EP UK Investments

Gale Common Extraction Project

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Sustainability and Carbon Review

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GLOSSARY

Abbreviation	Description
AONB	Area of Outstanding Natural Beauty
tCO_2e	Tonnes carbon dioxide equivalent
ggbs	Ground granulated blast furnace slag
GHG	Greenhouse gas
NPPF	National Planning Policy Framework
NYCC	North Yorkshire County Council
PFA	Pulverised fuel ash
tpa	Tonnes per annum
UKQAA	UK Quality Ash Association

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APPENDIX A: MARKET SCENARIOS, ASSUMPTIONS AND DATA SOURCES

1.0 EXECUTIVE SUMMARY

1.1 Sustainable development is central to national and local planning policy, including the National Planning Policy Framework (Ministry of Housing, Communities and Local Government (MHCLG), 2019) which sets out economic, social and environmental objectives to achieving sustainable development, including using natural resources prudently, mitigating and adapting to climate change, and moving to a low carbon economy.

1.2 Gale Common is an ash disposal site in North Yorkshire, which has historically accepted waste ash from the now closed Eggborough and Ferrybridge 'C' coal-fired power stations. This ash, known as pulverised fuel ash (PFA) can be used to replace primary aggregates (such as sand and clay) in construction materials and reduce the carbon footprint of those construction materials, thereby supporting the Government's sustainable development objectives.

1.3 EP UK Investments (EPUKI) is seeking planning permission for an increase in the rate of PFA export at Gale Common from 30,000 tonnes per annum (tpa) to 1 million tpa. The large deposit of PFA available would be used in a variety of applications in the construction industry, including the manufacture of concrete building blocks and cement, and EPUKI already has considerable interest from potential customers.

1.4 An assessment has been undertaken to identify the lifecycle sustainability benefits of using the PFA extracted at Gale Common as an alternative to the use of the following materials:

- primary aggregates (e.g. sand) from other sites in the UK; and
- imported PFA, as the demand for PFA exceeds current UK supply.

1.5 The various potential applications of the PFA will have different greenhouse gas (GHG) emissions savings associated with them; however the assessment has demonstrated that, regardless of exactly how the Gale Common PFA is used in the construction industry, significant carbon savings will be achieved. Increasing the export of PFA from Gale Common will therefore make a positive contribution to the UK's decarbonisation targets.

1.6 In addition to carbon savings, other sustainability benefits have been identified, including reducing the use of primary aggregates and restoring the site back to its original state for use for ecological, landscape and community benefit. Furthermore, increased export at Gale Common will help maintain the PFA secondary aggregates business and create associated employment opportunities.

2.0 INTRODUCTION

2.1 Gale Common is an ash disposal site in North Yorkshire, which has historically accepted waste ash generated from Eggborough and Ferrybridge 'C' coal-fired power stations (both now closed and no longer exporting ash to Gale Common). This ash, known as pulverised fuel ash (PFA), has a number of beneficial uses in the construction industry and can replace primary aggregates such as sand. In recent years PFA has been sourced for these uses directly from coal-fired power stations (with excess PFA being disposed of to landfill sites such as Gale Common), but as coal-fired power stations continue to close alternative sources of PFA are required.

2.2 Up to 30,000 tonnes per annum (tpa) of PFA have been exported from Gale Common since 2003, for use in the manufacture of aerated blocks (mainly for building internal walls in new housing developments). Planning permission is now being sought by EPUKI for the extraction to 1 million tpa of PFA. This review presents an evidence-based assessment of the carbon savings and wider sustainability benefits associated with this.

Uses of PFA

2.3 There are two key markets for PFA – 'non-cementitious' uses and 'cementitious' uses. These are described further below.

Non-Cementitious Applications

2.4 PFA is used in products such as aerated concrete blocks and grouts for ground stabilisation. In the case of aerated concrete blocks, if there was no PFA available, the alternative would be ground sand. Sand is a primary aggregate that is non-renewable (i.e. has finite amounts and the extraction and grinding carries a higher energy and environmental cost compared to extraction and screening of PFA from landfill). Moreover, screened PFA has better performance characteristics than ground sand as a result of its chemical and physical properties.

2.5 The PFA currently exported from Gale Common is used in non-cementitious applications.

Cementitious Applications

2.6 PFA can be used to partially replace shale or clay in clinker manufacture for the cement industry (up to 5% PFA), and, after some additional processing to remove some of its moisture and carbon content, PFA can also replace cement for use in concretes and mortars (up to 35% PFA). As cement manufacture is both energy intensive and a significant user of primary aggregates, the use of PFA therefore offers many environmental and sustainable advantages.

2.7 Furthermore, PFA can also be an essential material in certain high performance (durable) concretes where there is a need for chloride or sulphate resistance. The UK is a net importer of blast furnace slag (which is an alternative material providing chloride or sulphate resistance).

2.8 It is assumed that the processing required to make PFA suitable for use in some of the cementitious applications could be undertaken off site.

Assessment Scope

2.9 The assessment has been undertaken to identify the lifecycle sustainability benefits of using the 1 million tpa PFA extracted from Gale Common as an alternative to the use of the following materials:

- use of an equivalent quantity of primary aggregates (e.g. sand) from other sites in the UK; and
- use of an equivalent quantity of imported PFA, as the demand for PFA exceeds current UK supply.

2.10 The primary focus of the assessment has been the carbon or GHG emissions resulting from extraction, processing and transportation of the PFA, and also the carbon impacts of the alternative materials currently in use.

2.11 In addition, the assessment considers the wider sustainability credentials of PFA such as its contribution to resource efficiency and a more circular economy (where waste is minimised and

resources are kept in use for as long as possible) in comparison to alternative primary and secondary sources.

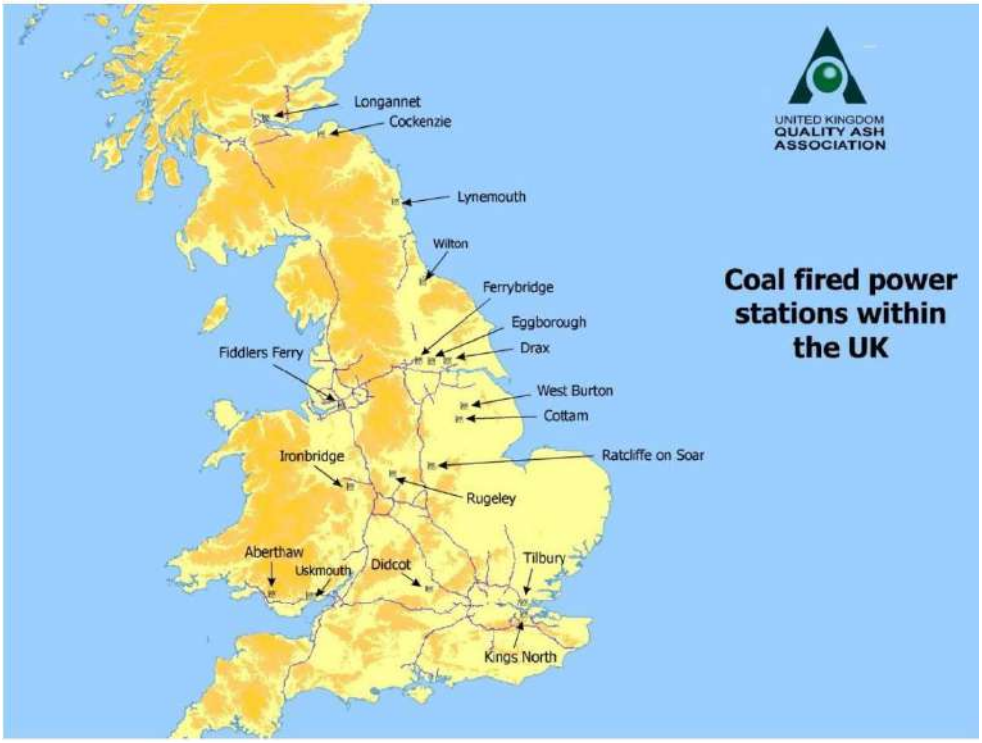
PFA Extracted in the UK

2.12 PFA is produced during the combustion of solid fuels at power stations and is regulated as a waste which, if not recovered, is disposed of to landfill. It is however readily recoverable from landfill when it has been the only waste deposited in a location, such as is the case at Gale Common.

2.13 It has been estimated by the UK Quality Ash Association (UKQAA) that there could be up to 100 million tonnes of PFA available from landfill. This may not all be accessible or suitable but clearly it represents a significant mineral resource. (Environment Agency, 2016).

2.14 The locations of PFA deposited in landfills are in well-known and clearly defined boundaries associated with coal fired power stations. The locations of current and former coal-fired power stations in England and Wales are shown in Figure 2.1 below.

Figure 2.1 - Locations of coal fired power stations in England and Wales



Source: UKQAA (n.d)

Primary Aggregates (UK)

2.15 Primary aggregates are materials that have been extracted from naturally occurring mineral deposits and are being used for the first time (i.e. not recycled materials such as PFA). Most primary aggregates used in construction are extracted from hard rock formations (and are crushed to produce crushed rock aggregate) or from naturally occurring particulate deposits such as sand and gravel.

2.16 The construction sector relies heavily on the supply of primary aggregates, which are obtained from around 1,300 quarries in the UK and also dredged from the sea bed by a fleet of 28 marine aggregate dredgers. Annual production from both sources is approximately 300 million tonnes in total each year (British Geological Society, n.d.).

2.17 The most important sources of crushed rock in the UK are limestone (including dolomite), igneous rock and sandstone. Sand and gravel can be either land-won or marine dredged (British Geological Society, 2013).

2.18 Primary aggregates sales in England and Wales for 2014 (the most recent available Government data) comprised 60.2% crushed rock, and 29.6% land-won and 10.2% marine-dredged sand and gravel. Limestone/ dolomite accounts for 66% of crushed rock aggregate, followed by igneous rock (25%), sandstone (9%), and minor chalk and ironstone (<0.5%) (British Geological Society, 2014).

2.19 In 2014, England was a net importer of an estimated 4.5 million tonnes of primary aggregates. Almost all of this was crushed rock (mainly igneous rock) imported into the South East and London mainly from Scotland and Norway, with small quantities from France and Northern Ireland.

2.20 The use of secondary and recycled aggregates is becoming more popular particularly in relation to reducing embodied carbon emissions from construction materials such as cement and concrete and in order to safeguard primary resources.

PFA Imports

2.21 The UK is a significant net importer of secondary aggregates such as PFA. It is estimated by the UKQAA that 254,000 tonnes of PFA was imported primarily via ship into the UK in 2018. This is approximately five times more than the amount of PFA imported in 2014.

2.22 Based on information from the UKQAA, the majority of PFA imports are from Spain, followed by Germany, Italy and Portugal. However, there is a shortage throughout Europe and there is not enough PFA in these markets to maintain the current level of use in the UK. Alternative sources of PFA are therefore required to maintain (or grow) the current levels of primary aggregate substitution.

2.23 Alternative sources could include sites such as Gale Common or imports from further afield, including from Turkey, India and Japan.

Policy Context

National Planning Policy Framework (NPPF)

2.24 Paragraph 7 of the NPPF (MHCLG, 2019) states that the purpose of the planning system is to contribute to the achievement of sustainable development. It continues that the objective of sustainable development can be summarised as meeting the needs of the present without compromising the ability of future generations to meet their own needs.

2.25 Paragraph 10 states that decision-makers at every level should seek to approve applications for sustainable development where possible.

2.26 Part of achieving sustainable development and a central aim of the NPPF is to use natural resources prudently, minimising waste and pollution, and mitigating and adapting to climate change, including moving to a low carbon economy.

2.27 In order to achieve this aim, the NPPF (paragraph 204) requires that planned and potential sites for recycled and secondary aggregate related uses are safeguarded and that decision makers take account of the positive contribution that secondary and recycled materials, such as PFA, have in terms of sustainability and carbon reduction.

Local Planning Policy

2.28 Planning policy produced by North Yorkshire County Council (NYCC) is supportive of the principle of using secondary and recycled materials, such as PFA, as a sustainable alternative to raw materials, such as sand and crushed rock.

2.29 Paragraph 7.17 of the North Yorkshire Waste Local Plan (adopted 2006) states "*there may be instances where the re-working of deposited waste is required … where changed economic circumstances support the re-use of deposited waste for example pulverised fuel ash (PFA).*"

2.30 Policy W09 (Managing power station ash and Incinerator Bottom Ash) of the emerging Minerals and Waste Joint Plan (2018) states that proposals to increase the utilisation of power station ash and incinerator bottom ash as secondary or recycled aggregate or for other beneficial use, in line with Policy M11 for the 'Supply of Alternatives to Land Won Primary Aggregate', will be permitted.

2.31 Policy M11 of the emerging plan states that, in line with the NPPF, proposals which would facilitate the supply and use of secondary, recycled and marine aggregate as an alternative to primary land-won aggregate will be permitted.

3.0 CARBON SAVINGS

Approach

3.1 This section sets out the potential carbon savings associated with the use of PFA from Gale Common in comparison to primary aggregates and PFA imports. The carbon savings are expressed in terms of GHG emissions and are presented as tCO_2e (where CO_2e means 'carbon dioxide equivalent', a standard unit for measuring carbon footprints).

3.2 It is expected that a combination of the following four market scenarios will occur:

1. the existing purchaser of the 30,000 tpa of PFA increases their purchase from Gale Common;
2. the additional PFA is used for other non-cementitious products by third parties still to be identified;
3. the additional PFA is used for cementitious applications by third parties still to be identified; and
4. the additional PFA exported from Gale Common is used to replace imported sources of PFA.

3.3 Current discussions with the existing customer have indicated that they would like to increase their demand from Gale Common to around 350,000 tpa (to replace material currently sourced elsewhere); additional markets are being identified for the remaining 650,000 tpa that it is proposed to extract.

3.4 A detailed assessment of the potential carbon savings for each of these scenarios is provided in **Appendix A** and summary is provided below.

3.5 It should be noted that there is less published GHG emissions data available for non-cementitious applications of PFA. This assessment has estimated the inferred carbon savings, however these are conservative and likely to be higher in practice.

Summary of Carbon Savings

3.6 A combination of the four potential market scenarios regarding the use of Gale Common PFA has been considered for the purposes of this assessment, as a full breakdown of its uses is not known at this stage, and may change through the 25 year operational period. The assumptions made for the purposes of the assessment are listed in **Appendix A**. The overall potential carbon savings from increasing extraction at Gale Common are set out below.

3.7 The potential total carbon savings over the 25 year operational phase of extraction at Gale Common are estimated to be in the order of 84,240 tCO_2e if all the PFA is used in non-cementitious applications, as shown in Table 3.1 (rounded to the nearest 10 tCO_2e).

3.8 As noted at paragraph 3.5 above, this estimate is conservative and the actual savings are likely to be even greater.

Table 3.1 - Summary of potential carbon savings assuming 100% use in non-cementitious applications (over a 25 year period)

Emissions saving source	Carbon savings (tCO_2e)
Transportation emissions savings from replacing imported PFA with PFA extracted from Gale Common	34,100
Replacement of primary aggregates (non-cementitious applications)	50,140
TOTAL EMISSIONS SAVING	**84,240**

3.9 Far greater carbon savings would be achieved if the PFA extracted at Gale Common was used in cementitious applications, as the cement industry accounts for approximately 8% of global GHG emissions (Chatham House, 2018). Based on initial conversations between EPUKI and

potential customers, a realistic assumption for the use of the PFA from Gale Common in cementitious applications would be approximately 50%.

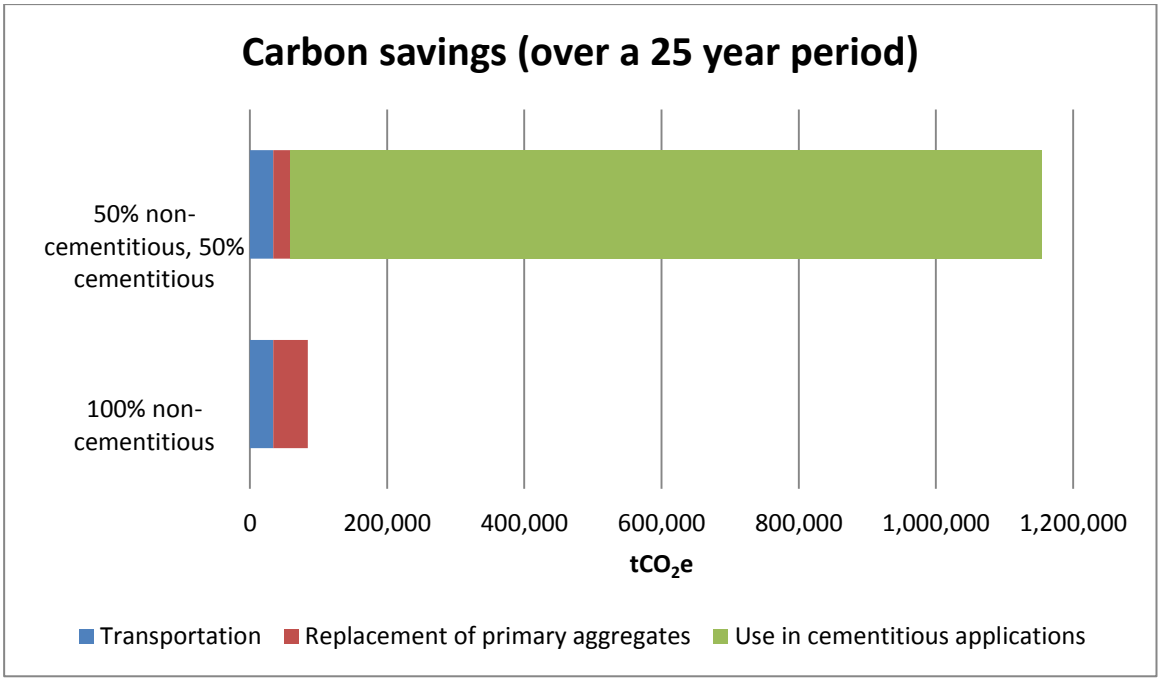
3.10 If 50% of PFA extracted each year is used in cementitious applications and the remainder is used in non-cementitious applications, the potential carbon savings could be in the order of 10,966,800 tCO_2e, as shown in Table 3.2 (rounded to the nearest 10 tCO_2e).

Table 3.2 - Summary of potential carbon savings assuming 50% use in non-cementitious applications and 50% use in cementitious applications (over a 25 year period)

Emissions saving source	Carbon savings (tCO_2e)
Transportation emissions savings from replacing imported PFA with PFA extracted from Gale Common	34,100
Replacement of primary aggregates (non-cementitious applications)	24,700
Use in cementitious applications	10,908,000
TOTAL EMISSIONS SAVING	**10,966,800**

3.11 The carbon savings set out in Table 3.1 and Table 3.2 are presented graphically below in Figure 3.1.

Figure 3.1 - Summary of potential carbon savings (over a 25 year period)



3.12 These carbon savings would make a significant contribution to the UK decarbonisation targets, especially in relation to the five-yearly carbon budgets which currently run until 2032. The carbon budgets restrict the amount of GHG emissions the UK can legally emit in a five year period.

4.0 WIDER SUSTAINABILITY BENEFITS

4.1 This section of the review provides information on the wider sustainability benefits of using PFA from Gale Common in comparison to primary aggregates, PFA from other UK sites and PFA imports.

4.2 Reusing PFA in the concrete and cement industries presents an important example of the circular economy where the waste output of one process can be used as a material component to another; reducing the need to extract primary resources. Additionally, unless stockpiled PFA deposits, like Gale Common are utilised, (aircrete) block manufacturers who currently use PFA will have to use substitute primary aggregates, such as sand and gravel.

4.3 The use of PFA such as that at Gale Common could avoid the need to extract primary aggregates from natural and protected habitats and landscapes, such as National Parks and Areas of Outstanding Natural Beauty (AONBs), which could result in adverse environmental impacts. In 2014, in England and Wales, 9.3% and 4.8% of total crushed rock sales were supplied from National Parks and AONBs respectively, and 0.5% and 3.3%, respectively for land-won sand and gravel (British Geological Society, 2014).

4.4 Over the proposed 25 year period, with the exception of Stage I the extraction of PFA at Gale Common will gradually restore the site back to its original state for ecological, landscape and community benefit.

4.5 It is estimated that 25-47 direct jobs will be created if the Gale Common expansion goes ahead, which may support between 2-4 indirect jobs per direct job, such as hauliers. Also, a number of the direct jobs will be skilled jobs such as engineers.

4.6 PFA has a considerably lower density than sand, which, combined with the cost per tonne of PFA, considerably reduces the cost of a grout mix.

4.7 Concrete containing PFA will also reduce the permeability and improve the long term strength and durability of the concrete when compared with ordinary Portland cement concrete (UKQAA, 2004).

5.0 CONCLUSIONS

5.1 PFA is a waste product from coal-fired power stations that has been used in the construction industry for many years. A large deposit of PFA is available for extraction from Gale Common.

5.2 PFA sourced from Gale Common could be used in a variety of applications, which are broadly separated into non-cementitious uses (block manufacture and grouting for ground stabilisation) and cementitious uses (as a replacement for other materials in cement). Both applications confer significant carbon savings and sustainability benefits, including reducing the use of primary aggregates, reducing the need to import PFA, and contributing to a more circular economy. In some instances PFA also performs better than alternative materials.

5.3 The potential total carbon savings over the proposed 25-year operational phase of extraction at Gale Common are estimated to be in the order of 84,240 tCO_2e when used in 100% non-cementitious applications.

5.4 Far greater carbon savings are available if the PFA extracted at Gale Common is used in cementitious applications. For instance, if 50% of PFA extracted each year is used in cementitious applications and the remainder in non-cementitious applications, the potential carbon savings could be in the order of 10,966,800 tCO_2e.

5.5 Overall, it has been demonstrated that, regardless of exactly how the Gale Common PFA is used in the construction industry, it is expected that significant carbon savings will be realised through its use. Increasing the capacity of extraction of PFA in the coming years will therefore make a positive contribution to the UK's decarbonisation targets.

5.6 In addition to these carbon savings, increasing PFA extraction at Gale Common will provide a range of wider sustainability benefits, including for the site itself and also through contributing to the circular economy in the construction industry and improving resource efficiency via reduced use of primary raw materials.

5.7 Lastly, extraction at Gale Common will help to ensure that the PFA secondary aggregates business is continued as coal power stations in the UK and across Europe close.

6.0 REFERENCES

British Geological Society (not dated) *Minerals UK – Aggregates*. Available at: https://www.bgs.ac.uk/mineralsUK/mines/aggregates.html [Accessed Feb 2019].

British Geological Society (2013) *Mineral planning factsheets – Construction aggregates*

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North Yorkshire County Council (2006) *North Yorkshire Waste Local Plan.*

UKQAA (not dated) *Technical Datasheet – Embodied CO2e of UK cement additions and cementitious material.*

UKQAA (2004) *Best Practice Guide No.1 The Placing and Compaction of concrete containing PFA / Fly Ash.*

University of Bath (2011) *Inventory of Carbon and Energy (ICE) V2.0.*

APPENDIX A: MARKET SCENARIOS, ASSUMPTIONS AND DATA SOURCES

Market Scenarios

Scenario 1: Existing Customer Increases Purchase

This assessment scenario assumes that the company that purchases the 30,000 tpa of PFA currently exported from the Site increases their purchase to 350,000 tpa. In this instance, the additional 320,000 tpa from Gale Common would directly replace 320,000 tpa of PFA that is currently purchased from other sources further afield, other secondary aggregates or sand. Table A.1 illustrates the embodied carbon of these different resources.

Table A.1 - Embodied carbon emissions per tonne of PFA compared to other materials

Material	Embodied carbon emissions (tCO_2e)
PFA	0.004
Ground granulated blast furnace slag (ggbs)	0.067
Limestone fines	0.075
Sand	0.0051

The embodied carbon of 1 tonne of PFA is 0.063 tCO_2e less than ground granulated blast furnace slag (ggbs) and 0.071 tCO_2e less than limestone fines; or 93% and 95% less respectively. The embodied carbon of 320,000 tonnes of PFA would be 22.4 tCO_2e less than ggbs and 22.72 tCO_2e less than limestone fines.

Whilst the embodied carbon of sand is slightly less than PFA when comparing equivalent weights, the density of PFA is considerably lower than sand (approximately 20% less), so by weight much more sand would be needed to produce the same volume of products. Consequently the carbon per product unit is less when using PFA rather than sand, as shown in Table A1. This lower volume of PFA also results in reduced material movements and therefore reduced carbon emissions associated with transportation.

Using PFA would also reduce material processing and thus would be expected to have a lower energy demand in converting from aggregate to aerated bricks. The company that currently purchases the PFA grinds sand to a powder for their aerated blocks, meaning overall emissions from using sand are significantly more than they would be if using PFA.

Other potential sources of PFA are further afield than Gale Common, and hence transportation emissions would be greater to this block manufacturer.

.Scenario 2: Non-Cementitious Applications

As identified in Section 1 of this report, PFA can be used as a replacement for sand to manufacture a variety of non-cementitious products.

The carbon savings of replacing approximately 1,000,000 tpa of primary aggregates and other types of secondary aggregates with PFA would be expected to be proportionally of the same order to the savings set out in Scenario 1 for the embodied carbon, however, transportation carbon emissions would be expected to vary marginally dependent on the sources of the replacements.

Scenario 3: Cementitious Applications

As identified in Section 1 of this report, similar to other secondary aggregates, PFA can be used as a cement replacement. There are two ways of using cement replacements. They can be blended with Portland cement to produce factory blended cement (Table A.2) or used as a separate 'addition' and combined with the Portland cement in the concrete mixer (Table A.3). The embodied carbon emissions (in CO_2e) for 1 tonne of factory blended cements with a variety of different % of PFA and other secondary aggregates are shown in Table A.2 and where a

separate 'addition' is combined with the Portland cement in the concrete mixer with a variety of different % of PFA and other secondary aggregates are shown in Table A.3 (data taken from UKQAA, not dated).

Table A.2 - CO_2e of 1 tonne of factory made cement

Cement (factory made)	**Secondary made constituent** ***low – high content (%)***	**Emissions (tCO_2e)**
CEM I *Portland Cement*	-	0.913
CEM II/A-ll or I *Portland limestone cement*	6 - 20 (limestone)	0.859 – 0.745
CEM II/A-V *Portland PFA cement*	6 - 20 (PFA)	0.859 – 0.746
CEM IIB-V *Portland PFA cement*	21 - 35 (PFA)	0.728 – 0.615
CEM II/B-S *Portland slag cement*	21 - 35 (ggbs)	0.743 – 0.639
CEM IV/B-V *Pozzolanic (siliceous PFA) cement*	36 - 55 (PFA)	0.598 – 0.441

Table A.3 - CO_2e of 1 tonne of combinations produced at concrete works (excluding transport of materials to the concrete plant)

Combination ***(CEM I and addition combined at concrete plant)***	**Additional** ***low – high content (%)***	**Emissions (tCO_2e)**
CCIA-ll or I	6 - 20 (limestone)	0.863 – 0.745
CIIA-V	6 - 20 (PFA)	0.858 – 0.731
CIIB-V	21 - 35 (PFA)	0.722 – 0.595
CIIB-S	21 - 35 (ggbs)	0.735 – 0.617
CIIIA	36 - 65 (ggbs)	0.608 – 0.363
CIIIB	66 - 80 (ggbs)	0.354 – 0.236
CIVB-V	36 - 55 (PFA)	0.586 – 0.413

Tables A.2 and A.3 show that compared to Portland cement with no recycled or secondary content, carbon emissions could be reduced by between 5% and 51% depending on the different % of PFA added as a replacement.

Whilst the sustainability benefits are clear regarding the use of PFA in cementitious applications there are a few practical considerations that need to be factored into construction and processing techniques and schedules:

- There is a potential seasonal limitation to PFA in comparison to primary aggregates. The winter season is problematic for concrete pouring, and mixtures high in PFA content require longer setting times at low temperatures requiring around; and
- Concrete is susceptible to damage from freeze /thaw cycles if it does not contain air. Tiny air bubbles can be created in concrete by using air-entraining admixtures that cause the concrete to foam in the mixing and pouring stage. PFA reduces the amount of air entrainment, and concrete mixtures high in PFA often require more air-entraining admixture.

Scenario 4: Imported PFA

As identified in Section 1, the UK is a significant importer of PFA, importing an estimated 254,000 tonnes of PFA into the UK in 2018. When comparing PFA from Gale Common to imported PFA – assuming all product stages are the same for both– the additional emissions associated with transportation of 254,000 tpa of imported PFA compared to PFA from Gale

Common is estimated to be in the order of 1,795 tCO_2e annually when taking into account current key import markets (Spain, Germany, Italy and Portugal).

It is assumed that PFA sources in Europe are less likely to be available in the future as resources will be used for domestic purposes, coal fired power reduces and existing power stations retire. UK imports would then need to be sourced from further afield, such as from Turkey, China and the Far East; which is not considered to be economically realistic (Environment Agency, 2016).

Emissions from transportation within the UK have not been considered in this assessment as they are assumed to be comparable for different sources.

Assumptions

Several assumptions were made associated with the carbon savings calculations:

- It has been assumed that Gale Common's current customer will increase the amount of PFA they will take from the site from 30,000 tpa to 350,000 tpa, based on discussions with that customer.
- It is assumed that within the first year of operation, Gale Common would aim to extract between 400,000 and 600,000 tonnes of PFA. For subsequent years, it has been assumed that – providing contracts are in place – 1 million tpa could be extracted.
- It has been assumed that PFA from Gale Common will replace the 254,000 tpa of PFA imports by 2025.
- It has been assumed that transport distances travelled within the UK are similar for all types of PFA and primary aggregates.
- It has been assumed that the GHG emissions from each of the product stages would be the same for UK PFA as it would be for imported PFA with the exception of transportation.
- Current import markets for PFA were assumed to be Spain, Portugal, Italy and Germany.

Data Sources

- UKQAA (not dated) *Technical Datasheet – Embodied CO_2e of UK cement additions and cementitious material*.
- Department of Environment, Food and Rural Affairs (2018) *2018 Conversion Factors.*
- University of Bath (2011) *Inventory of Carbon and Energy (ICE) V2.0*