NAC Executive Insights

Reducing Greenhouse Gases in Capital Project Construction

Key Points

- The construction industry has a strategic role to play in the reduction of greenhouse gases (GHGs).
- The EPA Scope 1, 2, and 3 emissions to be reduced are described in the Executive Insight entitled, "Environmental, Social and Governance Risks in the Engineering and Construction Sector."
- Recommendations are made with respect to both the materials of construction as well as the various aspects of construction operations.
- This Executive Insight focuses on net zero carbon as an industry goal.

Introduction

The industry collectively accounts for 39 percent of global greenhouse gas emissions with construction (versus facility lifetime operations) accounting for 11 percent globally. If true greenhouse gas reduction is to be achieved, the construction industry will have to lead the way. The growing focus on ESG (environmental, social and governance) has put reducing greenhouse gases (GHGs) front and center. The construction industry is at the heart of this focus.

Reducing greenhouse gases associated with capital projects requires a comprehensive life-cycle analysis that addresses traditional economic drivers as well as the range of ESG considerations that are increasingly being called for. This begins with decisions on facility need, sizing, siting, and an expanded basis of design that addresses construction and operations and maintenance (O&M).

Two key factors stand out in consideration of the greenhouse gas component of environmental life-cycle analysis: (1) the materials of construction and associated means and methods and (2) energy choices during construction and operations. As electricity use in construction increases, the electricity system must decarbonize significantly.

This Executive Insight focuses on the construction phase, recognizing that many decisions made during engineering will impact both construction and operations. Some strategic thoughts also are included to help guide industry actions as well as those of both owners and constructors.

Greenhouse Gas Reduction during Construction

Greenhouse gas reduction during the construction phase is a supply chain challenge, not one readily met by a lone constructor. It also is a challenge that requires the industry, clients, and constructors to carefully consider targets and the KPIs (key performance indicators) that will lead to reducing GHGs. This last area on measurement and assignment of responsibility for GHG reduction achievement is not a trivial matter. It is discussed in some detail in the Executive Insight on Environmental, Social, and Governance.

Looking at GHG reduction during construction, there are both strategic and tactical issues to consider. Project initiation and engineering stages must be examined. Other issues occur in distant parts of the supply chain. Tighter integration across the life cycle and the supply chain are required, which may alter the industry and the currently prevalent contracting models.

Terminology

At times two terms are used interchangeably, but are not the same thing. These two terms are:

- **Carbon neutral** – a policy of not increasing carbon emissions, achieving carbon reduction through offsets.
- **Net zero emissions** – making changes to reduce carbon emissions to the lowest amount possible, using offsets as a last resort.

This Executive Insight focuses on net zero carbon as its goal.

Changed Optimization Point—Carbon vs Purely Economic Optimization

Reduction of design margins to what is truly required to meet an owner's project requirements will reduce materials quantities and in turn reduce both GHG emissions from construction operations and embodied carbon. Two cautions, however, should be highlighted. The first is that the inherent resilience now taken for granted in many operating facilities as structures are reduced. This was a latent capacity that was only valued when these systems were stressed to near the breaking point. The second cautionary point, especially important for constructors, is that when design margins are reduced, the importance of meeting construction tolerances is increased, that is, quality control and inspection take on increased importance.

Big Thoughts

Reducing greenhouse gases in the construction of capital assets will require a combination of actions along the entirety of the design and construction supply chain. Embodied carbon presents special challenges and owners and designers have key roles to play in this regard.

Some other big thoughts that the industry and constructors must consider include:

- The engineering and construction (E&C) industry needs to begin a coordinated collection of embodied carbon across the construction life cycle:
    - The industry is data deficient.
    - A baseline needs to be established to assess progress.
- Materials production for capital projects is the main contributor to GHG emissions associated with construction. Two materials dominate: concrete and steel.

- Clients and contractors must send clear signals to the concrete and steel industries on the degree of change they seek and their receptivity to alternative materials and manufacturing and construction processes.
- The E&C industry needs to establish and define an inventory of GHG mitigation options and their potentials. Many of these will likely shape the project before a contractor is engaged, but must reflect an expanded basis of design in which ESG factors and risks are fully considered.
- Integrate carbon capture in cement clinker production and shift towards carbon absorbing concrete.
- Foster the research and development of new technologies to dramatically reduce GHG from steel production. Candidate technologies include:
    - Top-gas recycling blast furnaces with carbon capture
    - New smelting technologies
    - Electro winning
    - Hydrogen direct reduction
- Foster and support the circular use of plastics and the required thermochemical recycling plants.
- Fully integrate life cycle assessment into all design decisions:
    - Minimize design margins through a formal review before design begins.
        - Structural efficiency is essential for GHG reduction.
    - Conduct life-cycle assessments for selected materials.
        - Limit carbon-intensive materials like aluminum, plastics, and foam insulation.
        - Review Environmental Product Declarations for all materials (see EC3 database (Embodied Carbon in Construction Calculator)).
    - Ensure energy efficiency is factored into all aspects of project design—including construction and operating phases of a project.
    - Implement strategies to elevate carbon uptake of concrete pavements during the use and end of life phases of the life cycle.
    - Increase durability and resilience of structures that will extend their design life cycles.
- Utilize 4D BIM (building information modeling) to optimize carbon in plant layouts (more efficient use of space; structural optimization; shorter pipe runs; overall materials efficiency; and more efficient construction).
- Design with more recyclable materials and promote their recyclability by minimizing mixed materials waste and recycle streams.
- Promote closed material flows (circularity of building materials).
- Owners must lead by example:
    - Establish net zero embodied carbon goals.
    - Modify approach to vendor selection to achieve the goals set.
    - Modify project funding approaches to foster goal achievement.
- Collaborative engagement with stakeholders around GHG reduction promotes partnership and allows the benefits of efficient construction and life-cycle costs benefits to be emphasized.

Tactics to Consider

There are tactics the constructor may consider or adopt related to materials as well as to construction operations. Effective adoption and implementation of many of these tactics will benefit from partnership with designers and owners. The following can serve as a checklist to assess individual company efforts.

Tactics – Materials Related

Cement/concrete

GHG abatement options:

- Identify where low-strength cement is sufficient.
- Reduce cement clinker through use of supplementary cementitious materials (SCMs).
    - Slag, ash, pozzolan, calcined clays
- Evaluate cement clinker-free concrete (outside current standards).
- Optimize concrete recipes for specific location and design factors. This will lead to use of less cement as margins of design and construction are reduced to the essentials. Recipe improvements include admixtures, fillers, finer aggregates (reduced binder intensity).
- Pilot advanced concretes with client support and approval.
- Reduce design margins to reduce structural member sizes wherever possible.
- Reduce over-specification.
- Utilize pre-casting to reduce concrete wastage.
- Electrify cement/concrete manufacture, shifting from 100 percent fossil fuels to blended energy sources that will become increasingly renewables based.
- Substitute biofuels for fossil fuels in cement plants.
- Use damaged bridge beams from deconstruction as feedstock for clean fill or base course. Recycle all used rebar.
- Advanced nanotechnology applied to concrete allows kit to break down polluting chemicals it encounters.

Steel

GHG abatement options:

- Require increased scrap rate in construction/structural steel. Reinforcing steel is already primarily made from scrap.
- Specify increased use of bio-based fuels (versus fossil fuels) in steel manufacturing.
- Specify rebar produced with low-carbon electricity.
- Evaluate requiring increased use of reducing agents such as charcoal or bio-coke in steel manufacturing.
- Alternatively, establish carbon intensity goals for procured structural and reinforcing steels and reduce the intensity target in a planned way. Carbon capture will improve carbon intensity.
    - Carbon intensity factors are country-specific.
- Reduce design margins to reduce structural member sizes wherever possible.

- Reduce over-specification.
- Utilize AI (artificial intelligence) enabled steel design to minimize material and associated carbon.
- Separate and recycle all construction steel waste.

Wood

As an abatement option:

- Wood is typically considered carbon neutral over a capital asset's life cycle.
- Use low-carbon electricity in sawmills and processing plants.
- Reduce use of resins in wood products and/or substitute natural resins.
- Ensure sustainable timber is in use and fully utilize any trees removed as part of construction process (cribbing; crane mats).
- Replace steel with massive timber as a construction material using glue-laminated timber.
    - Prefabricate the structural skeleton.

Other materials

GHG abatement options:

- Material substitution, where possible, with lower embodied carbon materials (natural fibers; recycled glass; wood and other cellulose-based materials).
- Increased material efficiency through reduced design margins.
- Elimination of temporary construction, where possible, by integrating into final designs. Added benefit of improved accessibility to components during O&M stage and reduction in construction waste streams.
- Increased energy efficiency and fuel changes, including electrification, in manufacturing processes (examples: polystyrene; mineral wool).
    - Source stone wool produced in electric arc furnaces versus gas-driven furnaces
- Graphite as partial substitute for plastic in polystyrene-based insulation.
- Electrification of plastics manufacturing processes.
- Carbon capture in cracking and polymerization in plastics production.
- Pulverized plastic as concrete filler-reducing emissions from cement production.
- Source plasterboard with high recycled gypsum content.
- Utilize secondary versus primary aluminum.
- Identify and use aluminum with biofuels, low-carbon electrification (GHG emissions mirror electricity mix) of alumina refining, and inert anodes.
- Specify increased scrap rates in aluminum.
- Lower asphalt production temperature and increase recycle content.
- Alternately, establish reducing carbon intensity goals associated with the various materials supplied.

Tactics – Construction Operations

Management

- Incentivize performance for Scope 1 emissions.
- Manage the production and recycling of waste materials on site.
- During renovation or brownfield projects, develop a plan to recycle and reuse materials, including demolition materials.
- Establish equipment and fuel standards for construction equipment.
- Life-cycle emissions from construction equipment production and end of life are not easily calculated or readily attributed to a specific project. Industry guidance is required here.
- Concrete carbonization should be accounted for in Scope 3 end of life emissions.
- Material substitutions readily available:
    - Use natural resins as adhesives.
- Optimize site layout to minimize interferences.
- Increase overall construction efficiencies by minimizing the site footprint: build up, not out, and increase use of modules.
- Optimize material handling, carefully matching equipment and requirements.
- Evaluate different scheduling approaches for impacts on GHG emissions:
    - Shorter project timelines are generally linked to lower fuel consumption.
    - Improve fleet and construction operations efficiency.
- Sequence construction to improve efficiency and effectiveness of the on-site construction equipment fleet.
- Improve energy efficiency of general conditions of plants and facilities.
    - Avoid temporary power.
- Establish overall logistics chain biofuel/hybrid/electrification goals.
- Require Environmental Product Declarations (EPD)[1] from material manufacturers.
    - Shown to measurably reduce embodied emissions for concrete.
- Utilize 4D BIM to drive efficiency of construction operations by supporting improved decision making and reducing rework. Transition from paper-based workflows.
- Reduce emissions from corporate offices.
- Buy offsets for remaining emissions.

Supply chain and logistics

- Partner with suppliers on Scope 3 emissions.
- Optimize logistics, including transport distances.
- Source local materials to reduce transportation emissions when possible.
- Full and/or consolidated load shipments.
    - General reduction in shipments to the site
- Match material supply rates to utilization rates to reduce double handling of materials.

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[1] An Environmental Product Declaration (EPD) is a transparent, objective report that communicates what a product is made of and how it impacts the environment across its entire life cycle. A verified EPD can earn products credits for LEED v4 and other green building rating systems. EPDs satisfy all of the requirements of Product Category Rules (PCR) and follow international standards, including ISO 14044, ISO 14025, and ISO 21930.

- Utilize staging areas to reduce unnecessary idling at a congested site
    - Establish a no-idle policy.
- Utilize buses to transport employees to and from sites where public transportation is not readily available.
- Ensure material receipts clearly state actual quantities received and that they are as specified or equivalent.
    - EPDs should be provided as requested.
- Maximize prefab, preassembly, and modularization as a construction materials consolidation strategy.
    - Create point source and more readily mitigatable environmental impacts.
    - Utilize prefab and modules to minimize shipment of future waste streams to and from the site.
- Separate trash such as steel, copper, plastics, glass, sheetrock, cellulose materials (paper, timber) and oil-based wastes (fuels, lubricants) to maximize recycling.
- Single-material packaging to reduce mixed waste streams.
- Standardize at a component level to reduce over-ordering and waste streams.
- Purchase materials on “consignment.”
    - Suppliers can pick up surplus materials for use elsewhere.

Equipment

- Ensure high levels of operator expertise and training to optimize machine operations.
- Optimize working time of all equipment to avoid unnecessary idling time.
    - Idling can account for up to 40-50 percent of vehicle running time.
- Avoid deadheading.
- Maximize efficient planning of machinery not just across a project, but also across the contractor’s portfolio of projects.
- Utilize hybrid vehicles or identify fuel substitutions (bio-fuel; hydrogen) for heavy equipment.
    - When sourcing from waste-based feedstocks, select waste grease or cooking oil.
    - Soy diesel is acceptable, but avoid palm oil diesel.
    - Check carbon intensity factors.
- Begin shift to electric fleets, utilizing improving battery technologies or fuel cells.
- When practical, use electric hoists instead of small cranes that run on liquid fuels.
- Utilize all-electric excavators.
- Utilize all-electric mixer drums for concrete mixer trucks.
- Utilize equipment that directly uses renewable energy or indirectly uses it through energy purchases.
    - Where possible, allow for transition of this equipment to the operational phase of the project.
- Utilization of a micro-grid for improved power generation efficiency from on-site diesel power generation.
    - Dispatch generators at higher performance levels.
- Optimize materials handling equipment.
    - Conveyors versus truck
        - Excavated materials

  - Reduce haul distance through careful balancing of cuts and fills.
- Conduct regular maintenance of all plant equipment to sustain efficiencies and eliminate fugitive emissions from valves, seals, hoses, and gauges.
  - Proper maintenance of equipment, including lubrication and filter replacement or cleaning to improve fuel consumption.
  - Consider remote monitoring and maintenance technologies.
- Recover vent gases from tanks.

On-site construction

- Maximize use of more efficient/less wastage prefabrication, including use of precast concrete panels and beams (eliminates site-based formwork requirements; shifts construction into a more manufacturing-like facility).
- Reuse concrete elements at brownfield sites.
- More broadly recycle concrete.
- Consider non-steel options for traditional rebar uses.
- Reuse steel elements at brownfield sites.

Off-site construction

- Off-site construction and manufacturing to reduce waste from timber and concrete works.
- Reduces onsite energy usage by shifting production into a better controlled manufacturing-like environment.

New Technologies and Materials

- Evaluate and prototype usage of new technologies.
  - 3D printing with various materials, including concrete, steel, and nylon reducing waste streams and associated carbon footprints.
  - Carbon Clean® − reduces impact of CO_2 separation.
  - Carbon Upcycling Technologies® – captures CO_2 emissions to produce nanomaterials with greater reactivity and lower carbon footprint.
  - Arqlite® – technology to process unrecyclable plastic waste into artificial gravel for use in low CO_2 footprint.
  - Hydrogen direct reduction of iron ore with hydrogen produced by renewable energy.

- Evaluate new materials and products
  - Vertua® – new net zero concrete
  - CarbiCrete® – cement free, carbon negative concrete (typically block) made with industrial by-products, such as steel slag, and permanently captured carbon dioxide
  - BambooTECH® – bamboo fibers combined with organic resins and shaped into thin rods for use as reinforcement in concrete
  - Timbercrete® – compaction of concrete and recycled timber waste into composite material lighter than concrete but very durable

- Ferrock® - compaction of variety of recycled materials, including silica from ground up glass and steel dust, into material with concrete-like properties but stronger. It traps carbon as part of drying process.

Summary

The construction industry accounts for 39 percent of global greenhouse gas emissions with construction (versus facility lifetime operations) accounting for 11 percent globally. Greenhouse gas reduction requires the industry to lead the way. This Executive Insight focuses on the construction phase and is intended to provide insight into the strategies and tactics that the E&C industry can adopt to meet this imperative.

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