# Dry-Cast Low Carbon Concrete Masonry Units

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Technical Services
Jandris Block

THE MASONRY SOCIETY

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## AGENDA

- **Similarities and differences between dry-cast and wet-cast concrete**
- **Terms**
  - Difference between embodied carbon and operational carbon
  - Difference between carbon sequestration and carbon storage

**The Carbon Cycle**
  - The geologic carbon cycle
  - The concrete carbon cycle
  - What is Carbon Sequestration
  - Why the difference between wet-cast and dry-cast affects carbon sequestration

**Mini LCA wall comparison studies**
  - CMU
  - ICF
  - Tilt-up
  - Wood stud
  - Steel stud

**Other ways to reduce embodied carbon**
  - Plant operations & raw material choices
  - Reducing material use & efficient structural design
  - Durability and resiliency
  - Utilizing thermal mass
  - End of life (EOL)

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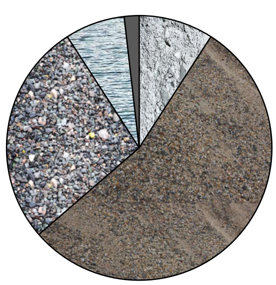
## SIMILARITIES

Raw materials essentially the same but:

- Different proportions
- Different gradations
- Different admixtures



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## DIFFERENCES

**Dry-cast (zero slump) concrete products**

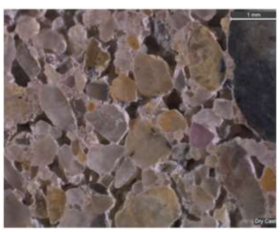

**Wet-cast concrete**



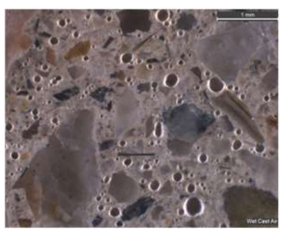


## DIFFERENCES

- Dry-cast structure



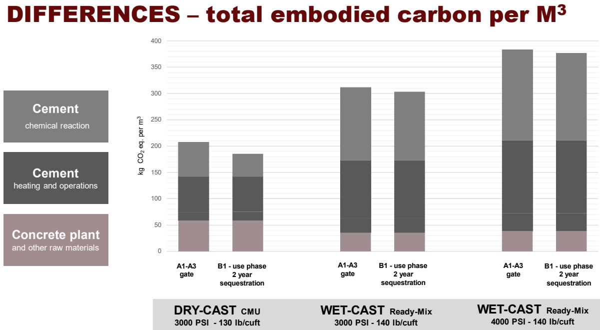
- Wet-cast structure



Photos courtesy of ACM Chemistries



## DIFFERENCES – total embodied carbon per M$^3$



## EMBODIED vs. OPERATIONAL CARBON


- Raw materials
- Manufacturing
- Transportation
- Construction

- Electrical loads
- Heating loads
- Cooling loads

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## CARBON STORAGE

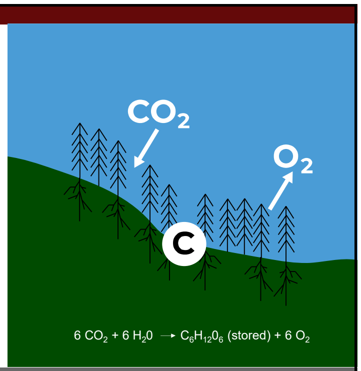
Carbon derived from a biological process

**Also knows as:**

Biogenic Carbon

**It is Impermanent**

When the material decomposes or is incinerated at the end of life, any stored $CO_2$ is released

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## CARBON STORAGE IS IMPERMANENT



| | |
|---|---|
| Recycled | 17% |
| Combustion | 16% |
| Landfilled | 67% |

https://www.epa.gov/facts-and-figures-about-materials-waste-and-recycling/wood-material-specific-data

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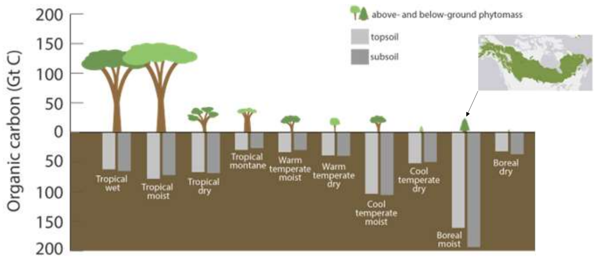
## CARBON STORAGE




https://www.fs.usda.gov/ccrc/topics/global-carbon

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## CARBON SEQUESTRATION

$CO_2$ converted to $CaCO_3$ (limestone) within concrete

**Also known as:**

- Carbon uptake
- Carbonation
- Limestone mineralization

**Permanent**

$CO_2$ will not be released unless exposed to temperatures above 1200 º F


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- ICF
- Tilt-up
- Wood stud
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**Other ways to reduce embodied carbon**

- Plant operations & raw material choices
- Reducing material use & efficient structural design
- Durability and resiliency
- Utilizing thermal mass
- End of life (EOL)

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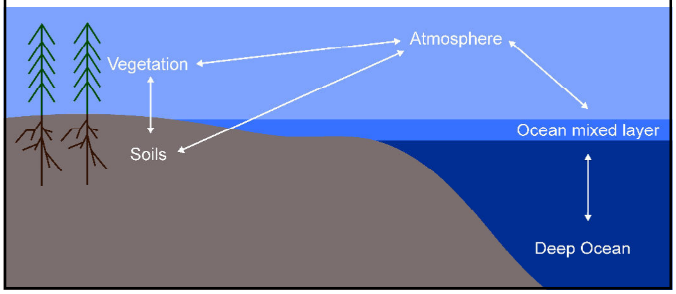
## THE EARTH'S MAJOR CARBON EXCHANGES

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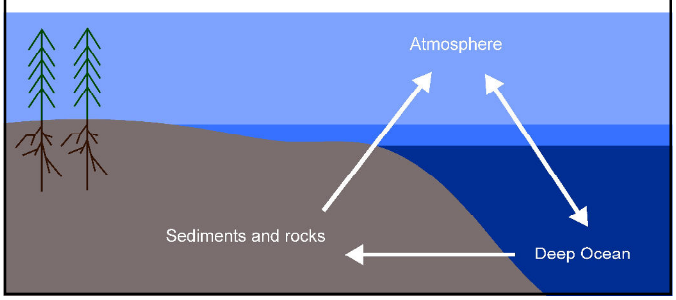
## THE EARTH'S MAJOR CARBON EXCHANGES

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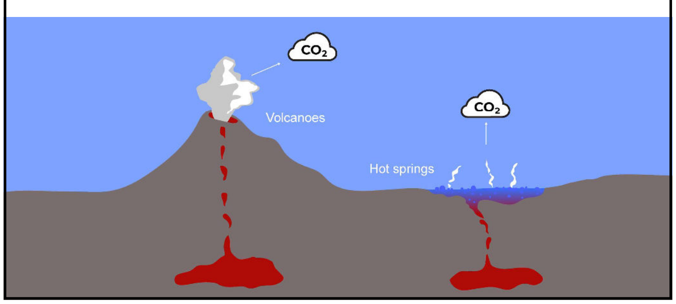
## $CO_2$ ENTERING THE ATMOSPHERE

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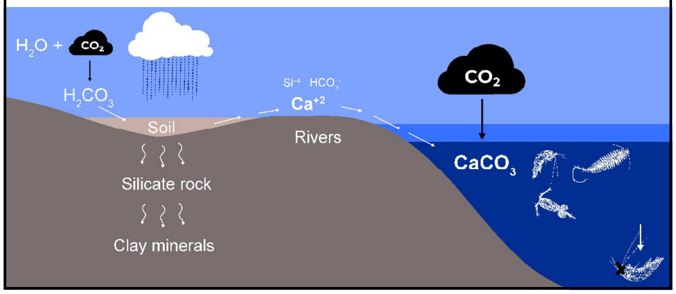
## $CO_2$ LEAVING THE ATMOSPHERE

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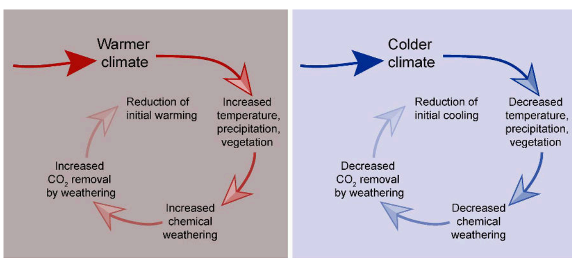
## CHEMICAL WEATHERING

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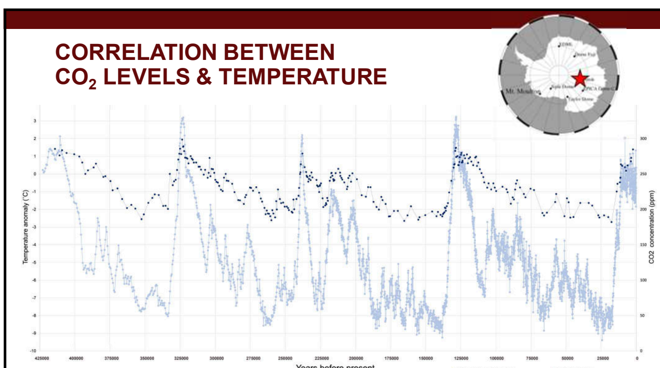
## CORRELATION BETWEEN $CO_2$ LEVELS & TEMPERATURE

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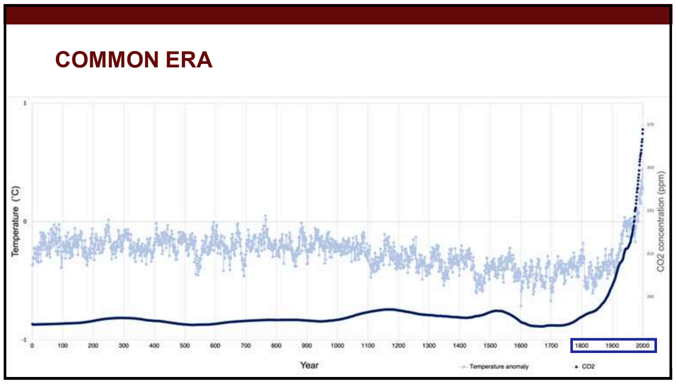
COMMON ERA
Temperature (°C)
CO2 concentration (ppm)
Year
Temperature anomaly
CO2

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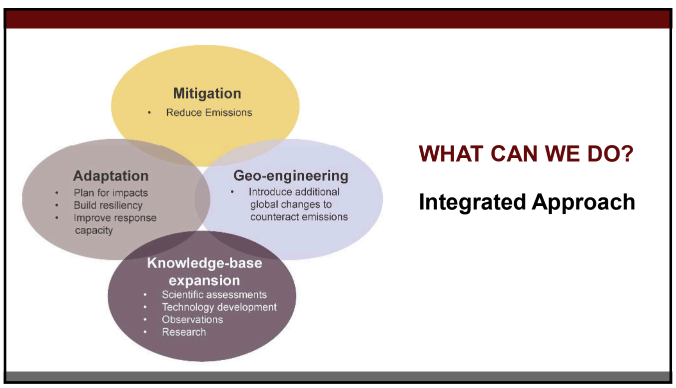
Mitigation
Reduce Emissions
Adaptation
Plan for impacts
Build resiliency
Improve response capacity
Geo-engineering
Introduce additional global changes to counteract emissions
Knowledge-base expansion
Scientific assessments
Technology development
Observations
Research
WHAT CAN WE DO?
Integrated Approach

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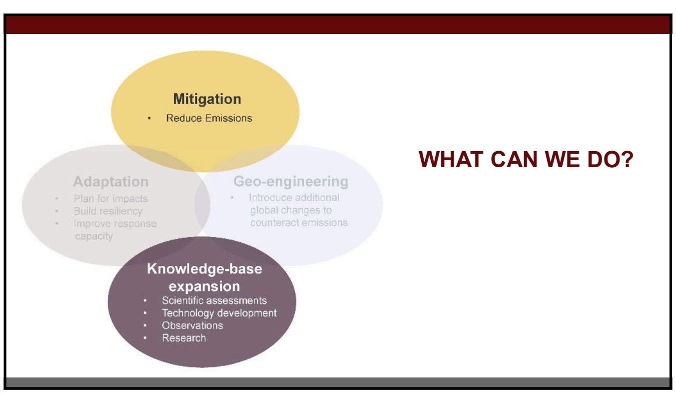
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WHAT CAN WE DO?

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## THE CONCRETE CARBON CYCLE

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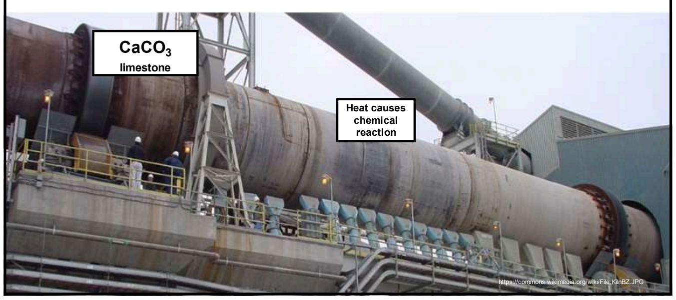
## CEMENT PRODUCTION

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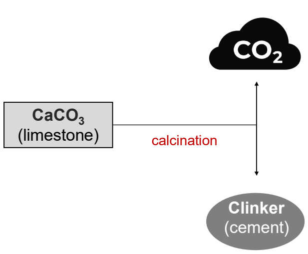
## CEMENT PRODUCTION RELEASES $CO_2$

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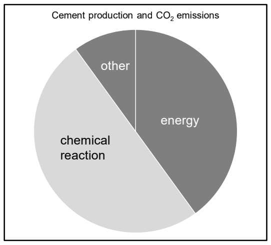
## $CO_2$ EMISSIONS OF CEMENT PRODUCTION




**Rough Estimation**

≈ 50% due to chemical reaction
≈ 40% due to energy required
≈ 10% other cement plant processes

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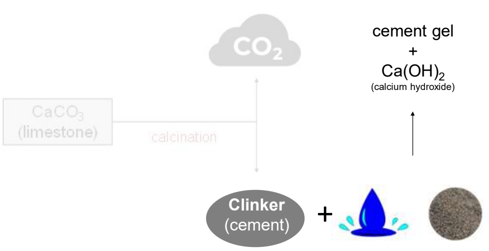
## CONCRETE HYDRATION ABSORBS $CO_2$

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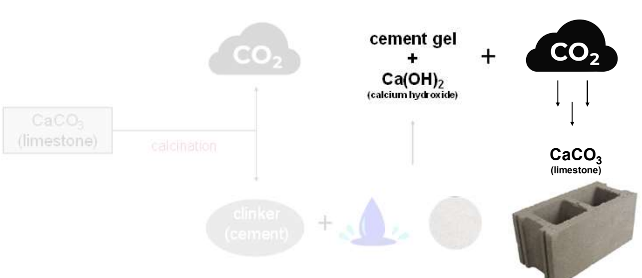


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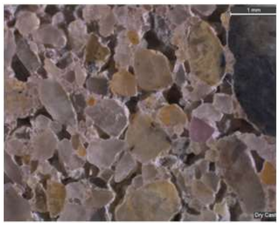
## CONCRETE STRUCTURE
**Determines how fast sequestration occurs**

Dry-cast structure



Wet-cast structure

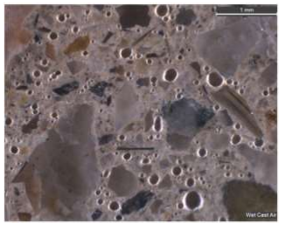


Photo courtesy of ACM Chemistries

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## WET-CAST Carbon Sequestration

Sequesters at the outer few mm


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## DRY-CAST Carbon Sequestration
***RESEARCH UNDERWAY***

**Sequesters faster and deeper into the concrete**

- CMU were collected from across the US and Canada and allowed to naturally carbonate
- TGA was performed periodically to measure carbon uptake

Set 6 4 Week | Set 6 13 Week | Set 6 26 Week

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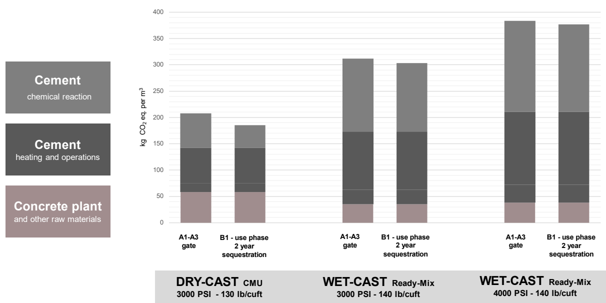
## DIFFERENCES – total embodied carbon per M3

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## 3 reasons why block is low embodied carbon

**Dry-Cast Concrete Products**

- Less cement
- More sequestration


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## 3 reasons why block is low embodied carbon

**Dry-Cast Concrete Products**

- Less cement
- More sequestration
- **Less volume of concrete in a wall assembly**


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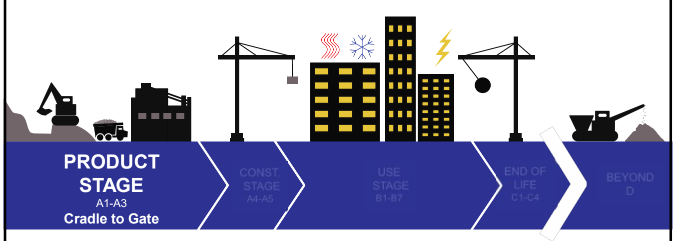
## LIFE CYCLE STAGES

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## MINI LCA

### Functional Unit
- 10' x 10' section of wall

### Major Assumptions
- A1 – A3 (Cradle to gate)
- Global Warming Potential (GWP) only
- GWP taken from industry average EPD where available, or specific product EPDs
- Mortar GWP estimates from raw material component EPDs
- All concrete is normal weight, with no SCM
- Does not include openings, fasteners, joint reinforcement, air/vapor barriers, accessories, etc.
- Does not include waste
- Biogenic carbon not included for wood assemblies

### Assemblies
**Structure only**
- CMU – 8", 10", 12" CMU
- ICF – 3000 psi concrete, air entrainment
- Tilt-up – 4000 psi concrete, air entrainment

**Structure & veneer**
- 2"x6" HDG steel stud with clay brick veneer
- 2"x6" wood stud with clay brick veneer
- 2"x6" wood stud with metal panel veneer
- 8" CMU backup with ground face CMU veneer
- 8" CMU ground face single wythe fully grouted
- Tilt-up with thin brick veneer
- ICF with anchored clay brick veneer

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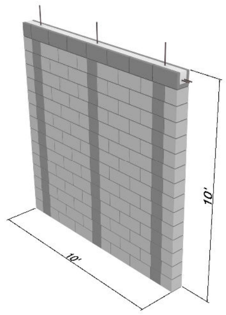
## MINI LCA

**For CMU assemblies**

- CMU reinforced with 3000 PSI coarse grout
- Vertical reinforcement at 48” OC or 32” OC
- Bond beam at top of wall

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## 8x8x16 CMU WALL

| 10x10 Section - 8" CMU 48" OC | | | |
|---|---|---|---|
| | | | |
| | GWP KG $CO_2$ EQ/$M^3$ | $M^3$ | GWP KG $CO_2$ EQ |
| **8" CMU - NW 3000 PSI** | 208 | 0.823 | **171** |
| | | | |
| Grout - Ready Mix | | | |
| 3000 PSI | 311 | 0.191 | **60** |
| | | | |
| | GWP KG $CO_2$ EQ/MT | MT | |
| Mortar C270 Type S | | | |
| Portland-Lime | 231 | 0.103 | **24** |
| | | | |
| #5 Rebar - 60ft | 854 | 0.020 | **18** |
| 48" OC | | | |
| | | | |
| **TOTAL GWP** | | | **272** |

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## 10x8x16 CMU WALL

| 10x10 Section - 10" CMU 48" OC | | | |
|---|---|---|---|
| | | | |
| | GWP KG $CO_2$ EQ/$M^3$ | $M^3$ | GWP KG $CO_2$ EQ |
| **10" CMU - NW 3000 PSI** | 208 | 1.018 | **212** |
| | | | |
| Grout - Ready Mix | | | |
| 3000 PSI | 311 | 0.247 | **77** |
| | | | |
| | GWP KG $CO_2$ EQ/MT | MT | |
| Mortar C270 Type S | | | |
| Portland-Lime | 231 | 0.106 | **24** |
| | | | |
| #5 Rebar - 60ft | 854 | 0.020 | **18** |
| 48" OC | | | |
| | | | |
| **TOTAL** | | | **330** |

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## 12x8x16 CMU WALL

| 10x10 Section - 12" CMU 48" OC | | | |
|---|---|---|---|
| | GWP KG $CO_2$ EQ/$M^3$ | $M^3$ | GWP KG $CO_2$ EQ |
| **12" CMU - NW 3000 PSI** | 208 | 1.204 | **250** |
| Grout - Ready Mix | | | |
| 3000 PSI | 311 | 0.305 | **95** |
| | GWP KG $CO_2$ EQ/MT | MT | |
| Mortar C270 Type S | | | |
| Portland-Lime | 231 | 0.108 | **25** |
| #5 Rebar - 60ft | 854 | 0.020 | **18** |
| 48" OC | | | |
| **TOTAL** | | | **388** |

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## 12x8x16 CMU WALL

| 10x10 Section - 12" CMU 32" OC | | | |
|---|---|---|---|
| | GWP KG $CO_2$ EQ/$M^3$ | $M^3$ | GWP KG $CO_2$ EQ |
| **12" CMU - NW 3000 PSI** | 208 | 1.204 | **250** |
| Grout - Ready Mix | | | |
| 3000 PSI | 311 | 0.415 | **129** |
| | GWP KG $CO_2$ EQ/MT | MT | |
| Mortar C270 Type S | | | |
| Portland-Lime | 231 | 0.114 | **26** |
| #5 Rebar - 60ft | 854 | 0.026 | **22** |
| 32" OC | | | |
| **TOTAL** | | | **428** |

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## INSULATED CONCRETE FORM (ICF)

| 10x10 Section - ICF | | | |
|---|---|---|---|
| | GWP KG $CO_2$ EQ/$M^3$ | $M^3$ | GWP KG $CO_2$ EQ |
| 10" Concrete | | | |
| 3000 PSI | **311** | 2.35 | **731** |
| | GWP KG $CO_2$ EQ/MT | MT | |
| #5 Rebar - 215 ft | | | |
| 12" OC | **854** | 0.10 | **87** |
| **Total without insulation** | | | **818** |
| | GWP KG CO2 EQ/M2 | M2 | |
| 5.5" Type II EPS | **13.8** | 9.29 | **128** |
| **TOTAL** | | | **946** |

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## TILT UP PANEL

| 10x10 Section - 10" Tilt Up Panel | | | |
|---|---|---|---|
| | | | |
| | GWP KG $CO_2$ EQ/$M^3$ | $M^3$ | GWP KG $CO_2$ EQ |
| 10" Tilt Up | | | |
| 4000 PSI | **383.6** | 2.35 | **900** |
| | | | |
| | GWP KG $CO_2$ EQ/MT | MT | |
| #5 Rebar - 215 ft | | | |
| 12" OC | **854** | 0.10 | **87** |
| | | | |
| **TOTAL** | | | **987** |

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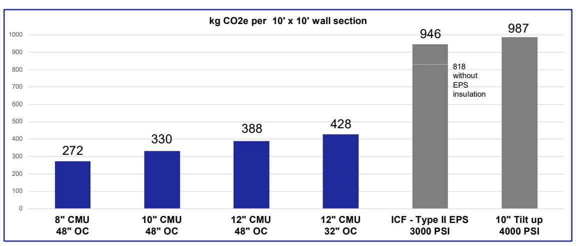
## CONCRETE STRUCTURES EMBODIED CARBON GATE (A1-A3)

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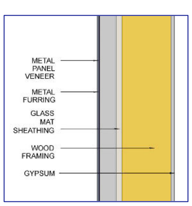
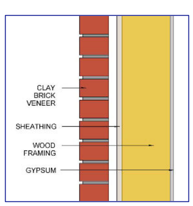
## ASSEMBLIES
### STRUCTURE & VENEER

2x6 stud
metal panel veneer




2x6 stud
clay brick veneer

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## 2x6 STEEL STUD clay brick

| 10x10 Section - HDG Stud Back Up 16" OC - Clay Brick Veneer | | | |
|---|---|---|---|
| | | | |
| | GWP KG $CO_2$ EQ/$M^3$ | $M^2$ | GWP KG $CO_2$ EQ |
| 1/2" gypsum | 3.90 | 9.29 | **36** |
| | | | |
| | GWP KG $CO_2$ EQ/$M^3$ | $M^3$ | |
| 5/8" plywood sheathing | 219 | 0.15 | **32** |
| Clay brick veneer (C216 75% solid) | 503 | 0.52 | **260** |
| | | | |
| | GWP KG $CO_2$ EQ/MT | MT | |
| Brick mortar C270 | | | |
| Portland-Lime | 231 | 0.28 | **65** |
| 1 5/8x6 20 ga HDG Steel Stud 95 LF | 2440 | 0.05 | **117** |
| | | | |
| **TOTAL** | | | **510** |

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## 2x6 WOOD STUD clay brick

| 10x10 Section - Wood Stud Back Up 16" OC - Clay Brick Veneer | | | |
|---|---|---|---|
| | | | |
| | GWP KG $CO_2$ EQ/$M^3$ | $M^2$ | GWP KG $CO_2$ EQ |
| 1/2" gypsum | 3.90 | 9.29 | **36** |
| | | | |
| | GWP KG $CO_2$ EQ/$M^3$ | $M^3$ | |
| 5/8" plywood sheathing | 219 | 0.15 | **32** |
| 2x6 wood studs 95 LF | 63 | 0.15 | **10** |
| | | | |
| Clay brick veneer (C216 75% solid) | 503 | 0.52 | **260** |
| | | | |
| | GWP KG $CO_2$ EQ/MT | MT | |
| Brick mortar C270 | | | |
| Portland-Lime | 231 | 0.28 | **65** |
| | | | |
| **TOTAL** | | | **403** |

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## 2X6 WOOD STUD metal panel

| 10x10 Section - Wood Stud Back Up 16" OC - Metal Panel | | | |
|---|---|---|---|
| | | | |
| | GWP KG $CO_2$ EQ/$M^3$ | $M^2$ | GWP KG $CO_2$ EQ |
| 1/2" gypsum | 4 | 9.29 | **36** |
| 1/2" glass Mat gyp. sheathing | 5 | 9.29 | **44** |
| Metal panel | 28 | 9.29 | **260** |
| | | | |
| | GWP KG $CO_2$ EQ/$M^3$ | $M^3$ | |
| 2x6 wood studs 95 LF | 63 | 0.15 | **10** |
| | | | |
| | GWP KG $CO_2$ EQ/MT | MT | |
| Metal Z clips 75 LF | 1929 | **0.026** | **50** |
| | | | |
| **TOTAL** | | | **400** |

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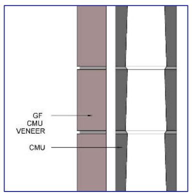
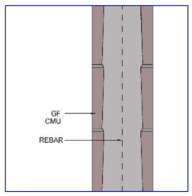
## ASSEMBLIES

8x8x16 NW back up 48" OC
ground face anchored veneer




8x8x16 ground face
fully grouted

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**8x8x16 NORMAL WEIGHT CMU**

**cavity wall**

**ground face cmu veneer**

| 10x10 Section - 8" CMU Back Up 48" OC - GF Veneer | | | |
|---|---|---|---|
| | | | |
| | GWP KG $CO_2$ EQ/$M^3$ | $M^3$ | GWP KG $CO_2$ EQ |
| **8" CMU - NW 3000 PSI** | 208 | 0.82 | **171** |
| **4" GF CMU 3500 PSI Veneer** | 310 | 0.56 | **173** |
| | | | |
| Grout - Ready Mix | | | |
| 3000 PSI | 311 | **0.19** | **60** |
| | | | |
| | GWP KG $CO_2$ EQ/MT | MT | |
| 8" CMU Mortar C270 | | | |
| Portland-Lime | 231 | **0.10** | **24** |
| 4" CMU Mortar C270 | | | |
| Portland-Lime | 231 | 0.10 | **22** |
| | | | |
| #5 Rebar - 60ft | 854 | **0.02** | **18** |
| 48" OC | | | |
| | | | |
| **TOTAL** | | | **467** |

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**8x8x16 NORMAL WEIGHT GROUND FACE CMU**

**single wythe fully grouted**

| 10x10 Section - 8" CMU 8" OC GF FULLY GROUTED | | | |
|---|---|---|---|
| | | | |
| | GWP KG $CO_2$ EQ/$M^3$ | $M^3$ | GWP KG $CO_2$ EQ |
| **8" GF NW open ended CMU** | 310 | 0.720 | **223** |
| 3500 PSI | \ | | |
| | | | |
| Grout - Ready Mix | | | |
| 3000 PSI | 311 | 0.983 | **306** |
| | | | |
| | GWP KG $CO_2$ EQ/MT | MT | |
| Mortar C270 Type S | | | |
| Portland-Lime | 231 | 0.096 | **22** |
| | | | |
| #5 Rebar - 310 ft | 854 | 0.147 | **125** |
| 8" OC vertical and horizontal | | | |
| | | | |
| **TOTAL GWP** | | | **677** |

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## 8x8x16 NORMAL WEIGHT GROUND FACE CMU

**single wythe fully grouted**

- High SCM Grout

| 10x10 Section - 8" CMU 8" OC GF FULLY GROUTED | | | |
|---|---|---|---|
| | | | |
| | GWP KG $CO_2$ EQ/$M^3$ | $M^3$ | GWP KG $CO_2$ EQ |
| **8" GF NW open ended CMU** | **310** | 0.720 | **223** |
| 3500 PSI | | | |
| | | | |
| **High SCM Grout - Ready Mixed** | | | |
| 3000 PSI 40-49% fly ash | 221 | 0.983 | **217** |
| | | | |
| | GWP KG $CO_2$ EQ/MT | MT | |
| Mortar C270 Type S | | | |
| Portland-Lime | 231 | 0.096 | **22** |
| | | | |
| #5 Rebar - 310 ft | 854 | 0.147 | **125** |
| 8" OC vertical and horizontal | | | |
| | | | |
| **TOTAL GWP** | | | **588** |

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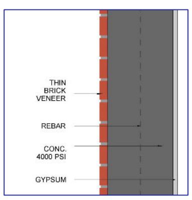
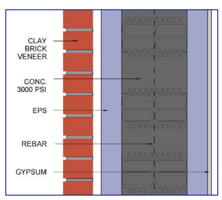
## ASSEMBLIES
**STRUCTURE & VENEER**

Tilt-Up with
1" Thin brick veneer




ICF
Clay brick veneer

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## TILT-UP clay thin brick

| 10x10 Section - 10" Tilt Up Panel - Thin Brick Veneer | | | |
|---|---|---|---|
| | | | |
| | GWP KG $CO_2$ EQ/$M^3$ | $M^3$ | GWP KG $CO_2$ EQ |
| 10" wet-cast conc. 4000 PSI | 384 | 2.35 | **900** |
| | | | |
| | GWP KG $CO_2$ EQ/MT | MT | |
| #5 Rebar - 220 ft - 12" OC | 854 | 0.10 | **87** |
| | | | |
| | GWP KG $CO_2$ EQ/$M^3$ | $M^3$ | |
| Clay thin brick veneer 1" | 503 | 0.19 | **95** |
| | | | |
| **TOTAL** | | | **1083** |

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## ICF
## clay brick

| 10x10 Section - ICF - Anchored Brick Veneer | | | |
|---|---|---|---|
| | GWP KG $CO_2$ EQ/$M^3$ | $M^3$ | GWP KG $CO_2$ EQ |
| 10" wet-cast conc., 3000 PSI | 311 | 2.35 | **731** |
| Clay brick veneer (C216 75% solid) | 503 | 0.52 | **260** |
| | GWP KG $CO_2$ EQ/MT | MT | |
| #5 rebar - 220 ft - 12" OC | 854 | 0.10 | **87** |
| Brick mortar C270 | | | |
| Portland-Lime | 231 | 0.28 | **65** |
| | GWP KG CO2 EQ/$M^2$ | $M^2$ | |
| Interior gypsum 1/2" | 3.90 | 9.29 | **36** |
| **Total without insulation** | | | **1178** |
| | GWP KG CO2 EQ/$M^2$ | $M^2$ | |
| 5.5" Type II EPS | 13.8 | 9.29 | **128** |
| **TOTAL** | | | **1307** |

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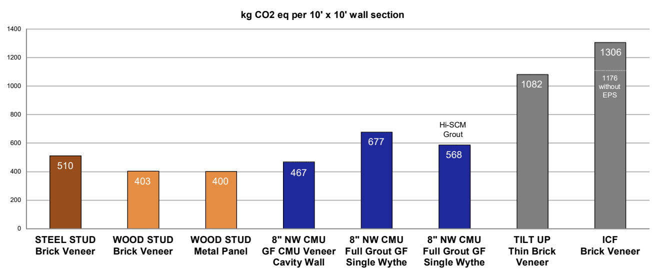
## ASSEMBLY EMBODIED CARBON
### Gate (A1-A3) 28 day sequestration included

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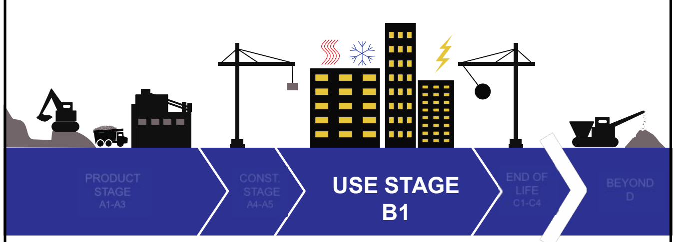
## LIFE CYCLE STAGES

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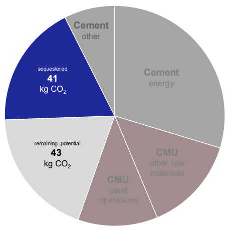
## DRY CAST $CO_2$ SEQUESTRATION OF CMU
PER $M^3$




**2 years**

Total sequestration ≈ **41 kg $CO_2$**

**49% of potential**

- emissions associated with chemical reaction only

**18% of total associated emissions**

- emissions associated with the whole process of CMU manufacturing

**GWP**

- **185** CO2e per $M^3$

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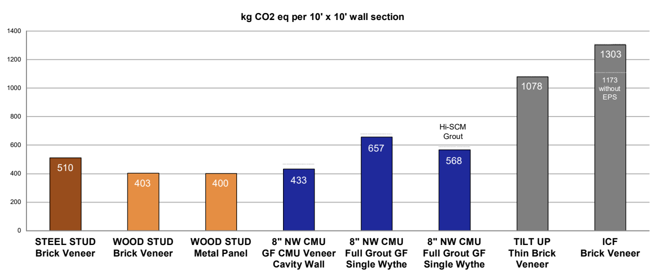
## ASSEMBLY EMBODIED CARBON
Use Phase (B1) 2 year sequestration included

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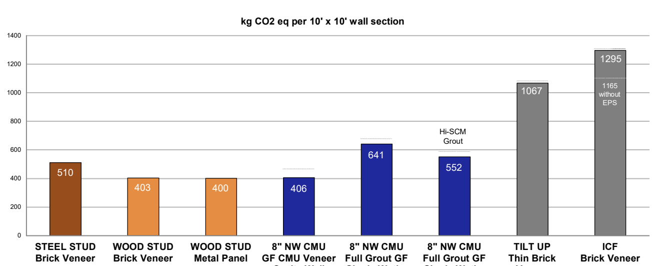
## ASSEMBLY EMBODIED CARBON
Use Phase (B1) 20 year sequestration projection

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## WHAT'S NEXT?

**COMPARATIVE EMBODIED CARBON LCA**

**3 building types compared**

- CMU cavity wall, ground face veneer
- Podium style, steel & wood frame, metal panel
- Precast sandwich panel, thin brick veneer

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## AGENDA

- Similarities and differences between dry-cast and wet-cast concrete
- Terms
  - Difference between embodied carbon and operational carbon
  - Difference between carbon sequestration and carbon storage

The Carbon Cycle

- The geologic carbon cycle
- The concrete carbon cycle
- What is Carbon Sequestration
- Why the difference between wet-cast and dry-cast affects carbon sequestration

Mini LCA wall comparison studies

- CMU
- ICF
- Tilt-up
- Wood stud
- Steel stud

**Other ways to reduce embodied carbon**

- **Plant operations & raw material choices**
- **Reducing material use & efficient structural design**
- **Durability and resiliency**
- **Utilizing thermal mass**
- **End of life (EOL)**

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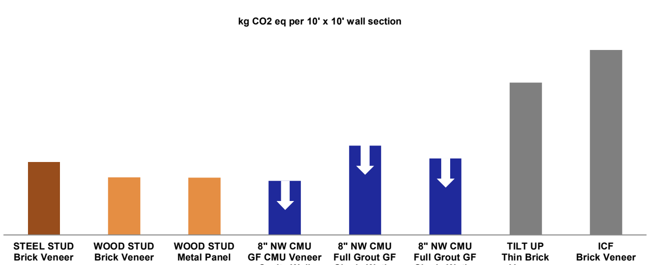
## ASSEMBLY EMBODIED CARBON

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THE MASONRY SOCIETY

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## Continuing Education Certificates (CEU / PDH / LU)

- Write down the code at the end of each session
- Find the 2024 Annual Meeting on TMS's Masonry Education Hub
  - Use the link on the meeting page
  - Or go to learn.masonrysociety.org
- Enter the codes into the quiz to generate and download your certificate

Session 3 Code:
**9057**

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