X-MAT®

Carbon Core Composites

Bluefield, WV

Carbon Ore for Advanced Building Materials

DE-FE0031985

Bruce V. Mutter

U.S. DEPARTMENT OF ENERGY

NATIONAL ENERGY TECHNOLOGY LABORATORY

Resource Sustainability Project Review Meeting: 27 October 2022 | Pittsburgh, PA

Carbon Ore Processing (COP): Building Materials / Additive Manufacturing | 8:00 a.m.

X-MAT® Project Overview

Carbon Core Composites
Bluefield, WV

DOE Funding		Cost Share	Total Project
Phase I	$ 498,442	$126,000	$624,442
Phase II	**$2,247,844**	**$700,000**	**$2,947,844**
Totals	**$2,746,286**	**$826,000**	**$3,572,286**

Phase I - Completed
1/1/2021– 3/31/2022

Phase II
1 April 2022 – 31 May 2024

August Brown
NETL NATIONAL ENERGY TECHNOLOGY LABORATORY
EERC
CART® Center for Applied Research and Technology, Inc.
Semplastics

Project Objectives

1. **Construct a *partial* building shell (section),** consisting of at least two walls, a partial roof, and a partial foundation, to test the assembly of materials under stress conditions.

2. **Perform testing** on various coal-derived building material **(CDBM)** products, individually and as part of the demonstration structure anchored to a foundation, to confirm that they meet all applicable state and federal building or housing codes (e.g., fire, earthquake, weather).

3. **Demonstrate CDBM** use alongside traditional building materials (**TBM)** in structural applications by strong bonding (X-MORTAR) techniques (and fastening systems).

4. **Design a prototype demonstration carbon-based building** consisting of four walls and a roof, and deliver detailed design documents for the building, including all construction guidelines required to meet state and federal housing code regulations and insurance requirements.

5. **Update techno-economic analysis (TEA)** performed in Phase I with the latest information on how CDBM will affect material and construction costs as well as market potential, a revised gap analysis describing what further development is necessary to achieve market acceptance of CDBM, and an expanded analysis to show how CDBM compare to TBM over their lifecycles.

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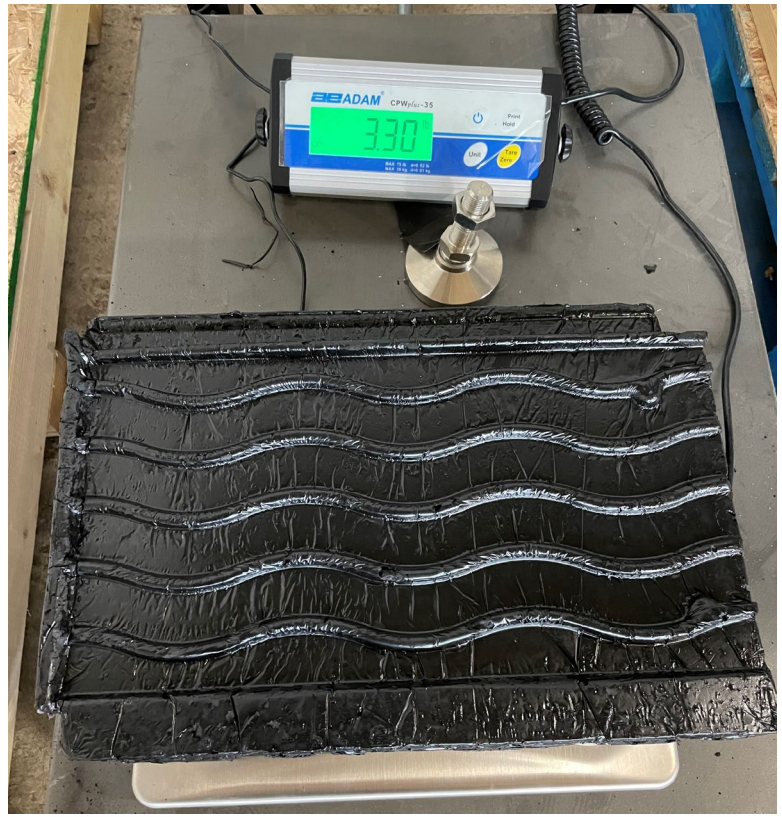
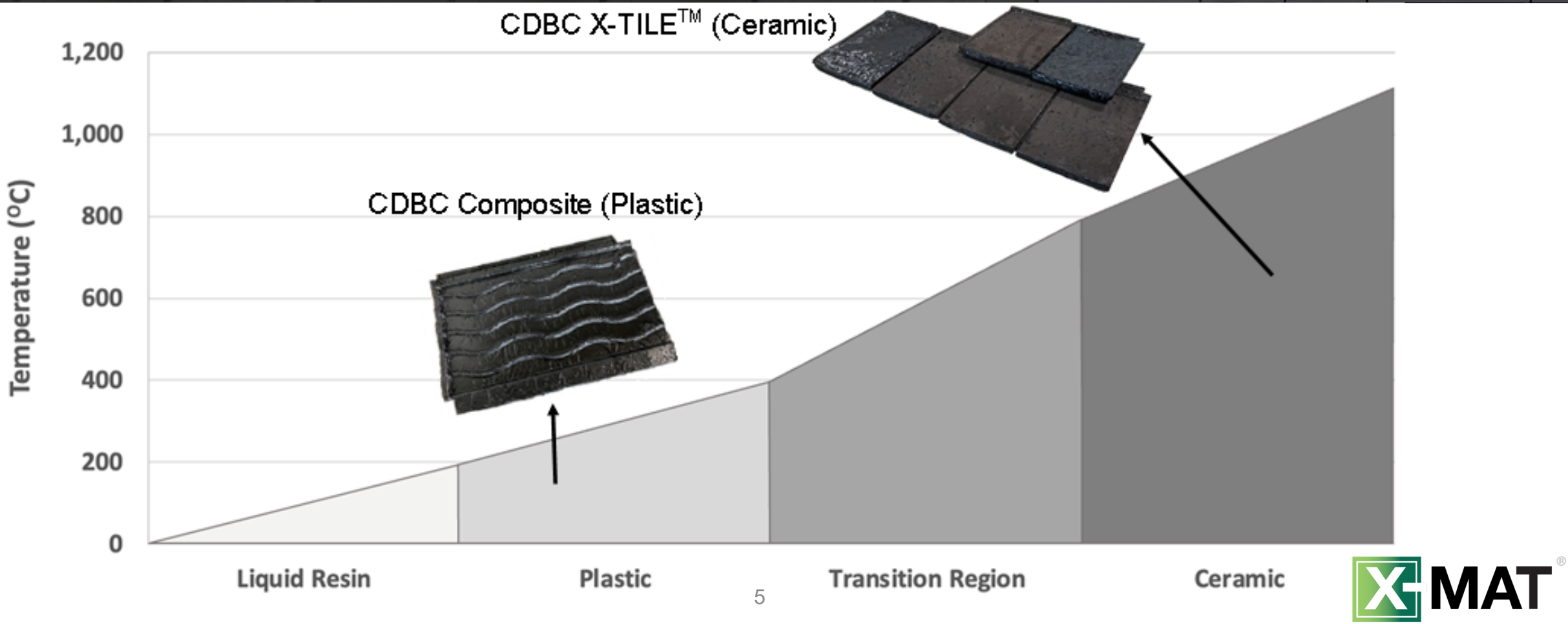
Technology Background



- Raw coal powder mixed with the Polymer-Derived Ceramic **(PDC) -** forming resins produce Coal-Derived Building Components **(CDBC)**
- PDC Resin is compatible with several powdered materials in an “as-is” state including Aluminum, **Coal, Coal Combustion Residuals (CCR),** Metal Carbides & Oxides
- Coal particles bond in resin when Mixed > Pressed > Cured > Fired
- CDBC’s can be Cast, Extruded or Molded

PDC Processing Cycle



Advantages & Challenges

Techno-economic **advantages** are demonstrated by prototyping high-performance, low-porosity, strong, lightweight, fire and heat resistant interlocking X-TILE™ , X-PANEL™ , X-BLOX™ , X-BRIX™ & X-MATRIX™ carbon core composite (CCC) lightweight aggregates.

Techno-economic **challenges** include process heat management, utilizing low-cost carbon ore, and creating a new market for innovative coal products vital to a modern & growing construction industry.

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Project Scope & Work Plan

Task	Description of Work
1.0	**Plan & Manage Project** – PMP – TMP – ESG – Economic Development, ES&H, Reports
2.0	**Scale-Up Production Methods** – for X-MATRIX Aggregates & CDBM Components
3.0	**Develop & Demonstrate Fastening Methodologies –** X-MORTAR & X-PANEL
4.0	**Test CDBM Components –** ASTM for X-TILES, X-PANELS, X-BLOX, X-BRIX & X-MATRIX
5.0	**Produce Technology Demonstrator –** Construction of Building Section (2 Walls & Roof)
6.0	**Design & Detail Carbon-Ore Based Building –** Meeting Applicable Building Codes
7.0	**Test & Analyze Markets –** Sample Product to Channel Partners for Market Testing
8.0	**Update Techno-Economic Analysis –** Based on Completion of Tasks 2.0 through 7.0

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Project Schedule

Key Milestones	Description of Project Success Criteria	Completion Date
M1 – ***Task 2.0***	***Complete Pilot Production Facilities for Operating***	***8 Dec 2022***
M2 – *Task 3.0*	Establish Binding/Fastening Methods CDBM & TBM Parts	27 Apr 2023
M3 – *Task 4.0*	Confirm Suitability of CDBC as TBM Alternatives	12 Oct 2023
M4 – *Task 5.0*	Complete Prototype Building Section Demonstrator	23 Nov 2023
M5 – *Task 6.0*	Complete Detailed Building Design for Phase III	4 Jan 2024
M6 – *Task 8.0*	Complete Techno-Economic Analysis (TEA) Update	28 Mar 2024

Risk Mitigation Strategies – Emphasize X-PANEL™ & X-MATRIX™ utilization in Phase II. Adjust CDBC Build Order as necessary to accommodate equipment supply chain issues. There are no known schedule deviations at this time.

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CART® Support Equipment

Mixing → **Pressing** → **Curing** → **Firing**

Hobart ™ Legacy
60qt Mixer

Carver Wabash ™
Monarch 100 Ton Press

SHEL-Lab ™ Large Capacity Forced Air Oven SMO28-2

L&L Kiln ™
48" x 54" Top-load

XMAT®

Pilot Line Equipment

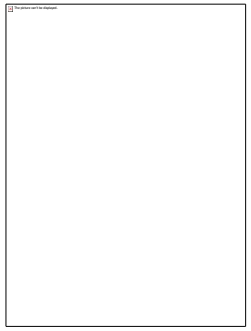
Mixing → **Extruding** → **Curing** → **Crushing** → **Screening** → **Drilling**

2HP Electric High Speed Disperser for up to 20 Gal Containers with Air Lift

Bluebird Model S Clay Mixer

Bluebird Power Star Deairing Pugmill

5'x5'x8' Curing Oven



K&M Krusher Chain Mill & Dust Collection

Gilson Screening Sieve

Keil Undercut Anchor Drill

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CART Equipment - 1672 Bluefield Avenue

Tormach ™ 1100M

JD Squared ™ MAD CNC
Plasma Table 5’x10’

JSB CNC™
5’x10’ Router

SketchUp
SOLIDWORKS
CS EAGLE
AUTODESK® REVIT®
PLM Software
SIEMENS NX

PLM Software

XMAT®

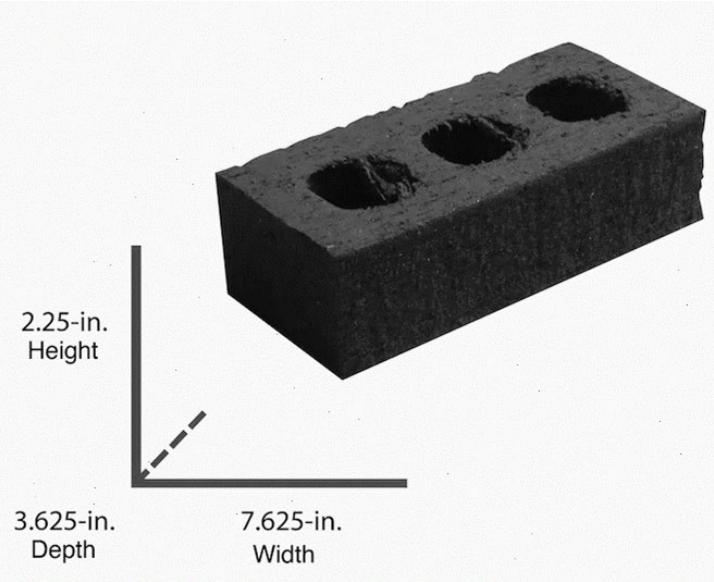
Pilot Line – Additional Equipment

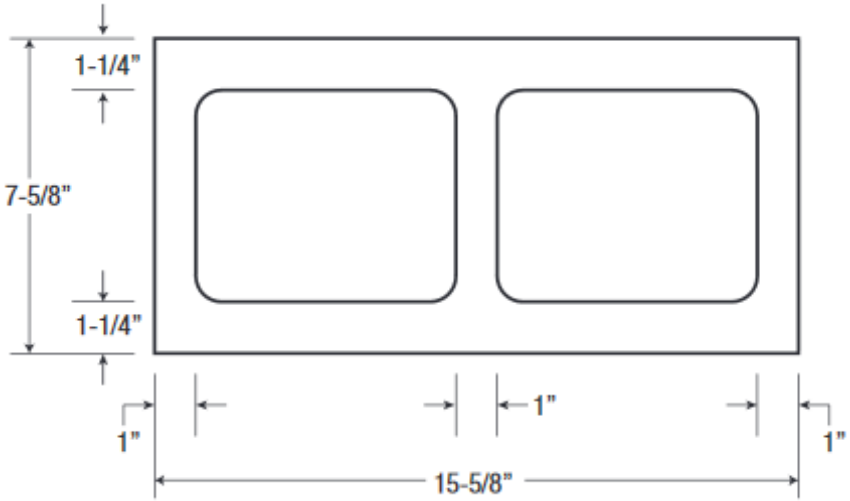
X-BLOX™ Making Machine

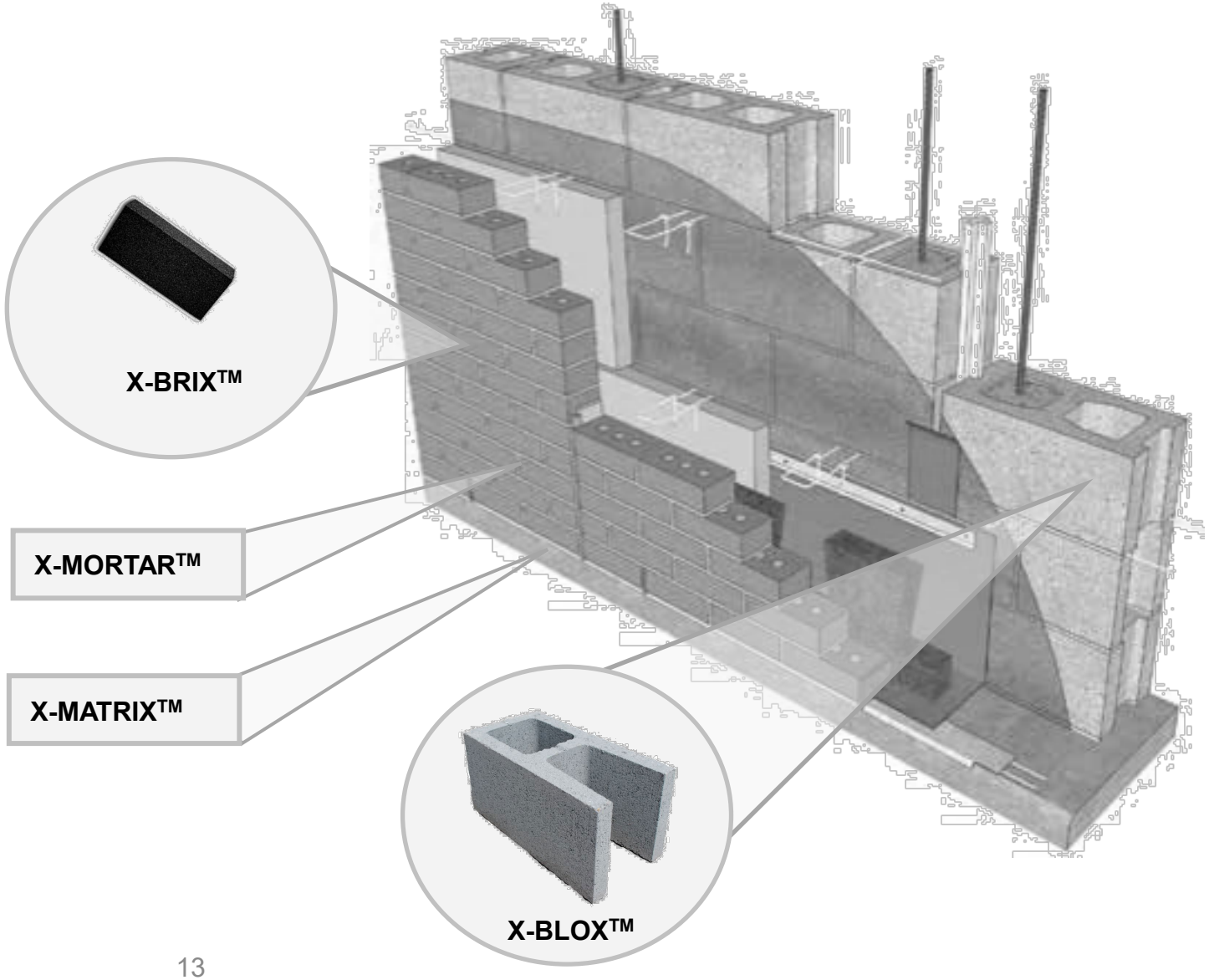
X-BLOX™ Cored Mold Insert Examples

X-MAT® - Kiln Upgrades

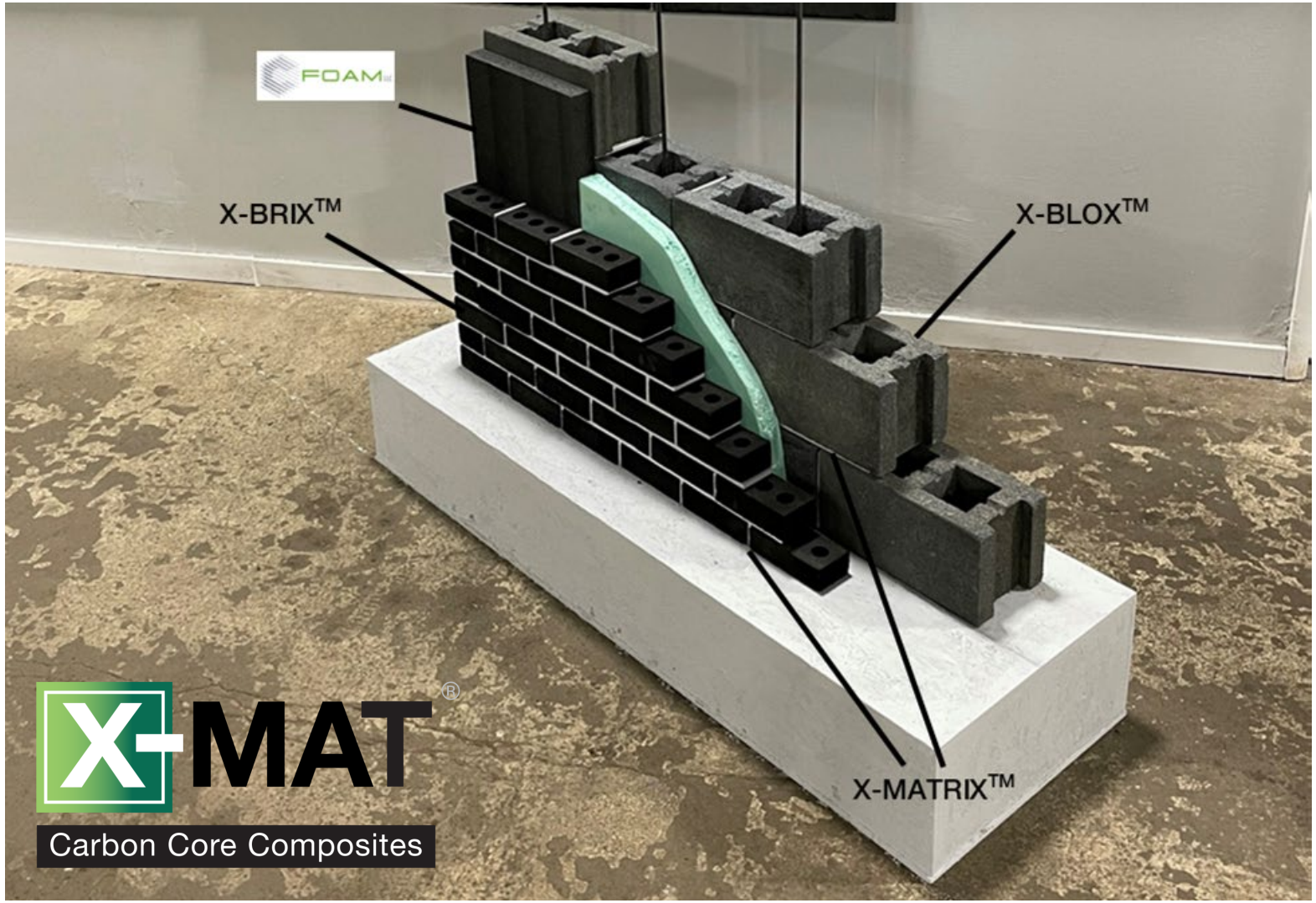
X-BRIX™ | X-BLOX™ | X-MATRIX™ | X-MORTAR™



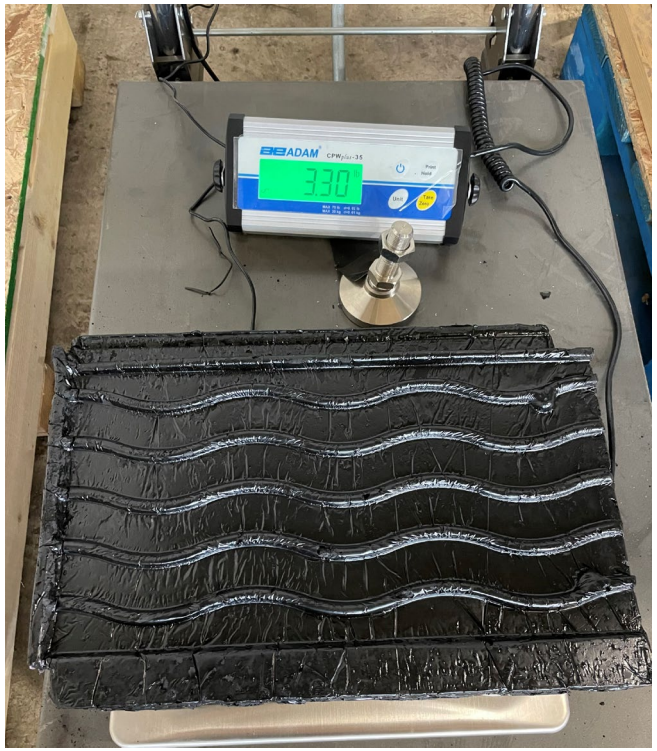




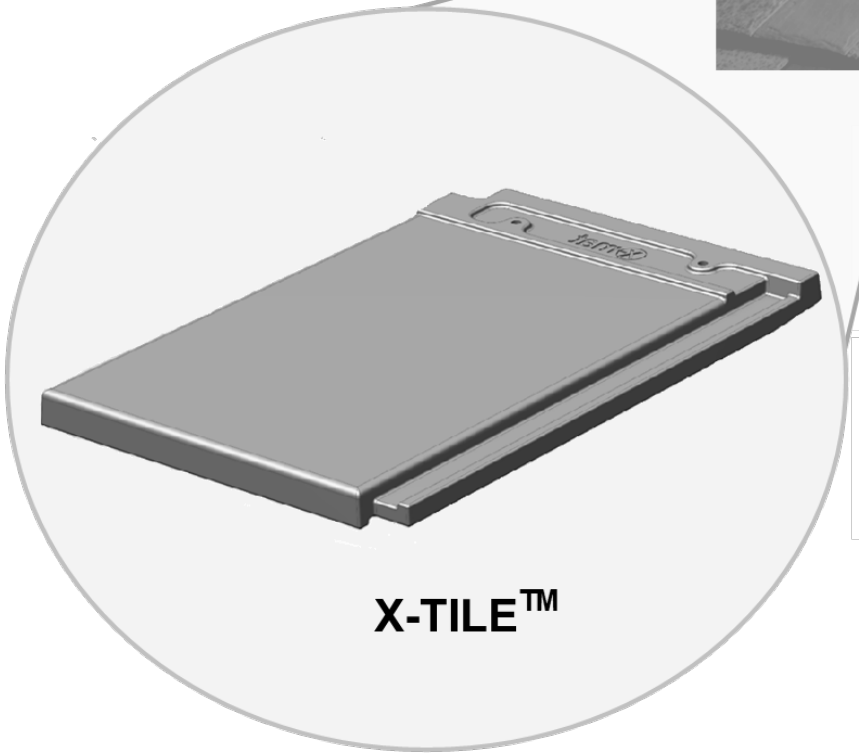
X-BRIX™ | X-BLOX™ | X-MATRIX™ | X-MORTAR™



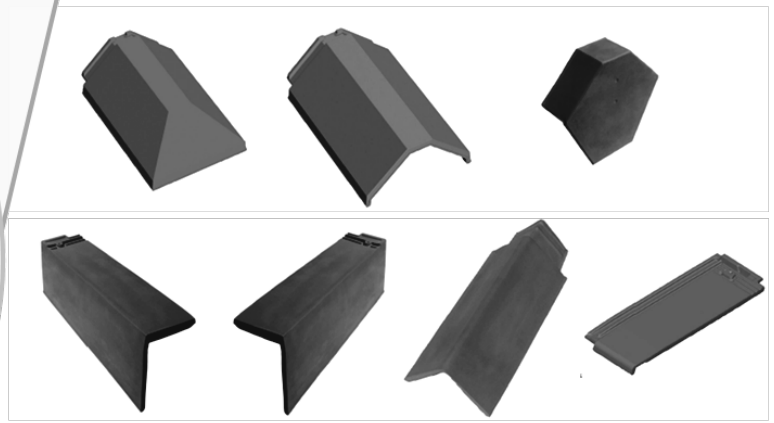
X-TILES™



X-TILE™ - Underside

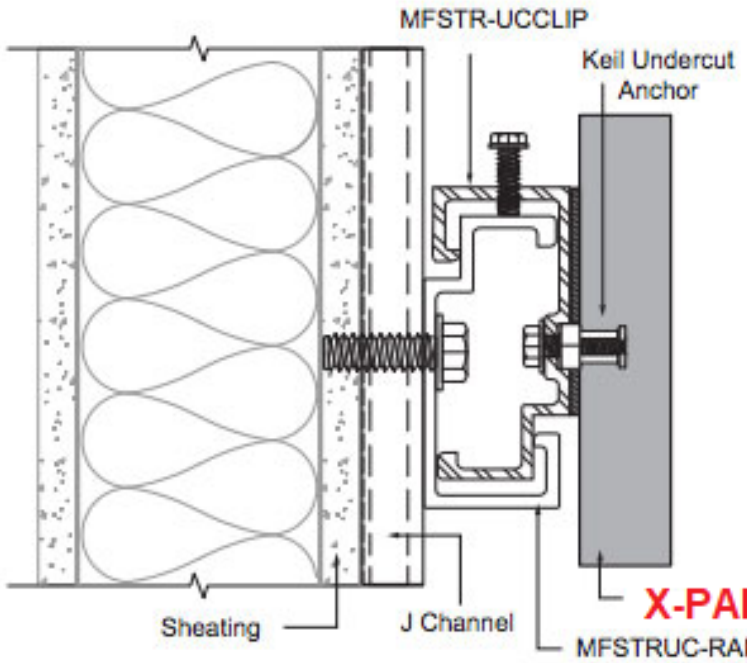


X-TILE™

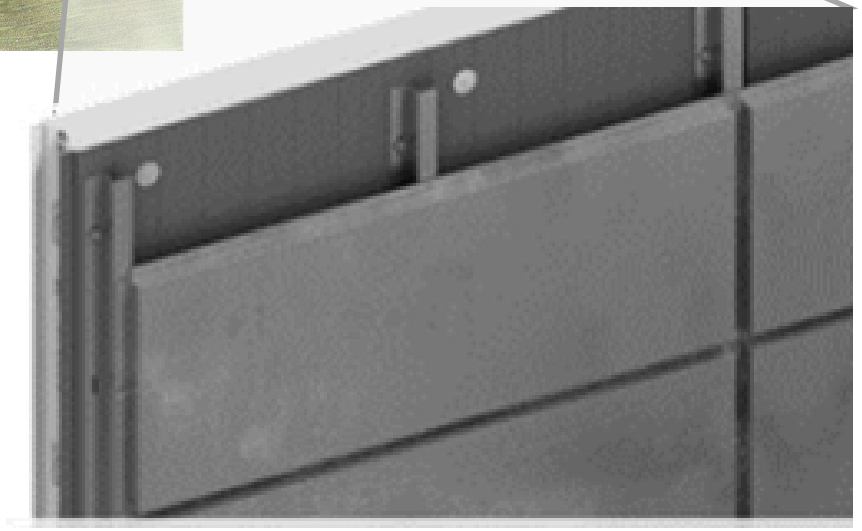


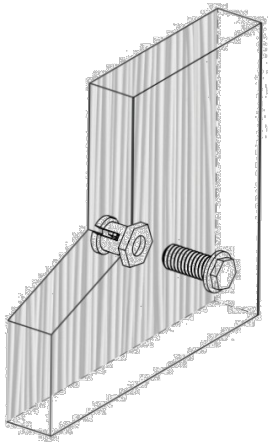
Hip / Ridge / Gable / Starter

X-PANEL™

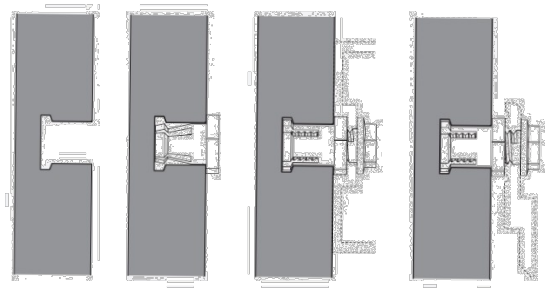


X-PANEL™



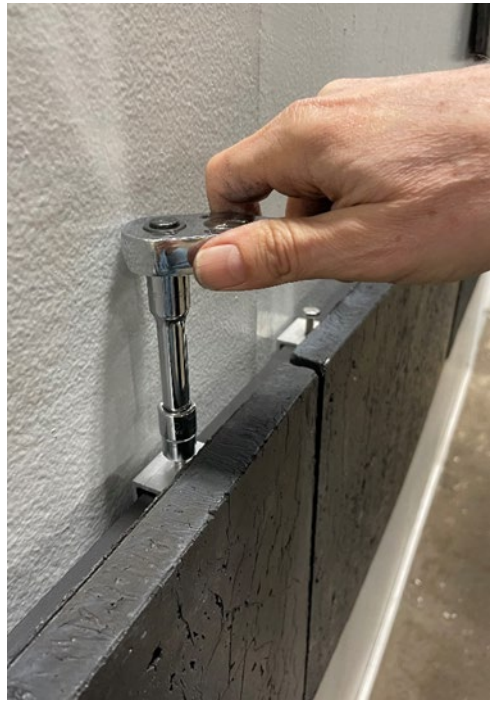


Concealed Undercut Anchor

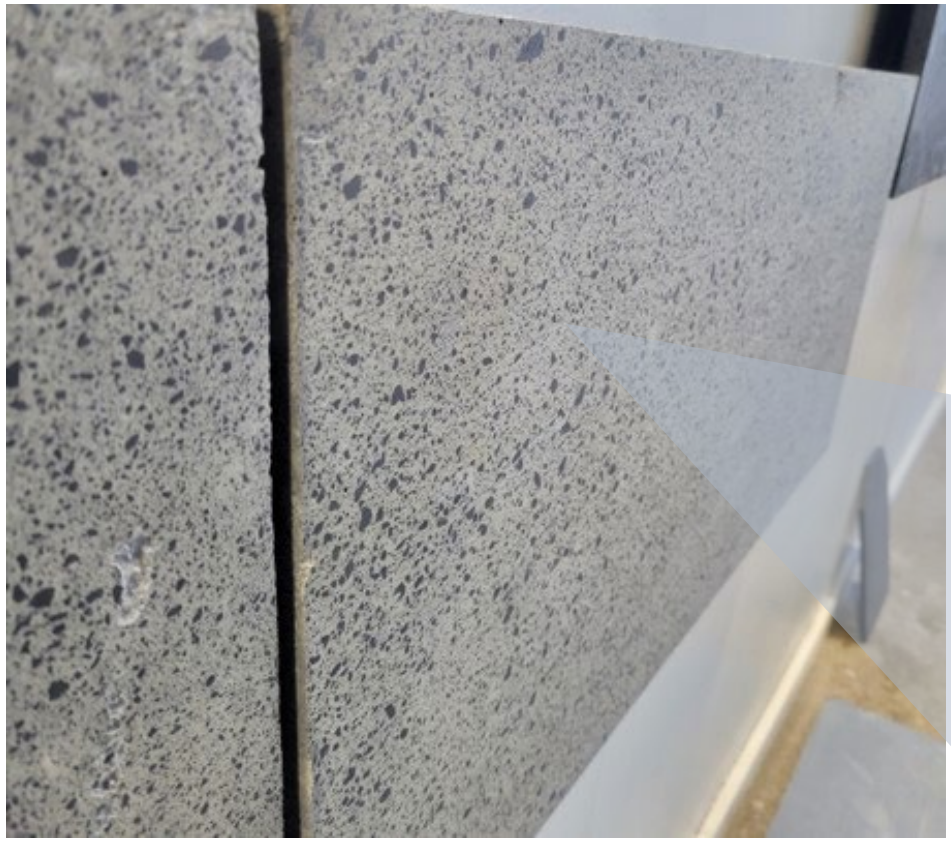


X-PANEL™

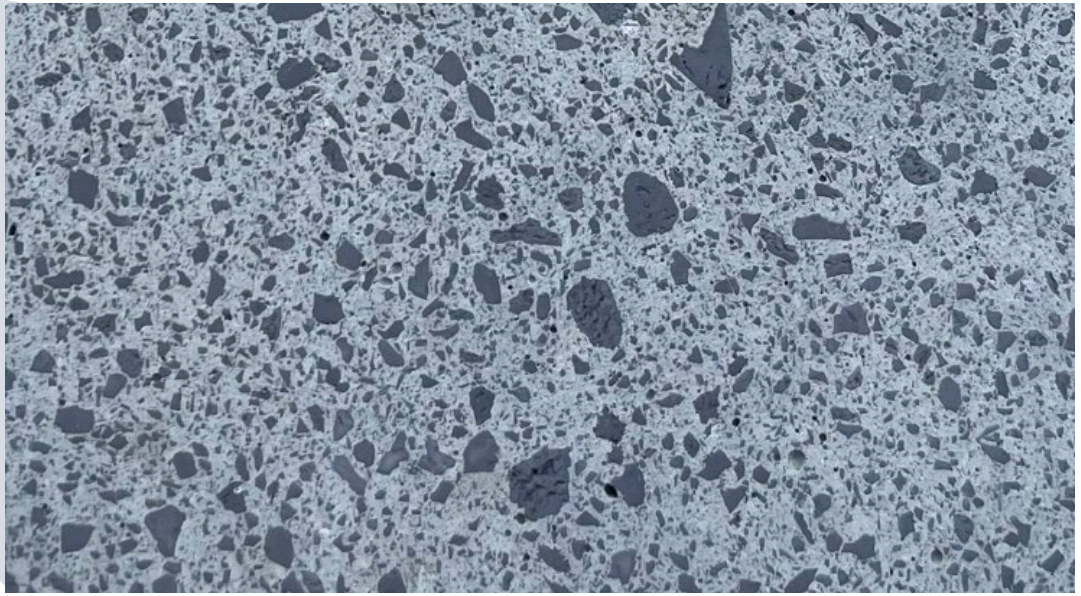
16” x 32” CDBM X-PANEL™ Rail Clips Fastened by Concealed Undercut Anchors



X-PANEL™

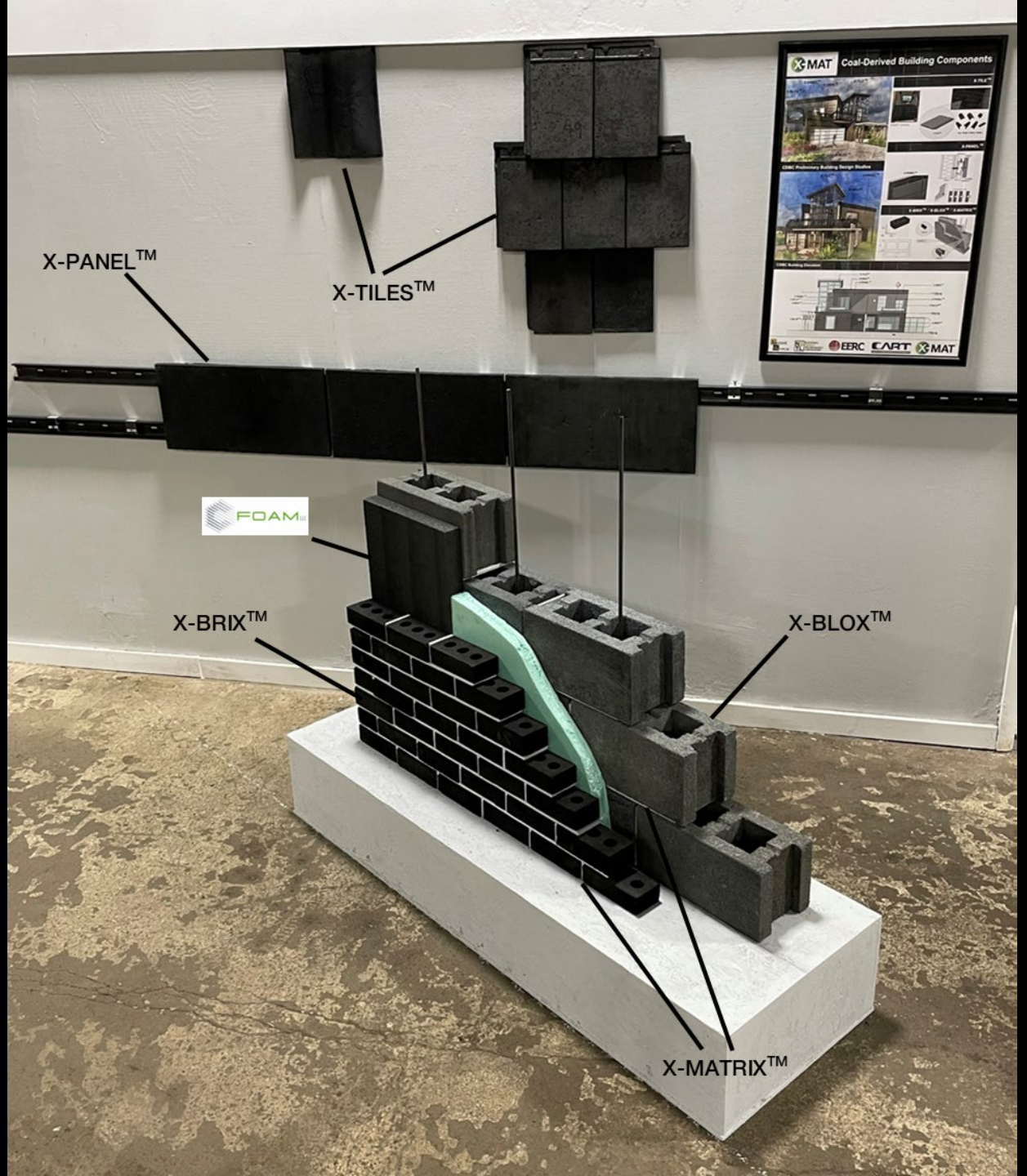


16” x 32” **Polished** X-MATRIX X-PANEL™

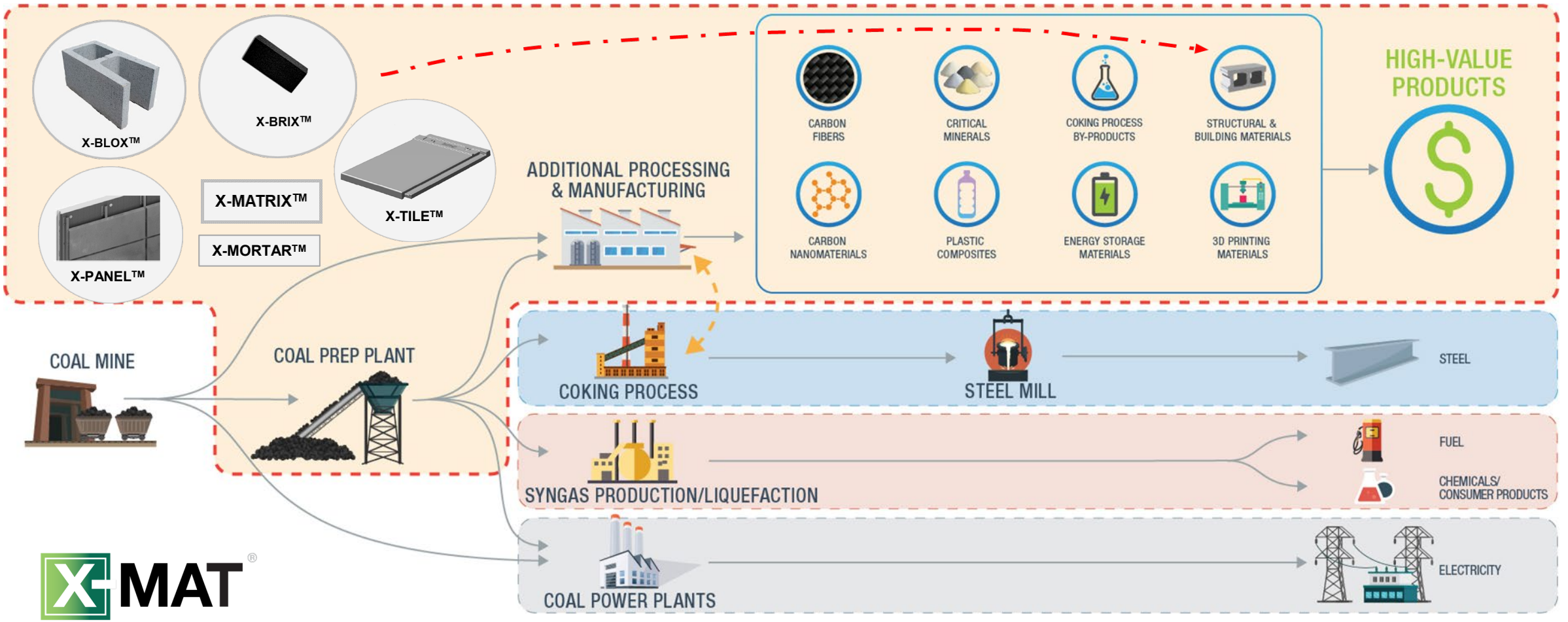


X-MAT®

Reimagining high performance materials


X-PANEL™
X-TILES™
X-BRIX™
X-BLOX™
X-MATRIX™
FOAM
X-MAT
Coal-Derived Building Components

NETL Coal Beneficiation Value Chain



X-MAT®

NETL – ACP - Coal to Building Materials

ACP

Coal to Building Materials

Revolutionizing Sustainable Building and Construction Materials

High-performance, energy-efficient, low-cost, and sustainable building materials are vital to a modern and growing construction industry. Utilizing coal enables production of superior building materials including roofing tiles, siding, decking, insulation, joists/studs, sheathing, and architectural block.

U.S. DEPARTMENT OF ENERGY | NETL NATIONAL ENERGY TECHNOLOGY LABORATORY

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https://www.netl.doe.gov/Advanced_Coal_Processing

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APRIL 2021

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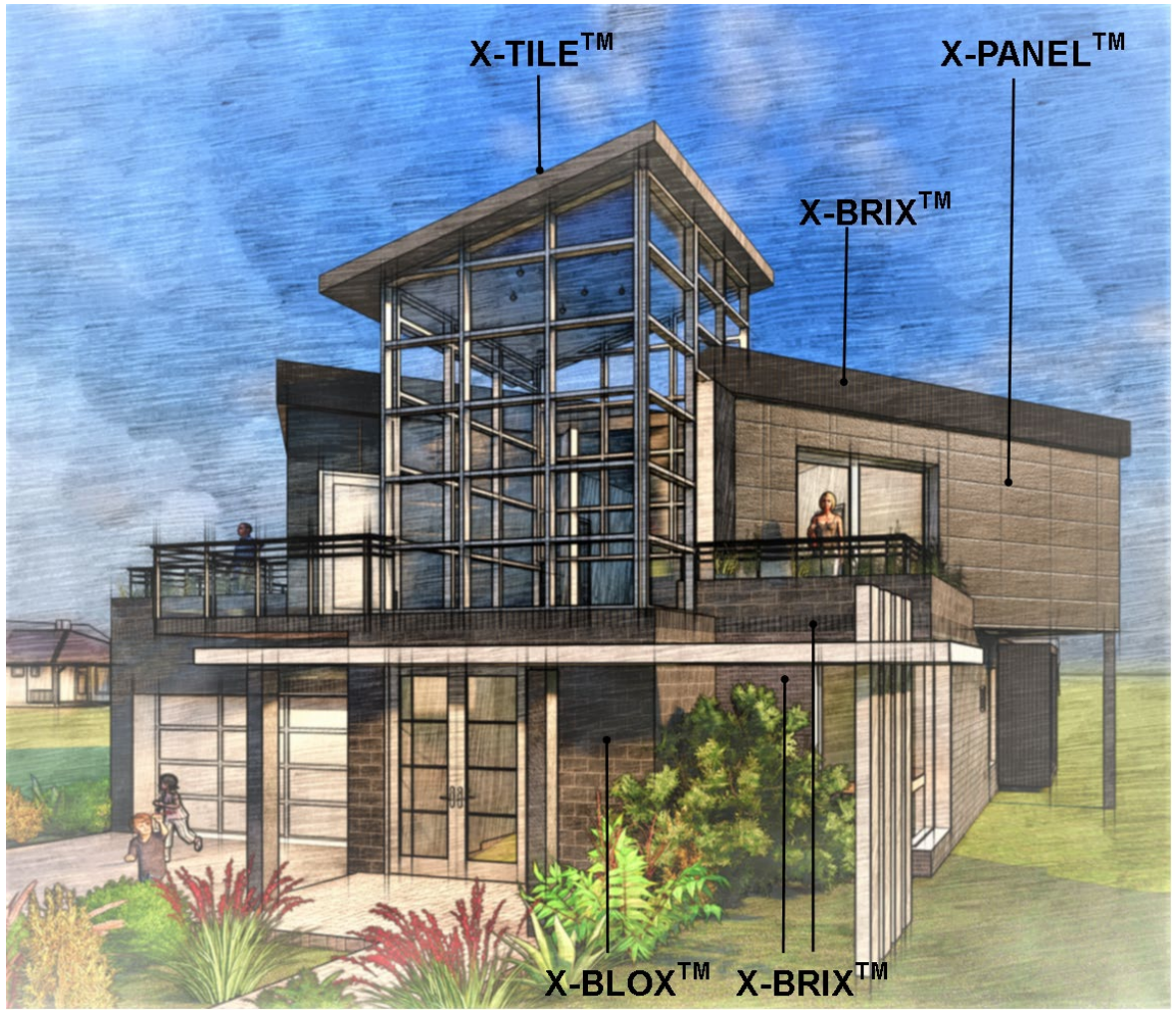
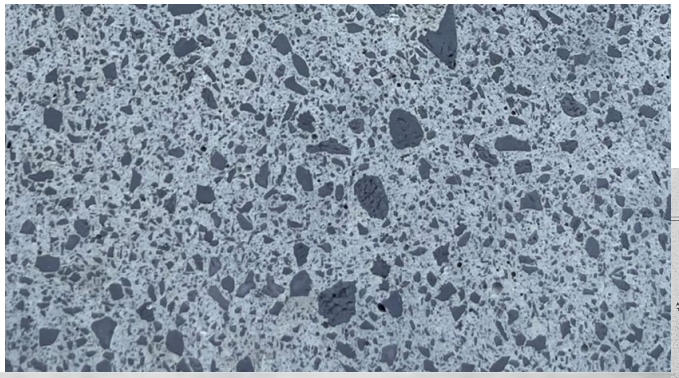
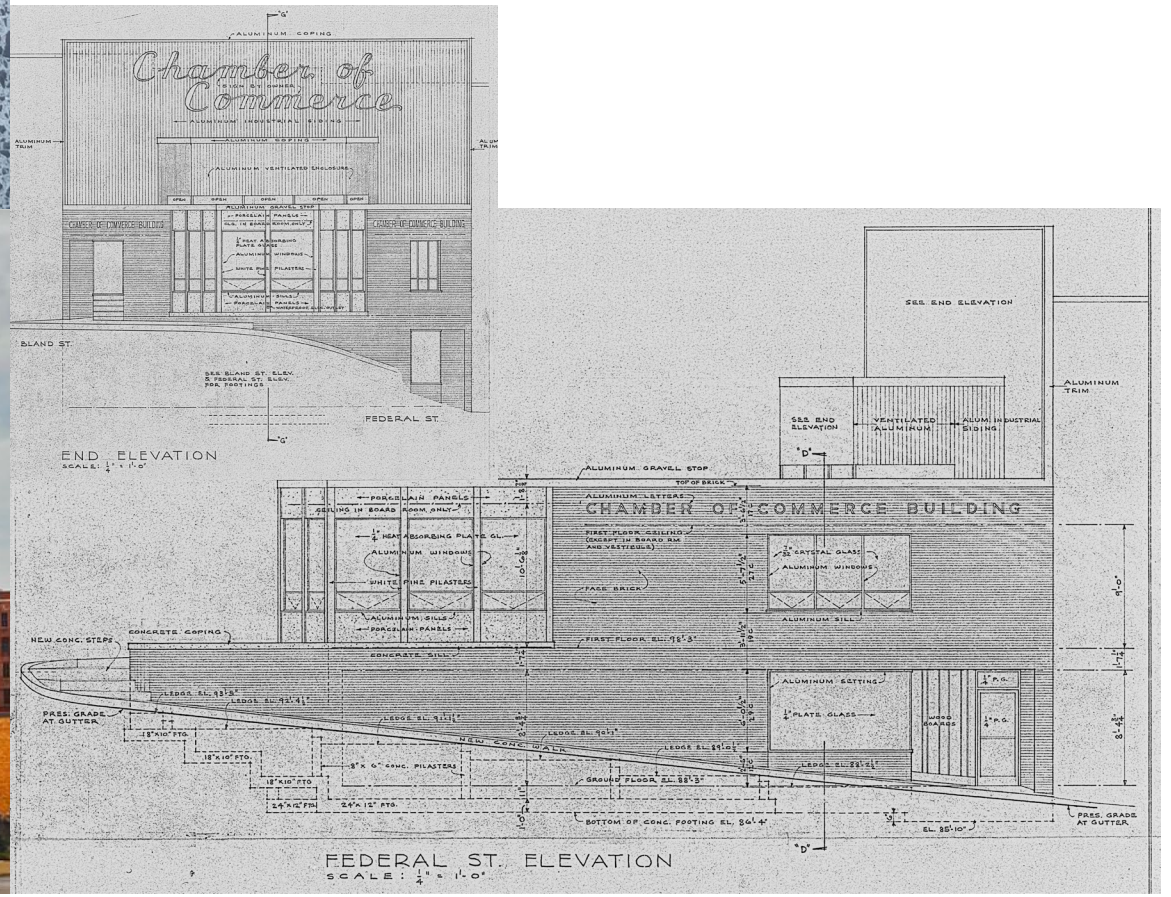


CDBC Concepts & Material Callouts

X-MAT®





X-PANEL™ Commercialization

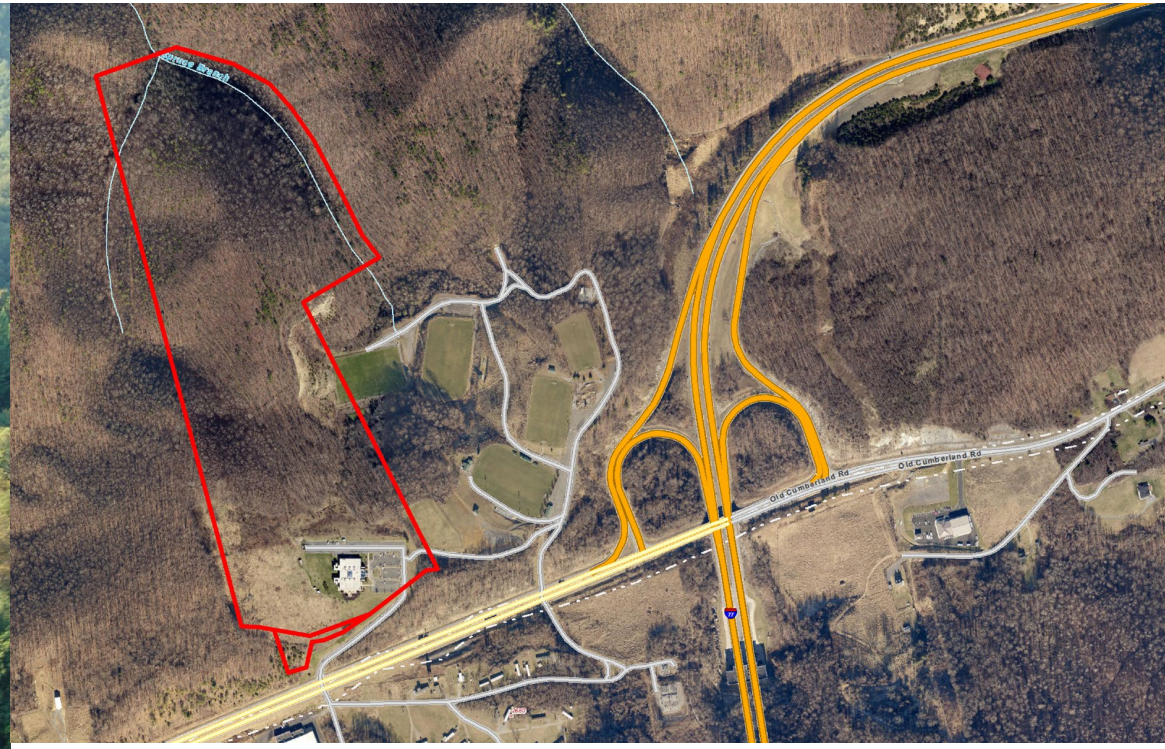
Carbon Corridor

VA: 8 Miles to border from Exit 1 | **KY:** 90 Miles from Elkhorn City, KY | **TN:** 91 Miles from Bristol, TN

CPIC – John Nash Boulevard

The **Carbon Products Innovation Center (CPIC)** is an industry-led, demand-driven innovation center.

By clustering collaborative businesses, expertise, the private sector and public economic development networks, the CPIC supports businesses that deliver transformational change in up-scaled carbon products commercialization such as the following:



(CIBU)
(CDBC)
(X-BATT)
(BPL)
(X-MAT)
(CART)

CPIC
Carbon Products Innovation

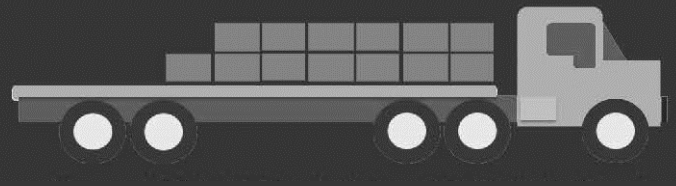
X-MAT CCC - Summary Key Benefits

Material Benefits

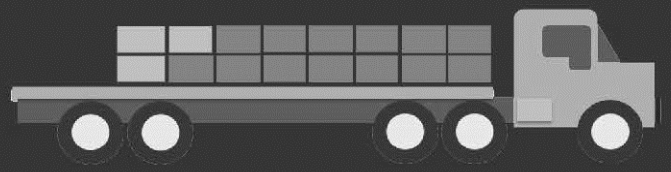
- Fireproof
- Light-weight
- Stronger
- More Insulating

Economic Benefits

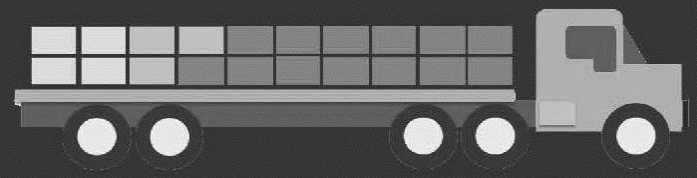
- Job Creation
- Coal Utilization
- Carbon Sequestered
- Improved Labor Productivity
- Reduced Transportation Cost



Normal Weight CMU (130pcf) 13 Pallets/Load - 44,000 lbs.



Lightweight CMU (105pcf) 16 Pallets/Load - 44,000 lbs.



X-BLOX™ < (105pcf) 20 Pallets/Load

X-MAT®

Carbon Core Composites

Bluefield, WV

Thank You!

Questions/Discussion

Organizational Chart

X-MAT® Carbon Core Composites

Semplastics

Semplastics will continue development and production of resin formulations that serve as binders in the various PDC composite material systems.

CART
Center for Applied Research and Technology, Inc.

CART will scale up production of CDBM components and will provide the CDBM building concept design utilizing the full-size components.

EERC
Energy & Environmental Research Center®

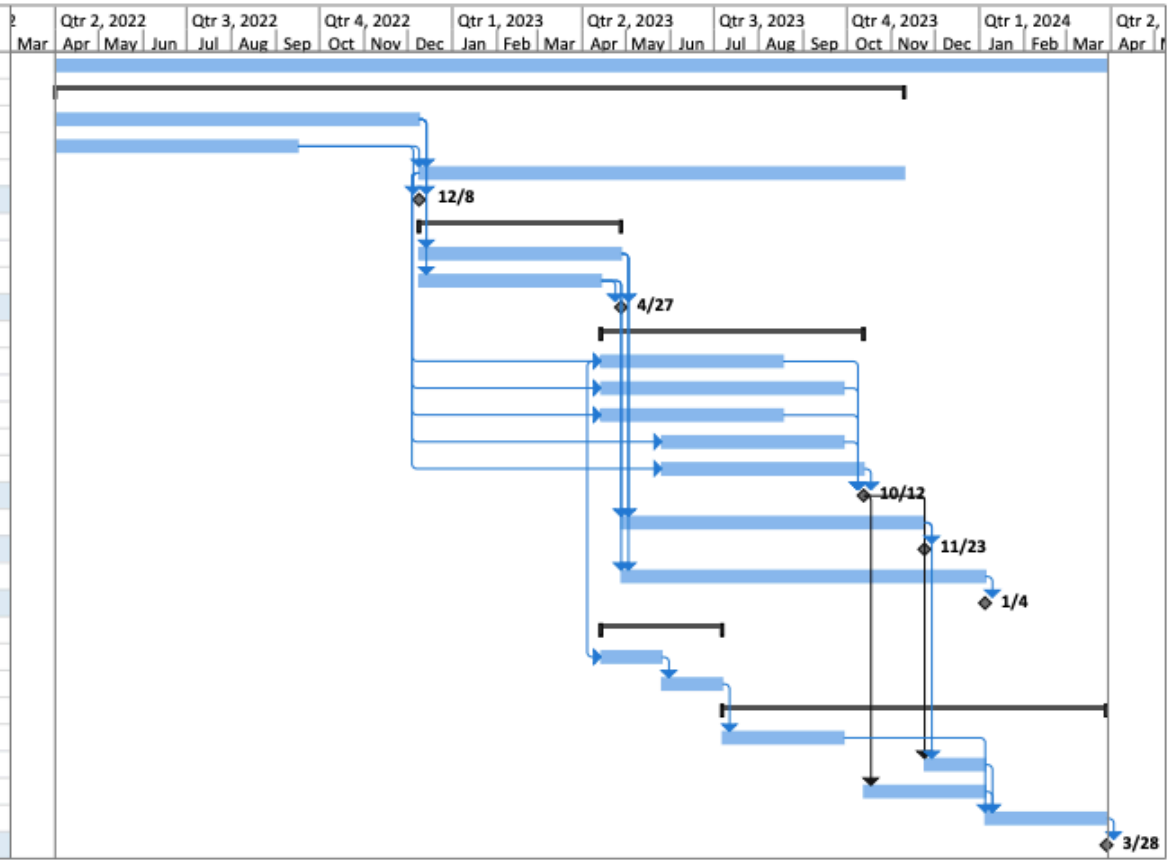
The EERC will scale up the aggregate production and produce the required amount of aggregate to support the fabrication of the required components.

August Brown

August Brown will support further market testing, analysis and commercialization as well as provide the expertise for Techno-Economic analysis.

Gantt Chart

ID	Task	Task Name	Duration	Start	Finish
1	**1.0**	**Project Management and Planning**	**521 days**	**Fri 4/1/22**	**Fri 3/29/24**
2	**2.0**	**Scale-Up of Production Methods**	**420 days**	**Fri 4/1/22**	**Thu 11/9/23**
3	2.1	Scale up ceramic aggregate production process	180 days	Fri 4/1/22	Thu 12/8/22
4	2.2	Scale up CDBM production process	120 days	Fri 4/1/22	Thu 9/15/22
5	2.3	Produce aggregate and CDBM using scale-up processes	240 days	Fri 12/9/22	Thu 11/9/23
6	***M1***	***Pilot production facilities complete and operating***	***0 days***	***Thu 12/8/22***	***Thu 12/8/22***
7	**3.0**	**Development and Demonstration of Fastening Methodolo**	**100 days**	**Fri 12/9/22**	**Thu 4/27/23**
8	3.1	Develop X-MORTAR	100 days	Fri 12/9/22	Thu 4/27/23
9	3.2	Develop X-PANEL fastening methodology	90 days	Fri 12/9/22	Thu 4/13/23
10	***M2***	***Binding / fastening methods for CDBM and TBM parts est***	***0 days***	***Thu 4/27/23***	***Thu 4/27/23***
11	**4.0**	**CDBM Component Testing**	**130 days**	**Fri 4/14/23**	**Thu 10/12/23**
12	4.1	Test X-TILES	90 days	Fri 4/14/23	Thu 8/17/23
13	4.2	Test X-PANELs	120 days	Fri 4/14/23	Thu 9/28/23
14	4.3	Test X-BRIX	90 days	Fri 4/14/23	Thu 8/17/23
15	4.4	Test X-BLOX	90 days	Fri 5/26/23	Thu 9/28/23
16	4.5	Test X-MATRIX as foundation material	100 days	Fri 5/26/23	Thu 10/12/23
17	***M3***	***Suitability of CDBM components for use as TBM alternati***	***0 days***	***Thu 10/12/23***	***Thu 10/12/23***
18	**5.0**	**Production of Technology Demonstrator**	**150 days**	**Fri 4/28/23**	**Thu 11/23/23**
19	***M4***	***Technology demonstrator prototype partial building com***	***0 days***	***Thu 11/23/23***	***Thu 11/23/23***
20	**6.0**	**Detailed Design of Complete Coal-Based Building**	**180 days**	**Fri 4/28/23**	**Thu 1/4/24**
21	***M5***	***Detailed building design complete***	***0 days***	***Thu 1/4/24***	***Thu 1/4/24***
22	**7.0**	**Market Testing and Analysis**	**60 days**	**Fri 4/14/23**	**Thu 7/6/23**
23	7.1	Supply CDBM samples to potential channel partners	30 days	Fri 4/14/23	Thu 5/25/23
24	7.2	Conduct test marketing and surveys	30 days	Fri 5/26/23	Thu 7/6/23
25	**8.0**	**Techno-Economic Analysis**	**190 days**	**Fri 7/7/23**	**Thu 3/28/24**
26	8.1	Update analysis of cost, benefits, and market potential	60 days	Fri 7/7/23	Thu 9/28/23
27	8.2	Update gap analysis	30 days	Fri 11/24/23	Thu 1/4/24
28	8.3	Update life-cycle analysis (LCA) for coal-based buildings	60 days	Fri 10/13/23	Thu 1/4/24
29	8.4	Update value chain, financial model, and sensitivity ana	60 days	Fri 1/5/24	Thu 3/28/24
30	***M6***	***Techno-economic analysis update complete***	***0 days***	***Thu 3/28/24***	***Thu 3/28/24***



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