Overcoming Barriers to Adoption of More Sustainable Concretes

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ACI San Francisco
NEU Luncheon April 4, 2023

Outline …But Enjoy your lunch…

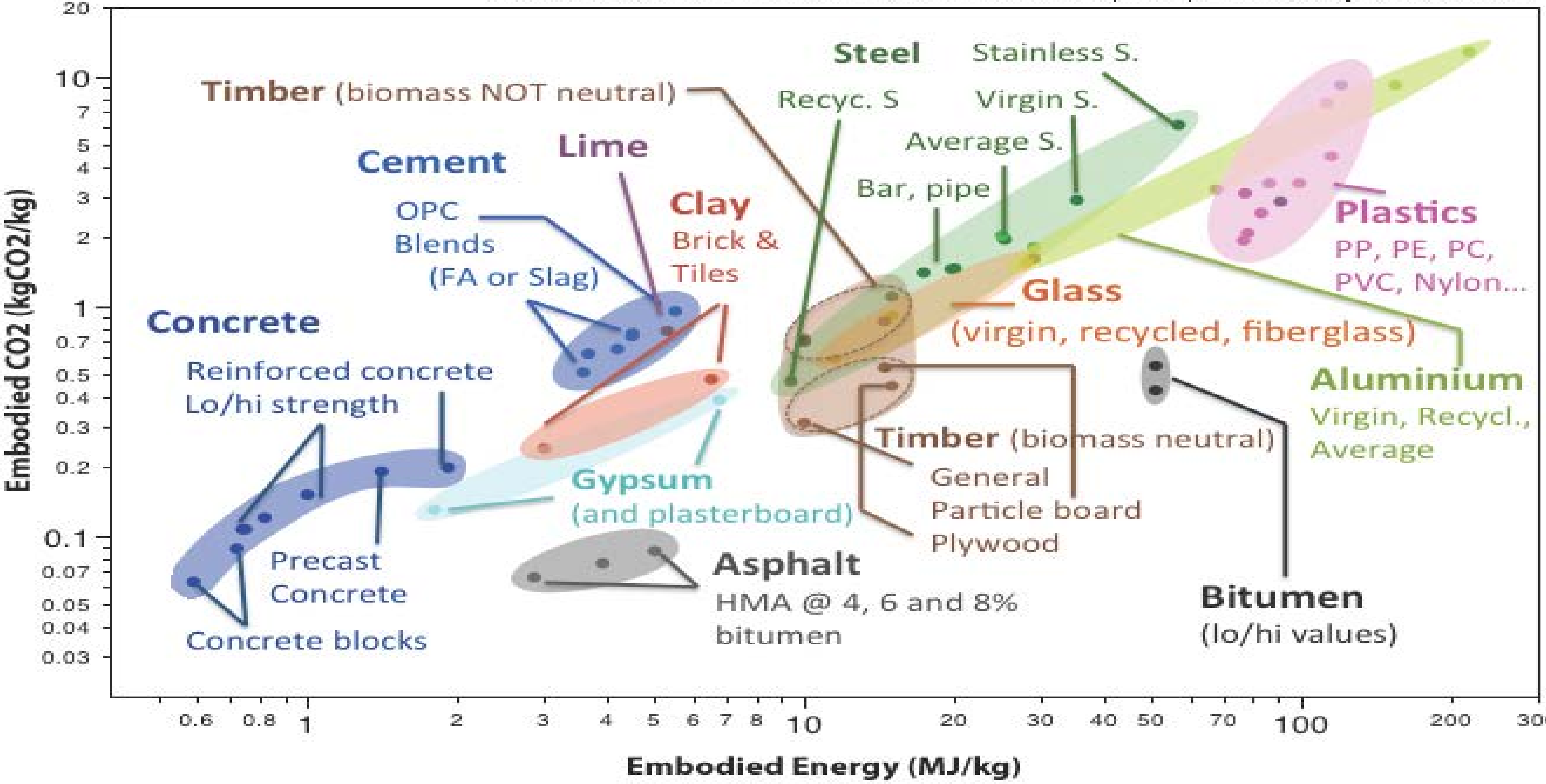
1. Where are we now?
2. Industry sustainability objectives
3. Recognizing the barriers to change
4. Developing Action Plans to overcome barriers

Concrete is a Sustainable Building Material

- Concrete has the **lowest embodied carbon and energy footprint** of any construction material (on a mass basis).
- It mainly uses **local materials**, and when properly designed and executed, has a **long service life**, and at the end-of-life is **recyclable**.

But we still need to adopt new technologies and approaches to make further reductions in GWP.

data extracted from Hammond and Jones (2011), University of Bath, UK



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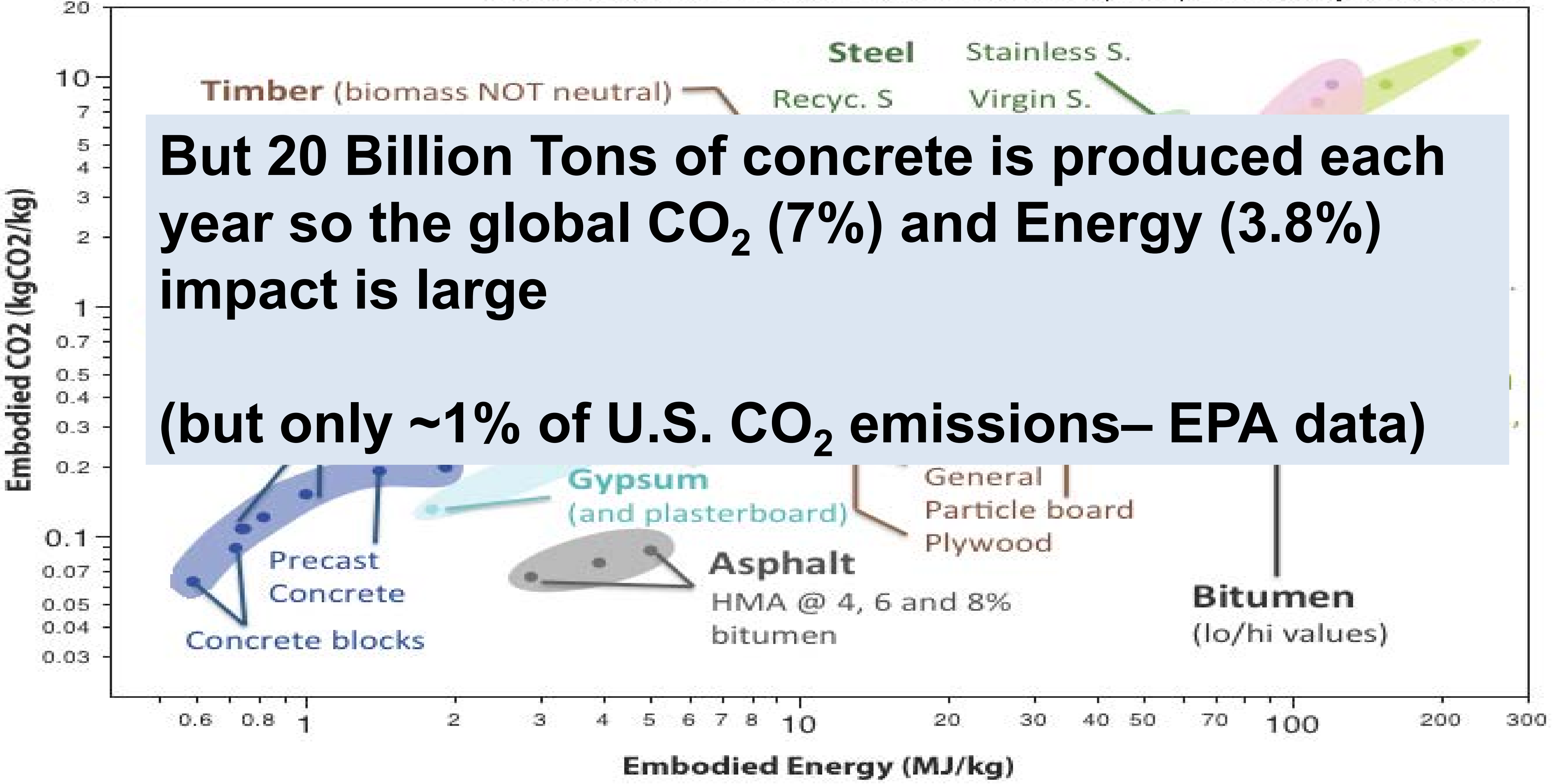
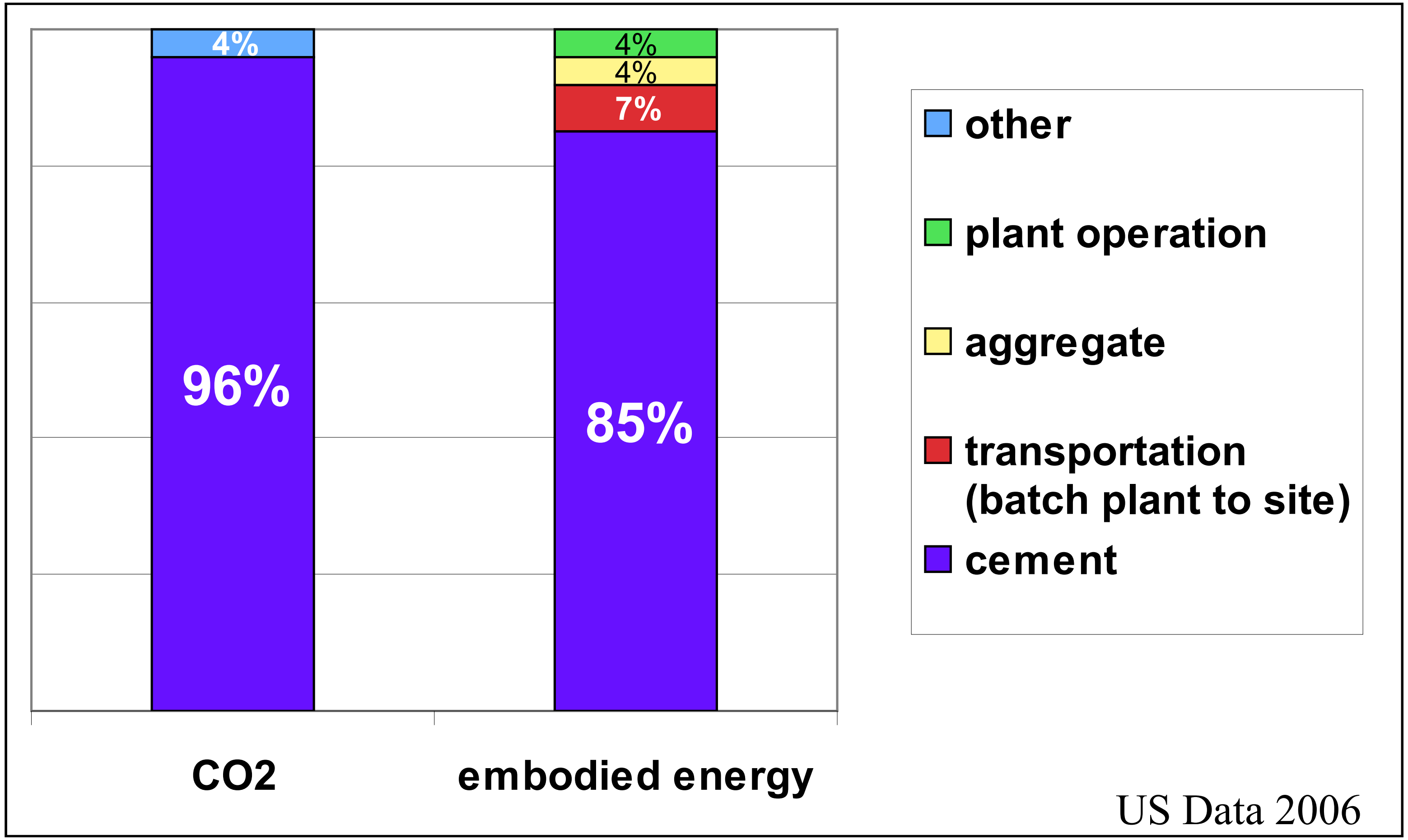


But 20 Billion Tons of concrete is produced each year so the global CO_2 (7%) and Energy (3.8%) impact is large

(but only ~1% of U.S. CO_2 emissions– EPA data)

Portland Cement Clinker Production accounts for Most of Portland Cement Concrete's GWP



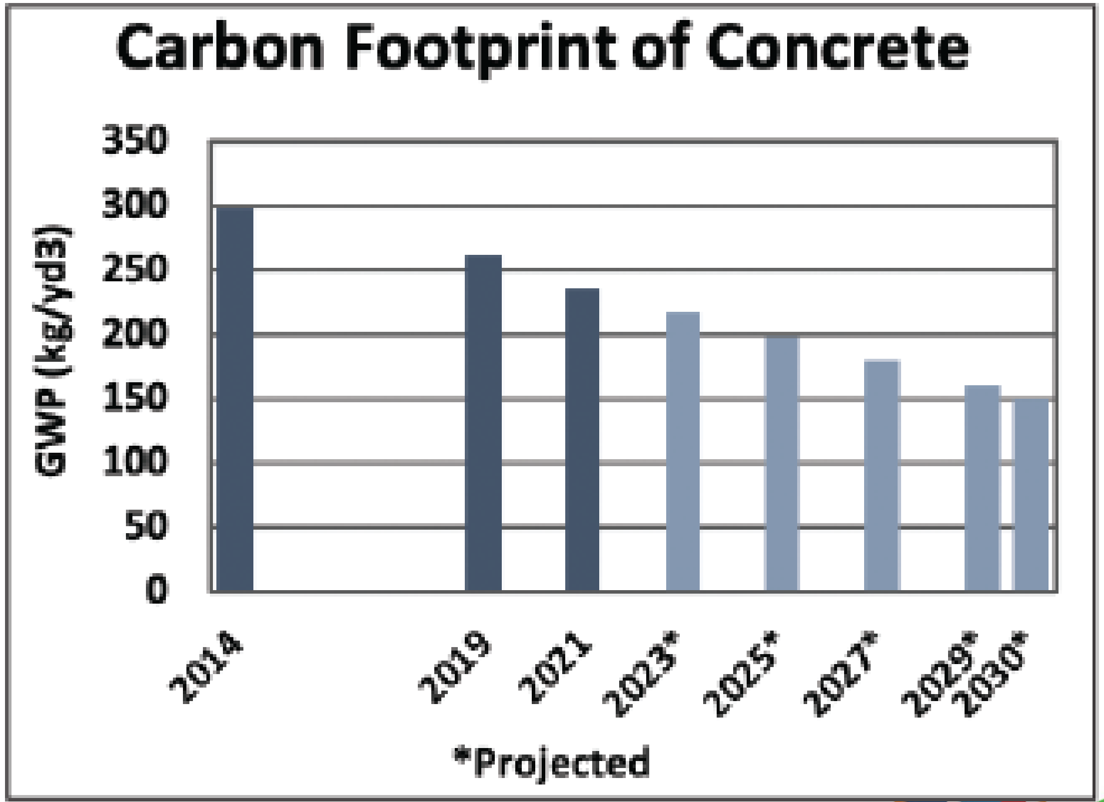
And the GWP of concrete is almost entirely based on its embodied CO_2

The US concrete industry has reduced it's Carbon footprint by 21% from 2014 to 2021

Based on Industry-wide EPD data using a survey of 155 NRMCA members representing nearly 2,000 ready mixed concrete plants, and is based on 4,000 psi (28 MPa) concrete, the most frequently used concrete in the United States.

This reduction is thought to be largely from increased use of SCMs.

In 2022, increased adoption of portland-Limestone cement will have provided further reductions.



(NRMCA Concrete-in-Focus Spring 2022)

The cement industry focus is to accelerate reductions in CO_2 emissions to meet short & long-term goals

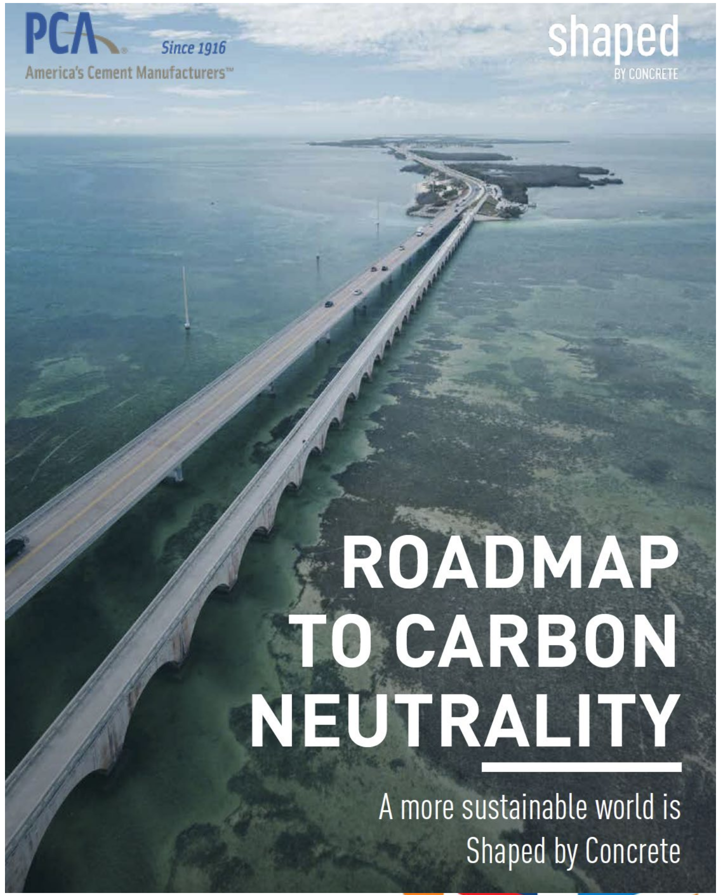
The cement industries in Europe (CEB), North America (PCA) and Globally (GCCA) have developed roadmaps to:

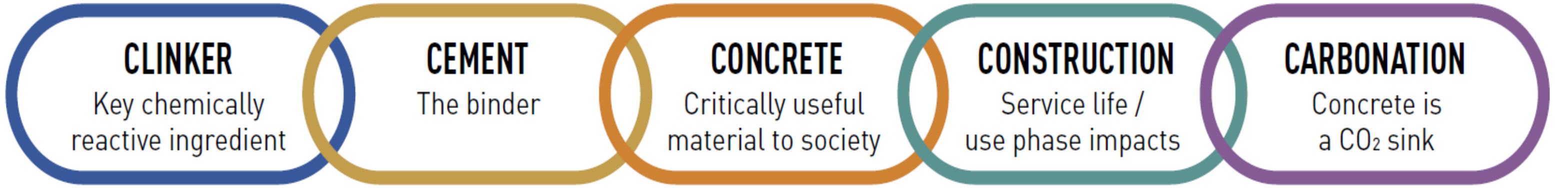
1. Significantly Reduced CO_2 emissions by 2030

- This can be attained using currently available options such as PLC and SCMs as well as more waste fuels to fire cement kilns

2. Attain net carbon neutrality by 2050

- this **will likely require carbon capture and sequestration** as well as use of non-CO2 emitting fuels (e.g. Hydrogen, electric)





For 2030 goals, start with the Low-hanging Fruit:

Use currently available levers to reduce CO_2 emissions

Adopt Materials, Mixtures, and Methods which meet current standards and codes without compromising performance or durability:

1. **Use Portland-Limestone Cements**: ---**10% CO_2** reduction over Portland cement with no change in performance.
2. **Increase levels of SCMs**: ---**CO_2 reduction is proportional to % replacement of cement (25-75%)**---- results in better durability in resisting chloride ingress, sulfate attack, ASR, and thermal cracking, but can impact set and early-strengths.
3. **Optimize total aggregate gradations and admixtures**: --- can **reduce cement paste fraction (and CO_2) by 5-15%,** while reducing both concrete shrinkage and permeability.

These levers are allowed by ACI 318, and in ASTM & CSA specifications, and can be done simultaneously

But

- But even when adopting low-hanging fruit, there will still be barriers that need to be addressed along the whole construction value chain.

- When any change in concrete takes place, the new material always gets blamed for all problems.

Example: Slow adoption of Type IL Cements

- **In 2012,** Type IL Portland-limestone cements with up to 15% raw limestone, were approved in ASTM C595 and AASHTO M-240.
- **Type IL cements meet the same setting time and strength development requirements as Type I/II Portland cements, but lower CO2 emissions by 10%.**
- Similar cements have been allowed in Europe for over 30 years and in Canada since 2008. They were also used in some US states since ~2005 under the ASTM C1157 specification.
- **Therefore, transitioning to Type IL cement should have been simple, but that has not been the case everywhere.**

Why was Type IL adoption slow until 2022?

1. Supply Chain Restraints (for Type IL)

- **Cement plants and terminals** also do not have silo capacity for holding a cement that is not being purchased by their customers.
  - To address this, In late 2021, several US cement plants switched over to only produce Type IL cements.
  - This forced the adoption of Type IL by concrete producers and specifiers.
  - As a result, **in 2022, Type IL grew to over 25% of total US cement produced.**

- Most **concrete plants** do not have **extra silos for adding additional cements** – so to use Type IL, they need to completely switch over from Type I/II cements.
  - But that meant that all of their customers, including DOTs have to allow Type IL cements.
  - By late 2021, Type IL had been accepted by almost all DOTs.

2. Reluctance of Specifiers

- Slow Adopters:
- Type IL cement was adopted by ASTM and AASHTO in 2012
- But some DOTs such as CalTrans did not accept Type IL until 9 years later (in late-2021) and only after commissioning a multi-year research study that showed it did no harm and offered benefits.
  - (Lack of industry trust and in the experience & research by others)

- For other new technologies needed to meet 2030 GWP reduction targets, we don't have 9 years left for such slow adoption by specifiers.

3. Push Back against Type IL by producers, contractors and trades

- In many states and regions, there have been no major concerns. Producers just made minor adjustments to their mixtures---similar to what they would do when they switch cement supplies, or other materials sources.

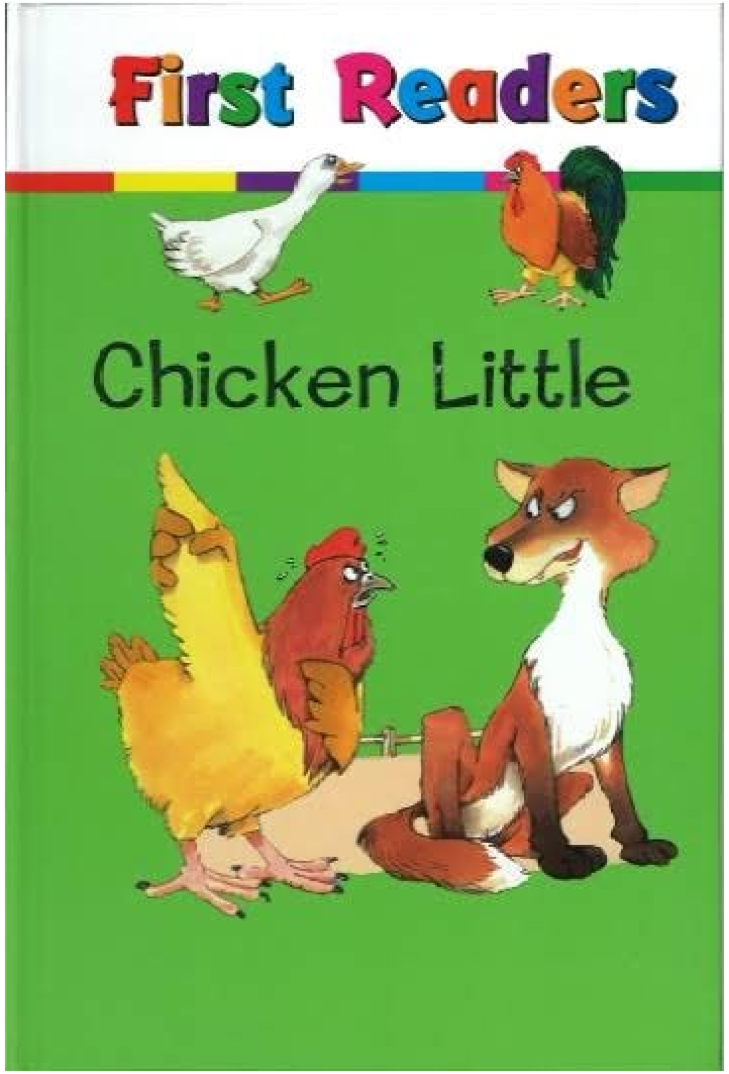
- But in some other regions, when Type IL was introduced, it was if the sky had fallen.---and this is a continuing saga.

3. Push Back against Type IL by producers, contractors and trades

- In many states and regions, there have been no major concerns. Producers just made minor adjustments to their mixtures---similar to what they would do when they switch cement supplies, or other materials sources.

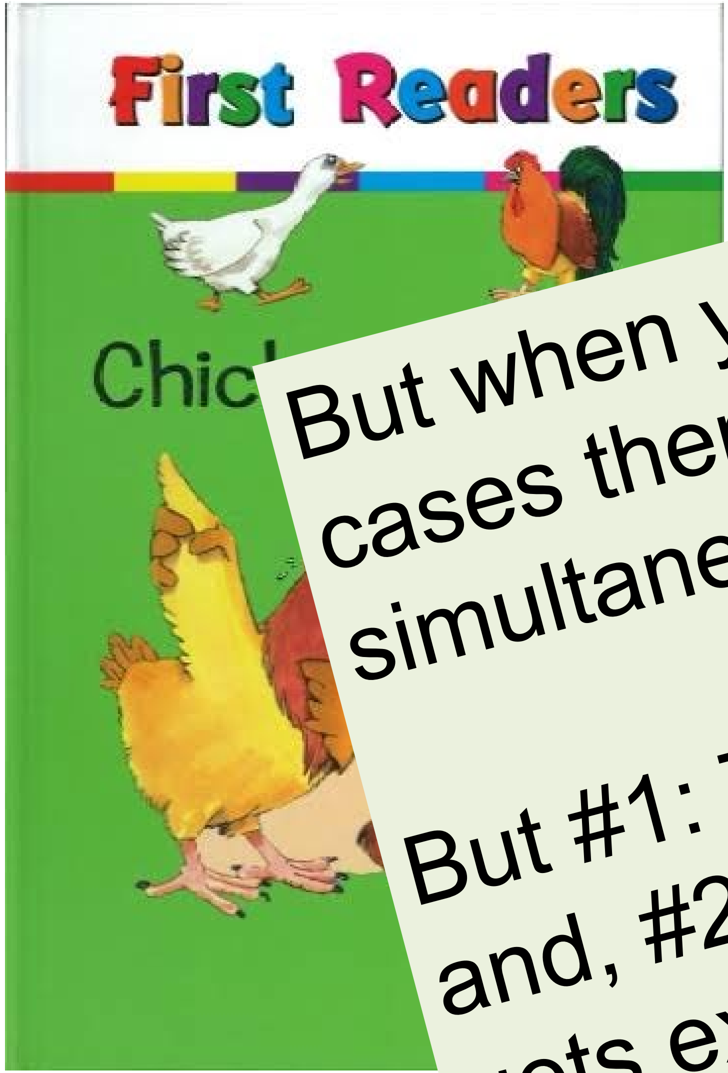
- But in some other regions, when Type IL was introduced, it was if the sky had fallen.---and this is a continuing saga.
- There maybe producer-specific problems, but
- Rule #1: The new material always gets blamed for any problem.

4. Some examples of claimed Type IL problems



1. **Strength loss on 28-day breaks** since switching to PLC cements. E.g. 1000 psi loss with a 5000psi mix
2. **More fluctuations with plastic air contents** than with Type I-II cement
3. **Having to increase the amount of PLC in our mixes** by at least 47 lbs./cubic yard in order to meet the specified strength required for our projects as compared to the same mix with Type I-II cement. (i.e. negating any GWP benefit)
4. **Slower set times with the new cement**. More obvious when used with fly ash.
5. **Increased shrinkage and cracking**.
6. One contractor claimed a 50% loss in strength !

4. Some examples of claimed Type IL problem…



1. Strength loss on 28 d… …ments.
   E.g. 1000 …

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…kage and cracking.

But when you start asking questions, in many cases there are other causes or simultaneous changes.

But #1: The new material always get blamed and, #2: Negative news travels fast and often gets exaggerated as it gets passed along.

So--- There are Lessons to be learned:

You only get one chance to make a first impression!

- When introducing any change,
- more customer support and communication could have been provided during the transition to Type IL, especially with the smaller independent producers.
  - e.g. helping with changes to admixture dosages and other minor mix adjustments

We need to recognize and overcome barriers to meet both 2030 & 2050 GWP reduction targets

- **The transition to Type IL cements should have been an easy change for adoption of more sustainable concrete**
  - but it has taken 11 years so far and is not yet complete.

- **If that relatively simple change can't be made within a short time frame, can 2030 reduction targets be met with other changes that may have bigger impacts on performance?**

- To accelerate adoption of different sustainable technologies, we need to better understand & address the barriers of all the players along the construction value chain.

1. Standards, Specifications and Codes?

- Standards and Codes are often seen as barriers to adoption of more sustainable concretes, but **many of the levers for improving sustainability are already allowed in Standards and Codes, but are not widely adopted in practice** either due to perceived risk (or supply chain issues).
- These underutilized existing levers include:
  - Portland-limestone cement
  - Sufficient levels of SCMs or use of blended cements.
  - Optimization of total aggregate gradations to reduce cement paste content



Specifications Are evolving

- In 2019, ASTM C1866 for Ground Glass Pozzolans was approved.
- In 2023, ASTM C618 will now allow land-filled coal ash to be harvested and processed for use as a pozzolan (potentially over a Billion tons to replace diminishing sources of fly ash as coal power plants close).
- ASTM is developing a performance specification for SCMs.
- The ASTM C1157 Performance Specification for Hydraulic Cement has existed since1992---but is rarely allowed by specifiers because apparently they don't trust performance.

Standards Challenges do exist for non-Portland Alternative Cements

- **Most cement standards are prescriptive** and only cover existing cement types.
- **ASTM C1157 is a performance-based specification, but it is rarely adopted** and its scope limited to hydraulic cements. (i.e. not for geopolymers or cements that set by carbonation)
- Without a national specification, novel and non-hydraulic ACMs cannot be included in building codes and will likely not be adopted by any state DOT.
- Non-hydraulic cements are not covered in ASTM C94 *Standard Specification for Ready-Mixed Concrete* & cant be tested using current test methods
- **ACI 318 does permit use of alternative cements** with the approval of the licensed design professional (LDP) and the code official with project jurisdiction

The International Code Council Evaluation Service (ICC-ES) has approved ***AC529 Acceptance Criteria for Low-Carbon Alternative Cements***. It provides an evaluation process to be followed by the LDP and code official to approve an alternative cement for use in code-governed construction.

Specification Barriers

Use of Outdated Specifications & adding Prescriptive requirements:

1. Some architectural, engineering design, and consulting companies cut and paste specifications from previous projects.—seen as easier and low risk
2. Some specifying authorities often add prescriptive limits on materials and mix designs, such as **prescriptive minimum cement contents and limiting max.% SCM.**

Adding prescriptive limits on materials and methods confuses Roles and Responsibilities in construction

Leads to in-place concrete that may not meet expected performance and results in less sustainable concrete being placed.

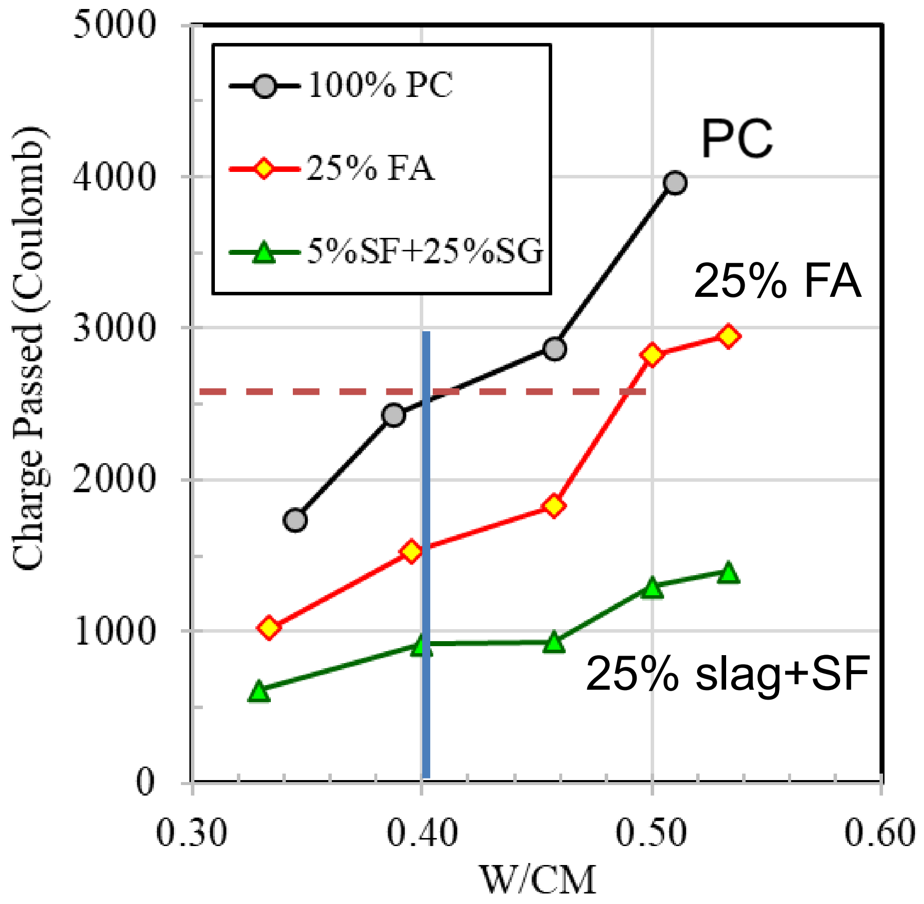
Prescription vs Performance in Codes

- Current prescriptive requirements in Codes, Specs and Standards make it difficult to adopt materials & mix proportions that can provide lower GWP concretes.

  For example:

  - **For durability exposures, ACI 318 only requires meeting max. w/cm limits and minimum 28-day *strength*.**
    - e.g **for C-2 Chloride exposure**: **0.40 w/cm and 5000 psi**
    - But **these requirements are not directly linked to durability**; i.e. resistance to ingress of aggressive chlorides.
    - These current requirements result in concretes with different levels of durability
    - 5000 psi is not needed for durability, but that the only property that can be measured.

Why w/cm limits in ACI 318 no longer provide concrete of equal durability (mainly influenced by permeability)



M. Thomas

1. w/cm limits do not consider the impact of SCMs on permeability

2. The permeability benefits of some SCMs are not attained at 28 days. Later-age limits are more appropriate
3. A SCM mixture at 0.5 w/cm may provide equivalent durability to a 0.4 w/c portland mixture.

2. Risk-Related Barriers:

- Risk can be broadly organized into two categories:
  1. **Life safety is not negotiable** and is a primary focus of a building code.

     & many novel materials have not been tested for structural properties.

  1. **Economic risk is more nuanced** and affects both those contracted to provide concrete products (e.g., producers & contractors) and those that ultimately are the owners of the structure.

Economic Risks Vary

- **Suppliers and contractors experience economic risk** when changes occur that lead to lost profitability, by negatively impacting productivity, or the ability to achieve full payment for their work.
  - There may need to be incentives in contracts to meet GWP reduction targets
- **Owners experience economic risk** from loss in functionality, increased maintenance, or reduced service life if the changes result in poorer material performance.
- **Adoption of new concrete technologies requires sharing risk.**
- A non-equitable distribution of perceived risk can result in overdesign and may derail the implementation of a new technology.

Action Plan: Provide Tech Transfer to Industry

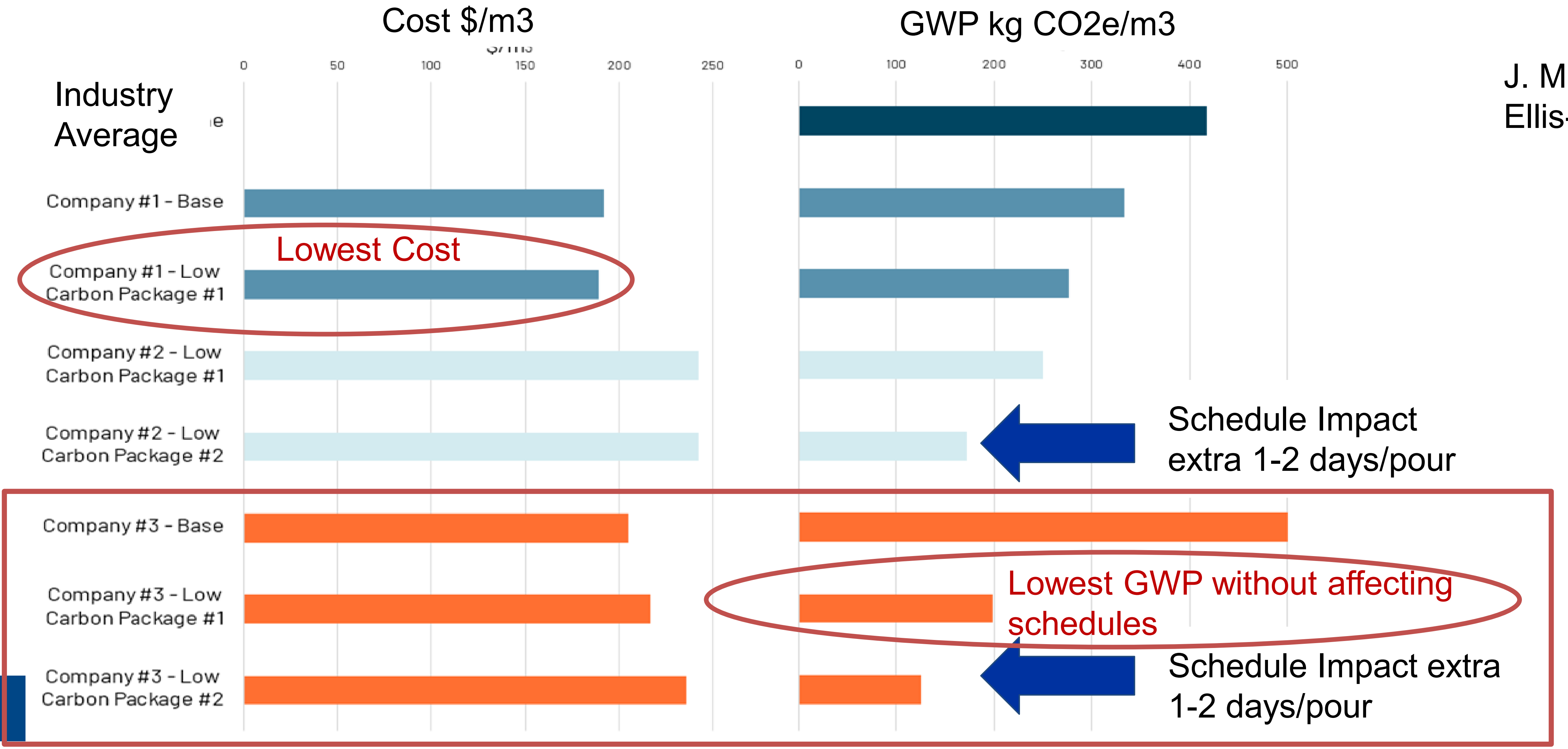
- To move forward on carbon reduction, **all stakeholders need to be engaged in the process.**
- Not knowing why changes are being made, ultimately leads to resistance.
- Engineers, designers, contractors, and trades people need specific technical training to effectively implement carbon-reduction strategies.
- **Licensed design professionals** need to implement new technologies in designs in ways that allow trades people to perform the construction.
- Technology transfer and skills training are imperative for success, and to avoid failure.
- **Nothing sets back innovation faster than a failure.**

Action Plan: Inform Design Professionals & Specifiers

- Many design professionals currently in positions of authority are not materials experts, nor are they always focused on methods for adoption of sustainable technologies.
- Need educational programs to make professionals aware of options and to inform on both the benefits and potential concerns with different sustainable technologies (including any impacts on scheduling).
- **Need to provide designers with practical tools** for specifying sustainability targets, for assessing responsive bids, and for monitoring construction.
- Need more industry tech support to reduce the risk for early adopters.

Owners/Specifiers need to consider schedule and cost impacts of low-carbon alternative concrete supply bids

(Contractor valuation of 3 concrete producer alternative submittals)



J. McLaughlin, Ellis-Don

Action Plan: Provide support to contractors & trades on impacts of change

- **Provide Contractors with sufficient information** to successfully bid and complete a project with sustainability requirements
- **Inform/educate and familiarize contractors and their construction work forces**, who are often hesitant toward trying new products.
- **Communication:** Impacts of new technologies maybe "small" but may require changes to traditional practices,

  Examples:

  - When **Self-consolidating concrete** was introduced, formwork design needed to be changed and heights of lifts were limited to prevent blowouts.
  - When **silica fume** was introduced, the lack of bleed water resulted in finishing and plastic shrinkage cracking problems---fog misting or evaporation retarders was needed.
  - Finishing Times for concrete with **high SCM levels** will be more sensitive to concrete temperature and may also require longer curing periods.

Action Plan: **Provide Workforce Education**

- There is an immediate need to work with organizations and associations that serve both tradespeople and professionals working in the concrete industry, to **provide training on carbon reduction strategies**.
- **ACI and other industry organizations could develop such courses.**
- Training sessions should be developed for individual workers but also to train key company and agency personnel who can then transfer that knowledge within their organization.

- This will come at a cost, and that needs to be included in the costs of implementing new technologies.

Action Plan: **Inform Policy Makers-1**

- There is significant activity on the policy side of the carbon issue and policies to create demand for low carbon technologies are needed.

- However, some policies are made in a technical vacuum as policy makers often do not have sufficient knowledge of the cement & concrete industry supply chain and infrastructure.

  e.g.There are many types of concrete used on a project, so a GWP budget need to be set for the project and not on specific concrete mixtures---to enable constructability

- Those making polices and laws, and approving public funding for carbon reduction initiatives, invariably do so not understanding the complexity of the problem.

  i.e. the cement & Concrete construction industry can not change overnight (Capex and time issues) or to only meet one segment of the market

  The level of technical knowledge varies widely across the concrete supply industry

Action Plan: Inform Policy Makers-2

- There is a need to provide technical information, delivered at the appropriate technical level, to educate policy makers so that laws and regulations are developed that are practical and implementable.

- Passing rules/legislation that cannot be technically achieved only serves to build resistance within the user community and hinders progress.
- **There is need to realise that when adopting new technologies, the "green premium" is not just materials costs, it includes costs associated with:**
  - **Capex for materials suppliers**
  - **Increased contractor bids due to perceived risk (initially)**
  - **Contractor work force training,**
  - **Additional QA/QC testing needed to monitor performance**

Novel Low-carbon materials must be able to be used with the existing construction infrastructure

1) Using the existing materials production and logistics infrastructure,

2) Fitting with how the industry designs concrete structures, and specifies & tests concrete.

3) Overcoming the risks of adopting new technologies in a risk adverse industry.

Given the massive capital investment required to change the existing infrastructure, advancements in carbon reduction must be made within this infrastructure.




Action Plan: Address Risk in Demonstration Projects

- In the construction industry, **the risk of adopting a new technology is the single largest barrier** other than cost (i.e., the green premium).
- Even if a technology comes at no increased cost, **few are willing to be a first adopter.**
- **To address risk, it is necessary to conduct demonstration projects** where innovative materials or technologies are put into practice under real-world conditions that is underwritten by a third party or taken on by an owner knowing that a risk of failure exists.
- Demonstration projects can show if a new technology can be successfully mixed, transported and placed in the field.
- Such projects need to be those that pose no risk of life safety if failure occurs.
  - The City of Portland has conducted Demo projects for low-carbon concretes in several applications

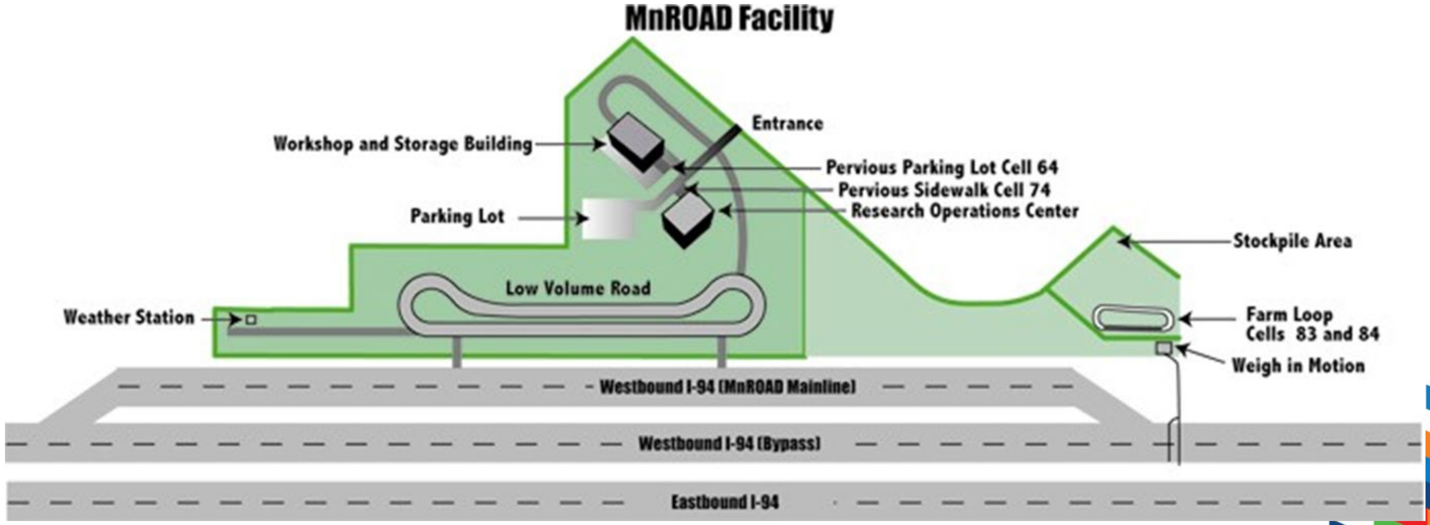
Demonstration Projects Are An Essential Step In Implementation

- Collaboration between materials suppliers, contractors, and owners
  - Risk is recognized and shared
- Technical assistance provided before, during, and after construction
  - Performance is monitored
- Broad dissemination of results to build confidence in the industry
  - Pathway to move from innovation to specification

The success and failure of several new technologies were demonstrated in the 2022 MnROAD tests---2 successes were Type IL(20) and ~~LC3~~ IP(30)

Demonstrating Innovation in Transportation Infrastructure

- State highway agencies have a long history of conducting research and demonstration projects
  - AASHO Road Test (1958-1960), Long-Term Pavement Performance Project (1987-present), MnROAD (1990-present)
- Pavements are a suitable place to demonstrate innovation
  - Greater tolerance for failure
  - Geometry is simple
  - behavior understood



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Action Plan Impact: Look to high-cement use applications

- **70 - 75% of portland and blended cement use in the United States is in ready mixed concrete.**
- Approximately 54% of portland cement is used in the building construction sector and 43% towards the public works sector.
- **The four largest uses are in:**
  - **residential buildings (~39%),**
  - **streets and highways (~29%),**
  - commercial and public buildings (~9%),
  - water and wastewater management (~9%).
- Both residential construction or public works represent similar high volumes of cement use and therefore similar opportunities for carbon reduction.---but Building Codes may limit the first option.

Action Plan: 2. Focus Initially on low barrier applications

- **Adoption of carbon-reducing technologies in the building sector will be slower** due to need for specific design information to meet Building Code requirements.
- Implementation in pavements and municipal applications do not have the restrictions imposed by Building Codes.
  - e.g., exterior parking, sidewalks, curb and gutter where life-safety is not a primary factor.
- Public sector changes can be approached on a push-pull basis from both the technology/engineering side and the policy/legislation side.
- Requirements for public works projects are the lowest common denominator for concrete producers but are often dictated/influenced by state DOT specifications.

Summary

1. While portland-based cements will continue to be used for most concrete applications, to meet 2030 GWP reduction targets, concrete's carbon footprint can be significantly reduced by adopting the materials & tools we have today.
   – But adoption rates have to be accelerated.

2. When adopting any new technology, barriers due to perceived risk all along the construction value chain need to be addressed.
3. **Education** of all parties along that value chain **is essential** for adoption of a new technology by the risk-adverse construction community.
4. Potential impacts of changes on construction activities schedules also need to be considered.
5. Real-world **demonstration projects** will show whether novel materials can be used with current construction infrastructure and processes.

Thank you for letting me interrupt your lunch