash production. However, in 2006, Didcot achieved record ash sales and, at one point, claimed to have sold more ash than they produced in that year[53]. This shows what can be achieved when necessity comes to the fore. It also shows that the most pessimistic assumption regarding future ash sales is an unlikely one. In fact, the power station operators are more likely to have to restrain ash sales to ensure that there is sufficient ash left to complete the filling of Thrupp Lake. With a realistic calculation (Appendix 1) and putting the lake's capacity closer to 800,000 tonnes than to 500,000 tonnes, this could potentially impact sales of beneficiated ash. This is both wasteful and destructive. That embarking on the Lake E ash filling project could put the power station in such a position is a clear an indication as any that it is the wrong way to go.

Even with the LCPD constraint of 20,000 hours, the power station will not be producing significantly more ash in a year, on average, than it does at present. If the power station closure is to be 2012, then the average load factor is similar to what it was in 2006, ie around 45%, compared with an average of 40% during 2001-6. If closure is in 2015, it will be 28.5%, a bit lower than what is has been, which is why they probably want to move the closure date forward. (A lower load factor means higher overheads and lower profits.)

They have managed for two years without being able to send any significant amount of ash to Radley. In spite of this, the total ash surplus on their stockpile at the end of May 2007 is just 164,000 tonnes[49], and declining rapidly.

Under the LCPD, the most electricity they can produce is 40,000GWh. That equates to about 1.6 Mtonnes of PFA. If that is produced over 8 years, then average PFA production is just 200,000 tonnes per year, well within what they can sell. However, if they run only to 2012 (5 years) then that rises to 320,000 tonnes per year, still manageable and within the capacity of their stockpile. In other words, with a stockpile of sufficient capacity, somewhere between 300,000 and 400,000 tonnes, they simply pile up the ash in winter, less the 8,000 tonnes per month going to Sutton Courtenay, and get rid of the surplus during the summer when sales are easier. Anything that is not sold, will need to be moved somewhere else though, and this is something they will be worried about. However, because it is so important to keep the power station operating, and because they are a resourceful effectively managed company, there is no doubt that they will succeed in doing this, even without Thrupp Lake, as indeed they are doing already. The residual amounts of ash are not likely to be huge, and much less than the quantities they frightened Councillors and local residents with in July 2006. It is certainly not a good enough reason to destroy Thrupp Lake, and there is no great threat to power station operations, as long as they resolve to start each production season with an empty or nearly empty stockpile.

RECOMMENDATIONS

Recommendations for RWE npower (Didcot A)

Npower should develop a more responsible attitude to waste disposal, developing ways to minimise waste production, finding alternative uses for it, and evaluating better places to dispose of it as waste. Dumping in Lake E at Radley is unnecessary, and has been chosen because of short-termism by Npower, who have not thought through their waste-management problems. The power station operators argue strongly that they have a “pressing need” for a disposal route that can operate 24 hours-a-day 7 days-a-week, and that filling lake E is their *only* option. While we fully accept the first half of this statement, we believe that, while, for operational and financial reasons, the Radley Lakes may be their preferred option, it is *not* the only one. The power station operators have had adequate time over the past two years, if not longer, to develop an acceptable contingency plan, and would be negligent not to have done so. The ash needs to be got rid of, preferably by putting it to beneficial use, either now or in the future. Disposing of it in the manner currently proposed is wasteful, harmful and irresponsible. The practice of disposing of PFA in lagoons is no longer acceptable, and is one that nearly every other power station operator in Britain has moved away from. More effort needs to be made to recycle the PFA, and any that does go to waste should be disposed of sustainably, in a manner that causes least environmental harm and that allows its future recovery for beneficial use.

Given that, from 2008, Didcot A power station has to operate within the LCPD limit of 20,000 operational hours, no more than 1.6 million tonnes of PFA will be produced in that time. The problem is how to deal with that amount on a 24/7 basis. We propose the following:

- First and foremost, the Company's management has to dispense with the mindset that says that it must have Thrupp Lake for PFA disposal. RWE npower has shown itself to be a resourceful company. When it sets out to achieve something, whether for good or bad, it generally succeeds. If it *needs* to or *wants* to find a more acceptable alternative to Thrupp Lake, it *can,* and undoubtedly *will,* do so. Therefore, in order to save Thrupp Lake, the most important thing this Company can do is make it an imperative that the lake will not be destroyed.
- From January 2008, the power station could be operated on a level annual production profile until 2015, thereby producing 200,000 tonnes of PFA per year. Of this, 100,000 tonnes would go straight to the neighbouring landfill site, and the remaining 100,000 tonnes, after beneficiation, would be sold to the concrete and cement industry.
- If an aim is to close the power station earlier than this (December 2012 is probably the earliest realistic date if the 20,000 hours is to be reached) then more PFA will need to be removed from the site. We have made a number of suggestions as to how this could be achieved. In practice, this means selling around 300,000 tonnes of PFA per year, which is achievable.
- In order to promote sales of ash to the construction industry, for example, the power station should give serious consideration to investing in further beneficiation capacity. (This is what they should have done in the first place, before spending £3.2M on buying Thrupp Lake.) They must ensure they are in a position fully to meet demand for beneficiated ash as and when it arises.
- The on-site stockpile, with its 300,000 – 400,000 tonne capacity, should be sufficient to cope with supply vs market demand fluctuations throughout each year and thus provide a 24/7 outlet for the PFA as it is produced by the power station. If a larger stockpile is considered desirable, a modest proportion of the coal stockpiling area could be given up.
- The ash stockpile should be cleared during the non-operational (summer) months – as appears to be happening at present.
- If necessary, as closure approaches, the stockpile can be allowed to build up to provide a reserve for infilling and other local uses after the power station closes.
- Limited amounts of PFA might be able to be stored on the neighbouring Sutton Courtenay Landfill Site to provide the operators of that site with a source of capping material after the power station closes. (See also bullet point above.)
- Thrupp Lake should be left alone. Filling it with ash will inevitably mean that ash that could be sold for beneficial use will not be. Apart from the lack of incentive, sufficient ash will have to he held back in order to complete the filling project.

Of course, Didcot may have developed other options and will certainly be looking at ways to minimise any risk. Whatever they are, with a properly thought out strategy, there should be no risk to power station operations if the Thrupp Lake scheme is abandoned or indeed has to be abandoned[k].

Although planning permission to fill Lake E has been granted, the power station operators could do well to reflect on their need to continue with the project. It is unnecessary, wasteful and contrary to public opinion of how a responsible company should behave in the 21st century.

Recommendations for Government

There is probably little that Government can do for Thrupp Lake through the implementation of existing policies or the imposition of new ones. However Government's taxation and regulatory policies, supposedly designed to protect the environment, have contributed significantly to the present unsatisfactory situation. There is a lot it can do to prevent similar situations arising in the future.

1. Significant CO_2 savings can be achieved through the recycling of PFA, so rather than allowing and even condoning its dumping, Government should be doing all it can to encourage PFA recycling under its Climate Change policies.

2. Government should review its Green Taxes and Environmental Regulations to

- Ensure that taxes are at levels that will make a difference, ie achieve the stated objectives.
- Ensure that they are not inadvertently causing harm through oversights and unintended consequences.

3. In the case of PFA from power stations, the tax and regulatory regime seems, by discouraging reuse and positively encouraging its dumping into landfill, to have conspired to create a regime where a potentially valuable material goes to waste, causing harm to the environment in the process, rather than being put to beneficial use. Government should therefore:

- Look at means whereby offsetting of CO_2 savings produced through the recycling of waste could be incorporated in the ETS or Climate Change Levy, in order to encourage the recycling of PFA into cement, concrete and bricks.
- Review and substantially increase the level of landfill tax applicable to PFA, while ensuring that PFA used for beneficial, or essential engineering purposes in connection with other operations, is not unnecessarily taxed.
- Review and substantially increase the aggregates levy on primary aggregates, in order that secondary materials, like PFA, are taken up in preference. The fact that clay is excluded from this levy appears anomalous. This needs to be looked at again. If there are reasons why clay has to be exempt, then the aggregates levy should be used to fund a positive subsidy on the use of PFA as a clay substitute.
- The automatic classification of PFA as waste under the European Waste Directive needs to be reviewed as a matter of urgency. PFA is a valuable by-product. Like most things, it should only be classified as waste when it *is* waste. In return, the power companies should agree not to dump it into permanent landfill. All unused PFA should be retained in stockpiles from whence it can be reclaimed.

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[k] An application to have the lakes registered as a Town Green under the Commons Registration Act 1965 is currently being determined. A public inquiry was held during April – June 2007 and a decision is expected imminently

- The responsibility for managing any PFA that has to go to waste should be contracted to accredited landfill site operators, and not left to power station operators to make their own arrangements. The current waste management policies and plans overlook the PFA problem, and the prevailing competition between PFA and other forms of waste has led to PFA being squeezed out of the system and disposed of in places where it should not be. As a general principle, the producers of waste should not be permitted to carry out the ultimate disposal of that waste.
- The disposal of PFA in lagoons, as is done at Radley, should be outlawed. Of the various disposal options, this causes the most pollution and causes the greatest harm to the environment.

4. In addition, planning law needs to be strengthened so that, when an applicant invokes "overriding need" as a reason to circumvent planning policies, the establishment of that need should be carried out more rigorously, by an independent authority, and be subject to rigorous public scrutiny.

5. In their emissions returns, power stations should be required to distinguish between FBA and PFA. Although these are subject to the same regulatory regime, they are subject to quite different markets and it is important to know the disposal position for each separately.

Coal, as a primary source of energy, seems likely contribute significantly to The Nation's energy mix for the foreseeable future. When planning new coal-fired power stations, or extending the operation of old ones, the issue of what will happen to the ash that will be produced has to properly addressed, and solutions put in place, at the start, that are sustainable and do not cause unnecessary harm to the environment. Government is fully aware of these issues[22,51], but needs to do more to promote change. The problem of what happens to the fuel ash from Britain's power stations is no longer one that can be swept under the proverbial carpet.

Appendix 1 Ash Production Statistics

In this appendix we examine the ash production statistics provided by RWE npower in their Emissions Returns for 2001-2006[52,53] to determine the basis of Didcot's stated need for Thrupp Lake and to assess the viability of alternative strategies for ash disposal.

During 2007, Npower published two different sets of data relating to ash disposals from Didcot A in 2006. The first set of figures, published in August, was taken up in the previous version of this report and the conclusions of Appendix 1 in that report seem to be very much based upon them. However, in September, Npower published a revised set of figures, which indicate a level of disposals that is 151,000 tonnes lower than previously indicated. At first sight, this might appear seriously to impact those conclusions. In fact this turns out not to be the case, and indeed the conclusions are, if anything, strengthened. However, those conclusions are now underpinned by the stockpile level at the end of May 2007, which Npower have told us stood at 164,000 tonnes. This fact is entirely unaffected by the ash figures for the previous year. If disposals were less in 2006, then they would have had to increase in the early part of 2007 by a corresponding amount. In fact, as discussed in the main text, Npower would have had to dispose of an estimated 150,000 tonnes of unprocessed ash, which would be in addition to any sent to Sutton Courtenay or reprocessed in their beneficiation plant, in order to achieve this result.

Whilst the original sales figures may have been greeted with some initial incredulity, they were accepted at face value and the Power Station managers appeared to confirm their validity when interviewed about them by the press. Since the information had (without explanation) been removed from the website at this time, they presumably then knew that the published data were erroneous. This being so, and particularly in the light of the case being built by objectors on these figures that there was no requirement for Thrupp Lake, the revised data must be regarded with some suspicion. For this reason, although Npower claim to have published corrected data, in view of the lack of a proper explanation for the changes, we have chosen to retain the original data in our tables. Where this is done, the figures are shown in red. It may be possible to make tentative inferences from the differences; for example, that the amount of ash sent to Sutton Courtenay for waste capping in 2006 was 70,000 tonnes (the difference between the original and revised landfill figures in Table 1.) Nevertheless we will attempt to base our conclusions on the revised (black) figures. For the reasons given above and in the main text, those conclusions are largely unchanged.

Whilst we do not need to speculate about where the ash has been going, it might be worth pointing out that their ash sales for 2006 include at least 150,000 tonnes of unprocessed ash, and this, we now know, does not include ash sales to Sutton Courtenay. (Another interesting observation is that the reduction in ash disposals is exactly the same as the reduction in the stockpile between April 2006 and May 2007. This may of course be a coincidence, and we can offer no explanation for it otherwise.) It seems likely that the reduction in disposals between the two sets of figures is merely the result of an accounting alteration whereby some disposals have been shifted into 2007. There is a certain look of arbitrariness to the new figures, eg the exact 2:1 split between sales and landfill. Anyway, as has been explained, these changes do not alter, or hide, the reality of the situation.

Table 1: Didcot ash production (tonnes)

Year	Total ash produced	Ash sold tonnes (%)	Ash landfilled tonnes (%)	Total ash disposed	Excess (Deficit) tonnes	End of year stockpile tonnes
2001	284,000	97,000 (33%)	196,000 (67%)	293,000	-9,000	0
2002	328,000	203,000 (62%)	125,000 (38%)	328,000	0	0
2003	517,000	205,000 (40%)	312,000 (60%)	517,000	0	0
2004	296,000	126,000 (46%)	150,000 (54%)	276,000	20,000	20,000
2005	371,000	131,000 (58%)	96,000 (42%)	227,000	144,000	164,000
2006	443,000	491,000 (88%)	64,000 (12%)	555,000	-112,000	52,000
	443,000	270,000 (67%)	134,000 (33%)	404,000	39,000	203,000
6yr Average 01-06	**373,167**	**208,833 (57%)**	**157,167 (43%)**	**366,000**	**7,167**	
	373,167	**172,000 (50%)**	**168,833 (50%)**	**340,833**	**32,334**	

Percentages are based upon amounts disposed of. Landfilled amounts (except for figures in red – see text) are those on which there was a landfill tax liability. All other disposals are shown under "Ash sold". Figures in red relate to the Emission Returns published at the beginning of August 2007. Since the beginning of 2005, very little ash has been disposed of at Radley, and only 1,350 tonnes between 1 Jan 2007 and 13 Aug 2007[49]. The final two columns give the excess (or deficit) of production over disposals, and the amount of ash (assumed to be PFA) accumulated on the stockpile at the end of each year, with the baseline taken to be any ash stockpiled at the end of 2001. In 2002 and 2003, disposals matched production, so no stockpiling was taking place at this time.

The published figures for the ash produced by Didcot A are given in Table 1. Assuming that 20% of the ash produced is furnace bottom ash (FBA)[4] and that all of this is recycled, allows us to estimate what proportion of the remaining PFA goes to landfill as shown in Table 2.

From these figures, it is possible to deduce (Table 3) that, during 2001-3, Didcot was burning coal with an ash content of between 14% and 14.5%, and producing ash at a rate of between 52 and 53 tonnes per GWh. In 2004, they appear to have moved to a slightly lower ash content coal (13%) and produced ash at a slightly lower rate of 51 tonnes per GWh. In 2005 and 2006 however the ash production rate rose to 53 and 54 tonnes per GWh respectively indicating a move to a higher ash-content fuel mix[l]. At maximum capacity (2GW) Didcot could produce up to about 100 tonnes of ash per hour or 80 tonnes per hour of PFA.

[l] Didcot A has a multi-fuel capability and has recently been varying its fuel mix to include biofuels, as well as oil and gas. The figures for 2005 were oil: 23,000 tonnes; gas: 29,000 tonnes and biomass: 40,000 tonnes. The corresponding figures for 2006 were oil: 19,000 tonnes; gas: 31,000 tonnes and biomass: 66,000 tonnes.

Table 2: Didcot PFA production (tonnes)

Year	Total PFA produced	PFA sold tonnes (%)	PFA landfilled tonnes (%)	Total PFA disposed
2001	227,000	40,000 (17%)	196,000 (83%)	236,000
2002	262,000	137,000 (52%)	125,000 (48%)	262,000
2003	414,000	102,000 (25%)	312,000 (75%)	414,000
2004	237,000	67,000 (31%)	150,000 (69%)	217,000
2005	297,000	57,000 (37%)	96,000 (63%)	153,000
2006	354,000[m] 354,000[m]	402,000 (86%) 181,000 (56%)	64,000 (14%) 134,000 (44%)	466,000 315,000
6yr Average 01-06	**298,500** **298,500**	**134,167 (46%)** **97,333 (37%)**	**157,167 (54%)** **168,833 (63%)**	**291,333** **266,167**

Differences between PFA production and disposal are presumed to be due to local stockpiling, and this is quantified in table 1. (Excess, deficit and stockpiled amounts would be the same as those shown in Table 1.) Percentages are based upon amounts disposed of. Figures are calculated from those in Table 1 assuming that 20% of total ash produced is FBA, and that all of this is sold. Figures in red relate to the earlier Emission Returns published at the beginning of August 2007.

Table 3: Didcot Ash production statistics

Year	Electricity generated (GWh)	Load factor (%)	Coal burn (ktonnes)	Total ash produced (tonnes)	Ash content of coal	Ash production (tonnes per GWh)
2001	5,436	31%	2,014	284,000	14.1%	52.2
2002	6,217	35%	2,292	328,000	14.3%	52.8
2003	9,924	57%	3,692	517,000	14.0%	52.1
2004	5,826	33%	2,252	296,000	13.1%	50.8
2005	7,009	40%	2,679	371,000	13.9%	52.9
2006	8,152	45%	3,070	443,000	14.4%	54.3
6yr Average 01-06	**7,094**	**40%**	**2,667**	**373,167**	**14.0%**	**52.6**

This table gives the total ash production statistics relative to coal consumption and electricity generation using data from refs.52,53. The load factor is the amount of electricity produced divided by the theoretical maximum load capacity of the power station (2.0 GWy)

[m] Npower inform us that 416,000 tonnes of PFA were actually produced in 2006[49]. The difference could be due to the discrete nature of FBA production, in which case the discrepancy should average out year-to-year. It would therefore be incorrect to use this figure in the table. In any case, the extra 62,000 tonnes of PFA that this might represent would not significantly alter our conclusions. Note also that this would not affect the end of year stockpiled amounts, as these are determined by the data in Table 1.

The PFA sales figures (Table 2) are not consistent from year to year, varying between 40,000 tonnes in 2001 and a possible, though now disclaimed, 402,000 tonnes in 2006. 2002 was a good year for sales, but, since then, new environmental regulations to reduce NOx emissions forced a change to the combustion regime. This now produces ash with a high carbon content, which is unattractive to the ash industry and caused sales to decline. However Npower have recently invested in new ash beneficiation plant to remove the unburnt carbon and make their PFA more marketable. It has a capacity of 125,000 tonnes per year. Adding this amount of presumably marketable ash to the 2004 PFA sales (Table 2) of untreated low quality ash yields a reasonable baseline estimate of potential PFA sales to be in the region of 200,000 tonnes per year[n]. However, despite this facility supposedly coming online in 2005, PFA sales that year fell to just 57,000 tonnes (19% of total production) during that year.

In contrast, 2006 was, it seemed, an exceptional year for ash sales, showing what could perhaps be achieved if they put their minds to it. Even after the later downward revision of their total disposals, the amount of ash sold for other than landfill purposes is still a record amount. Of the PFA sent to landfill in 2006, we believe about 100,000 tonnes went to Sutton Courtenay, and very little is believed to have been sent to Radley. It may be unrealistic to assume that these figures can be sustained, but with more ash now being taken by the neighbouring waste site at Sutton Courtenay and large construction projects, like the Olympics, and new housing development able to absorb more of the ash, it is certainly well within the realms of possibility.

Under the terms of the European Large Combustion Plant Directive 2001/80/EC, as an opt-out station, Didcot A power station will be limited to 20,000 operational hours between January 2008 and 31 December 2015. This limits the average load factor during that 8 year period to just 28.5%. Now, in order to maximise returns and capitalise upon the current coal vs gas premium, it is reasonable to assume that the power station operators will want to operate the power station at near 100% operational efficiency, ie they would wish to produce as close to 40,000 GWh as possible, during the 8 year period, and this will probably bring the power station to closure in or around 2012.

Using the data from tables 2 and 3, the annual PFA surplus X in ktonnes is found to be given by

$$X = 700L - S$$

Where L (<1) is the operating load factor and S is the annual sales of PFA in ktonnes. For S = 200 (the minimum sales projection) and a load factor of less than 28.5%, there would be no surplus ash. Coincidentally this is the maximum load factor, averaged over the 8 year period 2008-2015, that would be allowed by the LCPD. However Npower may wish to close the station earlier than this and run the station harder in the meantime. Closure in 2012 implies a maximum average load factor of 45% (ie, what they achieved in 2006). To reduce the surplus to zero, under these conditions, would require increasing ash sales to around 315,000 tonnes per year. Given what was achieved in 2006/7, this is certainly well within the bounds of possibility.

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[n] We know that the neighbouring waste site is currently absorbing about 100,000 tonnes per year for capping and restoration (this no longer impinges on their aggregate waste limit) and another 100,000 tonnes of beneficiated ash can be produced for construction materials.

Let us consider some scenarios. If we start by assuming that, between 1st Jan 2007 and 1st Jan 2008, the Power Station achieves a 45% load factor, and "sells" 200,000 tonnes[n]. We also estimate that they have, as of the end of May 2007, already disposed of a further 150,000 tonnes of unprocessed ash (see above). This means that, in 2007, disposals seem likely to be at least sufficient to match production. If however, during the following 5 years, they only manage to dispose of 200,000 tonnes per year, then we arrive at the following:

Table 4: Didcot Ash production projection 1

Year	Electricity Generated (GWh)	Ash Produced (tonnes)	PFA Produced (tonnes)	PFA Disposed (tonnes)	PFA Surplus (tonnes)
2007	8,150	440,000	350,000	350,000	nil
2008-2015	40,000	2,000,000	1,600,000	1,000,000	600,000
Totals	**48,150**	**2,440,000**	**1,950,000**	**1,350,000**	**600,000**

Electricity and ash production projection for Didcot A Power Station for the period from 1 January 2007 to 31 December 2015 based upon figures above and a 20,000 hour limit, as imposed by the LCPD, at around 100% operational efficiency, between 2008 and 2015. "PFA Disposed" means all ash leaving the power station site, other than to Radley. A residual surplus, of 203,000 tonnes stockpiled at the Power Station at 1 Jan 2007, as implied by the emissions returns (Table 1) has to be added to the surplus above, yielding a net PFA surplus of about 0.8 million tonnes.

Under this "worst case" scenario, the amount of surplus ash that will be accumulated between 1/1/2007 and closure of the station is close to our best estimates of the capacity of Thrupp Lake. If this is the basis of Npower's planning, it would seem to suggest that recycling *any* ash for beneficial use was not something that featured in their original plans.

On the other hand, if, in 2007, the power station continues to dispose of ash at the supposed rates of 8,000 tonnes per month of untreated ash to Sutton Courtenay, 10,000 tonnes per month of processed ash to the construction industry and 30,000 tonnes of untreated ash to elsewhere, then the existing stockpile (estimated to 203,000 tonnes at the start of the year) will be cleared by the end of 2007. To maintain the stockpile at its minimum operating level, the power station would only need to dispose of 320,000 tonnes per year, a figure that is certainly achievable for average disposals, if not actual disposals on a year by year basis without using Thrupp Lake. If moreover, the power station were to remain open until 2015, it would only have to achieve sales of 200,000 tonnes per year, as already noted. In practice, the power station could allow the ash pile to grow to over 300,000 tonnes by the end of 2015, and to dispose of this in subsequent year(s). Given that the power station has all of the summer months to dispose of the previous winter's ash production, there would be little risk to the power station's operations through striving to sell the surplus ash rather than dump it into the Radley Lakes. The lorry traffic required is not significant, 100,000 tonnes of ash goes to the neighbouring waste site for use as daily capping. Shifting the rest by lorry would require only between 100 and 220 (20 tonne) lorry movements per week, rather less than in 2006 and 2007.

Table 5: Didcot Ash production projection 2

Year	Electricity Generated (GWh)	Ash Produced (tonnes)	PFA Produced (tonnes)	PFA Disposed (tonnes)	PFA Surplus (tonnes)
2007	8,150	440,000	352,000	555,000	-203,000
2008-2015	40,000	2,000,000	1,600,000	1,600,000	nil
Totals	**48,150**	**2,440,000**	**1,952,000**	**2,155,000**	**-203,000**

Electricity and ash production projection for Didcot A Power Station for the period from 1 January 2007 to 31 December 2015 based upon figures above and a 20,000 hour limit, as imposed by the LCPD, at around 100% operational efficiency, between 2008 and 2015. "PFA Disposed" means all ash leaving the power station site, other than to Radley, which is presumed to be unavailable. A residual surplus, estimated to be 203,000 tonnes stockpiled at the Power Station at 1 Jan 2007 (Table 1) has to be added to the surplus above, yielding a net PFA surplus that is effectively zero tonnes.

A further conclusion is that, in order to justify destroying Thrupp Lake, the power station would need to constrain PFA sales to no more than 200,000 tonnes per year in order to have sufficient material to complete the filling of the lake.

Appendix 2 The Rocktron Process: A Sustainable Environmentally-friendly way of disposing of PFA?

The RockTron™ process[17] is an ash beneficiation process that can separate PFA, obtained from any source, which may be direct from the power station or from landfill, and completely convert it into valuable and highly marketable products that would be attractive to a range of industries. The process uses reliable well established technology, which has been available for around 15 years.

The level of investment per unit of PFA throughput is similar to that for the STI plant currently installed at Didcot. However a RockTron plant would offer increased added value and greater reliability together with several other advantages detailed below.

The RockTron process separates PFA into the following products:

Cenospheres – a readily marketable product already exploited through wet disposal.

High grade carbon powder – a high-purity carbon powder (50micron median particle size) suitable for metallurgical, chemical and gas/water treatment applications. The powder is also a low sulphur fuel suitable for reburning.

MagAsh™ – a fly-ash derived magnetite suitable for media separation and magnetic filtration.

Alpha™ **cement** - a high specification pozzolanic material predominantly consisting of spherical aluminosilicate particles. It is superior to EN450 or BS3892 Part 1 PFA material since it exceeds both specifications in terms of fineness and low residual carbon content.

Delta™ **cement** - a pozzolanic material predominantly consisting of spherical aluminosilicate particles. It has a coarser particle size distribution than άlpha™ cement constituent and is supplied as a wet filter cake for use in applications such as concrete block or roof tile manufacture. It is superior to EN450 and BS3892 PFA material.

The process consumes all of the ash. There is **no residual waste** product

The construction of a RockTron plant on the Didcot site would take around 18 months from date of decision to build. However ash produced during the intervening time can be temporarily stockpiled near the power station, either above ground or in wet-filled lagoons. The process can use dry ash or conditioned ash. The use of a temporary stockpile offers several important advantages:

a) To store surplus ash while the plant is being constructed.

b) To act as a buffer to cope with different rates of ash production and processing.

c) To provide a sustained supply of ash for processing as the power station is run down to end-of-life.

d) To provide processed ash production capability beyond the life of the power station and hence achieve extended capitalisation on the initial investment combined with minimisation of waste.

Because unprocessed ash need not be stored dry, the process can readily accommodate short-term disparities in market take up and ash production, without the need for expensive dry-storage facilities. Indeed we see little risk of failure of long-term take-up if the claims that building products offer higher performance for lower cost than conventional cementaceous materials are true. Moreover, a plant at Didcot would be the sole major source of such materials in Southern England. In view of these considerations, and the planned large-scale housing, and other, development in the SE, the proposal should carry little commercial risk.

The proposal makes good business sense. Supposing that Didcot produces 2 million tonnes of PFA over 9 years (a conservative estimate) and none thereafter, a rough statement of the profit and loss account would appear as follows:

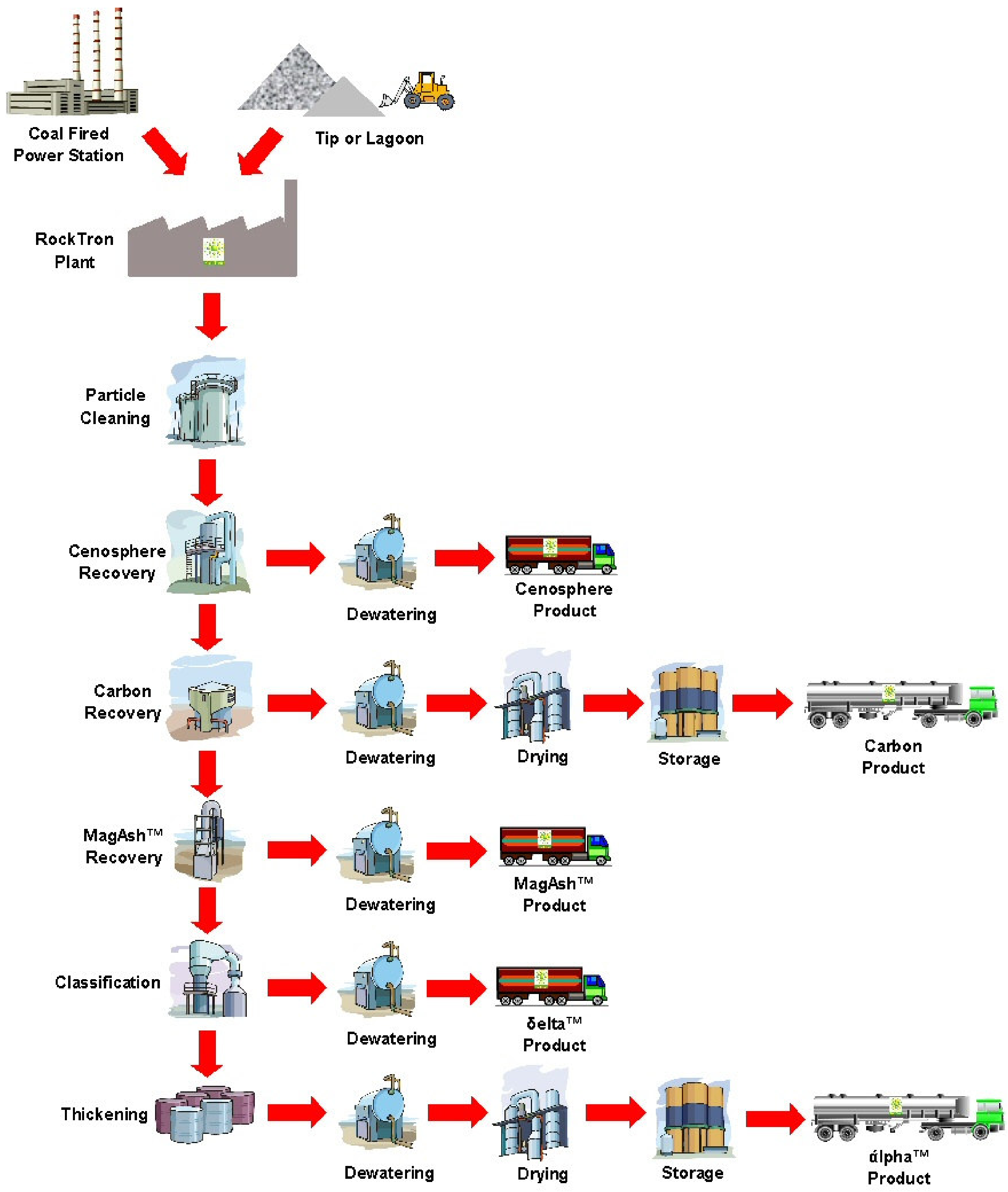
	Costs £M	Income £M
Initial cost of plant including land & buildings, access roadways, storage facilities and plant equipment	9	
Production costs at £8/tonne of PFA consumed	16	
Sales at £25/tonne of PFA consumed		50
Net profit over 9 years		**25**

The process thus values the PFA at about £17 per tonne, or £19 per tonne when set against the cost of landfill tax. For an initial outlay of £9M, a net loss, due to the cost of permanent disposal, can be turned into a £25M profit. The plant, as costed, would be capable of reliable 24/7 operation with a capacity to process up to 400,000 tonnes per year.

Moreover, in replacing conventional cement products derived from carbon-expensive kilning of limestone, the process would thereby have a significant beneficial impact on CO_2 emissions. If all of Didcot's ash production were to be processed and recycled this way, the potential saving in CO_2 emissions would represent around 4% of the emissions produced by the power station itself.

The plant could also provide sustainable long-term solution to ash production in the event that Didcot A opts into the LCPD and continues to operate beyond 2015.

This process has recently been adopted by Scottish and Southern Energy PLC[18] at their Fiddler's Ferry Power Station in Cheshire, in a joint venture with Rocktron. The new plant will be able to process up to 800,000 tonnes per year, which will serve to supply the products to the North West of England.



A simplified flow diagram of the RockTron Process

(from www.rocktronplc.com)

Appendix 3 Lake Capacity

This appendix describes the details of the calculations of the lake capacity for storing PFA. Reference is made to Figure 2, which shows a schematic section of the original lake showing the surrounding geology; and to Figure 3, which is a schematic section of the engineered disposal site when filling has been completed.

It is first necessary to understand how lake is to be engineered. First, the lake (Figure 2) will be drained ("dewatered"), then most of the silt and gravel from the bottom will be removed to expose the Kimmeridge Clay underneath. Clay will be dug out of "borrow pits" and used to create an embankment or bund all the way around the rim of the lake so as to create a sealed void (Figure 3) into which the PFA will be pumped as a water-borne slurry and allowed to settle. The water is then drained off from the surface, leaving the PFA in a solid or semi-solid state. In this way, the void will be filled up to 55.5m AOD, and finally covered with a layer of soil with an average thickness of 0.3m. The end result will be a trapezoidal plateau with a level top at 55.8m AOD.

The engineering is subject to two key principles, which are embodied in the planning permission, namely (1) that the only materials to be (permanently) removed from the lake are water and "sand, silt and gravel" taken from the edges and bottom of the lake, some of which will constitute the "soil" to be used for the restoration of parts of the final surface; and (2) the only material to be imported is (wet) PFA. These principles allow the capacity of the lake to be calculated from the balance of amounts of material imported and exported, as well as from the indicated volume of the void space.

In the "before" cross-section (Figure 2) the islands are considered to have been removed down to the nominal water level (52m AOD) and all remaining material levelled across the bottom of the lake. This puts the bottom at an average level of 49.6m AOD[55], yielding a nominal initial water depth of 2.4m.

SCHEMATIC CROSS SECTIONS

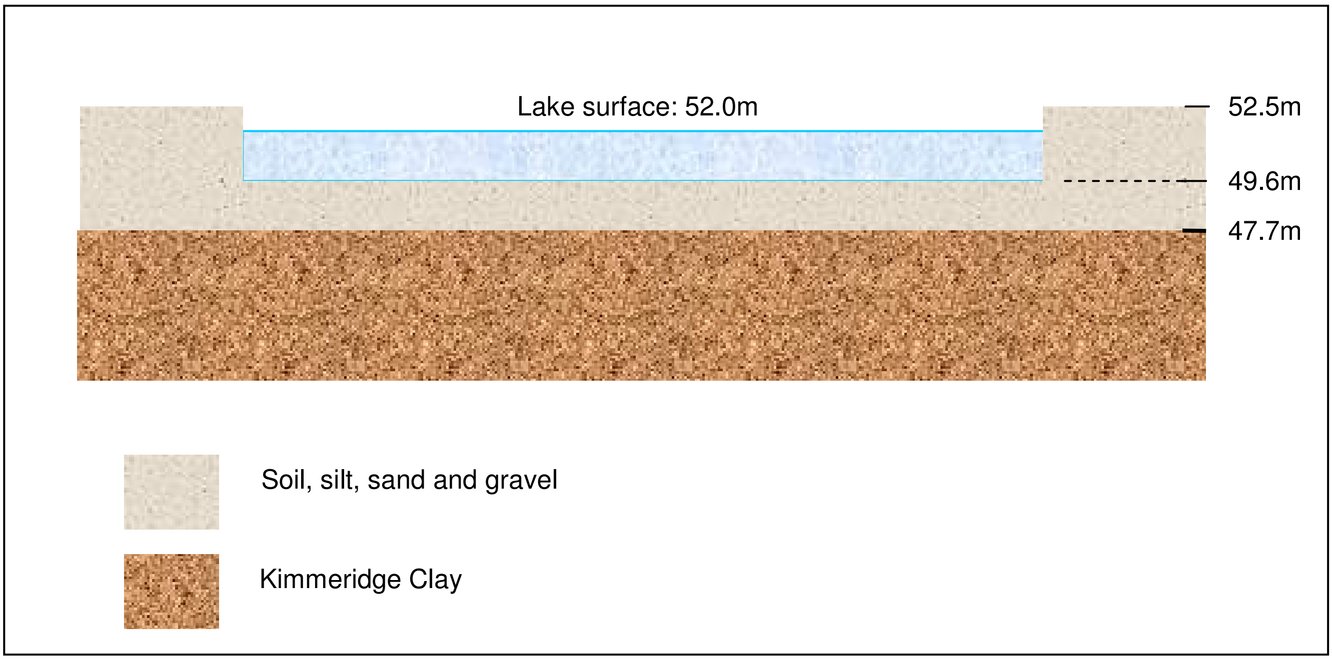


Figure 2: Schematic of vertical section of lake before filling, showing average levels (AOD) used in calculations. (Not to scale.)

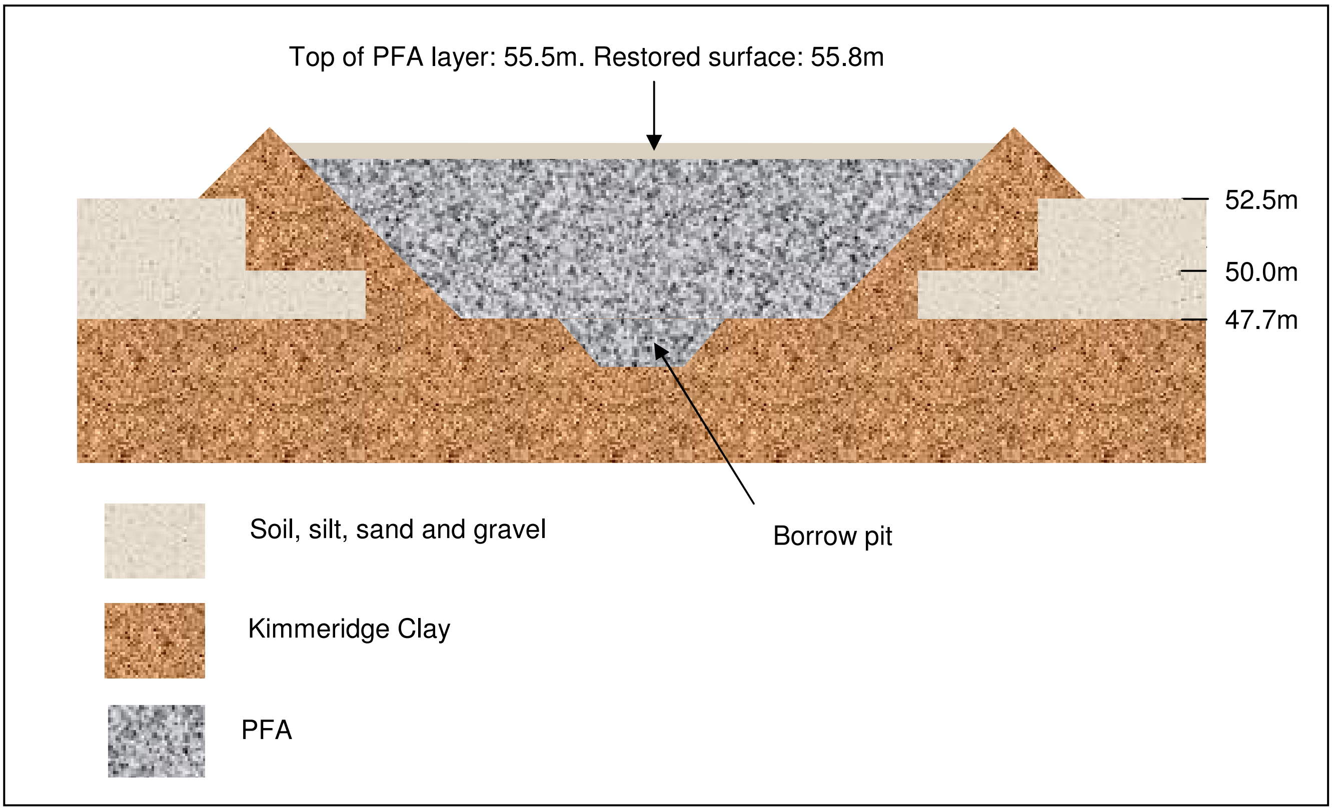


Figure 3: Schematic vertical section of lake after filling and restoration, showing schematised bund profiles (Figure 5) and average levels (AOD) used in calculations. (Not to scale.)

The approved engineering drawings[36] show the footprint of the finished Lake E site to be a roughly rectangular trapezoidal mound measuring, at its base, 365m east to west and 360 metres north to south, excluding an area measuring 65m east to west by 160m north to south in the northeast corner where the house is. The resulting shape is shown in the following schematic, the dimensions of which are given in Table 6.

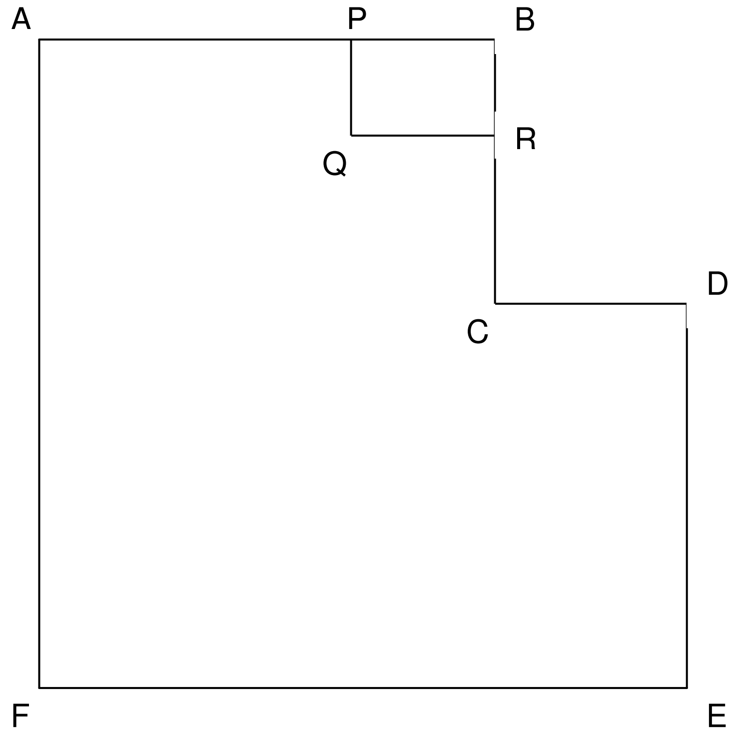


Figure 4: Schematic plan of lake. PQRB is the cenosphere harvesting area.

Table 6: Lake dimensions

Description	Height	AB	BC	CD	DE	EF	FA	PQ	QR	Area	Perimeter
Footprint	52.0	300	160	65	200	365	360	-	-	121,000	1,450
Final top surface	55.8	277	160	65	177	342	337	-	-	104,854	1,358
Bund Crests	56.1	275	160	65	175	340	335	50	60	100,500	1,350
Final overburden layer	55.65	272	160	65	172	337	332	50	60	98,484	1,338
Final PFA surface	55.5	271	160	65	171	336	331	50	60	97,816	1,334
Internal base of void	47.7	225	160	65	175	290	285	50	60	69,250	1,150
Exposed clay at base	47.7	249	160	65	199	314	309	50	60	83,626	1,246

Dimensions, in metre units, of various layers (Figure 3) in the Lake E disposal mound, with reference to the schematic shown in Figure 4. Each layer is defined by its height in metres AOD and accompanying description. The first two, the Footprint and the Final top surface are external dimensions taken around the perimeter ABCDEF, while the remainder are internal dimensions, ie to internal bund wall or as otherwise indicated, and which follow APQRCDEF.

The footprint area, A, is given in Table 6 as 121,000 sq.m. The height, h, of the structure will be 3.8 m above the nominal lake level, which is taken to be 52m, which is also the value indicated on the drawings. The total volume of the mound above the lake surface can now be calculated from the following formula for the volume of a rectangular-based truncated quasi-pyramidal structure with sides having a fixed slope of 1 in 3:

$$V = A_{eff}h \quad (1)$$

$$A_{eff} = A - h(1.5P - 12h) \quad (2)$$

where P is the perimeter at the base (1450 m). This formula is exact for volumes having rectangular sections or sections like the shape shown in Figure 4, in which the cut-out has a fixed area (ie does not vary with height). For the mound above the lake surface, this yields A_{eff} ~ 113,000 sq.m and V ~ 429,000 cu.m. Making an allowance for the banks (the mound overlaps them slightly) this is reduced by about 6,000 cu.m to 423,000 cu.m.

Npower say[54] that the volume of water in the lake is 410,000 cu.m, which, if removed, would create a void space of 840,000 cu.m *even before any solid material is removed*! Now, we think that Npower has over estimated the amount of water[o] – their amount would require the lake to have an average depth of around 4m, which is wrong. Using a contour map of the lake bottom, the average depth can be estimated more reasonably to be about 2.4 metres[55], which, taken over the surveyed lake area[35], gives 264,000cu.m of water.

It is important to note that this average depth is calculated over the whole lake area, including the islands, which are treated as areas of zero depth. This means that the volume of material making up the islands below water level (52m) is automatically taken into account in ensuing calculations. However, when determining the amount of solids that will be removed from the lake, we will need to account for any amount of material that is above the 52m level, which is estimated to be around 8,000 cu.m. This material is considered to have been removed for the purposes of the ongoing calculation.

Adding the volume of the water to the volume of the mound gives the capacity of the lake void to be about 687,000 cu.m *before any further solid material is removed.* So, if Npower additionally remove say 100,000 tonnes of overburden (silt and gravel) then the capacity is increased to around 790,000 cu.m. However Npower say they will remove the 1.9 m (average) depth of overburden over the entire *internal* area of the lake, and that none of this will be used in the construction of the bunds. The area to be removed is reduced by the internal faces of the bunds[p] but extends about 12m under them and is estimated in Table 6 to be about 83,600 sq.m. Allowing for the retention of material underneath the bunds to an average level of 50m (0.4m above the average level of the lake bottom) the volume of removed solid material is 83,600 × 1.9 – (110,000 – 83,600) × 0.4 ~148,000cu.m. However, of this, about 30,000 cu.m will be returned to provide a 0.3m average depth of overburden on the final ash surface[q]. The net amount of solid material removed from below 52m is therefore estimated to be around 118,000 cu.m, thus taking the capacity of the lake to around 808,000 cu.m.

There is an element of uncertainty in the final figure, since it inevitably depends upon how much material is ultimately removed from the lake. This could be subject to variation, as the material only *needs* to be removed from under the bund faces and from over the

[o] We think that npower has mistakenly indicated the volume of water *to be removed* to be that within the lake.

[p] The exposed clay area extends 12m under the bunds in order to provide sealing to the bund faces. This is allowed for in the calculation.

[q] This is the difference between the operating level , which is the level to which ash filling is possible, and the final restoration level as shown on the approved drawing (Earthworks Sections) J20115/E/201 Rev.C. The restoration plan indicates that this overburden will be laid in the NE and NW corners, leaving the rest of the surface as bare PFA.

borrow pit area. The maximum area of lake floor that could be left is about 12,000 sq.m, representing no more than about 25,000 cu.m of material, which still leaves over 780,000 cu.m of void. Whatever they decide to do about this, the capacity of the lake is 423,000 cu.m plus the volume of all material, water plus solids, that is permanently removed from the lake from below the 52m level. The result is obviously going to be nearer to 800,000 cu.m than 500,000 cu.m. If more or less all of the silt and gravel is removed down to the top of the Kimmeridge clay, then ~ 800,000 cu.m is a reasonable estimate. Note that this particular conclusion does not depend on the precise apportionment of lake contents between water and solids, though, of course, the actual amount of solids to be removed does.

The volume of solids that will be removed from the lake is also given by the above as 118,000 cu.m, to which we add 8,000 cu.m representing the volume of the islands above water level to give a total of 126,000 cu.m. Npower could leave as much as 25,000 cu.m in the lake, but this still means that they will have to remove at least ~100,000 cu.m.

Another way to estimate the void space is to calculate the PFA volume, which, using the figures in Table 6, is the depth, h, of the PFA multiplied by the effective mean area A_{eff} given by equation (2). According to Table 6, the relevant values for the PFA layer are A=97,816 sq.m, P=1,334 m, h = 7.8 m. This yields A_{eff} = 83,000 sq.m. and V = 647,000 cu.m to which must be added the volume of clay extracted to make the bunds (which is estimated in Appendix 4 to be 145,000 cu.m). This yields a total PFA volume of about 792,000 cu.m, which agrees acceptably with the above calculation.

Allowing for the accuracy of our calculations and the possible uncertainty in the amount of solids Npower will remove, we can say that the PFA storage capacity of Thrupp Lake is

785,000 cu.m ± 25,000 cu.m

The total volume of solids (silt and gravel) that will need to be removed is[r]

110,000 cu.m ± 20,000 cu.m

[r] Note that the uncertainties are correlated: The more material that is removed the greater the capacity.

Appendix 4 Bund Volumes

The bunds[37] are clay embankments having a basically triangular cross-section with inner and outer slopes of gradient 1 in 3. The bund cross section varies around the lake due to variation in surrounding topography. For the most part, the bunds rest upon the original lake floor, except for a 10.5 metre strip which extends fully down to the clay substrate to provide sealing and stability; and the outer edges, which, for the most part, rest on the bank. For the purposes of estimating the bund volume, a representative section is taken to be an isosceles triangle resting on a base at 50m, an average of the lake bottom under the bunds, with the outside corner removed below 52.5m (mean ground level) and the base stepped down to 47.7m (mean clay level) for a distance of 12m at the inside corner. This is illustrated in Figure 5.

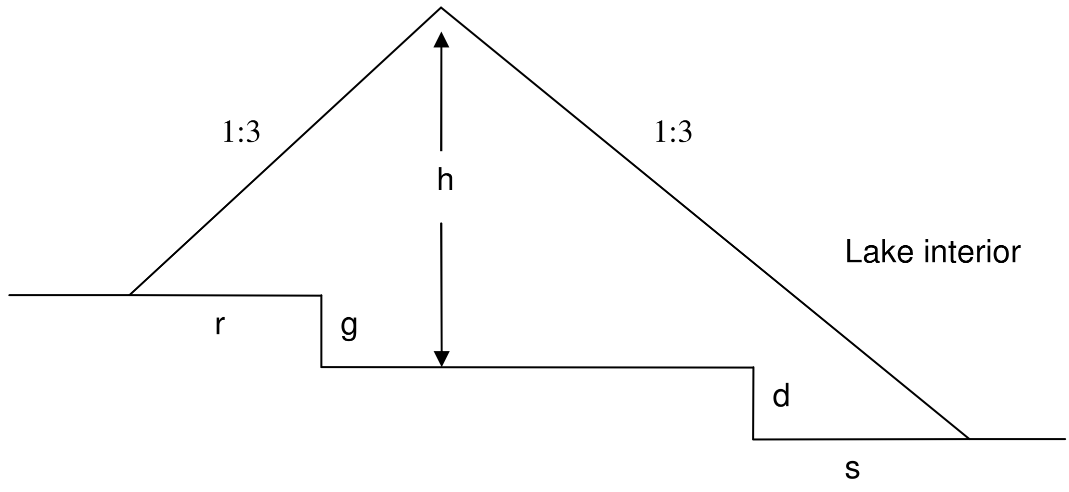


Figure 5: Schematic of bund cross section (not to scale)

The area of this section is given by elementary geometry as follows

$$A_b = 3h^2 - g(r+1.5g) + d(s-1.5d)$$

Where h is the height of the bund above its base = (56.2m – 50m) = 6.2m; d is the depth of the clay layer below the base = (50m – 47.7m) = 2.3m; g is height of the mean ground level above the base = (52.5m – 50m) = 2.5m; r is the overlap with the existing bank

= (footprint area – lake area) ÷perimeter = $(121{,}000m^2 - 110{,}000m^2)/1{,}450m$ = 7.6m

and s = 12m is the effective width (allowing for adjoining slopes) of the contact strip between the bund and the clay substrate. Inserting these values into the formula gives A_b = 107 sq.m. This figure is very approximate because it does not fully take into account details of the land and lake bed profiles around the lake. However it is accurate enough for our purposes. A metre of bund having the cross-section shown therefore requires 107 cu.m. The total length of bund, measured along the crests, is approximately 1,350m, giving a total bund volume in the region of 145,000 cu.m.

Appendix 5 Letter to Government about bricks from PFA

The following letter, on the subject of making bricks from PFA, was sent to Ruth Kelly, then Secretary of State for Communities and Local Government on 4th October 2006. The letter was copied to David Miliband, then Secretary of State for Environment Food and Rural Affairs, and Dr Evan Harris MP, among others.

SAVE RADLEY LAKES

www.saveradleylakes.org.uk

Date: 04 October 2006

Our ref: SRL/CLG/009

Rt Hon Ruth Kelly MP
Secretary of State for Communities and Local Government
Eland House
Bressenden Place
London
SW1E 5DU

Re: Radley Ash Disposal Scheme - Lake E.
Application for Planning Permission, dated: 31 January 2006.
Application No: RAD/5948/24-CM
Referral by Oxfordshire County Council – 10 July 2006

Dear Secretary of State,

Government, indeed your own Department, is committed to building 300,000 new homes in South East England in the next decade. I estimate that this will consume roughly 3.5 million cubic metres of blocks, concrete and mortar as well as 2.5 million cubic metres of bricks. This is just for the houses alone. More materials will be needed for the construction of roads and infrastructure. An important concern must be the environmental impact of producing and transporting all this material.

Save Radley Lakes has already drawn your attention to the potential for using pulverised fuel ash (PFA) from coal-fired power stations in the manufacture of concrete and cementaceous materials[56,57]. However there is a limited market for PFA in this area, mostly due to the fact that PFA is currently used only to replace part of the pozzolanic component of concrete and that increasing the PFA proportion beyond about 10% of the total mix reduces performance. Low carbon PFA is an essential component of high-performance concrete, but only in proportions of up to 8%. However it is important to note that PFA, from any source, can be converted into light-weight aggregate (LWA) and, in this way, can comprise up to 64% of the concrete mix[58].

Perhaps most significantly, technology now exists to make bricks composed of 100% PFA[58,59,60,61,62]. These bricks are superior, in virtually every respect, to conventional clay bricks: they are stronger and lighter, adhere better to ordinary mortar and require less energy (and hence produce less CO_2) for their manufacture and transportation. They possess low water absorbency, are highly resistant to frost and chemical attack. They can be manufactured in virtually any colour, shape and surface texture. Moreover the raw material, fly ash, comes at "zero cost". The potential of this application for exploiting surplus PFA produced by Britain's power stations is significant. Unlike concrete manufacture, which cannot guarantee a steady market for PFA, and which requires major projects in order to take appreciable amounts of ash, brick manufacture can readily soak up the remainder of the country's PFA production, both in the future as well as some that is currently "stockpiled" eg, in mounds or landfill. Britain currently produces somewhere in the region of 10 million tonnes of PFA per year. Most of this production occurs in the North.

Clearly there is capacity to utilise all of the country's current and future PFA production by converting most of it into building materials using one or more of the technologies we have put forward[56,57,58]. This utilisation would significantly reduce the impact, on the environment, in terms of CO_2 production, primary aggregate, limestone and clay extraction, not to mention the damage caused by the disposal of PFA as waste. The current practice, of digging up the countryside to extract primary aggregates, and clay (for brick manufacture) only to have to fill the holes back up with PFA, is madness. Government needs to follow the example of other countries and introduce stronger incentives to ensure the take up of fly-ash-based materials, by the construction industry, which would be in line with existing Regional[63] and European policy[64].

Didcot 'A' power station in Oxfordshire is expected to produce over 2 million tonnes of PFA in the next 10 years[65]. This amount of PFA is sufficient to make about 1.25 million cubic metres of bricks, a significant proportion of the total amount needed for proposed new build in the South East.

The disposal of 500,000 tonnes of PFA at Radley, over the same period, as currently proposed by RWE npower, who operate the Didcot power stations, is therefore not only unnecessary, but runs counter to EU and Regional policy on waste disposal and the recycling or reuse of secondary materials in preference to new extraction.

We therefore urge you to refuse this planning application and insist that RWE use available disposal facilities in the vicinity of the power station in order to stockpile the PFA while production facilities to make use of it are commissioned.

Didcot 'A' power station is due to close, under the terms of the LCPD[66], by the end of 2015. In the meantime it is geographically well-placed to meet much of the anticipated increased demand in the SE for building materials. It is therefore essential, in order that maximum benefit can de derived from this opportunity- as well as maximum return on capital investment – that no further PFA is wasted by pumping to Radley.

Government can do a lot to make these changes happen. To begin with, the meagre £2 per tonne landfill tax that applies to the permanent disposal of PFA needs to be substantially raised as a matter of urgency; investment in construction material manufacturing from PFA needs to be strongly encouraged and, at the same time, further discouragement of primary extraction of materials may be appropriate, eg, a levy on clay extraction; brick and aggregate manufacturing capability should be integrated into the design of new coal-fired power stations for maximum energy efficiency; and finally, PFA should only be disposed of in a manner that allows for its future recovery. Planning applications, like that submitted by RWE npower, should be refused.

Yours sincerely,

Appendix 6 List of Abbreviations used in this Report

This appendix lists and explains the various abbreviations used throughout this report.

AOD	Above Ordnance Datum (refers to height above "sea level")
CEGB	Central Electricity Generating Board, the government body that ran the electricity supply industry before it was privatised.
cm	centimetre
CO_2	Carbon dioxide
cu.m	Cubic metre
ECOBA	European Coal Combustion Products Association
EDF, E.ON	Names of power companies.
EIA	Environmental Impact Assessment
EN450	The European Standard for PFA that is suitable for use in the manufacture of concrete.
ES	Environmental Statement, specifically the one submitted by Npower in January 2006[3]
ETS	Emissions Trading Scheme , 2003/87/EC
EU	European Union
FBA	Furnace bottom ash – the coarse component of fuel ash recovered from the furnace floor.
GW	Gigawatt, a unit of power equal to 1 million kilowatts
GWh	Gigawatt hour, a unit of electricity, or energy, equal to one million kWh or one million standard "units" of electricity.
ktonne	kilo tonne, unit of mass equal to 1,000 tonnes = 1,000,000 kilograms
kWh	kilowatt hour, the standard "unit" of electricity.
LCPD	Large Combustion Plant Directive, 2001/80/EC
LyTag	Trade name for lightweight aggregate made from PFA[43]
m	metre
MBM, ARC	Names of companies in the construction industry.
MOD	Ministry of Defence
MW	Mega watt, a unit of power equal to 1 million watts or 1000 kilowatts
NOx	A term used to denote the various oxides of nitrogen, which are harmful pollutants produced by in-air combustion.
Npower	RWE npower
PFA	Pulverised fuel ash, also known as fly ash – the fine component of fuel ash extracted from the gas stream.
SLA	Synthetic lightweight aggregate
sq.m	Square metre
STI	Separation Technologies Inc. – manufacturers of ash beneficiation equipment.
UKQAA	UK Quality Ash Association
WRG	Waste Recycling Group

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