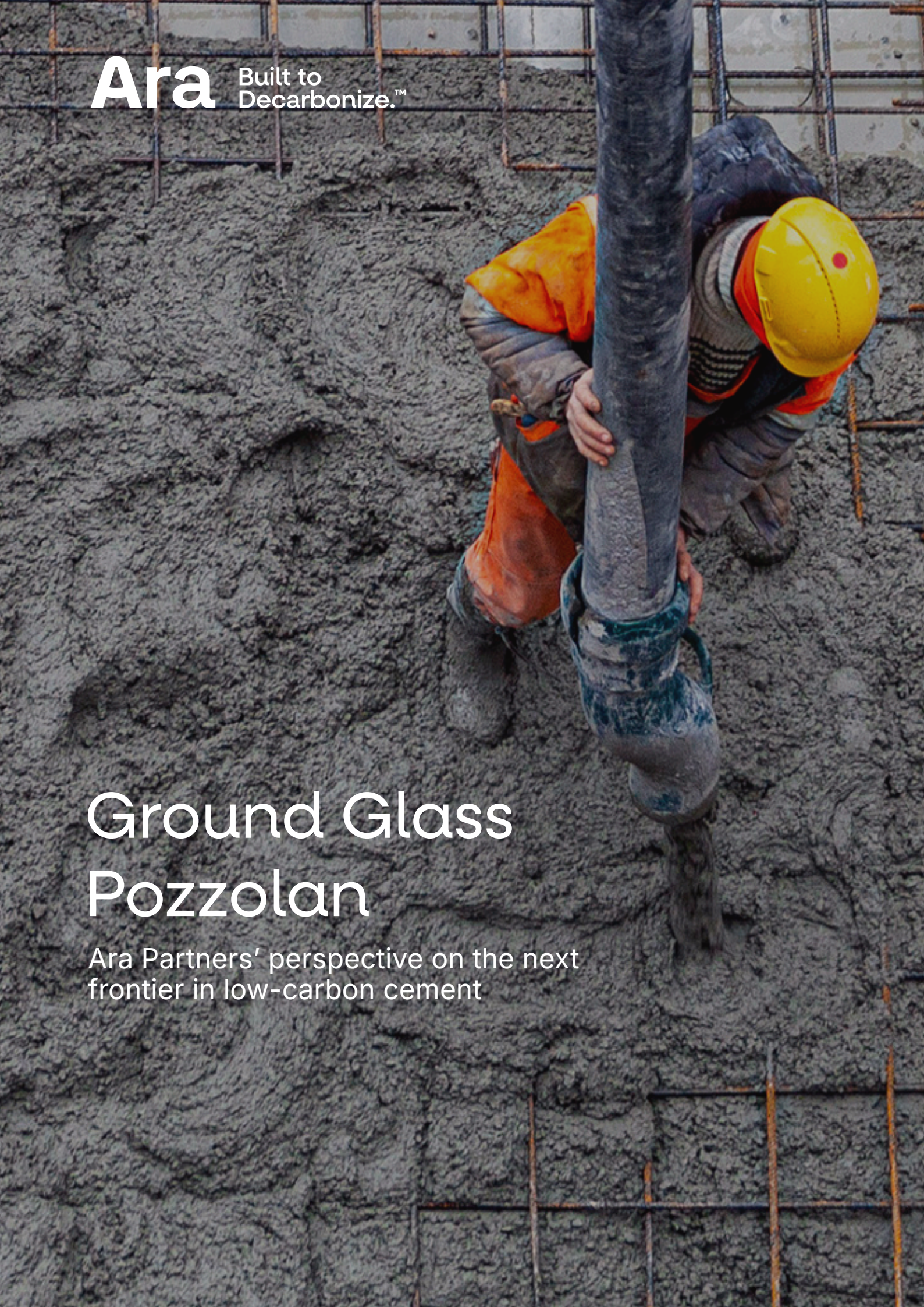
Ara Built to Decarbonize.™



Ground Glass Pozzolan

Ara Partners' perspective on the next frontier in low-carbon cement

8% of the world's CO_2 emissions come from cement production

The concrete industry stands at a crossroads

Cement is both the backbone of global infrastructure and one of the world's largest emitters of CO_2. The imperative to decarbonize is not just a regulatory or reputational issue—it is a generational investment opportunity. Supplementary cementitious materials (SCMs) are the linchpin in this transition, and among them, ground glass pozzolan (GGP) is emerging as a game-changer. GGP is not just a technical solution; it is a strategic lever for value creation, supply chain resilience, and circular economy leadership. For Ara Partners, the rise of glass pozzolan SCMs is a rare convergence of sustainability, scalability, and economic viability, an area where bold capital and operational discipline can unlock outsized returns.

PRIMARY DEMAND DRIVERS

Cost effectiveness

SCMs reduce total cement content, which is the most expensive component of concrete—leading to lower overall material costs.

Performance enhancement

SCMs often improve concrete's durability, workability & long-term strength—especially in harsh or demanding exposure conditions.

SECONDARY BENEFIT

Sustainability

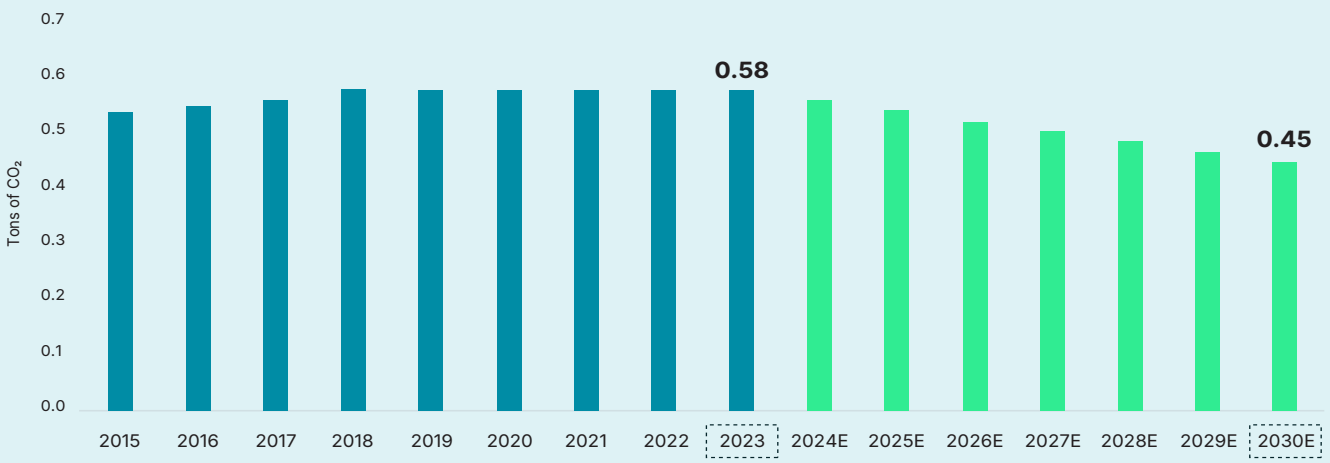
SCMs reduce clinker factor, which directly lowers embodied CO_2.

The imperative to decarbonize is not just a regulatory or reputational issue—it is a generational investment opportunity

Cement's carbon challenge: a sector ripe for disruption

Cement is the silent enabler of modern life, yet its environmental cost is staggering. Nearly 8% of global CO_2 emissions originate from cement production, with the lion's share coming from the calcination of limestone to make clinker—the "glue" in Ordinary Portland Cement (OPC). Despite decades of incremental efficiency, the sector is off track for net zero, and demand for cement is projected to remain robust through 2050. Today, the average emissions intensity of cement production sits at 0.6 tons of CO_2 per ton of cement produced; and despite growing efforts to decarbonize, this level is significantly higher than where it should be on a net zero scenario.

DIRECT EMISSIONS INTENSITY OF CEMENT PRODUCTION (TONS OF CO_2)[1]



The status quo is unsustainable. The world's largest cement producers face mounting regulatory, financial, and societal pressure to decarbonize. Emission intensity in cement is set to decline as producers increasingly incorporate SCMs. This will require rethinking of the very chemistry of cement and this is where pozzolans, and especially glass-derived pozzolans, come into play.

[1] Barclays

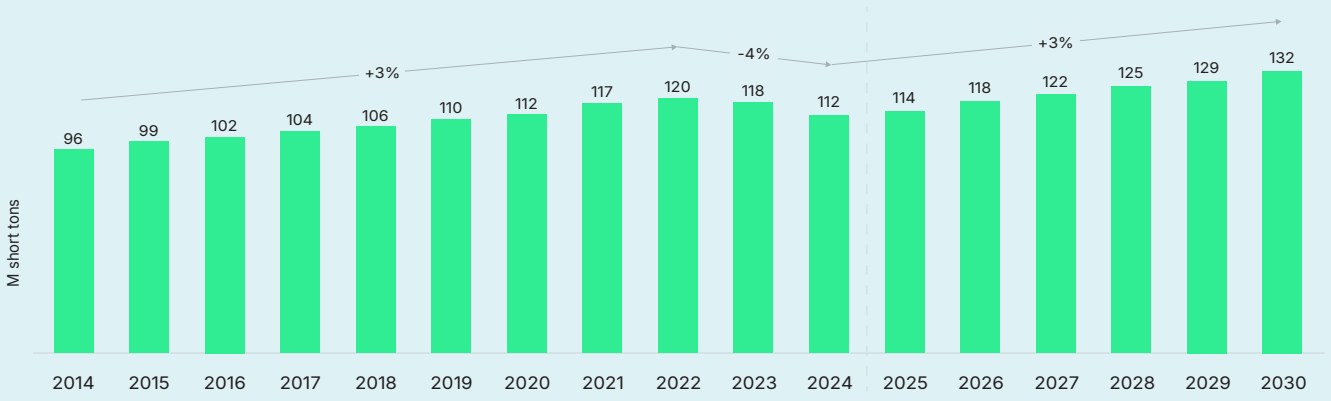
SCMs not only slash carbon emissions, they unlock new dimensions of performance and durability in concrete

From ash to glass: the new era of low-carbon cement solutions

As the world races to decarbonize construction, the search for greener cement has turned the spotlight on pozzolanic supplementary cementitious materials (SCMs)—the unsung heroes quietly transforming concrete from a climate culprit to a sustainability champion. These materials, when blended with ordinary Portland cement (OPC), not only slash carbon emissions but also unlock new dimensions of performance and durability in concrete. The trend of blending in lower-carbon materials into OPC is only increasing with the industry's greater focus on environmental impact and emissions.

3%
expected demand growth for cement, 2024-2030

CEMENT DEMAND BY YEAR[2]



[2] Barclays

By harnessing the power of nature, industry, and innovation, pozzolanic SCMs are reshaping the very foundations of modern construction

Pozzolans–nature's ancient secret

Long before modern chemistry, the Romans built enduring marvels with volcanic ash—one of the earliest natural pozzolans. Today, these naturally occurring materials, including pumice and diatomaceous earth, are making a comeback. Their high silica content and amorphous structure drive powerful chemical reactions that fortify concrete, offering a time-tested path to lower-carbon construction.

Slag–the steelmaker's gift

Ground granulated blast furnace slag (GGBFS), a byproduct of steelmaking, straddles the line between pozzolan and hydraulic binder. Its latent reactivity springs to life in concrete, delivering strength and resilience while dramatically reducing the need for carbon-intensive OPC.

Emerging innovations

The quest for decarbonization is also fueling innovation in calcined clays, rice husk ash, and other agricultural or industrial byproducts. These emerging pozzolans promise to localize supply chains and further reduce the environmental impact of concrete.

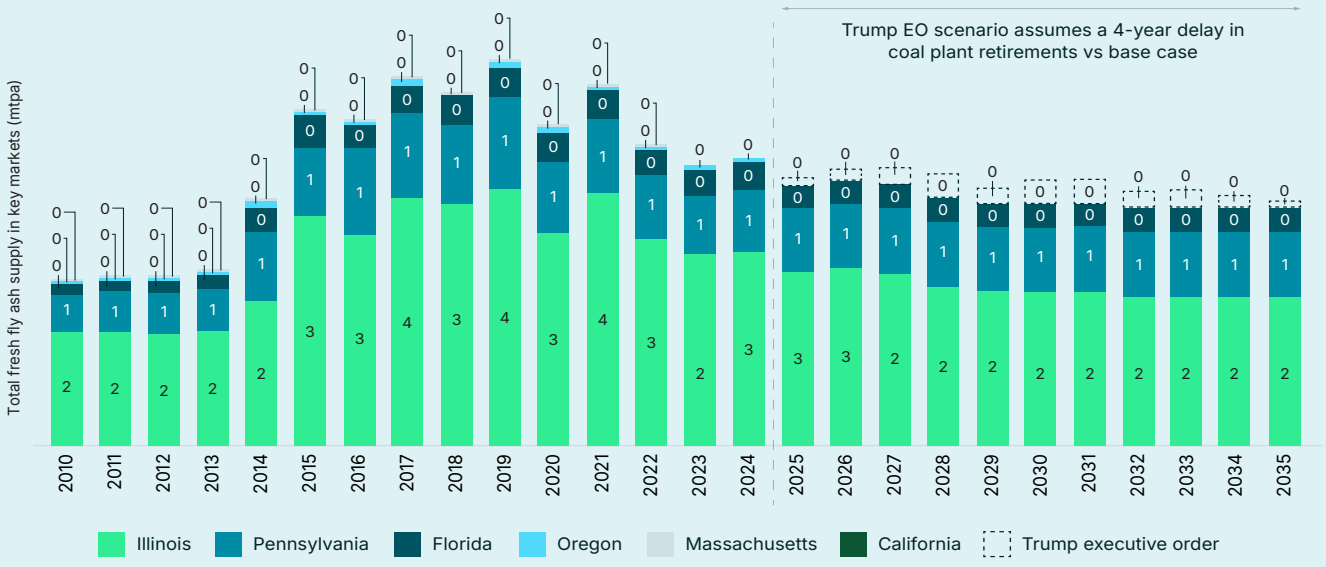
In this dynamic landscape, pozzolanic SCMs are more than just additives—they are catalysts for a low-carbon future. By harnessing the power of nature, industry, and innovation, they are reshaping the very foundations of modern construction.

The supply of high-quality fly ash has become increasingly constrained and inconsistent

Fly ash–industrial alchemy

The industrial revolution gave rise to new pozzolans—byproducts like fly ash from coal plants and silica fume from silicon manufacturing. Fly ash, especially the coveted Class F variety, became the backbone of sustainable concrete for decades. But as coal plants shutter, the industry faces a supply crunch, prompting a pivot toward alternative SCMs.

DECLINING FLY ASH AVAILABILITY CREATES OPPORTUNITY FOR ALTERNATIVE SCMS[3]



The availability of fly ash is declining primarily due to the rapid retirement of coal-fired power plants, which have historically been the main source of this supplementary cementitious material. As the energy sector shifts toward cleaner sources, the supply of high-quality fly ash has become increasingly constrained and inconsistent, creating significant challenges for concrete producers. This supply crunch is driving the industry to seek alternative SCMs that can deliver reliable performance, cost-effectiveness, and sustainability benefits.

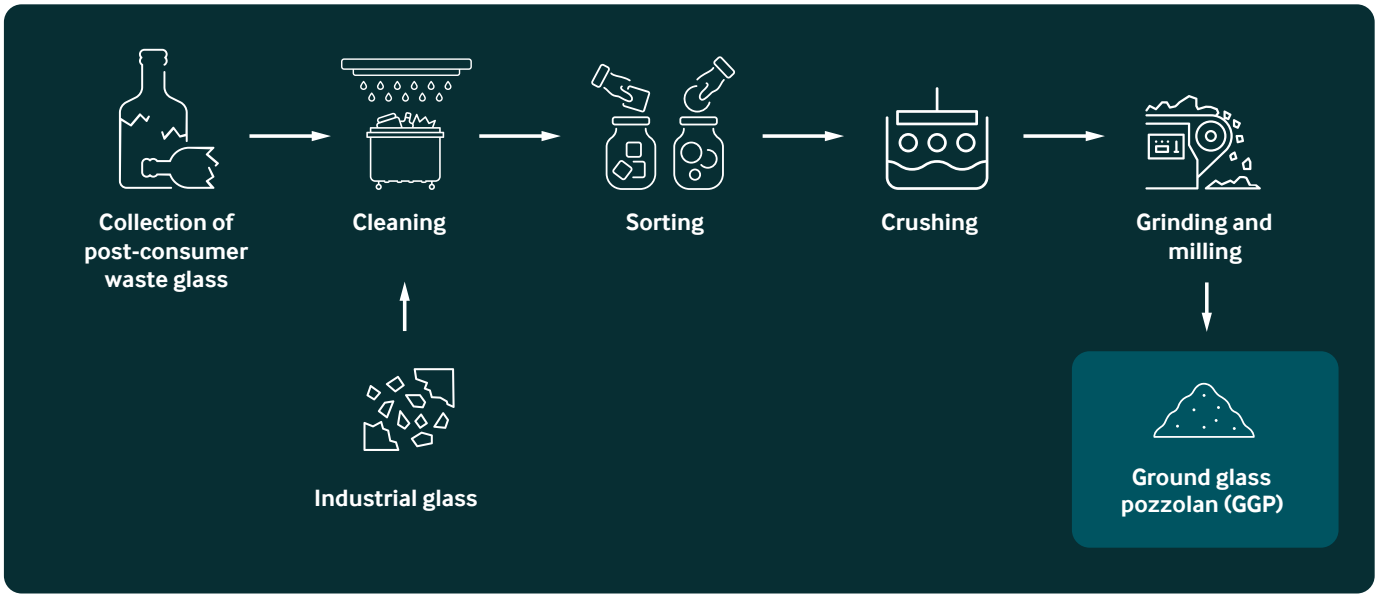
[3] BCG

GGP diverts waste from landfills and rivals traditional pozzolans in performance

Glass–waste reimagined

Perhaps the most exciting frontier is ground glass pozzolan (GGP). Imagine discarded bottles and windows reborn as high-performance SCMs. When finely ground, recycled glass becomes a highly reactive material, now recognized by ASTM C1866. Not only does GGP divert waste from landfills, but it also rivals traditional pozzolans in performance, especially when advanced activation processes are used. Its adoption is a win-win for both the environment and the circular economy. The following chart summarizes the key processing steps to go from landfilled or recycled glass to GGP:

FLOW CHART FOR THE PRODUCTION OF GGP[4]



[4] MDPI's Website https://www.mdpi.com/2075-5309/15/6/857

By partially replacing clinker, SCMs slash CO_2 emissions, cut costs, and often improve concrete's performance

SCMs: the decarbonization engine—and why glass matters

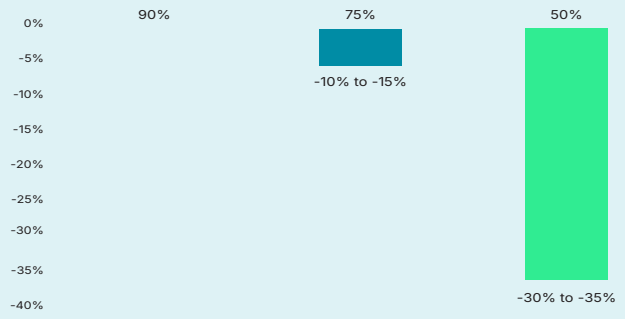
SCMs are the "secret sauce" for low-carbon cement. By partially replacing clinker, SCMs slash CO_2 emissions, cut costs, and often improve concrete's performance.

Historically, the industry has relied on fly ash and slag—byproducts of coal power and steelmaking. But as those industries decarbonize, SCM feedstock supply is shrinking, prices are rising, and the search for alternatives is urgent.

The urgency is driven by the fact that clinker substitution remains a critical component of cement decarbonization, accounting for 16% of the industry's carbon emissions reduction targets in a net-zero scenario.

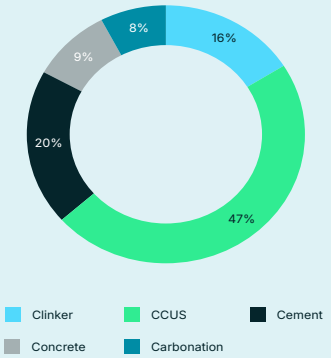
16%
of the industry's carbon emissions reduction comes from clinker substitution

CO_2 SAVINGS ASSOCIATED WITH LEVEL OF CLINKER SUBSTITUTION[5]



The relative level of emissions compared to those associated with production of cement with a 90% clinker factor.

CO_2 SAVINGS BY CEMENT DECARBONIZATION PATHWAY[6]



[5] Barclays
[6] Barclays

GGP is not just a substitute for fly ash or slag—it is a superior, circular economy solution

Ground glass pozzolan: from waste to value

GGP is a breakthrough SCM made by micronizing waste glass into a highly reactive pozzolan. It is not just a substitute for fly ash or slag—it is a superior, circular economy solution:

> **Abundant feedstock:** The U.S. alone landfills millions of tons of glass annually. This "urban ore" is now a strategic raw material.

> **Decarbonization impact:** GGP can replace up to 40% of OPC in concrete, delivering a 37-40% reduction in CO_2 emissions per ton of cement.[7]

> **Performance:** GGP matches or exceeds fly ash in strength, durability, and resistance to chemical attack. It is especially effective at mitigating alkali-silica reaction (ASR)—a major durability challenge for SCMs.

> **Cost and circularity:** GGP production is fossil-fuel free, energy efficient, and leverages local waste streams, making it both cost-competitive and resilient to global supply shocks.

GGP can replace up to

40%

of OPC in concrete, delivering

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reduction in co_2 emissions[7]

GGP IS WELL POSITIONED VS. CONVENTIONAL SCM SOLUTIONS[8]

Comparison of various SCMs

SCM	Max replacement	CO_2 reduction	Performance vs. OPC	Supply trend
Fly Ash	20-25%	~27%	Good	Declining
Slag	20-50%	~42%	Good (late strength)	Declining
GGP	20-40%	~37-40%	Excellent	Growing

[7] McKinsey & Company

[8] Ara Partners, McKinsey & Company

Ara's strategic lens: why glass pozzolan is a generational opportunity

Ara's strategic lens: why glass pozzolan is a generational opportunity

The SCM market is at an inflection point. As fly ash and slag supplies dwindle, GGP is positioned to fill a $1-2B+ addressable market in the U.S. alone by 2030. It sits within a larger $3-$6B total addressable market for SCMs. Regional shortages are acute in California, the Northeast, and Florida, where fly ash prices are soaring and GGP can be delivered at a discount to both fly ash and OPC.

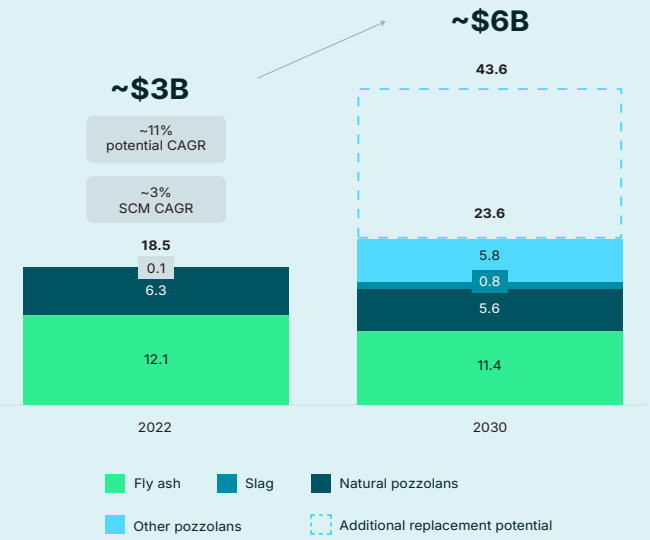
Competitive moat

GGP's value proposition is amplified by proprietary technologies—such as specialty mills—which deliver ultra-fine, highly reactive particles at industrial scale. This confers not just technical superiority, but also a defensible cost advantage and supply chain resilience.

Policy and carbon markets

Regulatory momentum is on GGP's side. Buy Clean initiatives, embodied carbon standards, and tightening landfill regulations are creating pull for low-carbon, circular materials and greater waste reduction or diversion programs. GGP's carbon avoidance can also be monetized via voluntary carbon markets, adding a new revenue stream for early movers.

MARKET OPPORTUNITY AND VOLUMES FOR SCMS ($B AND M TONS)[9]



[9] McKinsey & Company

The transformation of waste glass into high-quality pozzolan requires advanced sorting, cleaning, and grinding to ensure consistency and remove impurities

Overcoming barriers: what it takes to scale glass pozzolan

While ground glass pozzolan (GGP) is emerging as a promising solution for cement decarbonization, its adoption is not without challenges. One of the primary risks lies in the variability of glass feedstock. Post-consumer glass can come from a wide range of sources—each with different chemical compositions, particularly in terms of alkali content and the presence of potential contaminants.

This variability can impact the pozzolanic reactivity and durability of the resulting concrete, as well as its ability to mitigate alkali-silica reaction (ASR). Additionally, the recycling process itself is complex, requiring advanced sorting, cleaning, and grinding technologies to ensure consistent quality and performance. There are also concerns around the slow early-age strength development typical of GGP, which may limit its use in certain fast-track construction applications. Finally, regulatory acceptance and market familiarity with GGP are still evolving, which can pose barriers to widespread adoption despite recent progress in standardization. Key risks include:

> **Feedstock variability:** Post-consumer glass sources can have widely varying chemical compositions (e.g., alkali, silica, and potential contaminants), impacting pozzolanic reactivity and concrete durability.

> **Complex recycling process:** The transformation of waste glass into high-quality pozzolan requires advanced sorting, cleaning, and grinding to ensure consistency and remove impurities.

> **Alkali-silica reaction (ASR) concerns:** High alkali content in certain glass types can exacerbate ASR in concrete, potentially leading to durability issues if not effectively managed.

> **Slow early-age strength development:** GGP typically contributes less to early strength gain compared to OPC, which may limit its use in applications requiring rapid strength development.

> **Regulatory and market acceptance:** Despite recent progress, GGP is still relatively new in many markets, and some regulatory bodies and end-users may be hesitant to adopt it until more long-term performance data and standards are established.

> **Supply chain and logistics:** Ensuring a stable, local supply of suitable waste glass and the infrastructure for processing it at scale can be challenging in some regions.

Ara can accelerate GGP's path to mainstream adoption—capturing both economic and environmental alpha

From risk to reward: Ara's strategic edge in GGP

Mitigating risks

Ara Partners believes that the risks associated with ground glass pozzolan (GGP) can be readily overcome due to advancements in processing technology, robust regulatory frameworks, and the inherent versatility of glass as a feedstock. Modern mechanochemical activation and micronization techniques ensure that GGP achieves the necessary fineness and reactivity, addressing historical concerns about variable performance and slow early strength gain.

Regulatory acceptance has also advanced, with ASTM C1866 providing a clear standard for quality and performance, making it easier for producers and end-users to adopt GGP with confidence. Furthermore, the supply of post-consumer glass is stable, locally sourced, and insulated from the volatility affecting traditional SCMs like fly ash and slag. This resilience in supply, combined with the ability to tightly control particle size and chemical composition, means that issues such as alkali-silica reaction (ASR) and variable chemistry can be managed through careful material selection and processing.

As a result, Ara sees GGP not only as a technically viable SCM but also as a strategic, low-risk solution for decarbonizing concrete and strengthening supply chains in the face of evolving market and regulatory pressures.

The Ara advantage

Ara's advantage extends far beyond material science. With a proven track record of delivering projects on time and on budget, Ara leverages deep skillset from its builder expertise to ensure seamless integration of GGP into real-world construction. This operational excellence is complemented by Ara's dedicated Government Affairs team, which actively identifies and secures additional federal and state incentives—maximizing financial returns through non-dilutive subsidies and incentives. Moreover, Ara's best-in-class carbon accounting capabilities enable the platform to quantify, track, and communicate emissions reductions with unmatched rigor, unlocking further value for customers and investors alike.

Ara Partners' industrial decarbonization platform is uniquely positioned to catalyze the GGP market. By investing in scalable production, forging offtake agreements with regional ready-mix leaders, and unlocking non-dilutive sources of capital, Ara can accelerate GGP's path to mainstream adoption—capturing both economic and environmental alpha.

The formal adoption of standards such as ASTM C1866 has been a pivotal step for wider GGP adoption

Unlocking the market: what it takes for GGP to go mainstream

To achieve broader commercialization of ground glass pozzolan (GGP) as a mainstream supplementary cementitious material, several key milestones must be reached:

> **Further standardization and regulatory acceptance:** The formal adoption of standards such as ASTM C1866 has been a pivotal step, providing clear guidelines for quality, performance, and testing of GGP. Continued acceptance by major building codes, Departments of Transportation (DOTs), and project specifications will further legitimize GGP and facilitate its integration into concrete mix designs.

> **Proven performance in field trials:** Demonstrating consistent, high-performance results in a variety of real-world applications—such as ready-mix, precast, and infrastructure projects—will build confidence among engineers, contractors, and regulators. Successful field trials, especially those validated by third-party laboratories, are essential to showcase GGP's durability, strength, and compatibility with existing construction practices.

> **Scalable and reliable supply chains:** Establishing robust supply chains for post-consumer glass and developing regional processing facilities will ensure a consistent, high-quality feedstock. Investment in advanced sorting, cleaning, and micronization technologies is critical to deliver GGP at the scale and quality required for commercial adoption.

> **Economic competitiveness:** Achieving cost parity or advantage relative to traditional SCMs (like fly ash and slag) is vital. This includes optimizing logistics, leveraging local glass sources, and demonstrating that GGP can reduce overall binder costs while delivering environmental benefits.

> **Market education and stakeholder engagement:** Ongoing outreach to specifiers, contractors, and regulators is necessary to overcome skepticism and increase market familiarity. Sharing case studies, technical data, and sustainability metrics will help drive broader acceptance and demand.

> **Environmental certification and carbon credit monetization:** Securing Environmental Product Declarations (EPDs), Life Cycle Assessments (LCAs), and eligibility for carbon credits (such as through the Climate Action Reserve) will further position GGP as a low-carbon, sustainable solution and incentivize adoption by environmentally conscious builders and developers. Ara's carbon accounting team can unlock significant value on this front.

Achieving these milestones will pave the way for GGP to become a widely adopted, reliable, and sustainable SCM in the global cement and concrete industry.

In the race to decarbonize cement, glass pozzolan is the strategic catalyst for a new era of low-carbon construction

GGP is the cornerstone of decarbonization and value creation

Decarbonization in the cement sector, what historically felt like a distant aspiration, is now a near-term, actionable opportunity. Ground glass pozzolan is the rare solution that checks every box: scalable, circular, cost-competitive, and high-performing. For Ara Partners, GGP is more than a material innovation—it is a strategic wedge into the future of infrastructure, supply chain resilience, and sustainable value creation.

In the race to decarbonize cement, glass pozzolan is the strategic catalyst for a new era of low-carbon construction and essential to the circular economy. Ara Partners is committed to leading this transformation by turning waste into value and climate risk into generational opportunity.

Meet the author

Tuan Tran
Senior Managing Director,
Head of Ara Insights

Tuan Tran is a Senior Managing Director at Ara Partners, where he serves as the firm's Head of Strategic Relations and Head of Research across its Private Equity, Infrastructure, and Energy strategies. He has over 25 years of experience in private equity, investment banking, and equity research.

Ara Partners is a global private equity and infrastructure investment firm focused on industrial decarbonization. Founded in 2017, Ara Partners seeks to build and scale companies with significant decarbonization impact across the industrial and manufacturing, chemicals and materials, energy efficiency and green fuels, and food and agriculture sectors. The company operates from offices in Houston, Boston, Washington D.C., and Dublin. Ara Partners closed its third private equity fund in December 2023 with over $2.8 billion in capital commitments. As of June 30, 2025, Ara Partners had approximately $6.6 billion of assets under management.

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