Role of Coal Ash in Producing Low Carbon Cements of the Future

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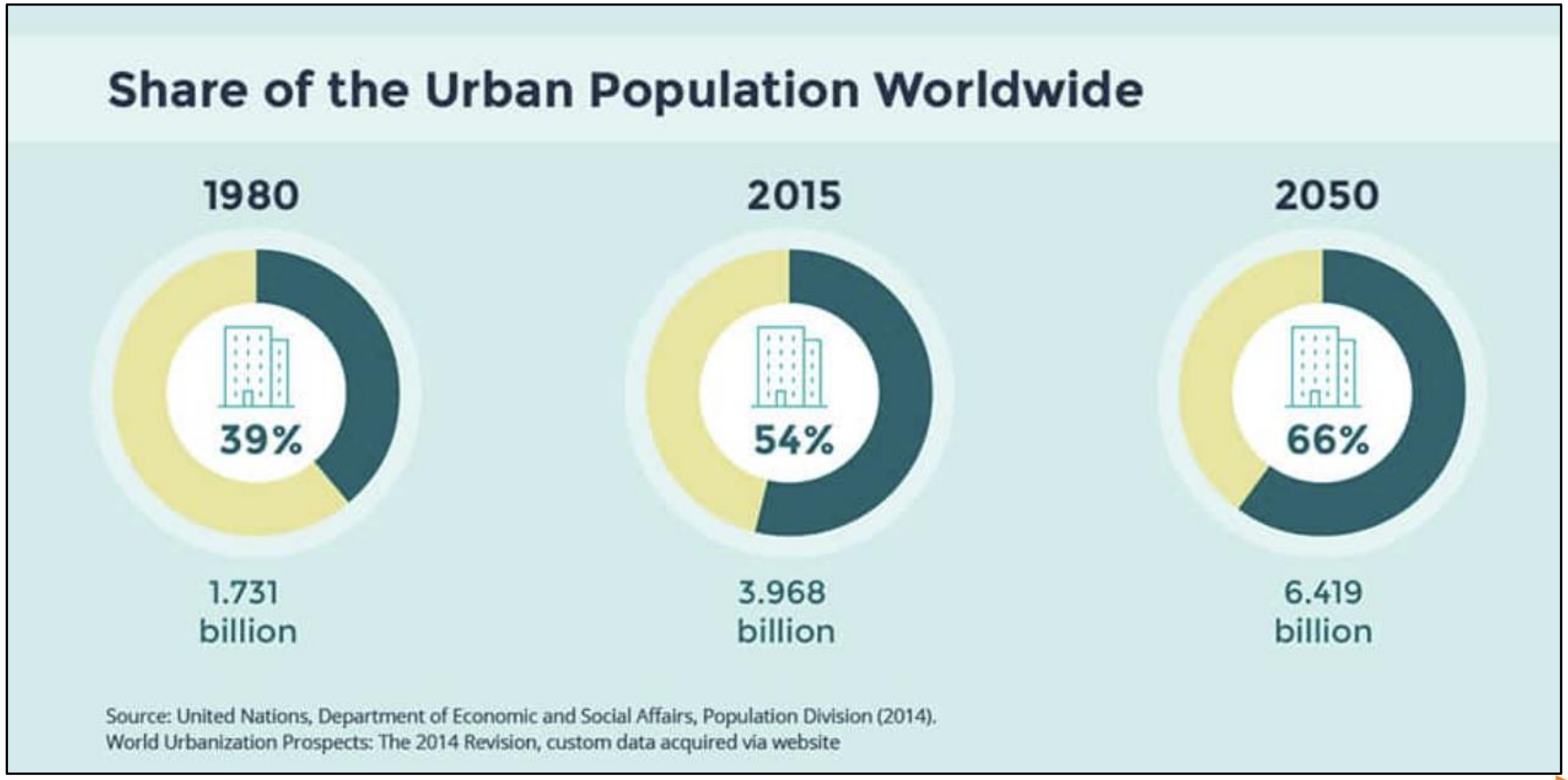
ASHCOR™

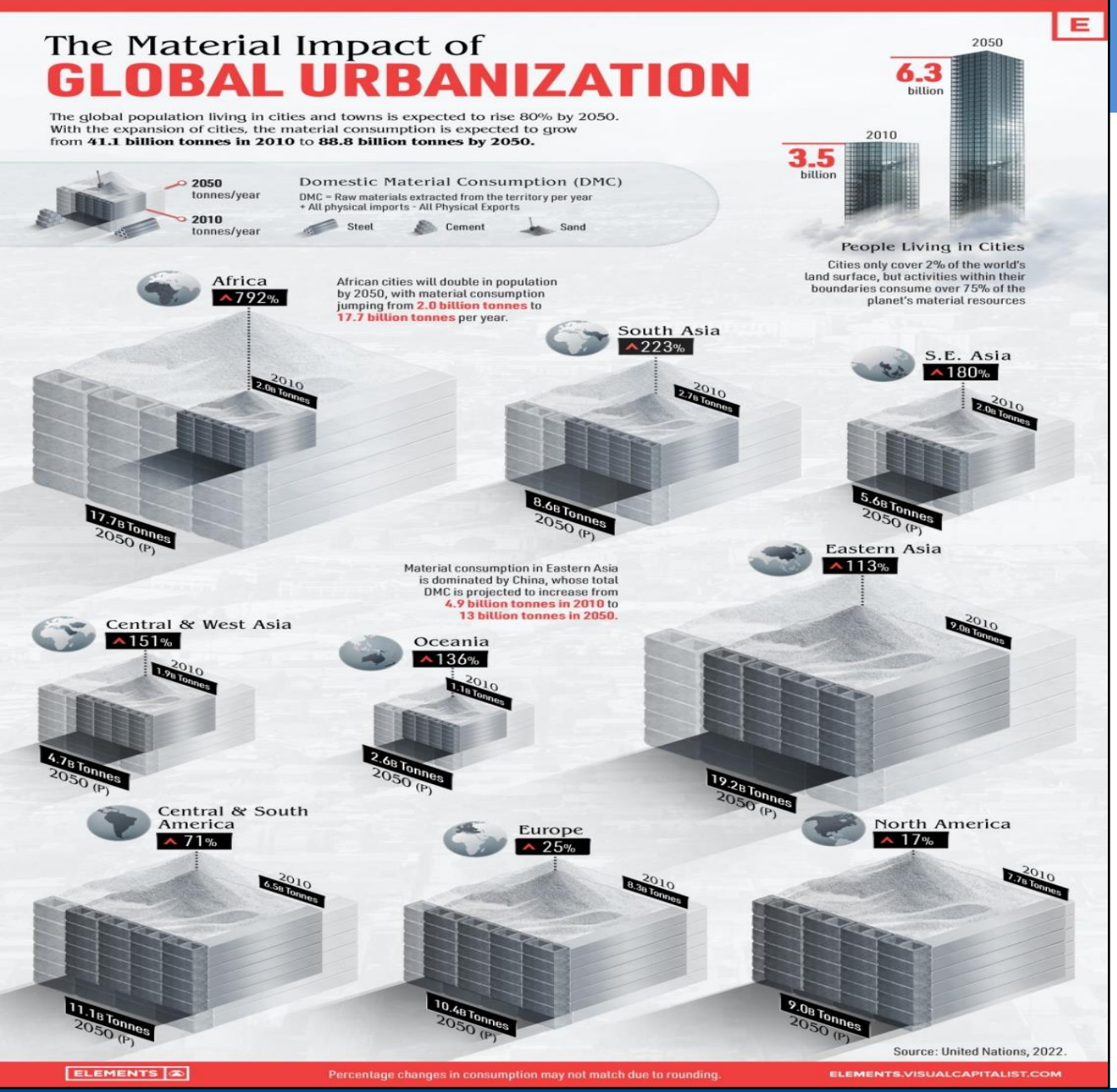
Globalization



Impact of Globalization

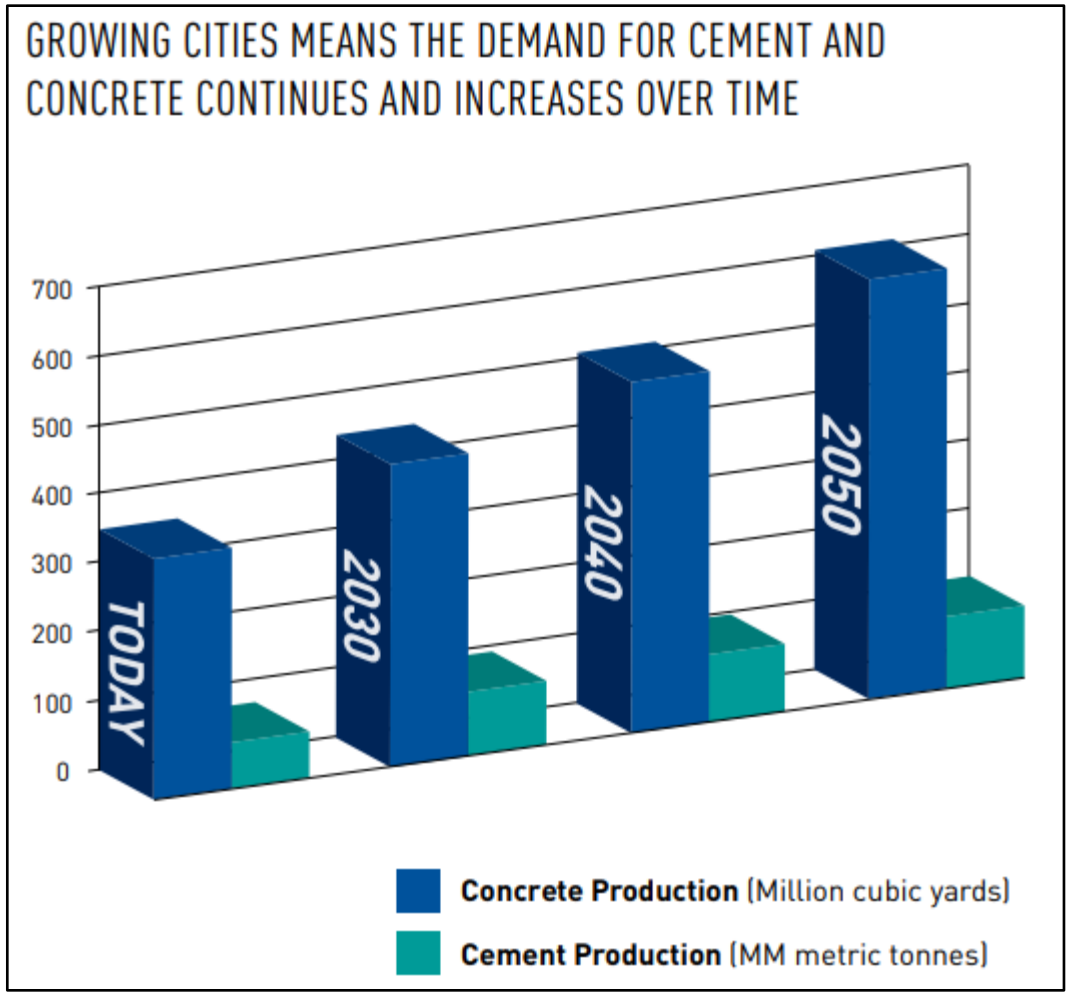
- The shift in population densities will lead to ever expanding megacities, which in turn will lead to immense pressure on already strained supply of construction materials
- Domestic Material Consumption is expected to double by 2050

Domestic material consumption (DMC) is **the total amount of materials used in an economy, including materials extracted domestically and imported, minus materials exported**. It's measured in metric tons per capita.



aci CONCRETE CONVENTION

Impact of Globalization

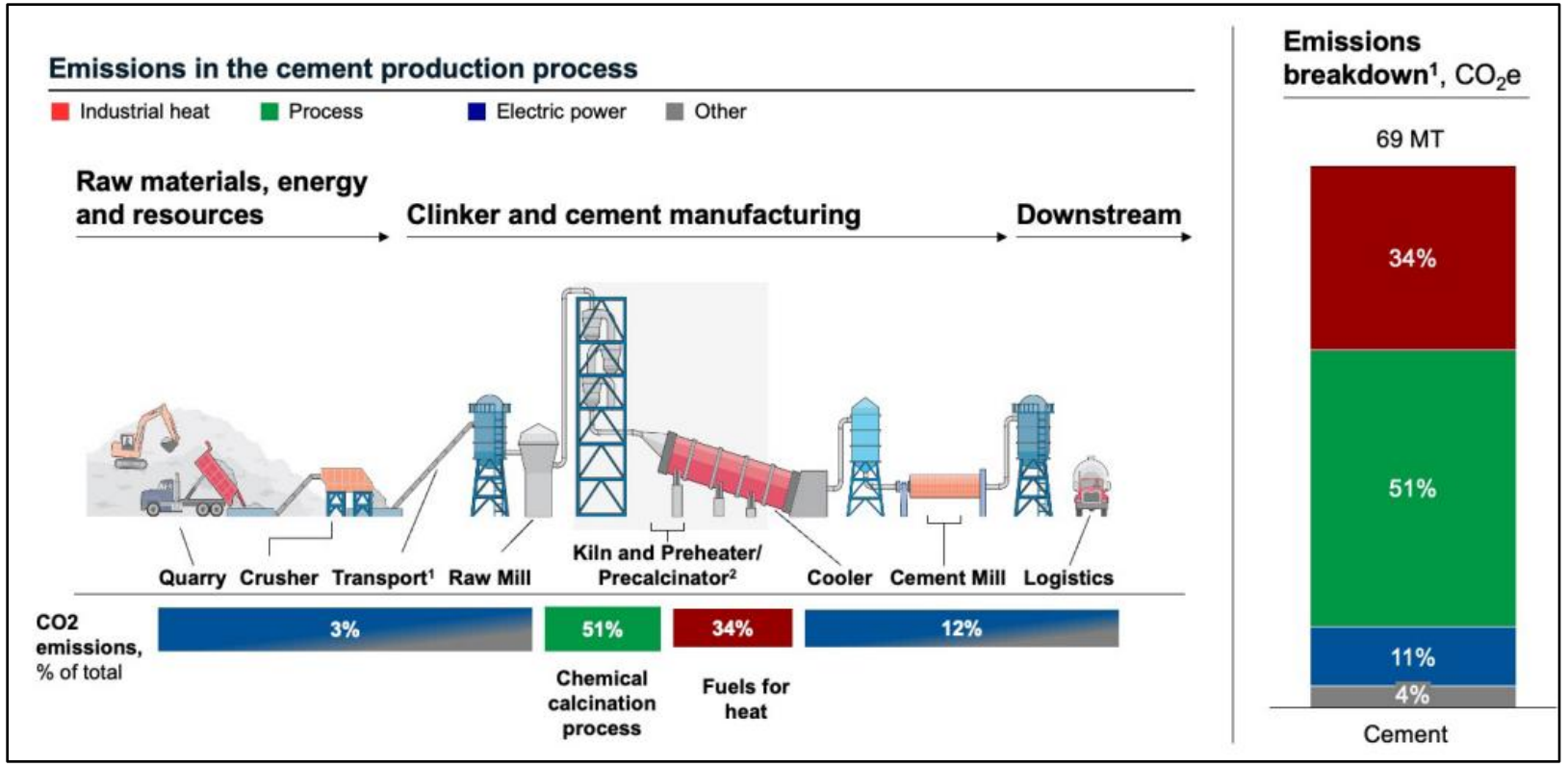


(***PCA Roadmap to Carbon Neutrality***)

- PCA roadmap agrees with the U.N. report on doubling the DMC, concrete production is estimated double by 2050

Material	U.S.	Worldwide
Concrete (Million Cu. Yd.)	350	5000
Cement (Million tons)	88	4000

Cement GHG



(***U.S. DOE Pathways to Commercial Liftoff: Low-Carbon Cement***)

- While concrete production is expected to double by 2050, cement production will only see a marginal increase ~ 15%
- This is because of GHG emissions associated with cement production; 1 MT of cement ~ 0.7 MT of CO_2

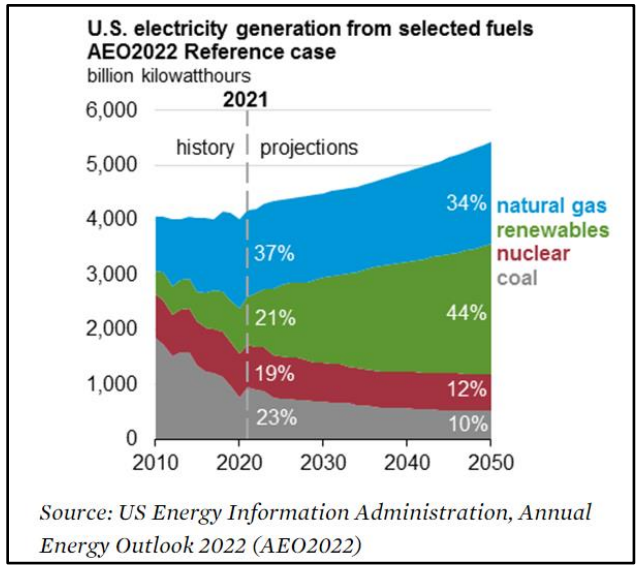
How will cement industry support doubled concrete production

Sustainable Cement Solutions

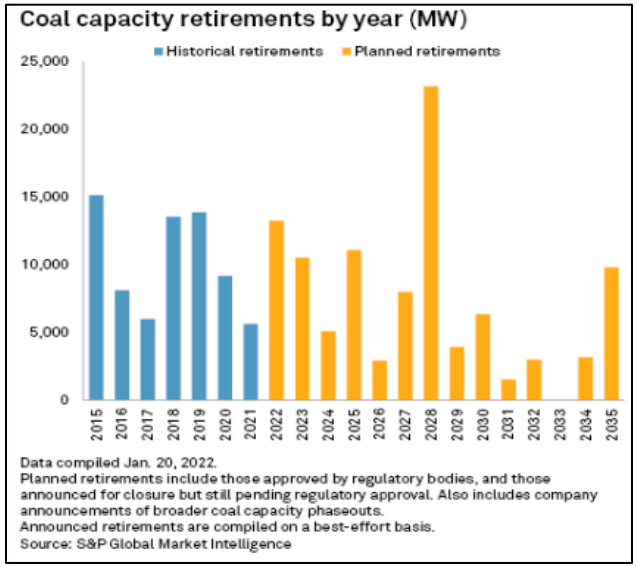
Cements	Clinker Content (%)	GHG (MT of CO_2 Eq.)
ASTM C150	95	0.7
ASTM C595 Limestone	80	0.6
ASTM C595 Ternary	60	0.5
ASTM C 1157 Performance	40	0.3

- One of the ways the cement industry is preparing to meet the increased demand is by reducing the clinker content by SCM substitution **AKA blended cements**
- Blended cements, in addition to meeting demand will also aid in GHG reductions **AKA more greener cements with less clinker**
- When it comes to voluminous SCMs, we tend to think of fly ash followed by slag (GGBFS). However, the same 2050 Net-Zero goals that led to cement GHG strategies are leading to supply shortages in fly ash and slag

Net-Zero Impact on SCMs

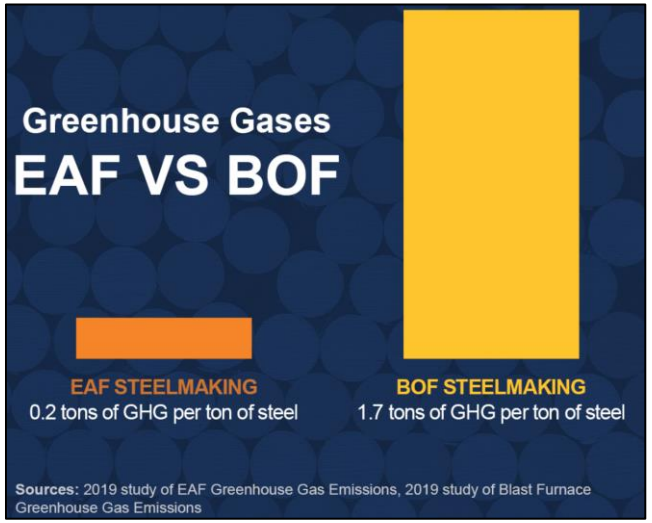


Source: US Energy Information Administration, Annual Energy Outlook 2022 (AEO2022)



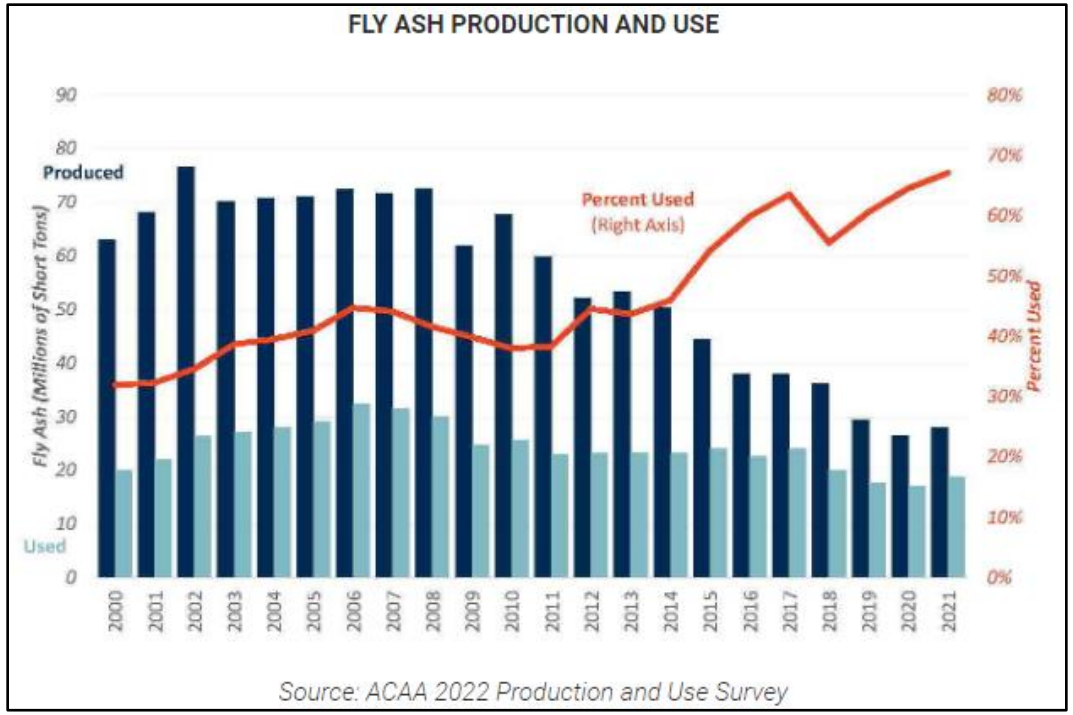
Shutdown of power plants = Less Fly Ash

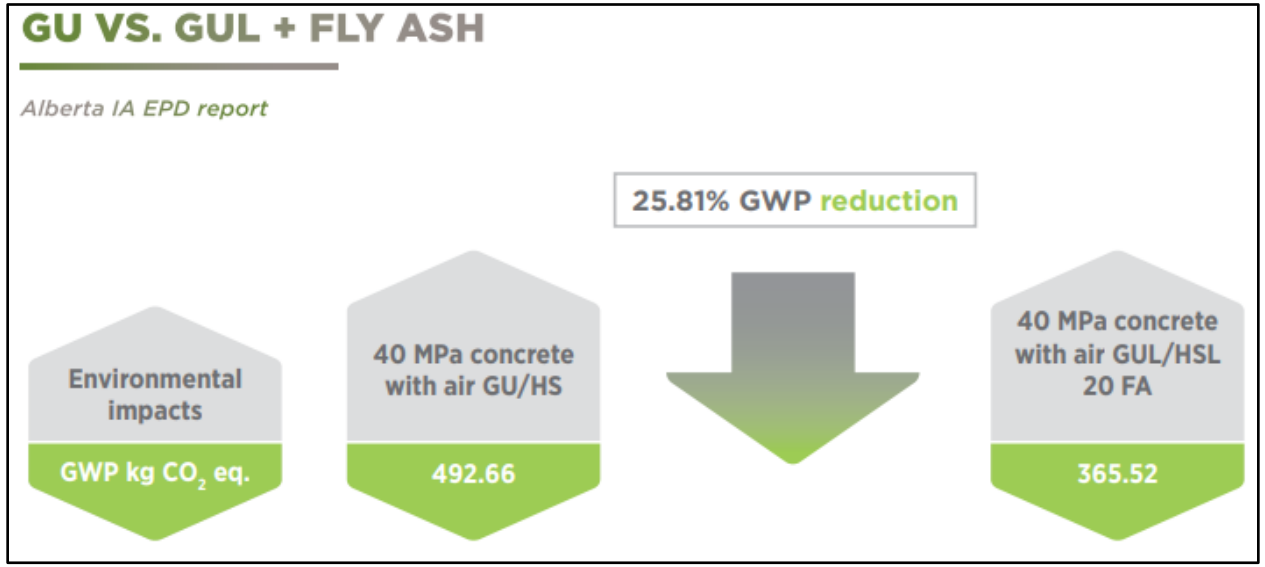
To meet the GHG emission goals, coal fired power plants and blast furnace steel makers are having to retire or transition to natural gas and other less energy intensive processes



Conversion to EAF = Less GGBFS

Net-Zero Impact on SCMs

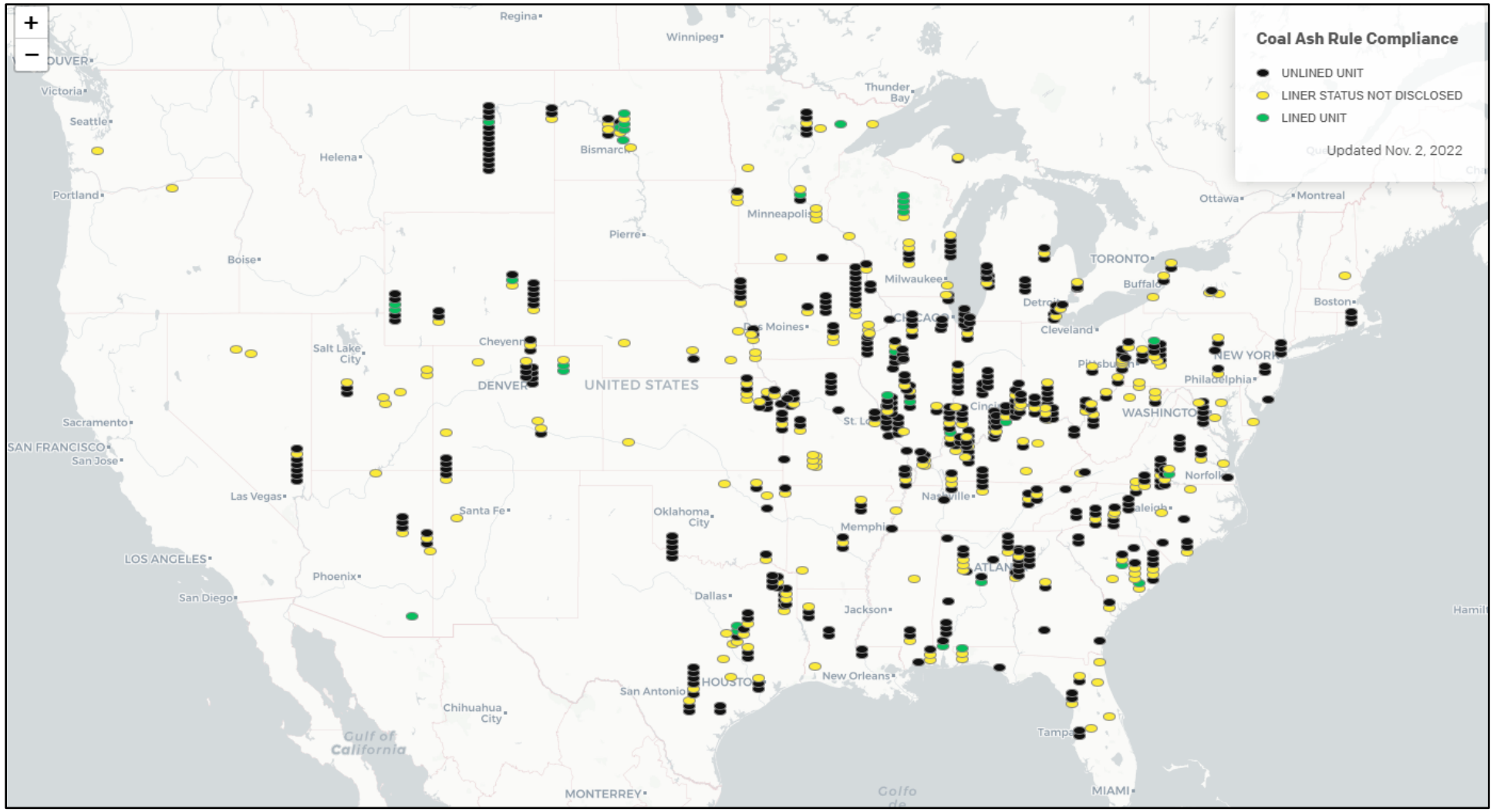




(***A guideline for specifying low carbon ready mixed concrete in Canada***)

While supply is getting constrained, demand is on the rise again, due to GHG reduction strategies

Harvesting of Coal Ash



In the U.S., there are over 740 coal ash storage sites with over 2 billion tons of material

(*Coal ash sites in the U.S. per Earthjustice*)

Harvesting of Coal Ash

- In situations where the storage sites are not contaminated and are in the region of influence of a big city with lots of construction, ash harvesting appears to be the solution for high quality coal ash

- Currently, both CSA and ASTM specifications have approved harvested coal ash as mainstream SCMs, and in some cases harvested ashes may contain ground bottom ash, which is also accepted under the specifications

- ASTM went a step further and established guidelines for characterizing (ASTM E3355) and harvesting CCR (ASTM E3183) buried in storage cells

CSA GROUP

CSA A3000:23

Cementitious materials compendium

*Harvested ash can be considered to fall under the definition of **Fly ash** provided it is tested at the frequency outlined in this Standard and that it conforms to the requirements outlined in this Standard. See the definition for **Harvested ash**.*

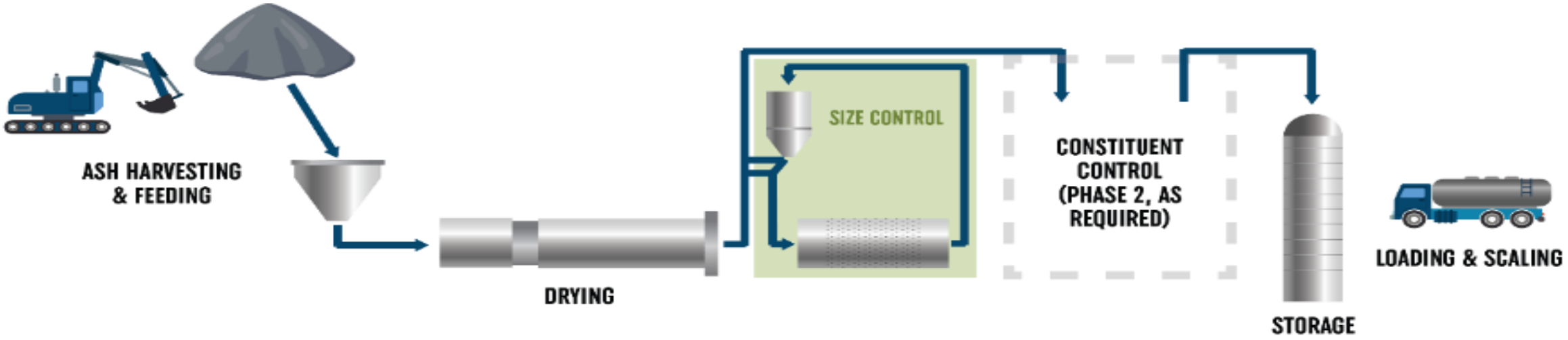
ASTM INTERNATIONAL

Designation: C618 – 23$^{\varepsilon 1}$

Standard Specification for
Coal Ash and Raw or Calcined Natural Pozzolan for Use in Concrete[1]

3.2.1 *coal ash, n*—fly ash and bottom ash resulting from the process of combustion of ground or powdered coal obtained either from current power plant production or harvested from landfills or impoundments.

Harvesting – in a “nutshell”



Essentially, there are Five stages in CCR harvesting

1. Reclaiming and feeding (Site engineering and permitting, CCR excavation and hauling, and feed bin)
2. Drying (generally natural gas aided)
3. Size control (vertical mill, ball mill, attrition)
4. Carbon reduction (extraction units or burn off units)
5. Storage and distribution (Silos)

Example of Harvested Coal Ash and its Performance

Ashcor's BR RAM Ash

	Avg. of Annual Composites			CSA A3001		
Chemical Analysis	**2022**	**2023**	**2024**	**Type F**	**Type CI**	**Type CH**
SO_3 %	0.2	0.2	0.3		5 max	
CaO %	6.0	6.2	6.8	≤15	>15 - ≤20	>20
Moisture %	0.3	0.3	0.3		3 max	
LOI %	2.3	2.4	2.4	8 max	6 max	6 max
Physical Analysis						
Fineness % Ret.	13.6	17.6	20.5		34 max	
Strength Activity 28 Day - % Cont.	85.0	80.8	83.7		75 min	
Soundness %	0.1	0.1	0.1		0.8 max	
Alkali Aggregate Reactivity %	0.1	0.1	0.1		0.1 max	

Ashcor's BR RAM Ash

BR RAM ash in concrete with 3 different GULs and 3 levels of replacement

Cement Used	GUL 1			GUL 2			GUL 3		
% Replacement	100% Cement	10% FA	25% FA	100% Cement	10% FA	25% FA	100% Cement	10% FA	25% FA
7d MPa	30	29	24	45	39	31	34	29	26
28d MPa	43	38	36	57	51	45	44	41	34
56d MPa	46	42	41	62	57	51	48	45	38
90d MPa	50	46	46	67	60	57	51	48	43
120d MPa	52	48	46	69	61	59	53	50	45
365d MPa	55	51	55	71	68	63	58	55	50

BR RAM Ash at both 10% and 25% replacement levels exceeded target strength requirements

1-year concrete strengths with ash replacements are close to controls

Ashcor's BR RAM Ash

BR RAM ash in Accelerated Mortar Bar with 3 different GULs and 3 levels of replacement

Cement Used	GUL 1			GUL 2			GUL 3		
% Replacement	100% Cement	10% FA	25% FA	100% Cement	10% FA	25% FA	100% Cement	10% FA	25% FA
ASR AMB (%)	0.4	0.3	0.1	0.4	0.4	0.1	0.4	0.3	0.1

Samples with BR RAM Ash replacement at 25% show high resistance to ASR

Ashcor's BR RAM Ash

BR RAM ash in RCPT with 3 different GULs and 3 levels of replacement

Cement Used	GUL 1			GUL 2			GUL 3		
% Replacement	100% Cement	10% FA	25% FA	100% Cement	10% FA	25% FA	100% Cement	10% FA	25% FA
RCPT 56d Coulombs	2862	2572	1508	1953	1473	999	2318	1985	1193
Bulk Resist 56d Ω*m	82	91	173	108	145	210	127	142	256

BR RAM Ash replacement at 25% significantly reduced chloride permeability and improved bulk resistivity

Ashcor's BR RAM Ash

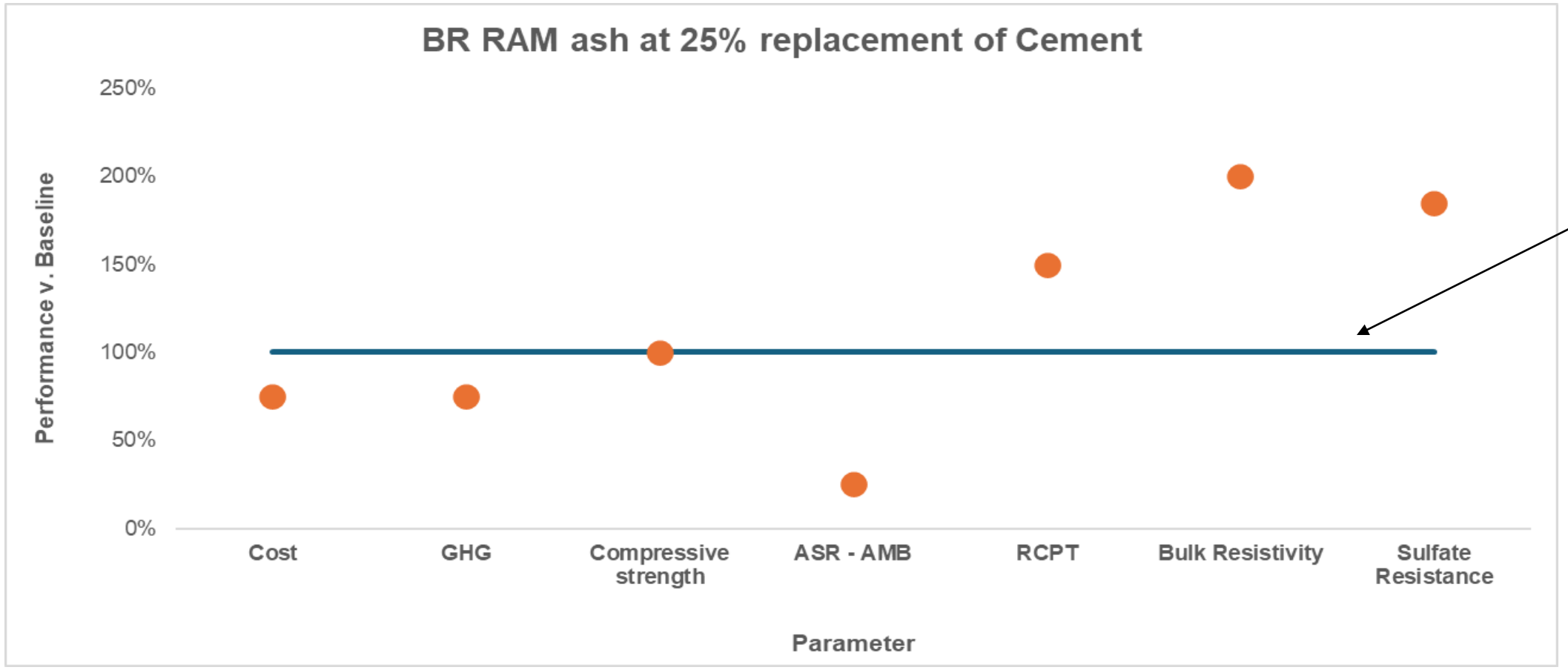
BR RAM ash in Sulfate resistance test with 3 different GULs and 3 levels of replacement

Cement Used	GUL 1			GUL 2			GUL 3		
% Replacement	100% Cement	10% FA	25% FA	100% Cement	10% FA	25% FA	100% Cement	10% FA	25% FA
Sulphate Resistance (6 months)	0.12	0.11	0.04	0.20	0.09	0.04	0.07	0.04	0.04
Sulphate Resistance (12 months)	0.68	0.33	0.07	0.85	0.30	0.05	0.22	0.10	0.05

Samples with BR RAM Ash replacement at 25% shows high sulphate resistance

Waiting on Freeze/Thaw and ASR Test Results

Ashcor's BR RAM Ash



Summary

- Irrespective of the political landscape, the “2050 Net-Neutrality goals” are not going away
- All studies point towards increased demand for concrete and sustainable construction materials
- To meet the demand for low carbon cements, industry is adapting by reducing the clinker content
- Consistent supply of harvested coal ash is one of the keys to providing sustainable cementitious materials for construction

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