EMBODIED ENERGY

CANNONDESIGN

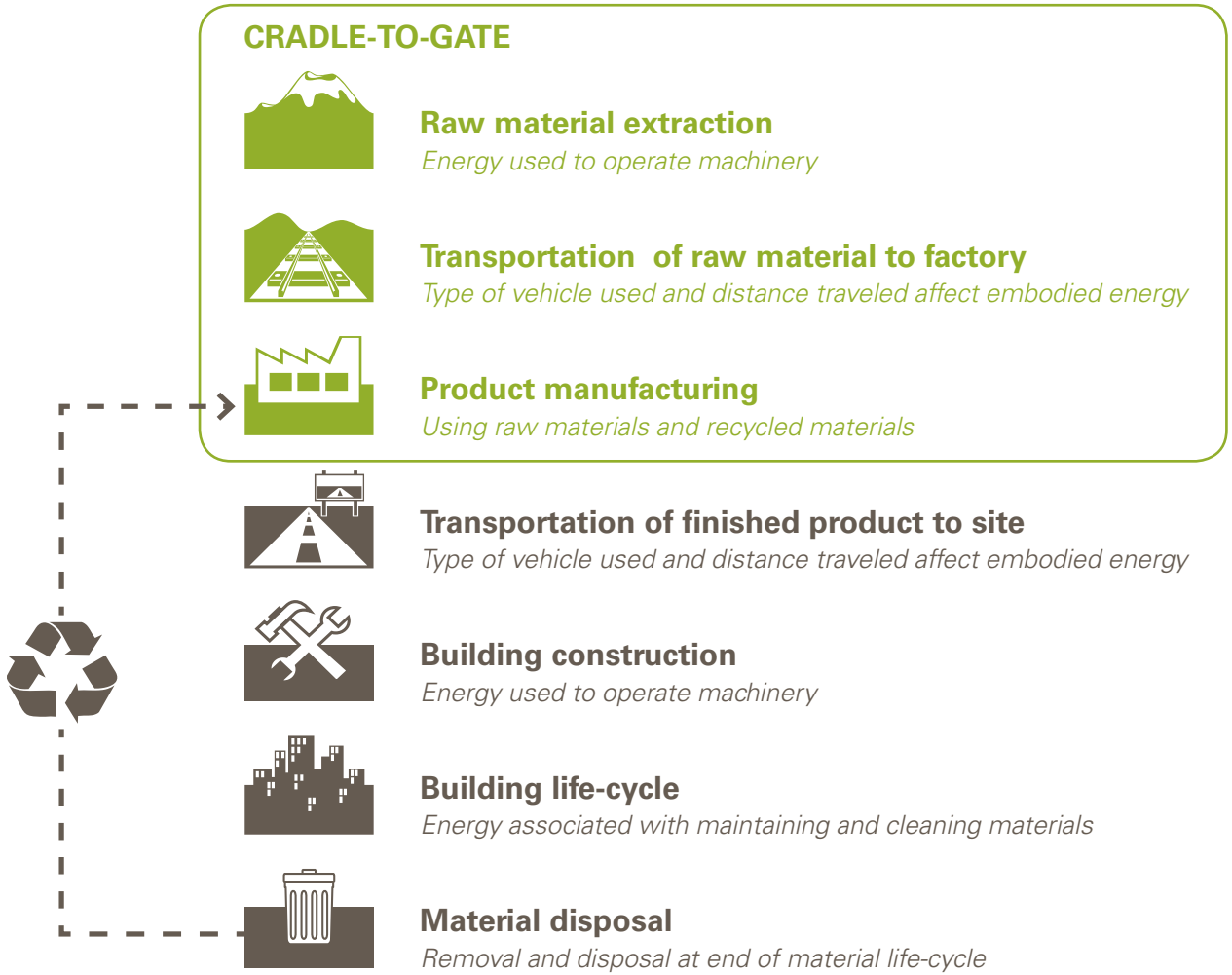
INTRODUCTION

What is Embodied Energy?

Embodied energy is defined as the total energy inputs consumed throughout a product's life-cycle. Initial embodied energy represents energy used for the extraction of raw materials, transportation to factory, processing and manufacturing, transportation to site, and construction. Once the material is installed, recurring embodied energy represents the energy used to maintain, replace, and recycle materials and components of a building throughout its life.

Embodied energy is typically expressed in MJ/kg, where a megajoule (MJ) is equal to 0.948 kBtu or 0.278 kWh.

The embodied energy values in Material LIFE have been converted to MJ per construction unit (i.e. ft^2 for flooring, LF for studs, etc.) and are listed for the cradle-to-gate portion of the product's life cycle, as highlighted in green in the diagram below.



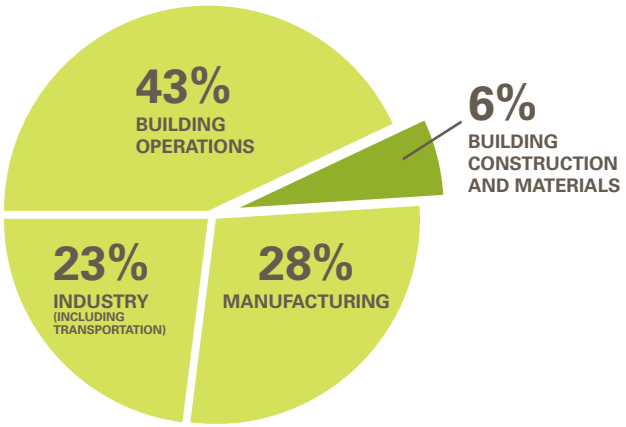
INTRODUCTION

Why Is Embodied Energy Important?

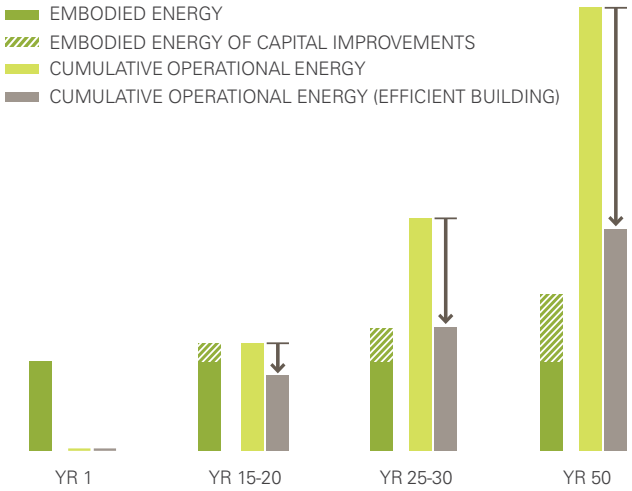
Energy is embodied in everything we use every day: from food to clothing to cars, as well as buildings and all materials used in them. In the United States, 6% of all energy consumed is used to manufacture and transport building materials (EIA 2009).

The architecture and engineering professions continue to drive down the energy buildings consume in their operations through initiatives like the AIA 2030 Commitment. As buildings consume less energy in operations, the energy embodied in the building's materials will become increasingly important as a percentage of a building's total energy footprint.

Academic studies have illustrated that embodied energy accounts for the majority of a building's energy footprint for approximately the first 15-20 years of a building's life-cycle. The bar chart below illustrates how reducing operational energy use extends the point at which operational energy adds up to equal embodied energy.



Annual Total Energy Consumed in the United States by Use Type (2009 Data)
Source: Architecture 2030 and Richard Stein (1977)



Comparison of operational and embodied energy over the life-cycle of a typical building

INTRODUCTION

What Can We Do to Reduce Embodied Energy?

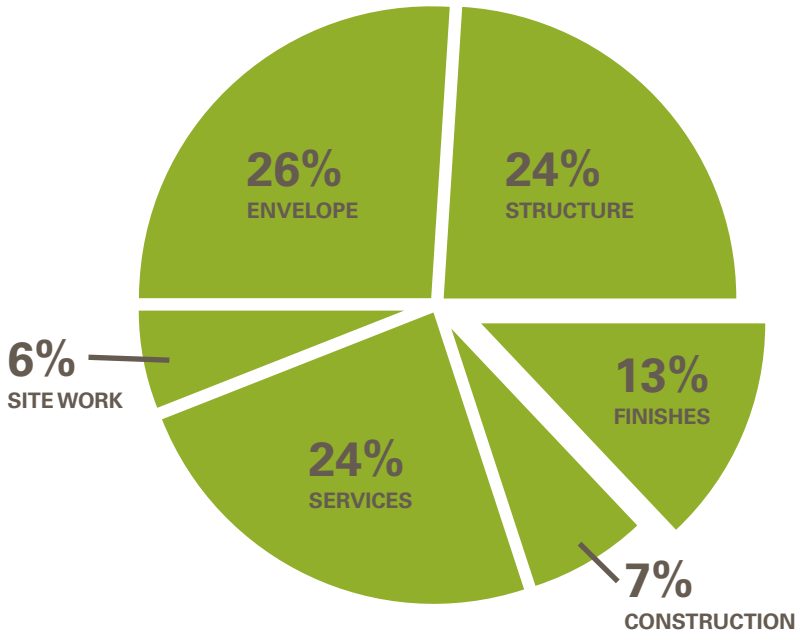
Architects, interior designers, and engineers need to be conscious of the embodied energy of the materials specified on projects so that they can select products that help reduce the overall energy footprint of buildings.

Given that the envelope and structure alone account for approximately 50% of a building's total embodied energy, we can reduce the footprint of our designs by selecting existing buildings for interior build-outs, renovations, or adaptive reuse projects.

Interior finishes account for approximately 13% of a building's embodied energy, so adaptive reuse or interior build-out projects have an overall smaller energy footprint that new construction.

A **study** conducted by Preservation Green Lab examined the impacts on climate, resource, human, and ecosystem associated with renovation and reuse projects. The study found that a building that is 30% more efficient than an average-performing existing building will take 10-80 years to overcome the negative climate change impacts related to the construction process.

However, selecting a renovation/reuse project is not enough; the quantity and type of materials used in the project is also important. For the most positive impact, we need to select materials with lower embodied energy, higher durability, lower levels of toxicity, and overall favorable life-cycle impacts.



Average initial embodied energy of an office building
Source: Cole and Kernan study (1996)

Embodied Energy of Transportation

Though Material LIFE focuses on the cradle-to-gate embodied energy of building materials, it is important to remember that large amounts of energy are then required to transport these materials to a project site.

The Regional Material credit in LEED begins to address the issue of embodied energy associated with transportation by limiting the distance from which building materials are manufactured and shipped to 500 miles. However, the mode of transportation should also be considered because different transport types have varying energy consumption per mile.

The figure below illustrates the energy consumed in megajoules per ton of material shipped a distance of 1 mile (data from Argonne National Laboratory). The most efficient transportation methods are ocean shipping and rail transport.

LONG HAUL AIRCRAFT - KEROSENE
9.49 **MJ/ton-mile** (6.5 MJ/tonne-km)

15 TON TRUCK - DIESEL (14 TONNE)
2.19 **MJ/ton-mile** (1.5 MJ/tonne-km)

35 TON TRUCK - DIESEL (32 TONNE)
1.37 **MJ/ton-mile** (0.94 MJ/tonne-km)

COASTAL SHIPPING - DIESEL
0.39 **MJ/ton-mile** (0.27 MJ/tonne-km)

RAIL - DIESEL
0.37 **MJ/ton-mile** (0.25 MJ/tonne-km)

OCEAN SHIPPING - DIESEL
0.23 **MJ/ton-mile** (0.16 MJ/tonne-km)

How to use Material LIFE

Material LIFE provides values for the **cradle-to-gate** embodied energy of common building materials and finishes (from extraction to factory gate). The document is organized into sections according to ASTM Uniformat categories and provides comparisons of materials based on their application in a building.

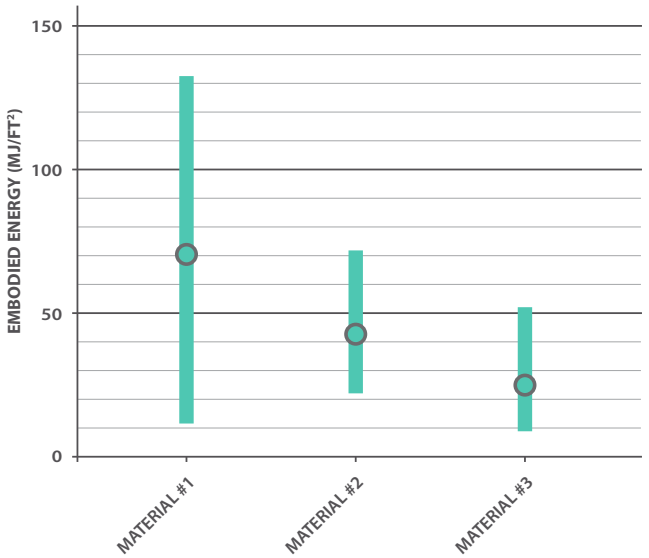
The current version of Material LIFE covers Interior Construction: Partitions and Doors; and Interior Finishes: Walls and Floors. Additional sections will be added once data is calculated for the following ASTM categories: Interior Finishes - Ceilings; Superstructure; Exterior Closure; Roofing; Staircases; and Furnishings.

Each section begins with an **'Summary' comparison graph** similar to the one below, followed by a list of detailed values for each material type and dimension. The comparison graph shows the embodied energy range for each material type and marks the mean value with a bubble.

Embodied energy is shown as a range for two reasons. First, each material includes different types of the specific material (i.e. virgin vs. recycled), as well as different dimensions (i.e. 1/4" glass vs. 1" glass). Second, not all materials are manufactured using the same process, so the embodied energy can vary from one manufacturer to the next. In most cases, a +/-30% range was used to account for these differences.

Once you have compared different material types using the summary graph, refer to the subsequent '**Values' table** to find more specific data points based on material type (i.e. natural vs. synthetic) or dimensions. Materials are organized in alphabetical order except for partitions and doors, which are organized according to type or tag.

Additional graphs are provided for materials with more detailed characteristics. For example, carpet has a graph in the 'Interior Finishes: Floors' section to compare fabrics, type, dye method, and backing options.

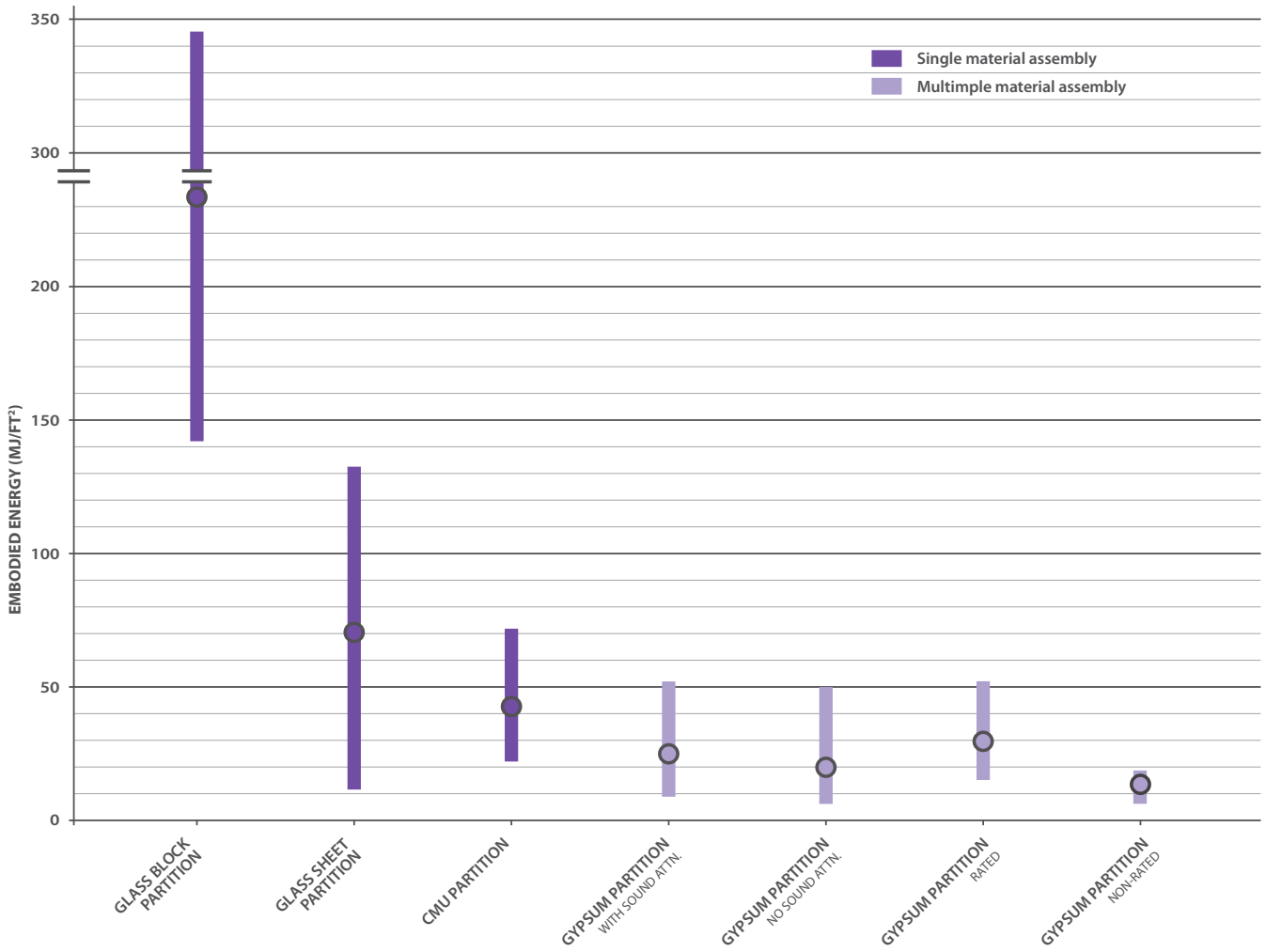


Sample ASTM category summary graph

Material	Emb. Energy MJ/ft²
Acrylic sheet (1/4" thick)	44.2 - 82.1
Acrylic sheet (3/8" thick)	66.3 - 123.1
Acrylic sheet (1/2" thick)	88.4 - 164.1
Acrylic sheet (3/4" thick)	132.6 - 246.2
Acrylic sheet (1" thick)	176.7 - 328.2
Brick (clay)	38.6 - 71.8
Ceramic Tile (1/16" thick)	2.6 - 4.8
Ceramic Tile (1/4" thick)	10.3 - 19.2
Ceramic Tile (5/16" thick)	12.9 - 24.0
Cork Tile (6 mm thick)	4.94 - 9.18
Cork Tile (painted, 6 mm thick)	6.09 - 11.32
Glass block, primary (3" thick)	185.8 - 345.1
Glass block, recycled (3" thick)	142.5 - 264.6
Glass sheet, primary (1/4" thick)	15.5 - 28.8
Glass sheet, primary (3/8" thick)	23.2 - 43.1
Glass sheet, primary (1/2" thick)	31.0 - 57.5

Sample 'Values' table for Wall Finishes

INTERIOR CONSTRUCTION:
PARTITIONS



VALUES

Material	Emb. Energy
CMU block (4" x 8" x 16")	15.9 - 23.8 MJ/block
CMU block (6" x 8" x 16")	24.7 - 37.0 MJ/block
CMU block (8" x 8" x 16")	33.4 - 50.2 MJ/block
CMU block (10" x 8" x 16")	42.2 - 63.3 MJ/block
CMU block (12" x 8" x 16")	51.0 - 76.5 MJ block
Glass block, primary (3" thick)	185.8 - 345.1 MJ/sf
Glass block, recycled (3" thick)	142.5 - 264.6 MJ/sf
Glass sheet, primary (1/4" thick)	15.5 - 28.8 MJ/sf
Glass sheet, primary (3/8" thick)	23.2 - 43.1 MJ/sf
Glass sheet, primary (1/2" thick)	31.0 - 57.5 MJ/sf
Glass sheet, primary (3/4" thick)	46.5 - 86.3 MJ/sf
Glass sheet, primary (1" thick)	61.9 - 115.0 MJ/sf
Glass sheet, primary (1-1/8" thick)	69.7 - 129.4 MJ/sf
Glass sheet, primary (1-1/4" thick)	77.4 - 143.8 MJ/sf
Glass sheet, primary (1-3/8" thick)	85.2 - 158.2 MJ/sf
Glass sheet, primary (1-1/2" thick)	92.9- 172.6 MJ/sf
Glass sheet, recycled (1/4" thick)	11.9 - 22.1 MJ/sf
Glass sheet, recycled (3/8" thick)	17.8 - 33.1 MJ/sf
Glass sheet, recycled (1/2" thick)	23.7 - 44.1 MJ/sf
Glass sheet, recycled (3/4" thick)	35.6 - 66.2 MJ/sf
Glass sheet, recycled (1" thick)	47.5 - 88.2 MJ/sf
Glass sheet, recycled (1-1/8" thick)	53.4 - 99.2 MJ/sf
Glass sheet, recycled (1-1/4" thick)	59.4 - 110.2 MJ/sf
Glass sheet, recycled (1-3/8" thick)	65.3 - 121.3 MJ/sf
Glass sheet, recycled (1-1/2" thick)	71.2 - 132.3 MJ/sf

Material	Emb. Energy
Gypsum + R.M.1 (1/2" regular)	2.8 - 5.3 MJ/sf
Gypsum + R.M.1 (5/8" regular)	3.5 - 6.5 MJ/sf
Gypsum + R.M.1 (1/2" type X)	2.8 - 5.3 MJ/sf
Gypsum + R.M.1 (5/8" type X)	3.5 - 6.5 MJ/sf
Gypsum + R.M.1 (1" shaftliner)	5.7 - 10.5 MJ/sf
Gypsum + S.C.2 (1/2" regular)	2.9 - 5.4 MJ/sf
Gypsum + S.C.2 (5/8" regular)	3.5 - 6.6 MJ/sf
Gypsum + S.C.2 (1/2" type X)	2.9 - 5.4 MJ/sf
Gypsum + S.C.2 (5/8" type X)	3.6 - 6.6 MJ/sf
Gypsum + S.C.2 (1" shaftliner)	5.7 - 10.6 MJ/sf
Insulation, cotton (1-1/2")	1.3 - 2.4 MJ/sf
Insulation, cotton (2")	1.7 - 3.2 MJ/sf
Insulation, cotton (3-1/2")	3.0 - 5.6 MJ/sf
Insulation, mineral fiber (1-1/2")	0.9 - 1.7 MJ/sf
Insulation, mineral fiber (2")	1.2 - 2.3 MJ/sf
Insulation, mineral fiber (3")	1.9 - 3.5 MJ/sf

[1] *R.M. = ready mix*
[2] *S.C. = setting compound*

VALUES

Material	Emb. Energy
Steel Stud, 25 gauge (1/2" R)	1.2 - 2.2 MJ/LF
Steel Stud, 25 gauge (7/8" H)	1.7 - 3.2 MJ/LF
Steel Stud, 25 gauge (1" Z)	1.3 - 2.5 MJ/LF
Steel Stud, 25 gauge (1-1/2" Z)	1.6 - 2.9 MJ/LF
Steel Stud, 25 gauge (1-5/8")	2.0 - 3.7 MJ/LF
Steel Stud, 25 gauge (2" Z)	1.8 - 3.3 MJ/LF
Steel Stud, 25 gauge (2-1/2")	2.4 - 4.4 MJ/LF
Steel Stud, 25 gauge (3-5/8")	2.9 - 5.4 MJ/LF
Steel Stud, 25 gauge (4")	3.1 - 5.7 MJ/LF
Steel Stud, 25 gauge (6")	4.0 - 7.4 MJ/LF
Steel Stud, 20 gauge (2-1/2")	3.8 - 7.0 MJ/LF
Steel Stud, 20 gauge (2-1/2" CH)	6.4 - 11.9 MJ/LF
Steel Stud, 20 gauge (3-5/8")	4.6 - 8.6 MJ/LF
Steel Stud, 20 gauge (4")	4.9 - 9.1 MJ/LF
Steel Stud, 20 gauge (4" CH)	7.1 - 13.2 MJ/LF
Steel Stud, 20 gauge (6")	6.4 - 11.8 MJ/LF
Steel Stud, 20 gauge (6" CH)	9.0 - 16.7 MJ/LF
Wood Stud (2" x 2")	1.0 - 1.9 MJ/LF
Wood Stud (2" x 3")	1.7 - 3.2 MJ/LF
Wood Stud (2" x 4")	2.4 - 4.5 MJ/LF
Wood Stud (2" x 6")	3.8 - 7.1 MJ/LF
Wood Stud (2" x 8")	5.0 - 9.3 MJ/LF
Wood Stud (2" x 10")	6.4 - 11.9 MJ/LF

VALUES

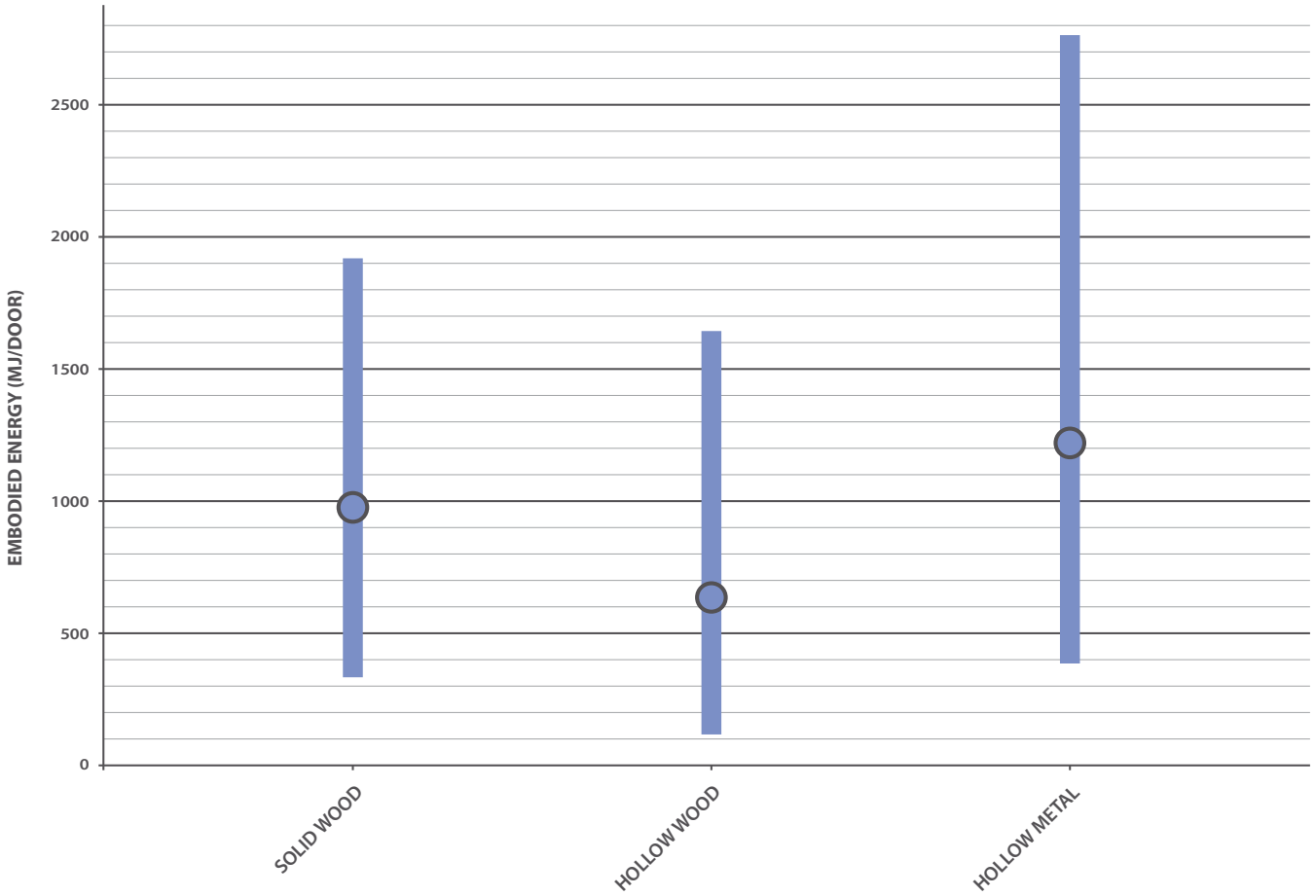
Cannon Design Partition	Emb. Energy MJ/ft²
10 (1-10-MAS-3-5/8)	2.4
11 (1-11-MAS-5-5/8)	34.7
12 (2-12-MAS-5-5/8)	34.7
13 (2-13-MAS-7-5/8)	47.0
14 (3-14-MAS-7-5/8)	47.0
15 (4-15-MAS-7-5/8)	47.0
20 (20-MAS-3-5/8)	22.4
21 (21-MAS-5-5/8)	34.7
22 (22-MAS-7-5/8)	47.0
23 (23-MAS-9-5/8)	59.4
24 (24-MAS-11-5/8)	71.7
A1 (1-A1-GWB-2SIDE-3-5/8-4-7/8-NONE)	16.6
A2 (1-A2-GWB-2SIDE-3-5/8-4-7/8-INSUL)	19.5
A3 (1-A3-GWB-2SIDE-4-5-1/4-NONE)	17.0
A4 (1-A4-GWB-2SIDE-4-5-1/4-INSUL)	19.9
A5 (1-A5-GWB-2SIDE-6-7-1/4-NONE)	19.1
A6 (1-A6-GWB-2SIDE-6-7-1/4-INSUL)	22.0
B1 (1-B1-GWB-2SIDE-5-1/2-NONE)	21.6
B2 (1-B2-GWB-2SIDE-5-1/2-INSUL)	24.5
B3 (1-B3-GWB-2SIDE-5-7/8-NONE)	22.0
B4 (1-B4-GWB-2SIDE-5-7/8-INSUL)	24.9
B5 (1-B5-GWB-2SIDE-7-7/8-NONE)	24.1
B6 (1-B6-GWB-2SIDE-7-7/8-INSUL)	27.0
C1 (2-C1-GWB-2SIDE-6-1/8-NONE)	26.6

Cannon Design Partition	Emb. Energy MJ/ft²
C2 (2-C2-GWB-2SIDE-6-1/8-INSUL)	29.5
C3 (2-C3-GWB-2SIDE-6-1/2-NONE)	27.1
C4 (2-C4-GWB-2SIDE-6-1/2-INSUL)	29.9
C5 (2-C5-GWB-2SIDE-8-1/2-NONE)	29.1
C6 (2-C6-GWB-2SIDE-8-1/2-INSUL)	32.0
D1 (3-D1-GWB-2SIDE-7-3/8-NONE)	36.7
D2 (3-D2-GWB-2SIDE-7-3/8-INSUL)	39.5
D3 (3-D3-GWB-2SIDE-7-3/4-NONE)	37.1
D4 (3-D4-GWB-2SIDE-7-3/4-INSUL)	39.9
D5 (3-D5-GWB-2SIDE-9-3/4-NONE)	39.2
D6 (3-D6-GWB-2SIDE-9-3/4-INSUL)	42.0
E1 (4-E1-GWB-2SIDE-8-5/8-NONE)	46.7
E2 (4-E2-GWB-2SIDE-8-5/8-INSUL)	49.6
E3 (4-E3-GWB-2SIDE-9-NONE)	47.1
E4 (4-E4-GWB-2SIDE-9-INSUL)	50.0
E5 (4-E5-GWB-2SIDE-11-NONE)	49.2
E6 (4-E6-GWB-2SIDE-11-INSUL)	52.0
F1 (1-F1-GWB-SHAFT-3-1/8-NONE)	22.3
F2 (1-F2-GWB-SHAFT-3-1/8-INSUL)	23.7
F3 (1-F3-GWB-SHAFT-4-5/8-NONE)	23.3
F4 (1-F4-GWB-SHAFT-4-5/8-INSUL)	26.2
F5 (1-F5-GWB-SHAFT-6-5/8-NONE)	26.0
F6 (1-F6-GWB-SHAFT-6-5/8-INSUL)	28.8
G1 (2-G1-GWB-SHAFT-3-3/4-NONE)	27.3

VALUES

Cannon Design Partition	Emb. Energy MJ/ft²
G2 (Basic Wall 2-G2-GWB-SHAFT-3-3/4-INSUL)	28.7
G3 (Basic Wall 2-G3-GWB-SHAFT-5-1/4-NONE)	28.3
G4 (Basic Wall 2-G4-GWB-SHAFT-5-1/4-INSUL)	31.1
G5 (Basic Wall 2-G5-GWB-SHAFT-7-1/4-NONE)	31.0
G6 (Basic Wall 2-G6-GWB-SHAFT-7-1/4-INSUL)	33.8
H1 (Basic Wall 1-H1-GWB-CHASE-2-1/2-NONE)	15.4
H2 (Basic Wall 1-H2-GWB-CHASE-2-1/2-INSUL)	18.3
H3 (Basic Wall 1-H3-GWB-CHASE-3-5/8-NONE)	16.6
H4 (Basic Wall 1-H4-GWB-CHASE-3-5/8-INSUL)	19.5
J1 (Basic Wall J1-GWB-1SIDE-1-1/2-NONE)	7.5
J2 (Basic Wall J2-GWB-1SIDE-1-5/8-NONE)	6.9
J3 (Basic Wall J3-GWB-1SIDE-2-1/8-NONE)	7.2
J4 (Basic Wall J4-GWB-1SIDE-2-5/8-NONE)	7.6
K1 (Basic Wall K1-GWB-1SIDE-1-1/8-NONE)	6.7
L1 (Basic Wall L1-GWB-1SIDE-2-1/4-NONE)	7.8
L2 (Basic Wall L2-GWB-1SIDE-3-1/8-NONE)	8.4
L3 (Basic Wall L3-GWB-1SIDE-4-1/4-NONE)	9.1
M1 (Basic Wall M1-GWB-1SIDE-2-1/4-NONE)	9.3
M2 (Basic Wall M2-GWB-1SIDE-3-1/8-NONE)	10.3
M3 (Basic Wall M3-GWB-1SIDE-4-1/4-NONE)	12.0
N1 (Basic Wall N1-GWB-2SIDE-4-7/8-NONE)	14.1
N2 (Basic Wall N2-GWB-2SIDE-4-7/8-INSUL)	17.0
N3 (Basic Wall N3-GWB-2SIDE-5-1/4-NONE)	14.4
N4 (Basic Wall N4-GWB-2SIDE-5-1/4-INSUL)	17.2
N5 (Basic Wall N5-GWB-2SIDE-7-1/4-NONE)	15.7
N6 (Basic Wall N6-GWB-2SIDE-5-1/4-INSUL)	18.5
P1 (Basic Wall P1-BWB-2SIDE-3-3/4-NONE)	13.4
P2 (Basic Wall P2-BWB-2SIDE-3-3/4-INSUL)	16.3
P3 (Basic Wall P3-BWB-2SIDE-4-7/8-NONE)	14.1
P4 (Basic Wall P4-BWB-2SIDE-4-7/8-INSUL)	17.0
P5 (Basic Wall P5-BWB-2SIDE-5-1/4-NONE)	14.4
P6 (Basic Wall P6-BWB-2SIDE-5-1/4-INSUL)	17.2
R1 (Basic Wall R1-GWB-2SIDE-4-7/8-NONE)	14.1
R2 (Basic Wall R2-GWB-2SIDE-4-7/8-INSUL)	17.0
R3 (Basic Wall R3-GWB-2SIDE-5-1/4-NONE)	14.4
R4 (Basic Wall R4-GWB-2SIDE-5-1/4-INSUL)	17.2
R5 (Basic Wall R5-GWB-2SIDE-7-1/4-NONE)	15.7
R6 (Basic Wall R6-GWB-2SIDE-7-1/4-INSUL)	18.5
S1 (Basic Wall S1-GWB-CHASE-2-1/2-NONE)	13.4
S2 (Basic Wall S2-GWB-CHASE-2-1/2-INSUL)	16.3
S3 (Basic Wall S3-GWB-CHASE-3-5/8-NONE)	14.1
S4 (Basic Wall S4-GWB-CHASE-3-5/8-INSUL)	17.0
T1 (Basic Wall T1-GWB-CHASE-2-1/2-NONE)	13.4
T2 (Basic Wall T2-GWB-CHASE-2-1/2-INSUL)	16.3
T3 (Basic Wall T3-GWB-CHASE-3-5/8-NONE)	14.1
T4 (Basic Wall T4-GWB-CHASE-3-5/8-INSUL)	17.0
X2 (Basic Wall X2-GWB-1SIDE-3-1/8-NONE)	8.4

INTERIOR CONSTRUCTION: DOORS

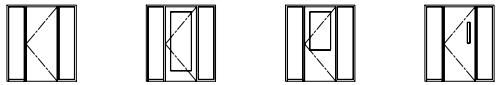


VALUES

Single Fixed

Single Fixed w/ 1 Sidelight

Single Fixed w/ 2 Sidelight



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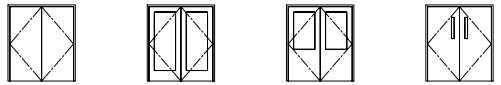

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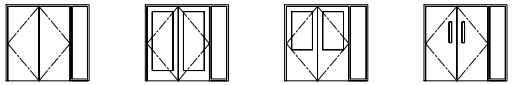

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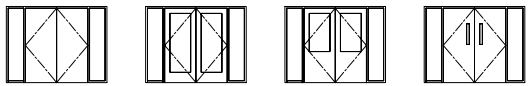


Cannon Design Door Type	Emb. Energy MJ/door
SOLID WOOD	
Single Fixed - Type F	504.9
Single Fixed - Type FG	483.8
Single Fixed - Type HG	491.4
Single Fixed - Type N	502.3
Single Fixed w/ 1 sidelight - Type F	737.2
Single Fixed w/ 1 sidelight - Type FG	716.0
Single Fixed w/ 1 sidelight - Type HG	723.7
Single Fixed w/ 1 sidelight - Type N	734.6
Single Fixed w/ 2 sidelight - Type F	969.4
Single Fixed w/ 2 sidelight - Type FG	948.3
Single Fixed w/ 2 sidelight - Type HG	956.0
Single Fixed w/ 2 sidelight - Type N	968.5
Double Fixed - Type F	1,009.7
Double Fixed - Type FG	967.5
Double Fixed - Type HG	982.9
Double Fixed - Type N	1,007.8
Double Fixed w/ 1 sidelight - Type F	1,242.0
Double Fixed w/ 1 sidelight - Type FG	1,199.8
Double Fixed w/ 1 sidelight - Type HG	1,215.2
Double Fixed w/ 1 sidelight - Type N	1,240.1
Double Fixed w/ 2 sidelight - Type F	1,474.3
Double Fixed w/ 2 sidelight - Type FG	1,432.1
Double Fixed w/ 2 sidelight - Type HG	1,447.4
Double Fixed w/ 2 sidelight - Type N	1,472.4

VALUES

Cannon Design Door Type	Emb. Energy MJ/door
HOLLOW WOOD	
Single Fixed - Type F	168.6
Single Fixed - Type FG	400.1
Single Fixed - Type HG	320.3
Single Fixed - Type N	207.2
Single Fixed w/ 1 sidelight - Type F	400.9
Single Fixed w/ 1 sidelight - Type FG	632.4
Single Fixed w/ 1 sidelight - Type HG	552.6
Single Fixed w/ 1 sidelight - Type N	439.5
Single Fixed w/ 2 sidelight - Type F	633.1
Single Fixed w/ 2 sidelight - Type FG	864.7
Single Fixed w/ 2 sidelight - Type HG	784.9
Single Fixed w/ 2 sidelight - Type N	655.1
Double Fixed - Type F	337.1
Double Fixed - Type FG	800.3
Double Fixed - Type HG	640.6
Double Fixed - Type N	381.1
Double Fixed w/ 1 sidelight - Type F	569.4
Double Fixed w/ 1 sidelight - Type FG	1,032.5
Double Fixed w/ 1 sidelight - Type HG	872.9
Double Fixed w/ 1 sidelight - Type N	613.4
Double Fixed w/ 2 sidelight - Type F	801.7
Double Fixed w/ 2 sidelight - Type FG	1,264.8
Double Fixed w/ 2 sidelight - Type HG	1,105.2
Double Fixed w/ 2 sidelight - Type N	845.7

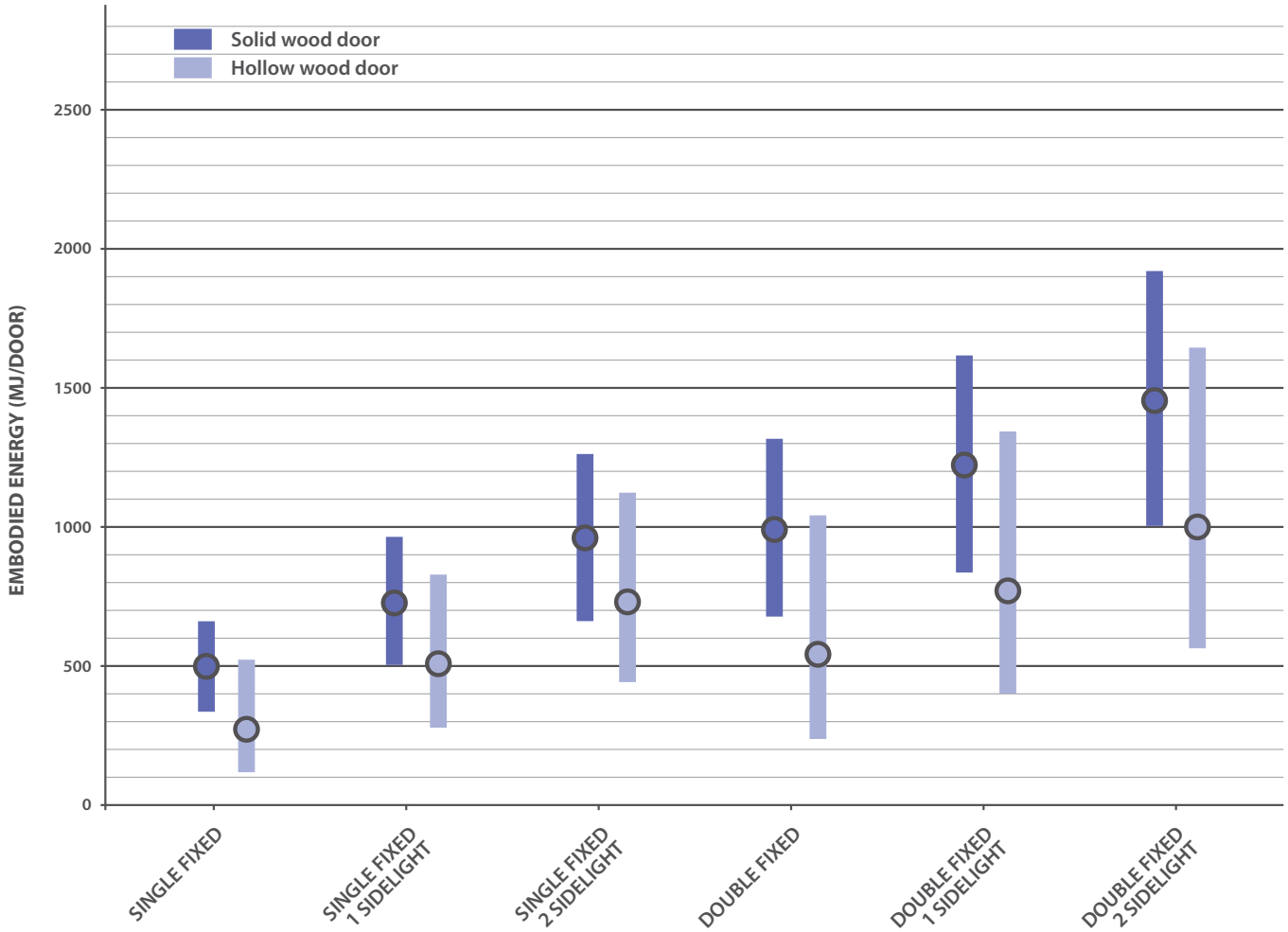
Cannon Design Door Type	Emb. Energy MJ/door
S.D. HOLLOW METAL - KRAFT-PAPER HONEYCOMB	
Single Fixed - Type F	596.7
Single Fixed - Type FG	546.6
Single Fixed - Type HG	564.9
Single Fixed - Type N	590.6
Single Fixed w/ 1 sidelight - Type F	829.0
Single Fixed w/ 1 sidelight - Type FG	778.9
Single Fixed w/ 1 sidelight - Type HG	797.1
Single Fixed w/ 1 sidelight - Type N	822.9
Single Fixed w/ 2 sidelight - Type F	1,061.3
Single Fixed w/ 2 sidelight - Type FG	1,011.2
Single Fixed w/ 2 sidelight - Type HG	1,029.4
Single Fixed w/ 2 sidelight - Type N	1,059.0
Double Fixed - Type F	1,193.4
Double Fixed - Type FG	1,093.3
Double Fixed - Type HG	1,129.7
Double Fixed - Type N	1,188.9
Double Fixed w/ 1 sidelight - Type F	1,425.7
Double Fixed w/ 1 sidelight - Type FG	1,325.6
Double Fixed w/ 1 sidelight - Type HG	1,362.0
Double Fixed w/ 1 sidelight - Type N	1,421.2
Double Fixed w/ 2 sidelight - Type F	1,658.0
Double Fixed w/ 2 sidelight - Type FG	1,557.9
Double Fixed w/ 2 sidelight - Type HG	1,594.3
Double Fixed w/ 2 sidelight - Type N	1,653.4

VALUES

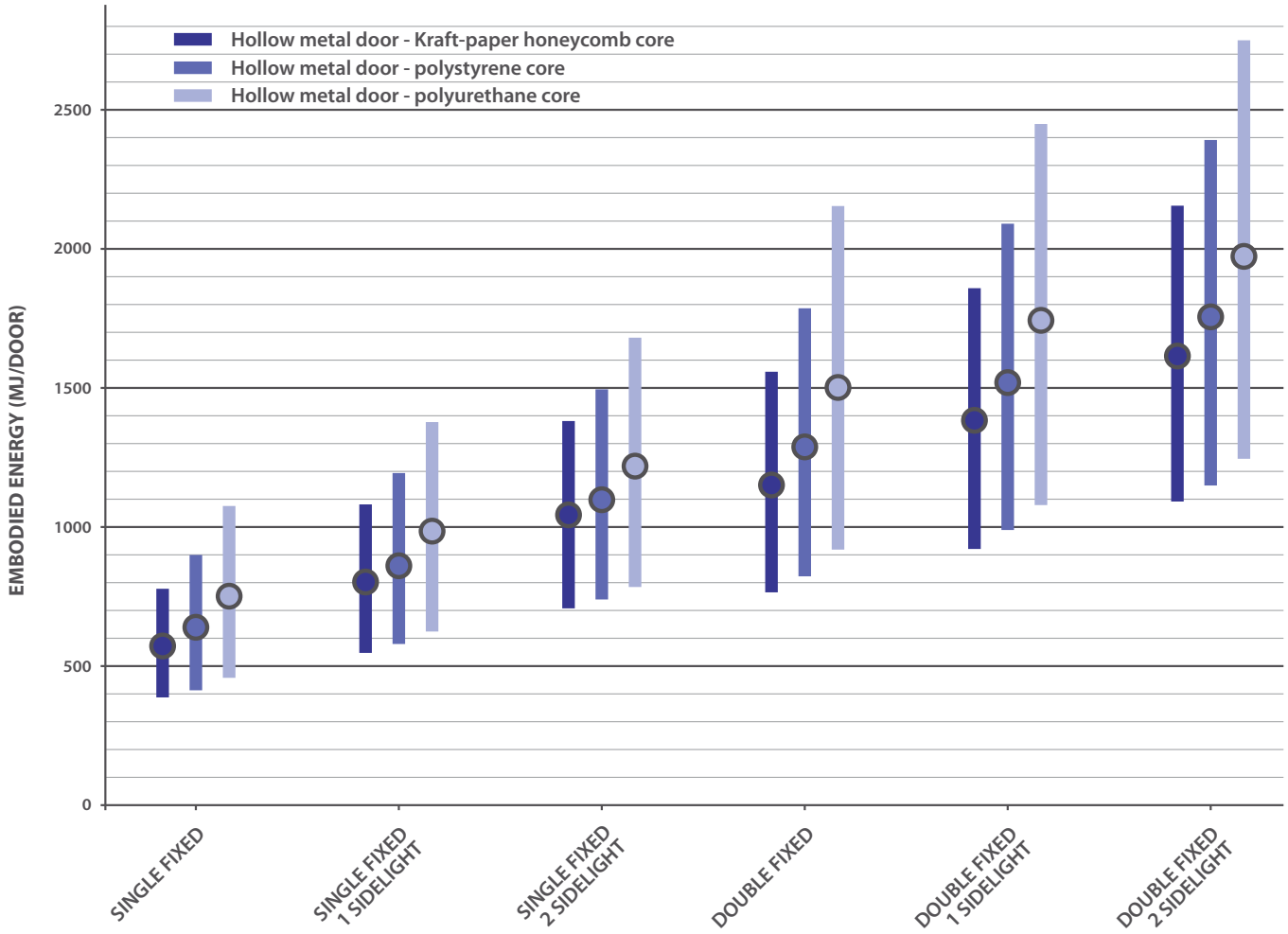
Cannon Design Door Type	Emb. Energy MJ/door
S.D. HOLLOW METAL - POLYSTYRENE CORE	
Single Fixed - Type F	686.0
Single Fixed - Type FG	589.2
Single Fixed - Type HG	624.4
Single Fixed - Type N	674.3
Single Fixed w/ 1 sidelight - Type F	918.3
Single Fixed w/ 1 sidelight - Type FG	821.5
Single Fixed w/ 1 sidelight - Type HG	856.7
Single Fixed w/ 1 sidelight - Type N	906.6
Single Fixed w/ 2 sidelight - Type F	1,150.6
Single Fixed w/ 2 sidelight - Type FG	1,053.8
Single Fixed w/ 2 sidelight - Type HG	1,089.0
Single Fixed w/ 2 sidelight - Type N	1,146.2
Double Fixed - Type F	1,372.1
Double Fixed - Type FG	1,178.4
Double Fixed - Type HG	1,248.8
Double Fixed - Type N	1,363.3
Double Fixed w/ 1 sidelight - Type F	1,604.4
Double Fixed w/ 1 sidelight - Type FG	1,410.6
Double Fixed w/ 1 sidelight - Type HG	1,481.1
Double Fixed w/ 1 sidelight - Type N	1,595.7
Double Fixed w/ 2 sidelight - Type F	1,836.7
Double Fixed w/ 2 sidelight - Type FG	1,642.9
Double Fixed w/ 2 sidelight - Type HG	1,713.4
Double Fixed w/ 2 sidelight - Type N	1,827.9

Cannon Design Door Type	Emb. Energy MJ/door
S.D. HOLLOW METAL - POLYURETHANE CORE	
Single Fixed - Type F	827.0
Single Fixed - Type FG	656.3
Single Fixed - Type HG	718.4
Single Fixed - Type N	806.3
Single Fixed w/ 1 sidelight - Type F	1,059.3
Single Fixed w/ 1 sidelight - Type FG	888.6
Single Fixed w/ 1 sidelight - Type HG	950.7
Single Fixed w/ 1 sidelight - Type N	1,038.6
Single Fixed w/ 2 sidelight - Type F	1,291.6
Single Fixed w/ 2 sidelight - Type FG	1,120.9
Single Fixed w/ 2 sidelight - Type HG	1,183.0
Single Fixed w/ 2 sidelight - Type N	1,283.8
Double Fixed - Type F	1,654.1
Double Fixed - Type FG	1,312.6
Double Fixed - Type HG	1,436.8
Double Fixed - Type N	1,638.5
Double Fixed w/ 1 sidelight - Type F	1,886.3
Double Fixed w/ 1 sidelight - Type FG	1,544.9
Double Fixed w/ 1 sidelight - Type HG	1,669.1
Double Fixed w/ 1 sidelight - Type N	1,870.8
Double Fixed w/ 2 sidelight - Type F	2,118.6
Double Fixed w/ 2 sidelight - Type FG	1,777.2
Double Fixed w/ 2 sidelight - Type HG	1,901.4
Double Fixed w/ 2 sidelight - Type N	2,103.1

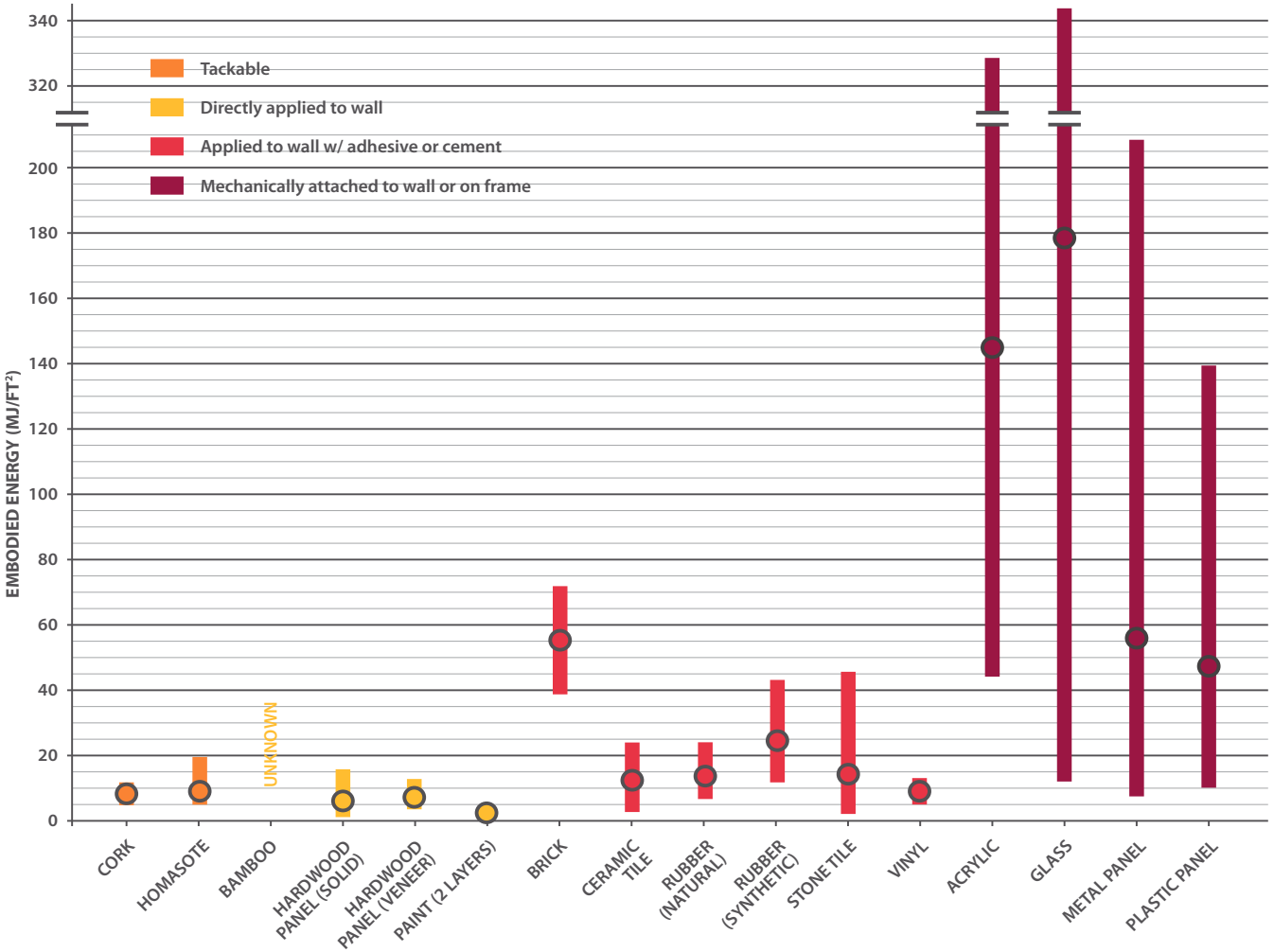
VALUES



VALUES



INTERIOR FINISHES:
WALLS



VALUES

Material	Emb. Energy MJ/ft²
Acrylic sheet (1/4" thick)	44.2 - 82.1
Acrylic sheet (3/8" thick)	66.3 - 123.1
Acrylic sheet (1/2" thick)	88.4 - 164.1
Acrylic sheet (3/4" thick)	132.6 - 246.2
Acrylic sheet (1" thick)	176.7 - 328.2
Bamboo[1]	unknown
Brick (clay)	38.6 - 71.8
Ceramic Tile (1/16" thick)	2.6 - 4.8
Ceramic Tile (1/4" thick)	10.3 - 19.2
Ceramic Tile (5/16" thick)	12.9 - 24.0
Cork Tile (6 mm thick)	4.94 - 9.18
Cork Tile (painted, 6 mm thick)	6.09 - 11.32
Glass block, primary (3" thick)	185.8 - 345.1
Glass block, recycled (3" thick)	142.5 - 264.6
Glass sheet, primary (1/4" thick)	15.5 - 28.8
Glass sheet, primary (3/8" thick)	23.2 - 43.1
Glass sheet, primary (1/2" thick)	31.0 - 57.5
Glass sheet, primary (3/4" thick)	46.5 - 86.3
Glass sheet, primary (1" thick)	61.9 - 115.0
Glass sheet, primary (1-1/8" thick)	69.7 - 129.4
Glass sheet, primary (1-1/4" thick)	77.4 - 143.8
Glass sheet, primary (1-3/8" thick)	85.2 - 158.2
Glass sheet, primary (1-1/2" thick)	92.9- 172.6

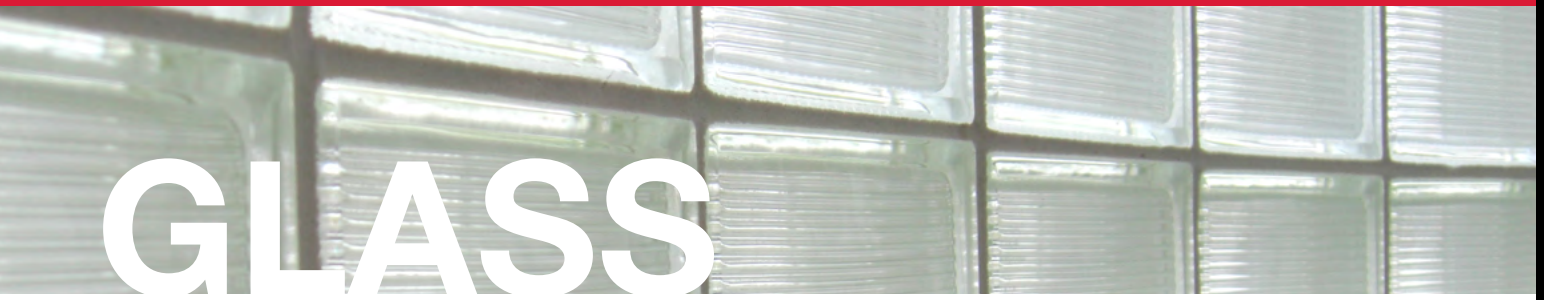
Material	Emb. Energy MJ/ft²
Glass sheet, recycled (1/4" thick)	11.9 - 22.1
Glass sheet, recycled (3/8" thick)	17.8 - 33.1
Glass sheet, recycled (1/2" thick)	23.7 - 44.1
Glass sheet, recycled (3/4" thick)	35.6 - 66.2
Glass sheet, recycled (1" thick)	47.5 - 88.2
Glass sheet, recycled (1-1/8" thick)	53.4 - 99.2
Glass sheet, recycled (1-1/4" thick)	59.4 - 110.2
Glass sheet, recycled (1-3/8" thick)	65.3 - 121.3
Glass sheet, recycled (1-1/2" thick)	71.2 - 132.3
Hardwood panel, solid (1/8" thick)	1.39 - 2.57
Hardwood panel, solid (3/16" thick)	2.08 - 3.86
Hardwood panel, solid (1/4" thick)	2.77 - 5.15
Hardwood panel, solid (5/16" thick)	3.46 - 6.43
Hardwood panel, solid (5/8" thick)	6.93 - 12.86
Hardwood panel, solid (3/4" thick)	8.31 - 15.44
Hardwood panel, veneer (1/8" thick)	3.4 - 6.4
Hardwood panel, veneer (5/32" thick)	4.3 - 7.9
Hardwood panel, veneer (3/16" thick)	5.1 - 9.5
Hardwood panel, veneer (1/4" thick)	6.8 - 12.7

[1] *Though cradle-to-gate embodied energy of bamboo is typically low (exact value unknown), building products using bamboo are typically manufactured and shipped from Asia and therefore have a high transportation embodied energy.*

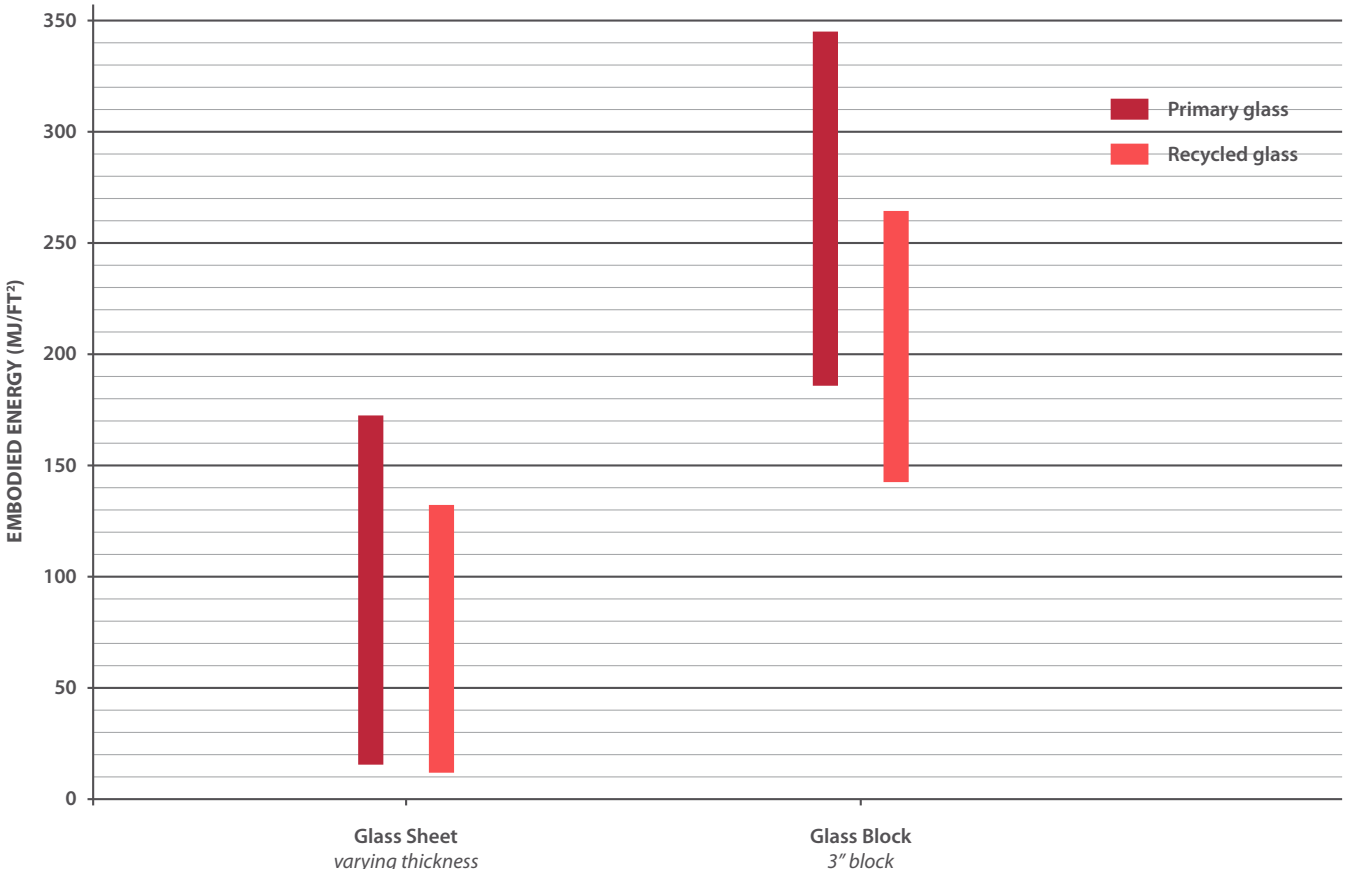
VALUES

Material	Emb. Energy MJ/ft²
Homasote, no cover (1/2" thick)	3.8 - 7.1
Homasote, no cover (5/8" thick)	4.8 - 8.9
Homasote, no cover (3/4" thick)	5.7 - 10.6
Homasote, polyester cover (1/2" thick)	13.6 - 25.3
Homasote, burlap cover (1/2" thick)	3.4 - 6.3
Metal panel, primary aluminum (0.063")	70.0 - 105.0
Metal panel, primary aluminum (0.09")	100.0 - 150.0
Metal panel, primary aluminum (0.125")	138.9 - 208.3
Metal panel, typical aluminum (0.063")	49.8 - 74.7
Metal panel, typical aluminum (0.09")	71.1 - 106.7
Metal panel, typical aluminum (0.125")	98.8 - 148.1
Metal panel, recycled aluminum (0.063")	9.3 - 14.0
Metal panel, recycled aluminum (0.09")	13.3 - 20.0
Metal panel, recycled aluminum (0.125")	18.5 - 27.7
Metal panel, galvanized steel (14 ga)	23.2 - 43.1
Metal panel, galvanized steel (19 ga)	13.5 - 25.0
Metal panel, galvanized steel (24 ga)	8.2 - 15.2
Metal panel, stainless steel (14 ga)	22.8 - 42.4
Metal panel, stainless steel (19 ga)	12.8 - 23.7
Metal panel, stainless steel (24 ga)	7.3 - 13.6
Paint, solventborne (2 layers)	1.89 - 3.52
Paint, waterborne (2 layers)	1.15 - 2.14

Material	Emb. Energy MJ/ft²
Plastic panel, polycarbonate (1/2" thick)	75.0 - 139.3
Plastic panel, HDPE (1/4" thick)	10.0 - 18.5
Plastic panel, HDPE (3/8" thick)	12.1 - 22.5
Plastic panel, HDPE (1" thick)	34.9 - 64.7
Rubber, natural (2 mm thick)	6.5 - 12.1
Rubber, natural (2.5 mm thick)	8.1 - 15.1
Rubber, natural (3 mm thick)	9.8 - 18.1
Rubber, natural (1/8" thick)	10.3 - 19.2
Rubber, natural (5/32" thick)	12.9 - 24.0
Rubber, synthetic (2 mm thick)	11.7 - 21.7
Rubber, synthetic (2.5 mm thick)	14.6 - 27.1
Rubber, synthetic (3 mm thick)	17.5 - 32.
Rubber, synthetic (1/8")	18.5 - 34.4
Rubber, synthetic (5/32" thick)	23.2 - 43.1
Stone panel, granite (3/8" thick)	18.4 - 34.2
Stone panel, granite (1/2" thick)	24.5 - 45.6
Stone panel, limestone (3/8" thick)	2.0 - 3.8
Stone panel, marble (10 mm thick)	7.4 - 13.8
Stone panel, sandstone (3/8" thick)	1.4 - 2.7
Vinyl, sheet (0.08" thick)	6.7 - 12.4

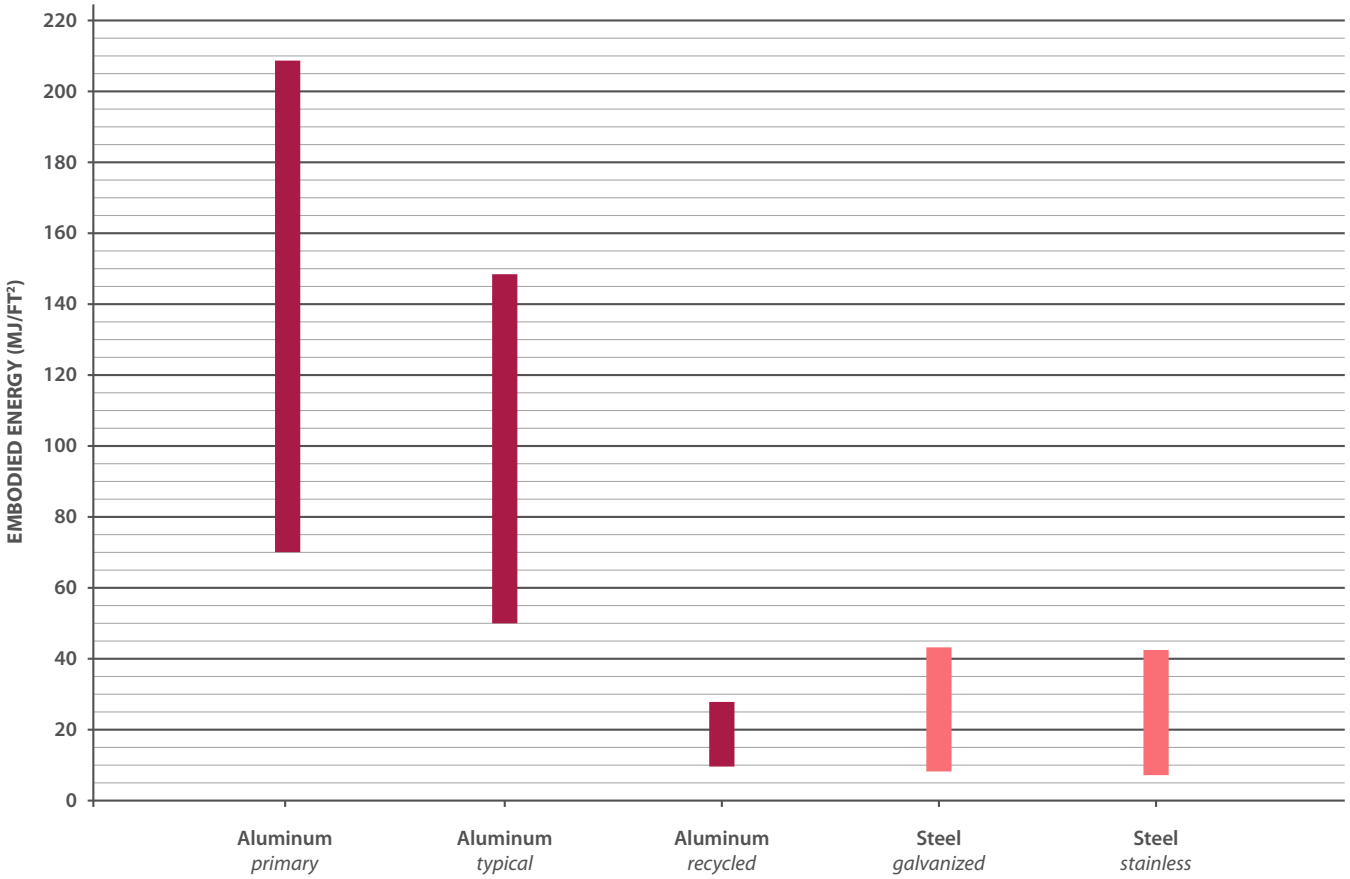


GLASS

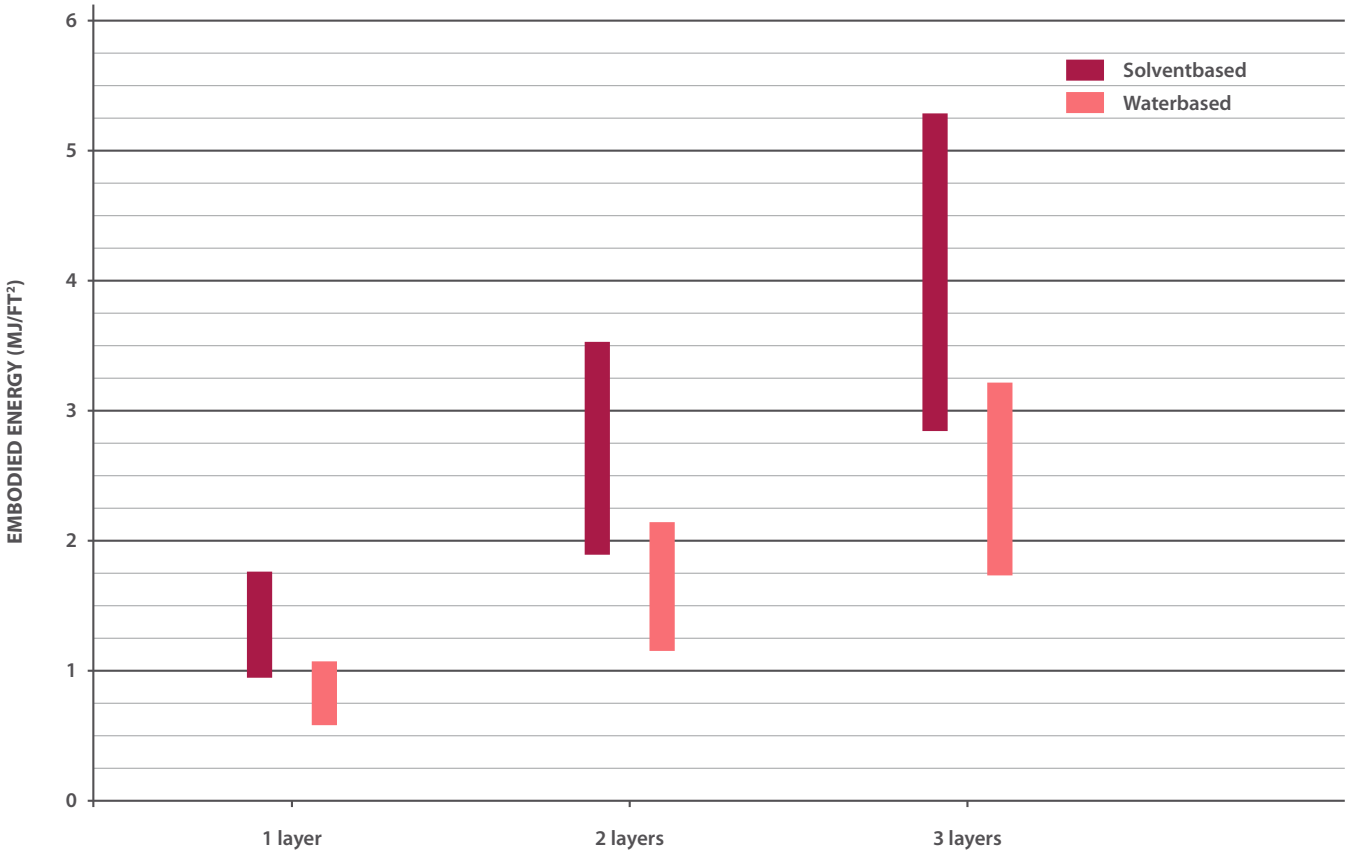


METAL PANEL

The range for primary aluminum is listed below to highlight the energy-intensive process used to produce aluminum. However, the worldwide average recycled content of aluminum is 33%, so an aluminum product rarely has 100% primary aluminum. If exact properties of aluminum are unknown, use "Typical" range.

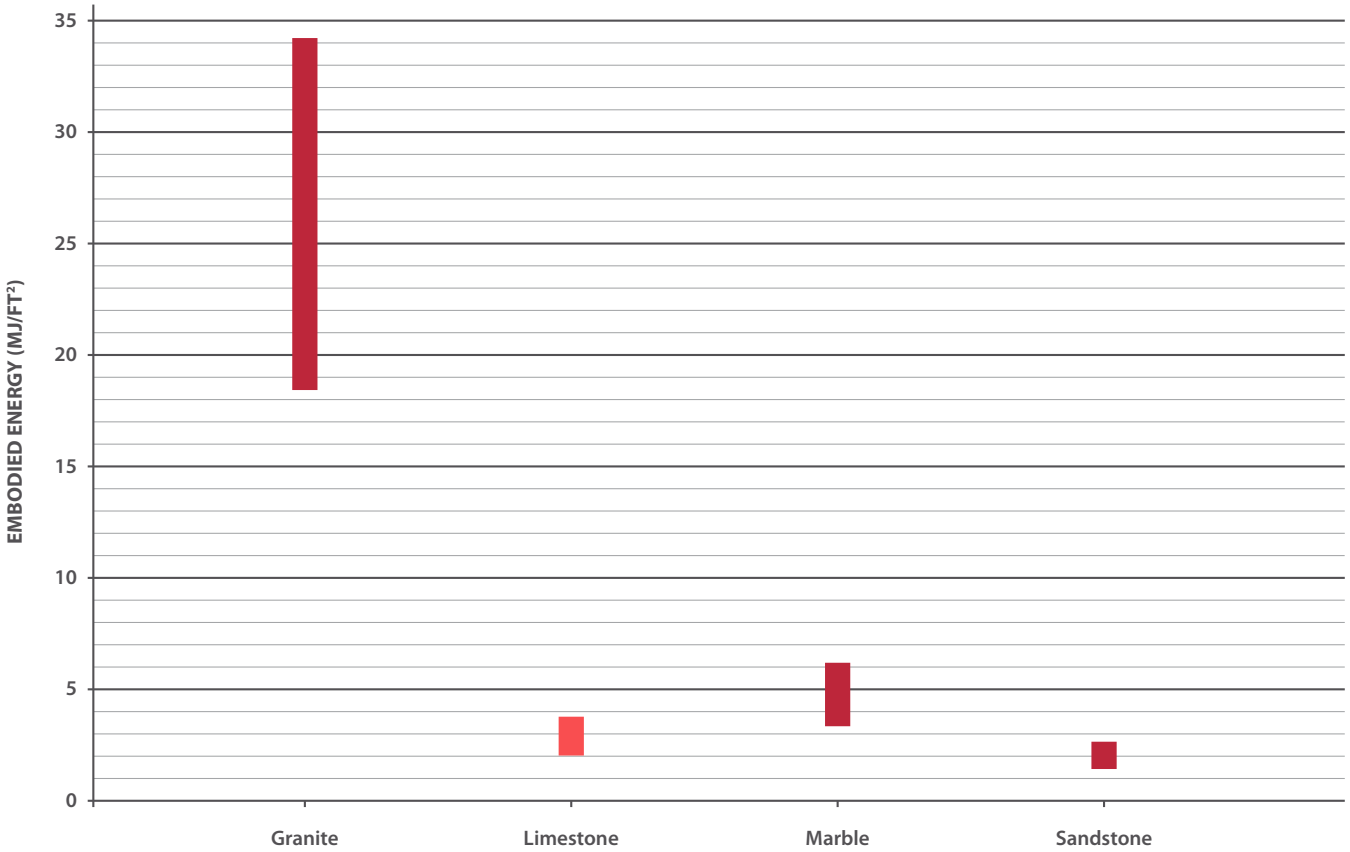


PAINT

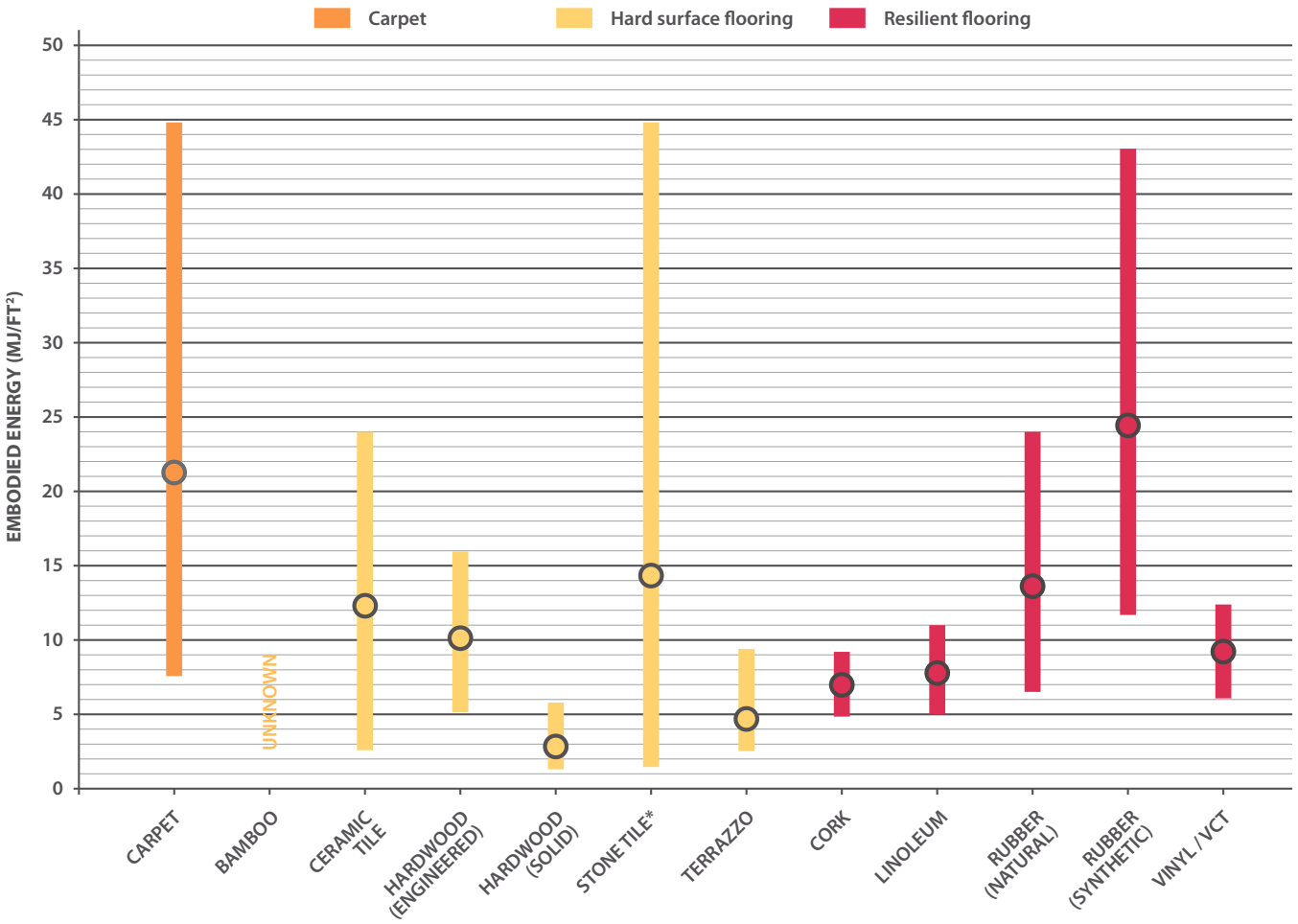


STONE

The embodied energy of stone is low because very little process energy is involved: the stone is quarried and then cut at the factory. However, since it is a heavy material, the energy embodied in the transportation of the stone is high. Selecting regional quarries can reduce carbon emissions and the embodied energy of transportation. Values collected for granite had a wide range, so the graph below may not accurately represent the embodied energy of granite. Numbers will be updated as more data becomes available.



INTERIOR FINISHES:
FLOORS



VALUES

Material	Emb. Energy MJ/ft²
Bamboo [1]	unknown
Carpet (modular, Nylon 6)	7.6 - 13.4
Carpet (modular, Nylon 6,6)	11.5 - 45.5
Carpet (broadloom, Nylon 6,6)	13.6 - 36.4
Ceramic Tile (1/16" thick)	2.6 - 4.8
Ceramic Tile (1/4" thick)	10.3 - 19.2
Ceramic Tile (5/16" thick)	12.9 - 24.0
Cork Tile (6mm thick)	4.9 - 9.2
Hardwood, engineered (3/8" thick)	5.2 - 9.6
Hardwood, engineered (1/2" thick)	6.9 - 12.8
Hardwood, engineered (9/16" thick)	7.7 - 14.4
Hardwood, engineered (5/8" thick)	8.6 - 16.0
Hardwood, solid (5/16" thick)	1.3 - 2.4
Hardwood, solid (3/8" thick)	1.6 - 2.9
Hardwood, solid (3/4" thick)	3.1 - 5.8
Linoleum (1/10" thick)[1]	5.0 - 11.0
Rubber, natural (2 mm thick)	6.5 - 12.1
Rubber, natural (2.5 mm thick)	8.1 - 15.1
Rubber, natural (3 mm thick)	9.8 - 18.1
Rubber, natural (1/8" thick)	10.3 - 19.2
Rubber, natural (5/32" thick)	12.9 - 24.0
Rubber, synthetic (2 mm thick)	11.7 - 21.7
Rubber, synthetic (2.5 mm thick)	14.6 - 27.1
Rubber, synthetic (3 mm thick)	17.5 - 32.5
Rubber, synthetic (1/8")	18.5 - 34.4
Rubber, synthetic (5/32" thick)	23.2 - 43.1
Stone tile, granite (3/8" thick)[2]	18.4 - 34.2
Stone tile, granite (1/2" thick)[2]	24.5 - 45.6
Stone tile, marble (10 mm thick)	7.4 - 13.8
Terrazzo tile (1/2" thick)	2.0 - 3.8
Terrazzo tile (5/8" thick)	2.5 - 4.7
Terrazzo tile (7/8" thick)	3.5 - 6.6
Terrazzo slab (1-1/4" thick)	5.1 - 9.4
Vinyl, VCT (1/8" thick)	6.1 - 11.3
Vinyl, sheet (0.08" thick)	6.7 - 12.4

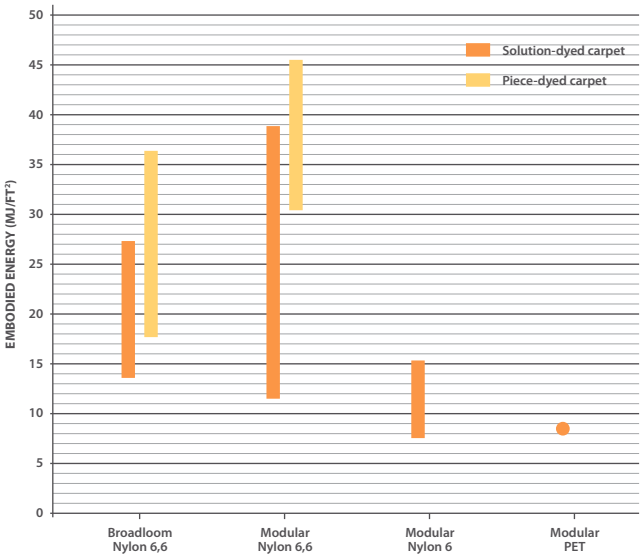
[1] Though cradle-to-gate embodied energy of bamboo, cork, and linoleum is low, these materials are typically manufactured and shipped from Europe (cork and linoleum) or Asia (bamboo) and therefore have a high transportation embodied energy.

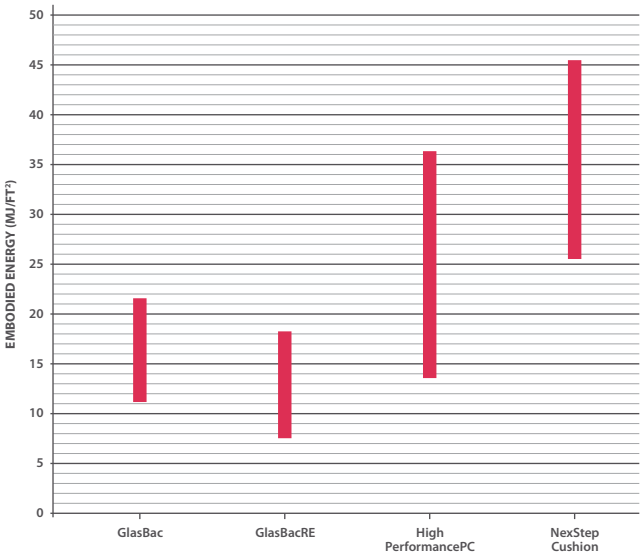
[2] Large range of values for granite; may not be accurate estimate.

CARPET

Several factors can affect the embodied energy of carpet:
- carpet type (broadloom vs. modular)
- face material (i.e. PET, wool, nylon 6, nylon 6,6)
- dye method (solution-dye vs. piece-dye)
- pile weight
- backing type/material

The graphs below and the following page show the variation in embodied energy calculated from EPDs (Environmental Product Declarations) published by Bentley Prince Street and InterfaceFLOR. The following conclusions can be made from these comparisons:
- Carpet that is piece-dyed has 15-25% more embodied energy than the same carpet that is solution-dyed.
- Nylon 6 has a lower embodied energy than Nylon 6,6; PET has similar embodied energy as Nylon 6.
- GlasBacRE, which is made from recycled materials, has a lower embodied energy than GlasBac.
- Embodied energy increases with pile weight.





These are trademarked carpet backings used by InterfaceFLOR and Bentley Prince Street.

CARPET

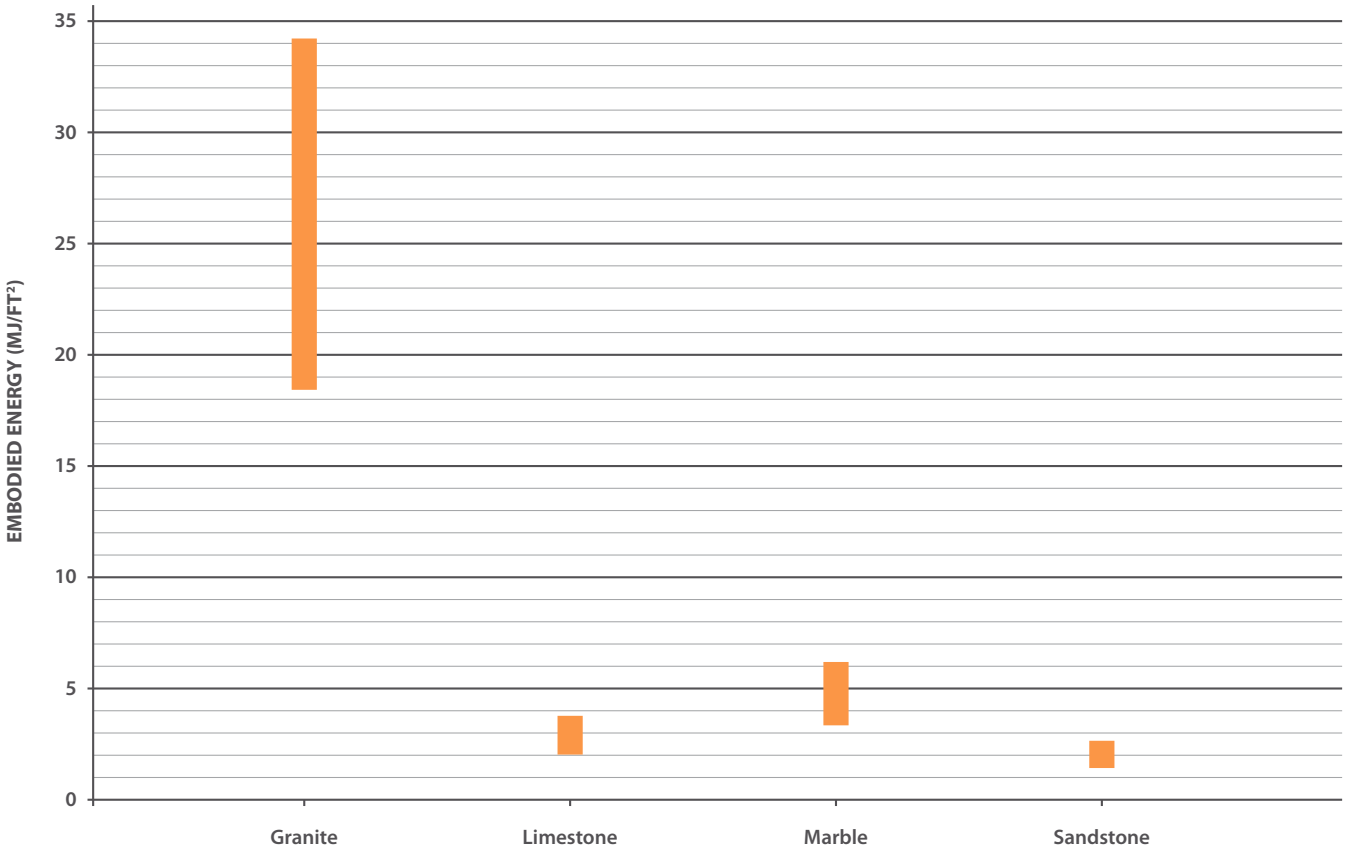
Manufacturer-Specific Embodied Energy Values

Use table to select carpet type, yarn type, dye method, backing, and pile weight to get estimated embodied energy value per square foot of material. Exact values will vary based on manufacturer.

MANUFACTURER	CARPET TYPE		YARN TYPE		DYE METHOD		BACKING	PILE WEIGHT	EMBODIED ENERGY
	Broadloom	Modular	Nylon 6	Nylon 6,6	Solution	Piece			
InterfaceFLOR		●	●		●		GlasBacRE	Low: 441 g/m^2	7.57 MJ/ft^2
								Medium: 712 g/m^2	8.75 MJ/ft^2
								High: 949 g/m^2	9.79 MJ/ft^2
InterfaceFLOR		●	●		●		GlasBac	Low: 441 g/m^2	11.21 MJ/ft^2
								Medium: 712 g/m^2	12.35 MJ/ft^2
								High: 1424 g/m^2	15.36 MJ/ft^2
InterfaceFLOR		●		●	●		GlasBacRE	Low: 441 g/m^2	11.53 MJ/ft^2
								Medium: 712 g/m^2	15.13 MJ/ft^2
								High: 949 g/m^2	18.29 MJ/ft^2
Bentley Prince Street	●			●	●		High PerformancePC	Low: 576 g/m^2	13.61 MJ/ft^2
								Medium: 1017 g/m^2	20.20 MJ/ft^2
								High: 1492 g/m^2	27.32 MJ/ft^2
InterfaceFLOR		●		●	●		GlasBac	Low: 441 g/m^2	15.05 MJ/ft^2
								Medium: 712 g/m^2	18.55 MJ/ft^2
								High: 1424 g/m^2	27.76 MJ/ft^2
Bentley Prince Street	●			●		●	High PerformancePC	Low: 576 g/m^2	17.69 MJ/ft^2
								Medium: 1017 g/m^2	26.68 MJ/ft^2
								High: 1492 g/m^2	36.36 MJ/ft^2
Bentley Prince Street		●		●	●		NexStep cushion	Low: 576 g/m^2	25.54 MJ/ft^2
								Medium: 1017 g/m^2	31.94 MJ/ft^2
								High: 1492 g/m^2	38.84 MJ/ft^2
Bentley Prince Street		●		●		●	NexStep cushion	Low: 576 g/m^2	30.42 MJ/ft^2
								Medium: 1017 g/m^2	37.67 MJ/ft^2
								High: 1492 g/m^2	45.49 MJ/ft^2

STONE

The embodied energy of stone is low because very little process energy is involved: the stone is quarried and then cut at the factory. However, since it is a heavy material, the energy embodied in the transportation of the stone is high. Selecting regional quarries can reduce carbon emissions and the embodied energy of transportation. Values collected for granite had a wide range, so the graph below may not accurately represent the embodied energy of granite. Numbers will be updated as more data becomes available.



INTERIOR FINISHES:
CEILINGS

VALUES

MATERIAL

REFERENCES

EMBODIED ENERGY DATABASES

Athena Sustainable Materials Institute, Product Life Cycle Inventory Studies
LCI reports and white papers on construction materials in North America.

greenspec
Summary table of embodied energy and density of common construction material (based mostly on ICE)

Institut Bauen und Umwelt e.V. / Institute Construction and Environment e.V.
Database of European Environmental Product Declarations (EPDs).

Inventory of Carbon and Energy (ICE), G.P. Hammond and C.I. Jones, University of Bath (2008)
Comprehensive inventory of embodied energy and embodied carbon of construction materials.

UL Environment Database of Validated and Certified Products
Searchable database of EPDs (among other certifications) that is updated as more EPDs become available.

ADDITIONAL RESOURCES

2030 Challenge for Products: Critical Points, Architecture 2030
Report summarizing the 2030 Challenge for Products, which includes guidelines on how to meet the challenge.

HOW CAN YOU HELP?

If you find Environmental Product Declarations (EPDs) or Life-Cycle Assessments (LCAs), **start a discussion** on the JIVE Sustainability page and provide the link or document so that we can add it to our Materials Resources library.

Ask product representatives and manufacturers if they have EPDs and/or LCAs for their products.

Contact Marion Lawson: **mlawson@cannondesign.com**, 312.960.8382