Vecor Australia Pty Limited
ABN: 42 130 066 492
119 Evans Street, Rozelle, NSW, Australia, 2039
P +61 2 9555 8654 E info@vecor.com
www.vecor.com

# NEW SOUTH WALES GOVERNMENT – THE DEPARTMENT OF PLANNING, INDUSTRY AND ENVIRONMENT

# BAYSWATER POWER STATION UPGRADE

Submission by **Vecor Australia**

Vecor Australia Pty Limited
ABN: 42 130 066 492
119 Evans Street, Rozelle, NSW, Australia, 2039
P +61 2 9555 8654 E info@vecor.com
www.vecor.com

## Table of Contents

Vecor Australia Pty Limited
ABN: 42 130 066 492
119 Evans Street, Rozelle, NSW, Australia, 2039
P +61 2 9555 8654 E info@vecor.com
www.vecor.com

# 1. Executive Summary

This submission is primarily focused on re-use options for fly ash and the significant boost this could bring the NSW economy while solving environmental and employment issues.

Coal ash waste makes up nearly 1/5 of Australia's total solid waste production, yet opportunities to re-use this resource are being squandered, allowing vast quantities of legacy ash to accumulate. In nearly a decade utilisation rates have increased only marginally[1]. Meanwhile, innovative technologies have been developed which are able to turn 'liability' fly ash into a valuable resource.

A failure to effectively deal with ash waste has meant ash dams now represent a significant liability for the State. Not only are power stations running out of space to store their ash, but contamination of surrounding areas, including some residential areas, is occurring. The need for a solution has been made increasingly urgent as dangerous levels of soil and water contamination are reported and public health concerns relating to airborne ash pollution are escalating.

While a lack of development policy has created a burden out of NSWs fly ash, it holds significant potential as a valuable resource, with a vast number of potential applications that positively benefit the economy and environment.

Policies which successfully achieve positive outcomes for re-use will focus on turning what is currently a liability into a profitable asset. This can be achieved in NSW by facilitating the growth of industries which turn fly ash into valuable construction materials that are in high demand. Vecor Australia is a company which has developed technologies able to produce manufactured sand (<5mm) and coarse aggregate (>5mm) from fly ash. Vecor is able to process this ash in a way which locks up all harmful components (including heavy metals), sintering[2] the fly ash into an aggregate to create a stable end product.

Fly ash recycling therefore represents an opportunity to:

---

[1] In 2011, 48% of CCPs produced were effectively utilised (ADAA, 2015). This reached 52% in 2013 but has fallen back down to 47% in 2018 (ADAA, 2018)

Ash Development Association of Australia (ADAA) 2015, *Annual membership survey results, January-December 2015,* Ash Development Association of Australia, Wollongong, < http://www.adaa.asn.au/uploads/default/files/adaa_mship_report_20162.pdf>.

Ash Development Association of Australia (ADAA) 2018, *Annual membership survey results, January-December 2018,* Ash Development Association of Australia, Wollongong, <http://www.adaa.asn.au/resource-utilisation/ccp-utilisation>.

[2] Sintering is a process in which fly ash is fused at high temperatures, forming a monolithic material with increased content of mullite and other aluminosilicate minerals.

Vecor Australia Pty Limited
ABN: 42 130 066 492
119 Evans Street, Rozelle, NSW, Australia, 2039
P +61 2 9555 8654 E info@vecor.com
www.vecor.com

1. Reduce the quantum of the NSW government's 'ash dam liability' by re-using fly ash waste in a way which encapsulates the ash, providing a solution to the environmental problems posed by the fly ash in existing waste disposal dams
2. Provide significant economic, employment and environmental benefits including:
    - Providing NSW with an abundant supply of cost-saving, lightweight aggregate materials that are not currently commercially available in Australia
    - Delivering a feasible substitute for diminishing local supplies of sand and aggregate, needed to fuel construction projects in Sydney and regional NSW.
    - Help to achieve a streamlined transition of workers out of coal and into a co-located fly ash recycling industry, in an undisruptive and fair manner.
    - Provide regional employment in a way which is adapted towards community needs and sensitive to community concerns.
    - Opening up opportunities for the production of low-GHG emitting, high-recycled-content construction materials.

**The core recommendation** is for the government to conduct a feasibility study into the composition of fly ash generated at Bayswater Power station and other the power stations within the State with a view to determining their suitability for manufacturing sand and aggregates from fly ash. This would result in one or more pilot plants being established to test novel technologies (such as Vecor's) for fly ash re-use. The NSW government should provide sustained support for resource recovery programs into later stages of industry growth, by providing funding assistance for capital investments. Importantly, policies and programs should be put in place to support this form of industry development, encouraging innovative methods of resource recovery and improving the circularity of the State economy.

**Further recommendations are:**

1. Utilising fly ash aggregates in government construction projects
2. Ensuring sustainable re-use
3. Incentivising good practice within the electricity generation sector

Vecor Australia Pty Limited
ABN: 42 130 066 492
119 Evans Street, Rozelle, NSW, Australia, 2039
P +61 2 9555 8654 E info@vecor.com
www.vecor.com

# 2. Background

## 2.1 Issues with fly ash: quantities, toxicity and their relation to the prospective quantum of government liability

Ash captured from power stations' smokestack filters makes up 18% of Australia's total solid waste stream[3]. Fly ash accounts for up to 90% of total ash produced when coal is burnt, otherwise known as coal combustion products (CCPs). Under the current regulatory regime, all of the five coal-powered electricity stations operating in NSW[4] mix their fly ash with water (70% water, 30% ash) before pumping this slurry into on-site dams. These dams can reach up to 250ha in size[5].

Fly Ash contains dangerous heavy metals like arsenic, lithium and mercury. While environmental legislation in jurisdictions such as the US, Europe, Canada and Australia does not consider Fly Ash to be a 'hazardous material', processes of leaching and bioaccumulation can occur which allow heavy metals within the ash to escape and gradually build up to reach hazardous levels in the surrounding environment. Over an extended period of time, these heavy metals can become toxic to animal and plant life. A number of recent studies – most notably the 'Out of the Ashes Report' by the Hunter Environment Community centre – have found that the leaching of such contaminants from Eraring and Vales Point ash dams in the Hunter region has resulted in soil and groundwater contamination[6].

However, fly ash is not only an environmental problem due to its heavy metal content but is a threat to human, animal and plant health when fine particulate ash becomes airborne. The fine ash can trigger asthma, cause respiratory damage and smother plants. A number of dust events have been reported in regional towns following the drying out of ash dams, including:

In 2017 Origin Energy (owner of Eraring Power station on the NSW Central Coast) was fined $15,000 after multiple community complaints were made regarding the quantities of dust

---

[3] Department of Environment and energy 2019, National Waste Report 2018, prepared by Blue Environment Pty Ltd, viewed 20 January 2020, <https://www.environment.gov.au/protection/waste-resource-recovery/national-waste-reports/national-waste-report-2018>.

[4] Bayswater, Eraring, Liddell, Mount Piper and Vales Point power stations. Munmorah Power station and Wallerawang Power stations are no longer operational but have associated ash dams (Munmorah Ash Dam and Sawyers Creek Coal Ash Dam).

[5] Independent Planning Commission (IPCN) NSW 2019, *Eraring Ash Dam MOD 1 Statement of reasons,* December 2019, IPCN NSW, Sydney, <https://www.ipcn.nsw.gov.au/projects/2019/10/eraring-power-station-ash-dam-expansion-mod-1 >.

[6] Winn, P., Lynch, J & Woods, G 2019, *Out of the Ashes: water pollution and Lake Macquarie's aging coal-fired power stations.* Hunter Community Environment Centre, Hamilton East, NSW, < http://www.hcec.org.au/content/out-ashes>.

Vecor Australia Pty Limited
ABN: 42 130 066 492
119 Evans Street, Rozelle, NSW, Australia, 2039
P +61 2 9555 8654 E info@vecor.com
www.vecor.com

escaping the premises[7]. This was considered a breach of the power station's environmental protection license. Origin Energy was directed to review its dust dam monitoring system to prevent the re-occurrence of such an event.

In 2019 Origin Energy was fined another $15,000 for excessive dust emissions from Eraring Power station[8].

While these penalty notices have allowed NSW power stations to pay a fine, rather than have an alleged offence dealt with in court, successively penalty notices are not generally issued for ongoing breaches[9]. Hence, court action may likely be pursued in the future if events such as this continue to take place. Indeed, with mismanaged dams sitting in close proximity to fast growing urban centres and residential homes (such as the Hunter Region), the financial liabilities relating to rising environmental and public-health costs are continually on the rise and so are the future risks to government.

## 2.2 Current practices: Australia compared to other jurisdictions

Issues around fly ash waste are not exclusive to Australia. Overseas markets have shown this issue can be solved in an efficient, economically viable and sustainable way. In other countries, where space for large dams is limited and environmental regulation is more advanced, the market for commercial solutions for recycling of ash waste is stronger, with the need to divert ash from dams an inherent issue for energy producers to overcome. Power stations in countries like the United States and Japan are far more focused on dealing with waste products. In contrast, due to the cost-effectiveness of on-site ash dumping in Australia, the status quo for ash management remains dumping, rather than selling for re-use. In nearly a decade Australia's effective utilisation

[7] NSW Environmental Protection Authority 2017, *Origin Energy fined $15,000 for ash dam dust* [media release], 6 February 2017, viewed 23 December 2020, https://www.epa.nsw.gov.au/news/media-releases/2017/epamedia17020602

[8] NSW Environmental Protection Authority 2019, *Origin Energy fined for dust emissions at Eraring Power Station* [media release], 5 March 2019, viewed 23 December 2020, <https://www.epa.nsw.gov.au/news/media-releases/2019/epamedia190305-origin-energy-fined-for-dust-emissions-at-eraring-power-station>.

[9] EPA 2013, *Environmental Protection Authority Compliance Policy,* NSW Environmental Protection Authority, Sydney, < https://www.epa.nsw.gov.au/-/media/epa/corporate-site/resources/legislation/130251epacompol.pdf >.

Vecor Australia Pty Limited
ABN: 42 130 066 492
119 Evans Street, Rozelle, NSW, Australia, 2039
P +61 2 9555 8654 E info@vecor.com
www.vecor.com

rate has failed to sustain any meaningful improvement (48% in 2011[10] and 47% in 2018[11]). By way of comparison, ten years ago other countries such as Japan, Europe and China had utilisation rates of 96.%, 90.9% and 67.1% respectively[12].

The main pathway for beneficial re-use in Australia is to use fly ash in the cement component of concrete. Since the mid 1960s[13], fly ash has been used as what is called a 'supplementary cementitious material' (SCM)- replacing a portion of the Portland cement[14] used in the cement mix. It is widely accepted that replacing 20-30% of the cement component of concrete with fly ash creates a more durable concrete than when using cement alone. Today, most of the fly ash re-use in NSW is based on purchases made by concrete companies for this purpose. The Green Building Council of Australia's 'Green Star' rating system rewards buildings which utilise fly ash in the cement mix. However, only a limited portion of fly ash (i.e. particular 'grades' of ash) produced by coal-burning power stations are able to replace cement.

In recent years many ash dams in NSW including Bayswater have begun to reach full capacity. This has prompted power stations like Eraring and Bayswater to seek approvals for expansion[15] in order to accommodate growing quantities of ash waste. As space runs out and our knowledge of the environmental consequences of these ash dams grows, it is important that NSW finds alternative ways to deal with its ash waste.

---

[10] Ash Development Association of Australia (ADAA) 2015, *Annual membership survey results, January-December 2015,* Ash Development Association of Australia, Wollongong, < http://www.adaa.asn.au/uploads/default/files/adaa_mship_report_20162.pdf>.

[11] Ash Development Association of Australia (ADAA) 2018, *Annual membership survey results, January-December 2018,* Ash Development Association of Australia, Wollongong, <http://www.adaa.asn.au/resource-utilisation/ccp-utilisation>.

[12] Heidrich, C, Feuerborn, J & Weir, A 2013, *Coal combustion products: A global perspective. World of Coal Ash (WOCA) Conference, 2013,22-25 April 2013,* Lexington, Kentucky, American Coal Ash association & University of Kentucky, Vol. 1, 17 pp.., http://www.flyash.info

[13] Cement Concrete & Aggregates Australia (CCAA) 2017, *Technical Note 77: Fly Ash: Properties, Characterisation and uses'*, CCAA, viewed 20 December 2020, <https://www.ccaa.com.au/iMIS_Prod/CCAA/Public_Content/PUBLICATIONS/Technical_Publications/Notes/Technical_Note_77_-_Fly_ash_properties__characterisation_and_use.aspx?WebsiteKey=4998d6ce-2791-4962-b1e2-6b717f54a8d3>.

[14] Portland cement is limestone that has been crushed, heated, then ground-up

[15] Eraring's proposal involved raising the ash dam wall by 14m

AGL's proposal involved expansion of the power station's coal ash dam to provide an additional 12.5 million cubic metres of storage capacity <https://www.abc.net.au/news/2020-07-13/bayswater-power-plant-upgrade/12448622>

Vecor Australia Pty Limited
ABN: 42 130 066 492
119 Evans Street, Rozelle, NSW, Australia, 2039
P +61 2 9555 8654 E info@vecor.com
www.vecor.com

The volume of fly ash which can be re-used as an SCM is clearly limited: even with use of fly ash as an SCM being widely adopted, national re-use rates have stagnated below 50%. Therefore, the State should pursue re-use opportunities that are non-cementitious applications for fly ash.

## 2.3 Opportunities for re-use: emerging technologies

Innovative technologies which can be applied to create high quality products, composed of up to 70% fly ash have been developed by Vecor Australia. These products include porcelain tiles, manufactured sand and lightweight aggregate. The technology used in this process was originally conceived at the University of New South Wales, and ongoing R&D operations are partially based there. Additionally, Vecor has provided technical and financial support to the University of Newcastle, collaboratively developing novel equipment that can be used in the processing of fly ash.

Rather than competing with the existing pathways for re-use (e.g. SCM), Vecor products complement them by utilising the portion of fly ash that cement companies cannot use. Indeed the portion of fly ash that is unsuitable for cement is useful in other construction materials. For the purposes of this submission, Vecor would like to focus on two particular products that it believes represent viable pathways for fly ash re-use in NSW:

1) Sand (<5mm)- a natural sand replacement (i.e. fine, spherical, dense) which has a ratio greater than 50% of fly ash.

2) Lightweight, high strength aggregate (>5mm) (i.e. coarse, jagged, low density) which has a ratio greater than 50% of fly ash.

Notably, the technical processes to create these products are different[16], however both involve a sintering step - which is critical to rendering any toxic components inert. These products are to be discussed in more detail in section 4.1.

A study by Vecor estimates that one plant could convert over 500,000 tonnes of fly ash per annum into sand and aggregate. This would represent a ~20% increase in the amount of CCPs being effectively utilised (on a national level) to generate an economic return[17], just from one plant. The

[16] Granulation and rotary calcining is used to create Vecor's fine, dense, manufactured sand product. Coarse aggregates are created through a process of pressing (to form a briquette), sintering then crushing. Whilst a portion of finer 'sand' sized aggregate is created during this crushing step, the majority of the product is coarse (larger grain size) aggregate.

[17] According to the ADAA's 2018 Annual Membership survey results, approximately 2.4 million tonnes out of a total 12.6 million tonnes of CCPs generate an economic return through effective utilisation (i.e. recycling). Since one Vecor plant is expected to utilised 0.5 million tonnes per annum, this would mean effective utilisation will increase by 20.8%. In 2018, approximately 3.56 Mt of ash was re-used in ways which typically generated no direct economic return (e.g. site remediation).

Vecor Australia Pty Limited
ABN: 42 130 066 492
119 Evans Street, Rozelle, NSW, Australia, 2039
P +61 2 9555 8654 E info@vecor.com
www.vecor.com

importance of re-use generating an economic return should not be underestimated: policies which successfully achieve positive outcomes for re-use will focus on turning what is currently a liability into a profitable asset.

## 2.4 Best practice: sintering and encapsulation

The best practice for preventing the escape of toxic heavy metals from fly ash is by preventing leaching from occurring- encapsulating the fly ash so that any heavy metal components are no longer free to escape when they come in contact with water. Encapsulation is achieved by the process of sintering, which involves heating the ash to high temperatures in order to fuse ash particles together. This creates a crystalline matrix which locks up any heavy metals present in the ash. Vecor uses this method of sintering, fusing the ash at 1200°C to create an inert, stable product that is highly resistant to leaching, abrasion and corrosion. Preliminary radiation testing completed at UNSW have also showed that Vecor product samples were within the normal background levels.

It is important that best practices are followed when considering re-use opportunities. Supposed ‘beneficial uses’ that do not adequately encapsulate the ash (such as using raw fly ash as mine fill) are not environmentally sound pathways for re-use and will only serve to re-locate the government’s liability to a new site. In an unencapsulated form, heavy metals are certainly capable of leaching out of fly ash deposits and may build up to hazardous levels in the environment over time.

Vecor Australia Pty Limited
ABN: 42 130 066 492
119 Evans Street, Rozelle, NSW, Australia, 2039
P +61 2 9555 8654 E info@vecor.com
www.vecor.com

# 3. Timing of expenditure

Other states are gaining a lead on NSW by actively pursuing opportunities for resource recovery and innovative pathways for waste recycling. For example, Queensland's Resource Recovery Industry Development Program has been designed to support investigations which may help the State make investment decisions into novel technologies or waste solutions. Meanwhile, in NSW the cost of inaction is mounting as the State loses opportunities for jobs and economic growth by not exploring new pathways for fly ash waste re-use.

Expenditure by the government towards developing programs which support the growth of the fly ash re-use industry is needed immediately. As power stations run out of space in their ash dams, they will be looking for alternative solutions. Without the government's support in developing a responsible recycling industry for fly ash waste, there are limited places for these power stations to look. Inevitably, short term fixes such as raising the ash dam walls (which has been approved at Eraring Power station[18] and have been proposed at Bayswater Ash Dam[19]) becomes the 'solution'.

It is particularly important that the government supports fly ash re-use now as it becomes apparent that the relative contribution of coal-burning power stations towards the State's total energy resources will be progressively downgraded in the coming decade. There is convincing evidence amongst the recently published materials of NSW's key energy suppliers that their long term strategy no longer includes a major role for coal-burning power stations. For example, Origin (owner of Eraring power station) has reported it plans to "exit coal-fired power generation by 2032" (Origin Energy 2019, p. 9[20]). Similarly CLP Group, the parent company of Energy Australia (owner of Mount Piper power station) wrote in their 2015 sustainability report: "In Australia, I think the future there is more renewable energy, and a gradual phasing out of coal-fired power" (CLP group 2015, p. 14[21]). Meanwhile Liddell and Bayswater power station have expected

---

[18] Independent Planning Commission (IPCN) NSW 2019, *Eraring Ash Dam MOD 1 Statement of reasons,* December 2019, IPCN NSW, Sydney, <https://www.ipcn.nsw.gov.au/projects/2019/10/eraring-power-station-ash-dam-expansion-mod-1 >.

[19] AGL Macquarie Pty Ltd 2020, *Bayswater Water and Other Associated Operational Works Project Environmental Impact Statement, p. 20,* viewed 27 July 2020, <https://majorprojects.planningportal.nsw.gov.au/prweb/PRRestService/mp/01/getContent?AttachRef=SSD-9697%2120200609T062617.698%20GMT >.

[20] Origin Energy 2019, *2019 Sustainability Report, pp. 9,* viewed 20 December 2020, <https://www.originenergy.com.au/content/dam/origin/about/investors-media/documents/2019-sustainability-report-final-oct.pdf>

[21] CLP Holdings Ltd 2015, *2015 Sustainability Report, p. 14,* viewed 20 December 2020, <https://www.clpgroup.com/en/Sustainability-site/Report%20Archive%20%20Year%20Document/SR_Full_2015_en.pdf>

Vecor Australia Pty Limited
ABN: 42 130 066 492
119 Evans Street, Rozelle, NSW, Australia, 2039
P +61 2 9555 8654 E info@vecor.com
www.vecor.com

decommissioning dates in 2022 and 2035 respectively[22]. This does not mean that the fly ash re-use industry will be forced to cease when the power stations do, on the contrary, there is 50 years worth of fly ash stored in seven ash dams across NSW which has potential to be utilised for many decades to come.

However, in the absence of any re-use industries being established, these power stations may cease work, rehabilitate to a limited extent (Sunset Power, which own Vales point power station will only be liable for $10 million worth of rehabilitation after the station is decommissioned[23]) and then leave the government with a massive liability in the form of leaking, dust-producing ash dams.

The government should take steps towards reducing its prospective liability immediately, since the trialling and testing of recycled fly ash products is needed before the industry can properly grow. By launching a program which allows trial investigations to take place, the government can assess the commercial viability of producing construction materials from fly ash, using technologies such as Vecor's. There is no such program currently in place in NSW which could oversee such investigations. As mentioned previously, an example program in another jurisdiction is Queensland's Resource Recovery Industry Development Program. It is worth noting that the program not only provides grants for building new resource recovery facilities but it supports projects that require investigations to assist in investment decisions for Queensland. These investigations - which may involve small scale trial operations to determine the viability of a new product or technology - are crucial to turning lab-scale innovations into large-scale commercial solutions.

[22] AGL 2019, *Energy Landscape: Power station transition and closure,* viewed 8 January 2020, < https://www.2018sustainabilityreport.agl.com.au/energy-landscape/power-station-transition-and-closure>.

[23] Mazengarb, M 2019, *NSW exposed to 'unquantifiable liabilities' for Vales Point decommissioning, documents show*, Renew Economy, viewed 5 January 2019, <https://reneweconomy.com.au/nsw-exposed-to-unquantifiable-liabilities-for-vales-point-decommissioning-documents-show-84435/>.

Vecor Australia Pty Limited
ABN: 42 130 066 492
119 Evans Street, Rozelle, NSW, Australia, 2039
P +61 2 9555 8654 E info@vecor.com
www.vecor.com

# 4. Economic, employment and environmental opportunities for re-use

The technology available to re-use coal ash is outlined in section 2.3. Benefits are outlined below.

## 4.1 Benefits to construction industry

Responsibly processed fly ash has huge potential as an economical, sustainable resource, particularly within the construction industry. According to Cement Concrete and Aggregates Australia, "if fly ash is not used constructively, it is disposed of by the electricity generators in either landfill or in 'ash dams'. These methods of disposal mean that a valuable resource, one that can bring significant benefit to the construction industry, is lost"[24].

Vecor technologies can benefit NSW's construction industry by providing an alternative source of scarce sand and aggregate. Not only are these products two of the key ingredients in concrete (Figure 1), but they have several other possible applications.

### *Manufactured sand*

Natural construction sand is mined from quarries all over NSW, heavily relied upon in the construction industry for the creation of mortars, renders and concrete, amongst other potential applications. Natural sands (which are often derived from rivers and coastal environments) tend to be have a smooth surface, spherical shape, high densities and high crushing strengths. Vecor has designed a manufactured-sand equivalent, made from over 50% fly ash, through a process of granulation, sintering and sieving. This product has been carefully engineered to have the technical properties[25] which make it suitable for specific applications such as render and mortar, as well as concrete. Compared to other manufactured sands on the Australian market, lab testing shows that Vecor's sand exhibits superior roundness, sphericity and durability.

### *High strength, lightweight aggregate*

Vecor has created a lightweight, high strength aggregate which has been shown to generate a high-quality concrete product. Lightweight aggregates made from fly ash have been produced overseas for several decades- one of the most successful of these being Lytag. Lytag has been

[24] Cement Concrete & Aggregates Australia (CCAA) 2017, *Technical Note 77: Fly Ash: Properties, Characterisation and uses'*, CCAA, viewed 20 December 2020, <https://www.ccaa.com.au/iMIS_Prod/CCAA/Public_Content/PUBLICATIONS/Technical_Publications/Notes/Technical_Note_77_-_Fly_ash_properties__characterisation_and_use.aspx?WebsiteKey=4998d6ce-2791-4962-b1e2-6b717f54a8d3>.

[25] These properties include roundness, sphericity, compressive strength, bonding strength and consistency.

available in the UK and across Europe for over 40 years and has been used in major construction projects such as the Canada Square Building in London. Vecor's lightweight aggregate possesses comparable but superior properties to Lytag: in the testing lab Vecor's lightweight aggregate had a higher compressive strength, required less cement and resulted in a significantly lower drying shrinkage when embodied in concrete[26]. The creation of Vecor's aggregate requires a crushing step, yielding a broad range of grain sizes, but with the bulk of the product being coarse aggregate (>5mm). Despite similar products being produced overseas for several decades, Vecor's lightweight fly ash aggregate would be the first of its kind to become available on the Australian market.

Importantly, lightweight concrete derived from Vecor's fly ash aggregates has numerous economic, technical safety benefits to the construction industry. These include but are not limited to:

- Space can be saved from reduced size of columns and slab/beam dimensions
- In reducing the concrete dead load, the number of reinforcements and the size of footings can be reduced[27]
- Smaller and less expensive transport equipment is needed. Higher volumes of concrete and aggregate can be moved by equipment such as cranes.
- Properties of the concrete include high thermal insulation and enhanced fire resistance
- Concrete made with Vecor aggregates is resistant to corrosion due to low absorption capacity (resists chloride and sulphate ion entry)

Hence, lightweight aggregates can be used to build large infrastructure projects such as bridges, stadiums and high rise buildings, resulting in considerable cost savings.

## 4.2 Economic benefits: Markets for sand and aggregate

Policies which successfully achieve positive outcomes for re-use will focus on turning what is currently a liability into a profitable asset. Since sand and aggregate are two of the main ingredients in concrete (Figure 1), demand for these resources is considerable.

---

[26] Kayali, O & Shaw, KJ 2002, *Aggregate for concrete and construction,* WO2002092530A1.

[27] Heeley,C., Butcher, R & Bernard, S 2014, '*Chapter 9: Manufactured Lightweight Aggregates form Coal Combustion Products'* in Coal Combustion Products Handbook: Second Edition, Ash Development Association of Australia (ADAA), Wollongong, NSW.


*Figure 1: Ingredients in a typical concrete mix*

NSW has historically claimed the highest sale price for natural fine and coarse aggregates, and therefore provides a strong opportunity to make fly-ash-based alternatives economically feasible[28].. However, several factors indicate that, as a way to reduce NSW's ash waste problem, these pathways for re-use would be highly advantageous to the State. These factors include:

1) Rising demands for natural sands and contentiousness around sand quarrying in NSW

2) The potential to pioneer the development of a product that is not yet commercially available in Australia, but which has had commercial success overseas (i.e. lightweight aggregate)

3) The potential to extend the operating life of sand and aggregate quarries across NSW by developing manufactured alternatives to natural materials that are in high demand

As the population of large urban centres such as Sydney grows, land use restrictions, community opposition and urban development have hindered the State's ability to develop new (or expand existing) quarries within a reasonable distance to their target markets. Over time this has pushed quarries further away from markets, thereby increasing transport costs[29], as well as increasing the carbon footprint of the material. As a result of the increasing price of natural quarried materials, manufactured sands and aggregates made from recycled material such as fly ash have become more commercially competitive.

Future demand for sand and coarse aggregate is strong, driven by a number of infrastructure and development projects across the State. For example, in the next 20 years Sydney is expected to require approximately 66 million tonnes of sand to meet the needs of the construction industry, according to a 2016 audit of NSW Sand Quarries by the Department of Planning and

[28] Wu, H., Elliot, A., Rossiter, A., Zhu, J., Zhang, D., 2005, *Technology Assessment Report 47, Part A: Manufacturing aggregates from coal ash.* Cooperative Research Centre for Coal in Sustainable Development, Queensland.

[29] Transportation costs are significant in the Sand and Aggregate industry, with freight costs consuming 18.5% of industry revenue.

Vecor Australia Pty Limited
ABN: 42 130 066 492
119 Evans Street, Rozelle, NSW, Australia, 2039
P +61 2 9555 8654 E info@vecor.com
www.vecor.com

Environment[30]. Similarly, the market size for coarse aggregates in NSW are significant, particularly compared to the national average (Table 2).

| | Market size (Australia) | Market Size (NSW) | Value (NSW market) |
|---|---|---|---|
| **Concrete aggregate (>5mm)** | 34 million tonnes per annum | 10 million tonnes per annum | $450 million per annum |

*Table 1: Markets for concrete aggregate in NSW and Australia*

As natural replenishment of both sand and aggregate begins to be outstripped by rapid extraction rates, it has become increasingly advantageous for quarrying companies to have an alternative supply of manufactured fine and coarse aggregates which can partially substitute natural materials. This will allow quarries to extend their operating life despite significant increases in demand. Therefore, as the State embarks on a number of large construction and development projects, it is sensible to develop new regional supply streams of these materials.

### 4.3 Employment benefits

Projections estimate that a full scale Vecor plant operating at full production would require 414 full time employees[31]. The fully industrial scale plant in Zibo, China previously owned by Vecor for producing porcelain tiles, at its full scale operation, employed 100 people full time, despite having only one production line (whereas a full scale plant is expected to have five production lines). Developing the fly ash recycling industry is therefore an opportunity to boost regional employment in NSW, at a time when the reform of the energy sector is an imminent threat to jobs in coal communities. As energy companies across the State begin to plan their gradual exit from coal-fired power, there is a critical need to have transition plans in place for the workers employed in this sector.

Fly ash recycling plants would be co-located alongside power stations, reducing the spatial disruption of workers as they transition from one industry to the other. The knock-on effects

[30] NSW Department of Planning and Environment 2016, *Summary of the Compliance Audit Campaign of NSW Sand quarries (May-August 2015),* NSW DP&E, <https://www.planning.nsw.gov.au/-/media/Files/DPE/Reports/sand-quarry-audit-060401.pdf?la=en>.

[31] This is expected to be made up of 105 corporate and 309 operational full time employees. Notably, these projections are based on plans for a ceramic tile manufacturing plant, however the figures are comparative to those expected for a factory producing sand and aggregates.

for regional towns would also include an increase in the local supply of scarce materials (i.e. sand) at a time when construction in regional communities in NSW is growing.

## 4.4 Environmental benefits of responsible re-use

Developing the fly ash industry would have a wider impact on the State's emission levels. Construction materials contribute to around one third of global greenhouse gas emissions and concrete accounts for majority (56%) of Australia's manufactured building products[32]. A large portion of the emissions associated with concrete are derived from the energy requirements needed to create cement. The average CO2 emissions associated with the manufacture of cement in Australia are 0.82 tonne/tonne[33]. Vecor has assessed the components needed to create a high strength concrete and found that by using Vecor aggregates the amount of cement needed could be reduced by around 20%. While the sintering process requires energy inputs (i.e. to heat the kiln), Vecor has a number of strategies to reduce its energy needs. An example of this is using excess heat from the kiln to heat up incoming gas, making performance more efficiently. As Australia looks towards a lower carbon economy, it is essential that NSW seizes opportunities in growing markets for these low-GHG-emitting, high-recycled-content products.

Vecor's unique solution to NSW's fly ash waste problem – namely, the production of sand and aggregates- is particularly appropriate since sand and aggregate extraction has been dubbed "one of the major sustainability challenges of the 21st century" by the UN Environment Programme. NSW should consider the opportunity to deal with its fly ash waste as an opportunity to benefit the environment in more than one way.

## 4.5 Changing technologies and growing acceptance for recycled materials in construction

Historically, sand and aggregates manufactured from fly ash have not been produced in NSW for a number of reasons. Two important barriers have been with 1) the technology and 2) the Australian Standards for concrete sand and aggregate. Notably, both of these barriers have been removed in the last two decades, meaning it is appropriate that the State re-examine the opportunity of developing a fly ash recycling industry.

---

[32] Foster, S.J. and Parvez, A., 2019, *CRC-LCL Impact Pathway 2 Summary Report: Delivering low carbon materials, products and designs.* CRC for Low Carbon Living, Sydney.

[33] Flower, D. M., Sanjayan, J., 2007, *Greenhouse gas emissions due to concrete manufacture*. International Journal of Life Cycle Assessment, 12(5), pp.282-288.

### *New technology for fly ash re-use*

Perhaps the most important change has been to the technology and processes available for turning fly ash into viable construction materials such as sand and aggregate. A good example of this is the novel technological process for creating lightweight aggregate that was conceived at UNSW in the early 2000s, and is now globally licensed to Vecor. Former experimental designs for creating concrete aggregates from fly ash had previously found that the resulting concrete had significant limitations such as a high drying shrinkage and poor strength performance (thereby requiring larger quantities of cement). In contrast, lab tests show that Vecor lightweight aggregate has a significantly higher compressive strength than both granite and Lytag. Additionally, concrete made from Vecor aggregate exhibited considerably less drying shrinkage than natural granite concrete. This particularly low shrinkage will result in a low degree of cracking in the resultant concrete, improving the performance of concrete structures. These are only a few examples amongst multiple physical-property tests that indicate Vecor's novel approach may allow past limitations to the commercial production of these construction materials to be overcome.

### *Reforms made to the Australian Standards for concrete aggregates*

In the last several decades progressive revisions have been made to the Australian Standards for concrete aggregates (AS 2758.1[34]). For instance, in 2014, the Australian Standards for concrete (AS 2758.1) were updated to include a full specification for manufactured fine aggregate. Customer acceptance of this new product (a risk to commercial viability) is strongly tied into the reform of AS 2758.1.

[34] Standards Australia, Australian Standard 2758.1 (2014), 'Aggregates and rock for engineering purposes, Part 1: Concrete aggregates', viewed 10 January 2020, retrieved from SAI Global database.

Vecor Australia Pty Limited
ABN: 42 130 066 492
119 Evans Street, Rozelle, NSW, Australia, 2039
P +61 2 9555 8654 E info@vecor.com
www.vecor.com

# 5. Adequacy and effectiveness of current regulatory regime

## 5.1 Issues with the current regulatory regime

The regulatory environment in NSW has failed to promote meaningful levels of re-use. As previously mentioned, in nearly a decade utilisation rates of CCPs in Australia have improved only marginally. Indeed, the regulatory environment as it currently stands does not provide a sufficiently positive environment for new technologies such as Vecor's to be recognised and adopted by the market. The result is that fly ash waste (as well as many other forms of waste) have accumulated to environmentally detrimental proportions, and are now considered a significant liability (further outlined in section 1.1). In order to push the market to adopt new technologies that have wider community benefits, programs must be in place to support innovation and industry growth, with an emphasis on promoting resource recovery. While in 2018 the State government took steps towards creating a new 'Circular Economy Policy', this has subsequently stagnated. Without any comprehensive programs facilitating the development of new ash re-use industries, NSW is falling behind in terms of growth opportunities and jobs. Meanwhile other states are gaining a lead with modern policy initiatives that support the development of more 'circular' industries.

## 5.2 An effective regulatory regime

An effective regulatory regime would:

- Support forms of coal ash re-use that has positive environmental outcomes
- Have a program in place which can conduct the necessary investigations (i.e. trial study, feasibility study and/or setting up of pilot plants) needed to direct NSW's investment decisions
- Support re-use opportunities which turn fly ash 'liabilities' into a *profitable* resource
- Focus on rewarding *good* industry practice (i.e. incentivise partnerships between power stations and fly ash manufacturing companies)

Vecor Australia Pty Limited
ABN: 42 130 066 492
119 Evans Street, Rozelle, NSW, Australia, 2039
P +61 2 9555 8654 E info@vecor.com
www.vecor.com

# 6. Risk and liabilities associated with inaction

Australian coal-burning electricity stations have kept costs down by storing their ash in onsite repositories - a practice which has been the industry's status quo for over 50 years. Yet the real costs of these ash dams have at the same time risen.

Policies which promote the re-use of fly ash must break through entrenched resistance to change. It is unacceptable to let industries stick to the status quo and operate as part of a linear economy, while ignoring opportunities to innovate and achieve circularity. The result of inaction is what the NSW 2019-20 Budget report refers to as the State's 'ash dam liability'[35]. The magnitude of this liability - including the associated public health costs and environmental damage- continues to rise each year as more and more ash is dumped into dams.

The risk is that NSW loses out on the jobs, economic growth and environmental benefits that can come from re-use.

# 7. Other related matters: Implementation issues

Communities surrounding coal-fired power stations may have concerns relating to a new industry in the area. Vecor has identified some of these concerns and has sought to address them in this submission.

### *Truck movements and transport*

Vecor ash-processing plants are best co-located beside the power station utility. This works to minimise any transportation of the unencapsulated, potentially hazardous raw fly ash. Instead, transportation of the stable, encapsulated end-product would reduce the risk of dust pollution and the risk of hazardous ash becoming airborne.

Vecor has investigated the potential to utilise existing rail networks to ensure truck movements through townships are not increased. Transport by rail to holding facilities located within proximity to ready-mix concrete batching plants is possible solution in some areas of NSW, according to preliminary Vecor investigations.

---

[35] NSW Treasury 2019, *Budget Statement 2019-20, Appendix C (contingent assets and liabilities) p. 3,* viewed 8 February 2020, <https://www.budget.nsw.gov.au/sites/default/files/budget-2019-06/2019-20%20Budget%20Paper%20No.%201%20-%20Budget%20Statement%20%281%29.pdf>.

Vecor Australia Pty Limited
ABN: 42 130 066 492
119 Evans Street, Rozelle, NSW, Australia, 2039
P +61 2 9555 8654 E info@vecor.com
www.vecor.com

### *Worker health and safety*

An important aspect of transporting, storing, handling and processing fly ash is the issue of silicosis. Silicosis is a disease caused by the release of fine silica dust, typically released when cutting, grinding or drilling stone products. Since sintering fly ash creates aggregates of aluminium silicates, this issue is relevant to our industrial process. Vecor is committed to ensuring a safe working environment that is dust free. Workers at Vecor labs are required to wear PPE including respirators, whose filter pads are regularly changed. At its former Zibo (China) factory, Vecor had installed a factory-wide vacuum system which collected dust into an enclosed bag house that was safely disposed of or recycled. All surfaces were wet-mopped and wiped down weekly. Vecor had invested considerable time and money into ensuring its Zibo factory was a facility with state-of-the-art dust control. In NSW, all Vecor facilities (regardless of the construction material being produced) would be required to meet these high standards.

### *Waste from manufacturing process*

Vecor utilises 100% of the fly ash, finding innovative ways to minimise any waste produced along the way. For example, all dust resulting from the crushing process is captured and reintroduced into the production process, allowing the plant to operate with very minimal waste discharge. Additionally, since approximately 10% of the weight of raw fly ash is made up of iron, this iron can be extracted and re-sold. Such industry partnerships are possible in NSW[36]. Finally, Vecor is committed to ensuring all waste heat energy is utilised to its full extent. For example, excess heat from the kiln is sent up to the drier (to help dry out the ash) and is also used to warm up incoming gas, to help it perform more efficiently.

[36] In Australia, magnetite mining has increased from 57,380 tonnes in 2001/02 to 996, 635 tonnes in 2011/12 [Australia Bureau of Statistics 2014, *Mining Operations , Australia, 2011-12*, cat no. 8415.0, Australian Bureau of Statistics, Canberra.]

Vecor Australia Pty Limited
ABN: 42 130 066 492
119 Evans Street, Rozelle, NSW, Australia, 2039
P +61 2 9555 8654 E info@vecor.com
www.vecor.com

# 8. Recommendations

Fly ash represents a staggeringly large proportion of Australia's total waste stream. As previously mentioned, of all the waste produced in the country, nearly 1/5 of it is fly ash[37]. The opportunities to turn the current linear system of fly ash wastage into a profitable, circular system of re-use is considerable. Yet these opportunities are being ignored: in 2018, 5.9 million tonnes out of a total of 11.1 million tonnes of fly ash produced that year in Australia was stored in ash dams and not used[38].

With no other adequate solutions to date, Vecor offers a readily available solution to NSW's fly ash problem, a solution which was first conceptualised in NSW at the University of NSW. Vecor's recommendations are focused on ways in which re-use can be promoted in a manner which is most advantageous to communities, environment, businesses and economic growth.

### *Recommendation 1: Conduct a feasibility study assessing the potential pathways for re-use*

The NSW government should establish and fund a feasibility study

- assessing the composition of the fly ash generated at a specific power station such as the Bayswater Power Station with a view to determine its suitability for manufacturing various products using Vecor technologies such as engineered sands and light weight aggregates
- assessing the commercial viability of a full scale facility to achieve large scale utilisation of fly ash generated at such power station including the factors such as the institutionalisation of the industry, the size of the ash dam, the investment required for building a co-located ash-processing plant, and the number of jobs such facility would create

In the last two decades no comprehensive feasibility study has been done to re-assess this potential pathway for fly ash re-use. Yet, a number of recent events (i.e. changes to markets, regulations, mounting public-health concerns and evidence of environmental damage) suggest that the outcome of such a study would conclude that manufacturing fly ash

[37] Department of Environment and energy 2019, *National Waste Report 2018,* prepared by Blue Environment Pty Ltd, viewed 20 January 2020, <https://www.environment.gov.au/protection/waste-resource-recovery/national-waste-reports/national-waste-report-2018>.

[38] Ash Development Association of Australia (ADAA) 2018, *Annual membership survey results, January-December 2018,* Ash Development Association of Australia, Wollongong, <http://www.adaa.asn.au/resource-utilisation/ccp-utilisation>.

aggregates is a commercially viable way to achieve a more circular economy. Relevant companies, including Vecor, may be able to submit a proposal for their unique manufacturing process, with the government choosing a select some to fund for further testing. Importantly, the second stage of an effective feasibility study will involve setting up a pilot plant which manufactures smaller quantities of the ash into aggregates, before full scale production is commenced. Numerous studies have shown that this form of 'test, learn, adapt' approach to policies is the best way to develop effective programs which are sustainable in the long term[39]. Hence Vecor recommends that the NSW government immediately begin the process of trialling a solution, capitalising on the benefits that a fly ash re-use industry can offer and avoiding being left with an unmanageable liability.

To ensure its success, the NSW EPA should direct all power stations to comply with the proposed feasibility study (i.e. provide ash for a pilot study). Local industries should also be directed to comply by providing any other materials necessary during the trial stages of this process (for example, Vecor can use a portion of coal shale in it's manufacture sand).

### *Recommendation 2: Developing a program to help build new resource recovery facilities, specifically relating to the recovery of coal ash waste*

Critical to the success of any re-use operation is ensuring a strong market is available for the final fly ash product. Economic models suggest that the initial one-off fixed capital investment needed to set up a fly ash manufacturing plant heavily determines its final sale price[40]. If the fixed capital investment is reduced, businesses like Vecor can sell their product at a lower price that is more competitive with existing market prices. This would ensure that the product is economically viable and quarries are less likely to undercut the price to exclude these recycled products from the market. Hence, the government has a high degree of control over whether a manufactured fly ash aggregate operation would be commercially viable or not. Since manufacturing fly ash aggregates has significant environmental benefits, community-health benefits and regional employment benefits, investments into new capital works which are designed to achieve these outcomes should be encouraged by the government. A fund should be in put place that provides financial support to resource recovery facilities which specifically deal with sustainable coal ash re-use.

---

[39] Biddle, N. and Gray, M., 2018, *Support for policy trials in Australia: level and predictors.* ANU Centre for Social Research & Methods (CRSM), Canberra.

[40] Wu, H., Elliot, A., Rossiter, A., Zhu, J., Zhang, D., 2005, *Technology Assessment Report 47, Part A: Manufacturing aggregates from coal ash.* Cooperative Research Centre for Coal in Sustainable Development, Queensland.

Vecor Australia Pty Limited
ABN: 42 130 066 492
119 Evans Street, Rozelle, NSW, Australia, 2039
P +61 2 9555 8654 E info@vecor.com
www.vecor.com

### *Recommendation 3: Utilising fly ash aggregates in government construction projects*

Consideration may be given to preferencing the use of recycled aggregates in government construction, once the aggregate has become available. Another approach may be to mandate a minimum percentage of recycled-content products in construction projects. Many large construction projects which require specialised, lightweight concrete (that can be created using fly ash aggregates), such as stadiums and bridges, are in fact government-funded projects. Hence the government would be in a suitable position to kick-start market penetration and provide demonstration sites for hesitant customers. This would not only mean cost-savings for the government by using a more efficient material, but would help encourage the adoption of fly ash aggregates in more projects.

### *Recommendation 4: Ensuring sustainable re-use*

Public policy objectives should require a regulatory environment that is supportive to coal ash re-use. However, the end result of re-use should be a positive environmental outcome and so re-use should be subject to stringent environmental controls. The best practice for fly ash re-use is one which encapsulates the ash, preventing the leaching of contaminants and the safest methods of encapsulation should be pursued when considering re-use opportunities. Yet, the State should avoid regulation which prevents fly ash resources from being responsibly excavated and utilised. While it is a liability in its current form (due to unlined, leaking dams made of ash slurry), solutions that profitably utilise the waste stream in an environmentally beneficial manner are changing that. With the correct management this value can be captured in a way that is sustainable.

### *Recommendation 5: Incentivising good practice within the electricity generation sector*

Given that ultimate liability for ash dams remains with the State government, Vecor suggests that the government's approach to incentivising good fly ash management be focused on rewarding re-use, as opposed to punishing the existing industry practice of dumping ash in dams. Suggestions that a levy be put on ash dam dumping are unlikely to be productive, as this financial burden is prone to being passed on to the consumer and ash dams are likely to remain the lowest cost solution. Unless all levy payments are directed into a pool of funds dedicated to promoting the ash re-use industry, the effectiveness of such a measure is limited. Instead, Vecor suggests that companies operating power stations be rewarded for meeting achievable goals set for re-use. Realistic goals may be set by the government or EPA, based on the feasibility study (mentioned above) which would determine the amount of fly ash which can be viably re-sold and re-used. These goals may be outlined explicitly in each power station's environmental protection license.

Vecor Australia Pty Limited
ABN: 42 130 066 492
119 Evans Street, Rozelle, NSW, Australia, 2039
P +61 2 9555 8654 E info@vecor.com
www.vecor.com

# 9. Concluding remarks

Historically, NSW's approach to ash dam management has ignored the hazards and consequences associated with unlined dams and the harmful leaching that they permit. As knowledge has grown on this topic it is unacceptable to maintain the status quo: not only will communities suffer the costs, but eventually so too will the government. Indeed the costs of action today are far less than the prospective costs of inaction in the future.

Vecor recommends that the actions taken today be ones which focus on supporting the growth of the coal ash recycling industry. Not only would this revolutionise NSW's coal waste management system, but it would support private investment in regional NSW, create significant new skilled employment opportunities, and assist in creating a sustainable, more circular economy.

# 10. Glossary

**Fly ash:** a by-product from the combustion of coal. It is the portion of coal combustion residue which rises in the exhaust stack and is collected by electrostatic precipitates. It differs from bottom ash, which is heavier and settles at the bottom of the boiler.

**Manufactured sand:** particles between 0.75mm and 4.75mm manufactured to achieve the sphericity and roundness index conductive to use in mortar, render and concrete applications.

**Aggregate:** particles of a nominal size between 4.75mm and 20mm, suitable for use in concrete. Vecor aggregates of 7, 10 and 14mm represent the most significant opportunity in the NSW concrete aggregates market. *NOTE:* smaller quantities of sand-sized particles (i.e. 0.75mm-4.75mm) are produced as a by-product during the crushing process needed to make coarse aggregate. This sand which is suitable for use in concrete (but not render or mortar) may be sold alongside larger aggregates.