DENVER AMENDMENT PROPOSAL FORM
FOR PROPOSALS TO THE 2019 DENVER BUILDING CODE AMENDMENTS AND THE 2021 INTERNATIONAL CODES

2021 CODE DEVELOPMENT CYCLE

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2) One proposal per this document is to be provided with clear and concise information.

Is a separate graphic file provided ("X" to answer): ___ Yes or _X_ No

3) Highlight the code and acronym that applies to the proposal

Acronym	Code Name	Acronym	Code Name
DBC-AP	Denver Building Code–Administrative Provisions	**IPC**	International Plumbing Code
IBC	International Building Code	**IRC**	International Residential Code
IECC	International Energy Conservation Code	**IFGC**	International Fuel Gas Code
IEBC	International Existing Building Code	**IMC**	International Mechanical Code
IFC	International Fire Code	**DGC**	Denver Green Code

AMENDMENT PROPOSAL

Please provide all the following items in your amendment proposal.

Code Sections/Tables/Figures Proposed for Revision:
Instructions: If the proposal is for a new section, indicate (new), otherwise enter applicable code section.

Proposal:
Instructions: Show the proposal using ~~strikeout~~, underline format.
Place an "X" next to the choice that best defines your proposal: __ Revision _X_ New Text __ Delete/Substitute __ Deletion

Add new definitions as follows:

carbon dioxide equivalent (CO2e): A measure used to compare the impact of various greenhouse gases based on their global warming potential (GWP). CO2e approximates the time-integrated warming effect of a unit mass of a given greenhouse gas relative to that of carbon dioxide (CO2). GWP is an index for estimating the relative global warming contribution of atmospheric emissions of 1 kg of a particular greenhouse gas compared to emissions of 1 kg of CO2. The following GWP values are used based on a 100-year time horizon: 1 for CO2, 25 for methane (CH4), and 298 for nitrous oxide (N2O).

concrete: mixture of cementitious material, fine aggregate, coarse aggregate and water, with or without admixtures

concrete, lightweight: concrete containing lightweight aggregate and having an equilibrium density, determined by ASTM C567

Environmental Product Declaration (EPD): independent third-party multi-attribute product declaration or certification containing documentation consistent with ISO Standards 14025 and 21930, with at least cradle-to-gate scope.

Add new section as follows:

1903.4 Embodied CO2e of concrete materials. Projects shall comply with either Section 1903.4.1 or 1903.4.2

Exception: Precast concrete and concrete masonry units are not required to comply with this section.

1903.4.1 CO2e Mixture Limit. The total CO2e of the concrete mixes used in the project shall not exceed the value given in Table 1903.4 based on the compressive strength of the product. CO2e content shall be documented by a product-specific Type III Environmental Product Declaration (EPD) for each product. Type III EPDs shall be certified as complying with the goal and scope for the cradle-to-gate requirements in accordance with ISO Standards 14025 and 21930 and be available in a publicly accessible database.

Exception: Projects where no concrete suppliers with product-specific EPDs for concrete are located within 100 miles of the project site, anduse Type III industry-wide EPDs for compliance with this section and provide an inventory of CO2e values for all concrete mixes to the AHJ.

Table 1903.4[a]
CO2e Limits in Mixture

Minimum specified compressive strength f', psi	Maximum kg/m3 (SI)	High-early strength Maximum kg/m3 (SI)	Lightweight concrete Maximum kg/m3 (SI)
up to 2499	324	421	578
2500-3499	397	516	578
3500-4499	449	584	626
4500-5499	494	642	675
5500-6499	523	680	N/A
6500 and greater	539	679	N/A

a. Values in this table represent limits for concrete produced in the United States and are based on the 75th percentile of EPDs collected by Building Transparency as of April, 2021. They may or may not pertain to concrete production in other countries, and therefore Co2e, is always based on the unique availability in any location at any particular time of aggregate, cement, supplements, admixtures and other factors.

1903.4.2 CO2e Project Total Limit. Project Total CO2e ($CO2e_{proj}$) of all concrete placed at the building project shall not exceed the project limit ($CO2e_{allowed}$) determined using Table 1903.4 and Equation 1903.4.2

Equation 1903.4.2

$$CO2e_{proj} < CO2E_{allowed}$$

where

$$CO2E_{proj} = \sum CO2E_n v_n \quad \text{and} \quad CO2E_{allowed} = \sum CO2E_{lim} v_n$$

and

n = the total number of concrete mixtures for the project
$CO2E_n$ = the global warming potential for mixture n per mixture EPD, kg/m^3
$CO2E_{lim}$ = the global warming potential limit for mixture n per Table 1903.4, kg/m^3
v_n = the volume of mixture n concrete to be placed

Supporting Information (Required):
All proposals must include a written explanation and justification as to how they address physical, environmental, and/or customary characteristics that are specific to the City and County of Denver. The following questions must be answered for a proposal to be considered.

Purpose: What does your proposal achieve?

The purpose of this proposal is to reduce the embodied carbon impact of new building construction by applying carbon dioxide equivalent (CO2e) limits for the concrete products specified in the project.

Reason: Why is your proposal necessary?
Building operations and building construction are responsible for 39% of today's global carbon emissions.[1] About 11% of these emissions are embodied carbon emissions, the emissions associated with building materials and construction activities.[1]

Over the next 5 years, projections show Denver will construct about 54 million ft^2 of new buildings.[2] Denver's Climate Action Plan has set specific goals for reducing building energy use, including a 50% reduction in commercial building energy use by year 2050. As the operational efficiency of Denver's buildings increases, embodied carbon is becoming an ever more significant source of emissions. Unlike operational emissions, which can be improved over the lifespan of a building through deep-energy retrofits and the decarbonization of the electric grid, the majority of embodied carbon emissions occur before a building is occupied and cannot be reduced over time. Therefore, addressing embodied carbon in the construction of buildings presents an urgent and valuable opportunity to reduce carbon emissions in Denver.

Commercial & Multifamily Buildings	5-Year Increase (sqft)
Apartments & Condos	19,300,199
Office and Bank	6,716,497
Warehouses	1,725,054
Hotels	1,638,085
Schools	1,289,142
Misc. Non-Res	1,200,500
Hospitals	1,158,273
Stores/Restaurants	1,106,037
Source: Dodge Data and Analytics – Denver City and County New Construction Projections	

Homes	5-Year Increase (sqft)
One Family Houses	18,876,629
Two Family Houses	859,211
Source: Dodge Data and Analytics – Denver City and County New Construction Projections	

Denver's Net Zero Energy New Buildings & Homes Implementation Plan, Page 21

Concrete is one of the most widely used materials in building construction and a primary contributor to embodied carbon in buildings. A recent case study analysis by RMI shows that simply by specifying concrete products with lower CO2e content, the embodied carbon of a commercial construction project can be reduced up to 33%.[3]

To build a building, construction professionals buy concrete (which contains cement used with water as a binder to adhere particles of sand and rock, known as aggregate) from a ready-mix supplier. Although each of concrete's constituent materials offer opportunities for reductions in embodied carbon, the high EC of concrete is primarily driven by the manufacture of one key ingredient—ordinary Portland cement. Portland cement is the most common cementitious binder used in concrete mixtures in the United States, and the US cement industry is one of the largest contributors to US-borne emissions at 68.3 million metric tons (MMT) of CO2 eq. per year.[4] The building construction industry's demand for concrete accounts for an estimated 51% of total Portland cement produced in the United States.[5]

Denver can drive significant embodied carbon reductions by implementing regulations that address the reduction of CO2e in concrete used in building construction. Including embodied carbon considerations in building code will not only decrease the carbon impact of Denver's building construction industry, but it will also support local economic development towards low carbon business models.

Substantiation: Why is your proposal valid? (i.e., technical justification)

Concrete is one of the most widely used materials in the construction of new buildings; concrete products also have the largest availability of Environmental Product Declarations (EPDs) which disclose the impacts of materials including the material's carbon dioxide equivalent (CO2e) as represented as global warming potential (GWP). GWP is the most common metric for measuring and evaluating materials' greenhouse gas emissions over a product or building's lifecycle, also called embodied carbon. Third-party rating systems like LEED, and procurements policies like the U.S. General Services Administration's (GSA) Recommendations for Procurement of Low Embodied Carbon Materials, have put demand on building product manufacturers to disclose the environmental impacts of their products, but steel manufacturers have been slow to respond to these demands.[6]

Data availability and environmental impact combine to make concrete a good candidate for building code requirements. By using the existing data from EPDs, limits can be applied in the code to lower the embodied carbon in construction projects through straightforward, material-specific requirements.

The material approach has been proposed here instead of a whole building approach. While a whole building, lifecycle embodied carbon analysis (WBLCA) that would incentivize the use of lower embodied carbon materials over higher embodied carbon materials is necessary in the long term to address all materials, the comprehensive material and product data, calculation tools and market expertise necessary to implement LCAs in code are not yet sufficiently available to support a code requirement. Therefore, a materials-based policy offers the best, market-ready option to achieve meaningful embodied carbon savings in Denver today.

NBI collected 36,601 US-based ready mix concrete environmental product declaration (EPD) data from Embodied Carbon in Construction Calculator (EC3) tool database to evaluate the ready-mix concrete's carbon dioxide equivalent (CO2e) as represented as global warming potential (GWP). GWP is the most common metric for measuring and evaluating materials' greenhouse gas emissions over a product or building's lifecycle, also called embodied carbon.

The data represents mixes in 23 states with 455 EPDs from Colorado concrete suppliers. The data was separated into seven strength categories: up to 2,500, 3,000, 4,000, 5,000, 6,000, 7,000, and 7,000+. The EPD data evaluated does not address lightweight concrete. Each category represents the compressive strength of concrete, represented as pounds per square inch (psi). A higher psi represents a stronger concrete.

The GWP of the strength was evaluated to determine the percentiles at: 90%, 80%, 75%, 50%, 25%, and 20%. The same analysis was applied nationally as well as to the Colorado-specific data.

Table 2: Concrete EPD Count per Strength

Strength Category	Number of National EPDs	Number of Colorado EPDs
Up to 2499	992	2
2500-3499	6,364	30
3500-4499	12,752	125
4500-5499	10,357	233
5500-6499	3,606	28
6500+	1,331	36
Total:	***35,402***	***454***

The EPDs are not equally distributed across all concrete strength categories. The 4,000 and 5,000 psi categories hold the most EPDs. Of the Colorado data, five of the seven strength categories do not provide data sufficient to set GWP limits. NBI recommends using the national values over state-specific data.

The 80% percentile GWP values are recommended for the base code. Using the GWP limits at the 80% percentile, the national EDP data is higher, or more conservative, than the Colorado data. Comparing this data to the National Ready Mix Concrete Association (NRMCA) industry average GWP, the proposed GWP are higher, allowing more products to comply.

The national GWP at the 80% percentile is also higher than Marin County's concrete code GWP limits, the only other concrete GWP limit in code. In Marin, regional data was collected to set the ready mix GWP,

understanding that Northern California's concrete is generally of higher quality than the national average, which allows for lower cement in the standard mixes. As the City collects project-level ready mix concrete EPDs, the data can be analyzed based on regional information and adjust the GWP limits for the next code.

The following tables highlight the suggested GWP limit for each concrete strength category.

Table 3: GWP Limits and Number of EPDs Evaluated/Complying for up to 2499 psi strength concrete

Percentile	National GWP (CO2e)	Colorado GWP (CO2e)	Marin County GWP (CO2e)
90% Percentile	358	86	
80% Percentile	324	80	260
75% Percentile	302	77	
50% Percentile	222	63	
25% Percentile	127	49	
20% Percentile	102	47	
Total EPD Count:	**992**	**2**	
EPDs that meet the 80% percentile:	**791**	**1**	

Table 4: GWP Limits and Number of EPDs Evaluated/Complying for 2500-3499 psi strength concrete

Percentile	National GWP (CO2e)	Colorado GWP (CO2e)	Marin County GWP (CO2e)
90% Percentile	439	338	
80% Percentile	397	334	289
75% Percentile	382	328	
50% Percentile	336	303	
25% Percentile	290	239	
20% Percentile	279	291	
Total EPD Count:	**6,364**	**30**	
EPD count within 80% percentile:	**5,071**	**24**	

Table 5: GWP Limits and Number of EPDs Evaluated/Complying for 3500-4499 psi strength concrete

Percentile	National GWP (CO2e)	Colorado GWP (CO2e)	Marin County GWP (CO2e)
90% Percentile	484	451	
80% Percentile	449	401	313
75% Percentile	432	395	
50% Percentile	376	352	
25% Percentile	322	333	
20% Percentile	311	329	
Total EPD Count:	**12,752**	**126**	
EPD count within 80% percentile:	**10,188**	**100**	

Table 6: GWP Limits and Number of EPDs Evaluated/Complying for 4500-5499 psi strength concrete

Percentile	National GWP (CO2e)	Colorado GWP (CO2e)	Marin County GWP (CO2e)
90% Percentile	528	473	
80% Percentile	494	457	338
75% Percentile	481	434	
50% Percentile	409	386	
25% Percentile	354	370	
20% Percentile	340	366	
Total EPD Count:	**10,357**	**233**	
EPD count within 80% percentile:	**8,284**	**185**	

Table 7: GWP Limits and Number of EPDs Evaluated/Complying for 5500-6499 psi strength concrete

Percentile	National GWP (CO2e)	Colorado GWP (CO2e)	Marin County GWP (CO2e)
90% Percentile	568	473	
80% Percentile	523	469	356
75% Percentile	505	461	
50% Percentile	433	393	
25% Percentile	371	388	
20% Percentile	353	386	
Total EPD Count:	**3,609**	**28**	
EPD count within 80% percentile:	**2,884**	**22**	

Table 8: GWP Limits and Number of EPDs Evaluated/Complying for Concrete with 6500+ psi Strength

Percentile	National GWP (CO2e)	Colorado GWP (CO2e)	Marin County GWP (CO2e)
90% Percentile	561	484	
80% Percentile	522	456	394
75% Percentile	504	451	
50% Percentile	426	435	
25% Percentile	366	422	
20% Percentile	352	417	
Total EPD Count:	**1,331**	**36**	
EPD count within 80% percentile:	**1,063**	**28**	

The proposed provisions are located in section 1903 (Specifications for Testing and Materials) since they set new requirements for concrete specifications. The provision is set up to provide a 30% additional CO2e allowance for early high-strength concrete that may have difficulty meeting the requirements.

Bibliography and Access to Materials (as needed when substantiating material is associated with the amendment proposal):

[1] Bringing Embodied Carbon Upfront: Coordinated Action for the Building and Construction Sector to Tackle Embodied Carbon, World Green Building Council, 2019, https://www.worldgbc.org/sites/default/files/WorldGBC_Bringing_Embodied_Carbon_Upfront.pdf

[2] *Denver's Net Zero Energy New Buildings & Homes Implementation Plan*, January 2021, Page 21, https://denvergov.org/files/assets/public/climate-action/documents/denver-nze-implementation-plan_final_v1.pdf

[3] Matt Jungclaus, Rebecca Esau, Victor Olgyay, and Audrey Rempher, *Low-Cost, High-Value Opportunities to Reduce Embodied Carbon in Buildings*, RMI, forthcoming 2021.

[4] *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2018*, US Environmental Protection Agency, 2020, https://www.epa.gov/sites/production/files/2020-04/documents/us-ghg-inventory-2020-main-text.pdf; and "Manufacturing Energy and Carbon Footprint," US Department of Energy, https://www.energy.gov/sites/prod/files/2018/10/f56/2014_mecs_cement_energy_footprint.pdf.

[5] *2019 U.S. Cement Industry Annual Yearbook*, Portland Cement Association, 2019, https://www.cement.org/morereports/2018-us-cement-industry-annual-yearbook.

[6] *GSA Green Building Advisory Committee Advice Letter: Policy Recommendations for Procurement of Low Embodied Energy and Carbon Materials by Federal Agencies*, U.S. General Services Administration, February 17 2021, https://www.gsa.gov/governmentwide-initiatives/federal-highperformance-green-buildings/policy/green-building-advisory-committee/advice-letters-and-resolutions

Other Regulations Proposed to be Affected

***For proposals to delete content from the 2019 Denver Green Code in conjunction with adding it to other mandatory Denver codes and/or regulations, only.**

Please identify which other mandatory codes or regulations are suggested to be updated (if any) to accept relocated content.

N/A

Referenced Standards:

List any new referenced standards that are proposed to be referenced in the code.

ISO Standards 14025 and 21930

Impact:

How will this proposal impact cost and restrictiveness of code? ("X" answer for each item below)

Cost of construction:	___ Increase	___ Decrease	_X_ No Impact
Cost of design:	___ Increase	___ Decrease	_X_ No Impact
Restrictiveness:	_X_ Increase	___ Decrease	___ No Impact

Departmental Impact (City use only):

This amendment proposal increases/decreases/is neutral to the cost of plans review.
This amendment increases/decreases/is neutral to the cost of inspections.