BY CRAIG YEACK

Rethinking Concrete Innovations for a Sustainable Future

THE READY MIXED CONCRETE INDUSTRY IS WELL-EQUIPPED TO TACKLE GLOBAL WARMING WHILE MAINTAINING PROFITABILITY WITH TOOLS LIKE EPDS, GRAPHENE, BIOCHAR, AND THE HYBRID DRUM.

Author's note: French philosopher, mathematician, and scientist René Descartes famously wrote, "I doubt, therefore I think, therefore I am." ("Dubito, ergo cogito, ergo sum.") His philosophical argument was shaped by his predecessor, philosopher and theologian St. Augustine of Hippo, who said, "If I am mistaken, I exist." ("Si fallor, sum.") To engage in objective discussion about carbon reduction, scientific and political humility is essential. Therefore, if my objectivity offends you, apologies … but no apologies.

PART I: The carbon gambit

The effects of carbon dioxide (CO_2) on the atmosphere come down to a few core physical mechanisms tied to how energy moves through Earth's system. At its heart, CO_2 doesn't create heat; it traps heat that would otherwise escape to space.

- The sun emits shortwave radiation (visible light) that passes through the atmosphere easily.
- Earth absorbs this energy and re-emits it as longwave infrared radiation (heat).
- CO_2 molecules absorb specific wavelengths of this infrared radiation.
- Instead of letting that heat escape into space, CO_2 re-radiates it in all directions, including back toward the Earth's surface.

Too little CO_2 and the temperature goes down. Too much, and it gets hot.

Worse, CO_2-driven warming creates a loop-back function that amplifies the situation. More water vapor is created, which also holds heat. Melting ice caps increase solar absorption. And as the permafrost thaws, which is about a quarter of the exposed land in the Northern Hemisphere, CO_2 is released. This is marginally offset by more organic growth absorbing CO_2.

Oceans, which cover about 71 percent of Earth's surface, absorb about a quarter of the CO_2 emitted. While the carbon sink is beneficial, it also lowers pH, which kills coral and shellfish and alters marine ecosystems. Given that this is the ecosystem for the vast majority of the planet, the impact is staggering.

Why it matters

CO_2 in excess of what is needed to balance the Earth's atmosphere sets off a chain reaction. Energy imbalance temperature rise system stress feedback loops economic consequences.

Rising temperatures lead to excessive heat and heat waves, which directly affect human mortality. Water availability is reduced regionally, impacting food availability and fresh water for human survival. In the portion of the world that can afford it, cooling energy use will increase dramatically, as will CO_2-heavy energy production. The massive oceans will contribute fewer food sources for humans and more chronic flooding and saltwater intrusion to reduce freshwater supplies. Food availability and pricing will become volatile, forcing human migration in desperate areas.

Even for those not concerned about human mortality, provided it is not them or those they care about, diminishing resources set the stage for economic instability and the inevitable violent conflict over control.

Why it's ignored

Human nature is rooted in survival, and the most pressing threats are in the present. If there is no tomorrow, there is no next year. Global warming, despite its massive potential threats, remains slow-moving and, in global perspective, shows only incremental change for the worse each year. With all the daily concerns, we simply do not prioritize in terms of years, let alone decades.

National leaders of all stripes come to power and stay in power in the present. Addressing global warming demands some level of present change and pain. Regardless of the political system, self-inflicted change and pain can and do lead to ousting.

Yet, ignorance and inaction will not ameliorate the problem. On its current course, the Earth will reach a tipping point of loop-back systems from which there will be no turning back. While the Earth will continue to exist, civilization as we know it may not. Have a nice day!

PART II: What can be done in the present?

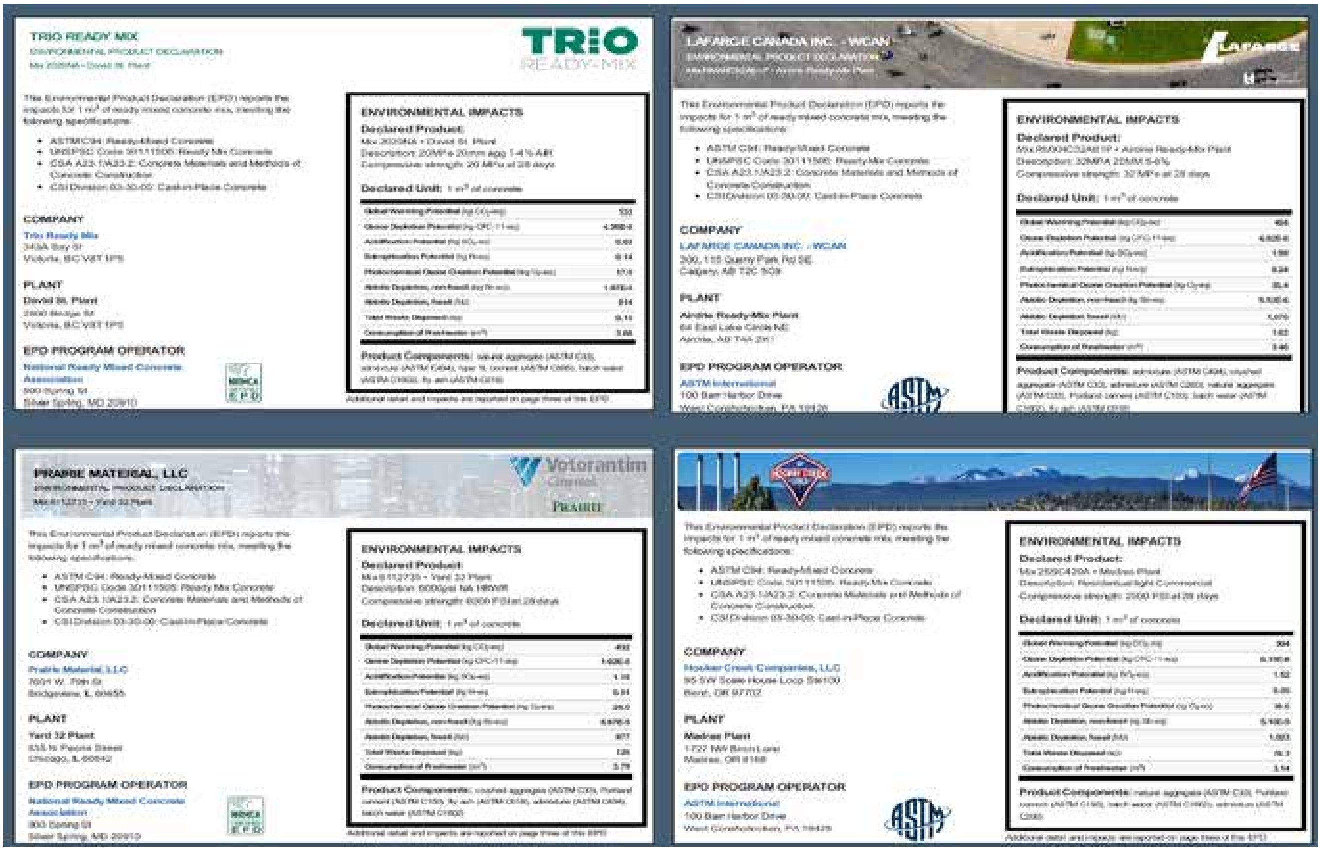
In his autobiography, Mark Twain popularized a spot-on saying: "There are three kinds of lies: Lies, damned lies, and statistics." The statistics for global warming and CO_2 abound, confuse, and fuel circular debate. Regardless of where we rank things like bovine burps (CH4) and any other oddities, the fact remains that traditional, ordinary portland cement (OPC) production is in the top range of emitters—and that matters.

Yet, let's be very clear that even if we completely eliminate CO_2 emitted by OPC production, the world will still face an urgent problem of global warming. The usual suspects of energy (75 percent), agriculture (12 percent), and industrial processes (6.5 percent) must also be addressed. (These percentages come from the World Resource Institute report, "Where Do Emissions Come From? 4 Charts Explain Greenhouse Gas Emissions by Sector.")

Given that the civilized world is literally built on concrete (ala OPC), it is politically and economically impossible to eliminate demand. The carbon footprint, however, can be reduced by clever science. Enter the bipolar world of reduction through OPC reduction (via admix for strength) or replacement (supplementary cementitious materials, aka SCMs), alongside transportation efficiency.

Enter the EPD

The key thrust for encouraging a reduced carbon footprint in construction is to provide financial incentives across the entire ecosystem. To create a level playing field, a uniform standard has been created and is currently used extensively in North America. The core process is represented by an environmental product declaration (EPD) for concrete.



Climate Earth is a leading provider of life cycle assessments critical to validated environmental product declarations.

An EPD is a verified, transparent report detailing a specific mix's environmental impact, primarily focusing on Global Warming Potential (GWP, or carbon footprint). These "cradle-to-gate" documents cover raw material extraction (section A1), transportation (A2), and manufacturing (A3), allowing architects and builders to compare sustainability impacts to meet green building standards.

"There are many promising approaches to reducing carbon in concrete, from lowering cement content to introducing new materials. The key is making sure we're measuring the full impact of those changes consistently," explains Hossein Tavakoli, PhD, senior director of Global LCA Services at Climate Earth, Inc.

While EPDs are often seen as a final report, Tavakoli says the real value is upstream. Climate Earth works with producers before a mix is submitted for an EPD, helping them understand what's driving the carbon footprint and where there's flexibility to reduce it.

"Sometimes it's cement content, sometimes it's materials, sometimes logistics—but once you can see the drivers clearly, there are usually multiple ways to meet a GWP target without compromising performance," says Tavakoli. "In the end, it's less about which solution sounds best, and more about which one actually delivers measurable reductions."

Tavakoli's role as a life cycle assessment and EPD expert is critical to meaningful progress in CO_2 reduction in the RMC industry. His work creates an objective, level playing field for full-cycle evaluation upon which progress and economic incentives can be measured.

OPC reduction and the "four Itys"

Ready mixed concrete (RMC) is both structural and perishable. OPC is the critical constituent that impacts both. Any change to the proportion of OPC used in a mix must not unbalance the long-term structural integrity, durability, and short-term perishability, including workability. Let's name these the "four Itys."

Consider recent changes in the U.S. market introducing portland limestone cement (PLC) to replace OPC. The manufacture of cement clinker—which when ground, is the key ingredient in OPC—is the primary source of CO_2 emissions. Substitute a meaningful ratio of ground limestone for ground cement clinker and *voila!* The CO_2 global warming footprint is reduced.

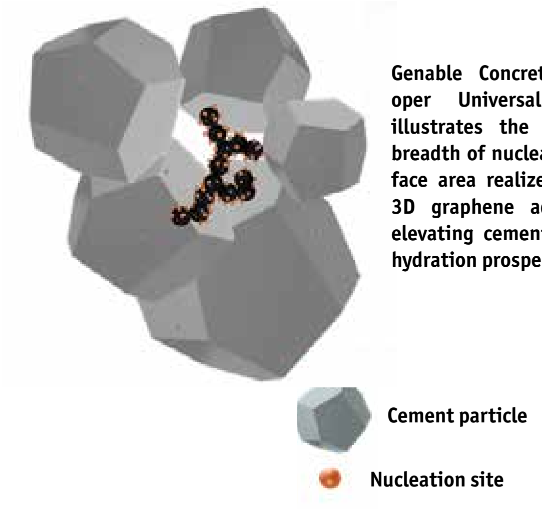
The reality of PLC has been a significant impact on the Itys, of which the industry is just beginning to reconcile. Hesitating to onboard even more "tweaks" for a low-margin, high-liability industry is understandable. However, two approaches show real promise: graphene and biochar.

Graphene enhancement

Graphene has been shown to increase the compressive strength of OPC concrete by up to ~25 percent and make it more water-resistant. That matters because we can convert the 25-percent strength increase to a direct reduction of OPC. However, rheological limits and the loss of binder is a concern for many applications. Assuming there is about 0.9 lb. CO_2/lb. OPC, and for a typical 4,000-psi mix, around 600 lbs. per cubic yard (cy) of cementitious material is used, a 25-percent reduction relative to 100-percent OPC would be 135 lbs./cy. Of course, we already use significant SCMs, and the ratio of graphene may be limited due to other factors, so the OPC offset would be smaller in proportion.

Numerous graphene suppliers exist and extensive research has been conducted, yet concerns remain:

1. **The overall carbon impact.** Historically, manufacturing graphene



Genable Concrete developer Universal Matter illustrates the potential breadth of nucleation surface area realized with a 3D graphene admixture, elevating cement particle hydration prospects.

consumed large amounts of electricity. There is debate over whether the additional energy consumption offsets the carbon benefits of reduced OPC use. However, newer manufacturing methods require much less energy consumption, and some traditional methods are harnessing renewable energy sources.

2. **Dispersion has been clunky**. Poorly dispersed graphene negates strength increases. Much has and is being done to improve this issue.

3. **Cost.** Graphene substitution has historically been a net cost increase for proven mixes. That is OK for large, EPD-centric projects. But that dog will not hunt for the huge retail, non-EPD portion of business.

Companies like Universal Matter have been working to address these issues. The advanced applied materials provider currently offers Genable Concrete, a graphene-enabled admixture technology designed to support the industry's transition toward lower-clinker, lower-carbon concrete systems without sacrificing performance or constructability. The technology is engineered to improve the efficiency of SCM-rich mix designs by enabling higher levels of cement replacement while maintaining strength development and durability.

"In practical terms, Genable Concrete supports producers in reducing cement content—the primary cost and carbon driver in concrete—while mitigating common challenges associated with optimized mixes, such as slower early strength gain and variability in performance," says Universal Matter COO Dru Kefalos. "By enhancing early-age strength development and overall matrix performance, we can help improve production efficiency, facilitate faster formwork cycling, and support more consistent quality outcomes in both plant and field conditions."

According to Kefalos, this approach aligns with the increasing need for solutions that deliver measurable reductions in embodied carbon while maintaining the performance standards required for infrastructure and commercial applications. He says the technology has been deployed in multiple field applications across North America and the UK, where it has demonstrated the ability to balance clinker reduction, constructability, and in-place performance under real-world conditions.

Kefalos, the quintessential scientist, politely resists stating a few worthy facts. Universal Matter may have solved the two biggest problems for graphene: energy consumption during production and uniform dispersion in the load. While producers must do their own math for their business, graphene combined with EPD incentives just might be a game changer.

Nova Scotia's Casey Concrete recently demonstrated the cement optimization potential in a slab mix designed with the AlterBiota biochar agent.

Biochar sequestration

Biochar takes a completely different approach. The charcoal-like additive captures carbon that otherwise would (or could) escape into the atmosphere and sequesters it into concrete. Whereas graphene improves unit strength with incidental sequestration, biochar sequesters vast amounts of carbon for low cost with incremental—but real—strength and durability improvement potential.

Up to 60 lbs. of biochar per cubic yard can be sequestered without adverse impact on the concrete and may even show strength gains. The energy required to convert the biochar into a usable substance for sequestration can be autogenous (i.e., not requiring external thermal energy so there is no net negative energy impact).

When used correctly, says Mark Masotti, CEO of AlterBiota, biochar has the unique ability to replace 5-10 percent of cement with a renewable, biogenic industrial byproduct material that stores approximately 2-3 kg of carbon dioxide per kilogram of biochar. In doing this, he says there is a double effect of cement reduction (i.e., CO_2 avoidance) and biocarbon sequestration (i.e., CO_2 removal and storage).

"Another feature of biochar is it has a 50-percent lower specific gravity than cement, so every unit volume added to concrete displaces one unit of cement by volume, but 1.5 units of cement by weight," says Masotti. "The decarbonization effect is measurable with just 5-6 percent of biochar by weight of cement in a mix achieving 20-25 percent decarbonization rates."

Masotti adds that biochar offers an interesting opportunity to create an outlet for an important forestry industry byproduct (sawdust, woodchips, shavings) that once had a reliable offtake by pulp and paper mills that are now closing at alarming rates. This would also allow this natural, renewable material to replace other non-renewable ones that are in decline due to the transitioning legacy industries of coal-fired power generation and blast furnace steel production, which cannot support the concrete industry in its traditional capacity for much longer.

Given that the overriding objective is to reduce atmospheric CO_2, biochar sequestration is a valid and workable approach today, with the added bonus of reducing OPC.

Revolution Concrete Mixers primed the industry with a pre-show alert on its ConExpo-Con/Agg centerpiece.

Transportation mitigation

A dark horse in the running is the transport of RMC. Typically, a mixer gets around 4.5+ mpg all-in for a 10-cy load. The problem is that when burned, 1 gallon (3.7 lbs.) of diesel fuel produces 22 lbs. of CO_2 due to oxygen binding. For a mythical average of 50 miles per round trip, that's 244 lbs., or 24 lbs. CO_2/cy.

It's worth noting that engine and chassis manufacturers are valiantly trying to challenge the laws of thermodynamics, but they are making slow improvements. Even 125 years after the foundational work of mathematical physicist Rudolf Clausius in thermodynamics and entropy theory, it's painstakingly difficult to poke him in the eye and tweak additional efficiencies in diesel engines.

Reducing CO_2 due to transport is a clear goal. The three key approaches that could help are:

1. Electric RMC trucks.
2. Route optimization for CO_2.
3. A hybrid drum, plus incremental engine efficiency gains.

Due to my extensive coverage of prototype electric mixers in *Concrete Products*' Tech Trends column, this author can confidently say that today's battery and recharge technology will not economically permit approach No. 1. The future will get better, but … that's one down.

As for approach No. 2, based on the best available AI for routing—with which I am quite familiar from my previous work as founder and CEO of BCMI Corp.—the carbon savings will be secondary and incidental to time savings, given capital and variable labor constraints of a perishable and structural product. EPD incentives could change this, but it will be hard … two down.

That leaves approach No. 3: the hybrid drum. If, through an intrepid adaptation of a hybrid-electric drum, the fuel efficiency could be improved to 6 mpg, that would significantly and directly reduce fuel costs AND cut CO_2/cy to 18 lbs./cy, or 6 lbs./cy reduction. This dog can hunt, and now!

Bryan Datema, executive VP of engineering, innovation, and product performance at Revolution Concrete Mixers, offers some insight:

"While fully electric chassis are not yet widely available in North America, there is a clear opportunity today to move the concrete mixer toward a hybrid model," says Datema. "Our first patent-pending e-HYDRIVE system has now been operating with Amrize in Northern Alberta, Canada, for just under a year in its current configuration. The system can spin the drum up to 15 rpm and eliminates the need to run the chassis engine while the truck is stationary. It represents the latest step in a multiyear development effort and investment between our company, London Machinery, and Amrize Western Canada."

Over the past several months, with the latest upgrades in place, Datema says the truck has reduced fuel usage per load (approximately 10 cubic meters/13 cy) from about 18.5 gallons to roughly 9.8 gallons. He equates that to a reduction of approximately 194.8 lbs. of CO_2 per load.

"This data was collected through winter and early spring under intermittent use," says Datema. "During that period, the operator achieved approximately 35 percent engine-off operation. With more consistent use, further reductions are expected. Importantly, less idle time means the engine runs more frequently under load, which is beneficial for after-treatment performance."

An upgraded system is scheduled for release this summer, which Datema says is designed to eliminate the need to run the engine while loading under the plant.

"This is a meaningful opportunity, as trucks typically operate at elevated engine speeds during loading, as well as during post-load mixing and jobsite adjustments. The system also reduces the need for oil changes, providing an additional benefit," says Datema.

A key advantage of this hybrid approach is ease of adoption. According to Datema, the system charges during normal driving, eliminating the need for external charging infrastructure or facility investment. It operates like a traditional mixer, allowing fleets to reduce fuel use and emissions without changing how they work today.

Datema's numbers imply a CO_2 reduction of ~15 lbs./cy *AND* a fuel savings of ~3.30 USD/cy at 5 USD/gal. To his credit, he strongly asserts that this is a limited trial and subject to further field validation. Even if a broad-based evaluation cuts the numbers by 50 percent or more, it's still a clear win.

Good choices abound

To borrow from Rick Blaine, played by Humphrey Bogart in Casablanca, "Of all the gin joints, in all the towns, in all the world …" the RMC industry may be the best equipped to deal with inconvenient change. Let's be honest: Most of us have built careers navigating complexity, variability, and daily chaos. Global warming mitigation? Bring it on!

The encouraging reality is that strong options exist in solutions that deliver both higher ROI and lower atmospheric carbon. With EPDs serving as neutral referees, the industry now has the tools to do more with less and do it profitably. Of course, producers need to conduct a financial analysis for their organization to identify the right combination of tactics in terms of USD/lbs. of CO_2 mitigated.

To explore what's possible today, contact the people and organizations mentioned in this article. They are seasoned operators—grounded, apolitical, and committed to the science—who will tell the truth, even when it points you in a different direction from their offerings. Contact Hossein Tavakoli of Climate Earth at hossein@climateearth.com, Dru Kefalos of Universal Matter at druk@universalmatter.com, Mark Masotti of AlterBiota at mark.masotti@alterbiota.com and Bryan Datema of Revolution Concrete Mixers at bdatema@revolutionmixers.com.