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Building with Brick: Sustainable and Energy Efficient

A White Paper on Performance Benefits of One of Man's Oldest Building Materials

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Boral USA

"Treat the Earth well. It was not given to you by your parents. It was loaned to you by your children."
- Kenyan Proverb

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Introduction

When people build today, whether it is a commercial project or a residential development or even a single home, they often seek the latest innovations that signal a commitment to treading lightly upon the Earth. Their goal is sustainability, defined by the United Nations in 1987 as "meeting present needs without compromising the ability of future generations to meet their needs." Their challenge is to identify construction materials and techniques that are not only Earth-friendly, but also durable and affordable. All too often, newly invented materials are not only disproportionately expensive, but also lack a time-tested track record that can provide reassurance about their expected performance.

As builders evaluate their options, they may be surprised to learn that one of man's oldest building materials is both natural and efficient – the very essence of sustainability. Brick offers sustainability advantages from at least three different perspectives: 1) It is made from the most abundant resources found on the planet; 2) it enhances a building's efficiency, both in short-term use and in long-term upkeep; and 3) when manufactured in an environmentally responsible manner, brick outranks other construction materials in terms of key sustainability metrics.

What is particularly notable is that in an era when many manufacturers make extravagant claims about the environmental virtues of their products, a trend that has come to be known as "greenwashing," the makers of brick can produce solid, measurable evidence to back their promise of sustainability. The following white paper lays out the well-documented underpinnings for the case that brick is a sustainable product that can satisfy today's desires to be environmentally responsible without adding extraordinary cost.

Historical Context

Historians trace man's earliest manufacturing of bricks to the banks of the Mesopotamian rivers, where overflowing water would turn earth into mud that could be shaped and baked in the sun once the waters receded. Archeologists have found manmade bricks dating back 10,000 years, and one brick arch still standing in the Middle East today was constructed around 4,000 B.C.

Early civilizations soon moved beyond using the sun's drying power when brick makers discovered that fire strengthened bricks and made them more durable. As people gathered together to form towns during medieval times, brick became the building material preferred over wood because of its resistance to the destructive fires that often swept through these communities. Eventually, brick was used throughout the world, wherever longevity was the goal. Examples abound of ancient structures built with brick, including the Great Wall of China in Asia, the Parthenon in Europe and the most venerable mosques in the Middle East.

Today's manufacturing techniques are much more sophisticated, but in some ways modern brick making would be very familiar to early man. Mixing together materials taken from the earth with moisture and then drying the shaped forms with fire is still the general formula for producing bricks. In addition, the abundance of brick-making materials and the durability of the finished product are as true today as they were thousands of years ago.

Natural Abundance

Scarcity is one of the concerns at the core of sustainability. However, the primary ingredients of brick are clay and shale, which can be found in every region of the world. The Mineral Information Institute notes that feldspar, a rock-forming mineral that weathers into clay continuously, is the "single most abundant mineral group on Earth. Together, the varieties of feldspar account for one-half of the Earth's crust." In addition, the Mineral Information Institute reports that geologists estimate that shale, rock that is composed of very fine clay particles, represents almost three-quarters of the sedimentary rock on the Earth's crust.

According to the Institute, these materials are so abundant that geologists and economists have not compiled data on potential deposits of feldspar for future consumption because it is widely assumed that there will be adequate supplies to meet needs stretching into the foreseeable future. The United States is self-sufficient when it comes to clay; in fact, the country exports nearly half of its production worldwide.

Because clay and shale "float" to the Earth's surface through weatherization, they are easily removed from the ground without the damaging environmental effects that accompany the mining of much more elusive resources that may only occur deep in the earth or in isolated pockets. Areas that are mined for clay and shale can be reclaimed to a natural state, or even turned into small lakes and parks for recreational uses.

Building Efficiency

A key element of construction sustainability is employing architectural design to reduce the use of energy over a building's usable life. Brick provides an energy-efficient envelope for a building that reduces the amount of energy necessary to heat or cool the interior. Because of its durability, brick also all but eliminates the need for exterior maintenance and outlasts most exterior cladding products on the market today, avoiding the energy usage involved in upkeep and replacement.

According to the U.S. Department of Energy's 2008 Buildings Energy Data Book, residential buildings consumed 37 percent of all electricity produced in the United States in 2006, while the share for commercial buildings was 36 percent. Space heating was responsible for the largest energy use (20 percent), followed by lighting and space cooling. This data makes it clear that controlling internal temperature is an important way to reduce energy usage and, therefore, improve sustainability.

Because brick provides the thermal mass necessary to insulate a building, it allows for a lower level of heating and air conditioning use. In summer, brick has the ability to absorb heat and shield the interior from a rapid rise in temperature. The heat is later released into the cooler night air. In winter, it effectively blocks cold and winds externally while retaining warmth generated internally. Brick veneer construction, with the standard one-inch air space between brick and the sheathing, achieves even higher insulating results.

Numerous evaluations by independent experts have verified the superior insulating qualities of brick. For example, a study by CTLGroup, a well-regarded materials technology research firm, compared different claddings for homes in 10 different climate zones across the United States. The study found that homes with brick veneer use 2 to 7 percent less energy than those with fiber cement siding and 1 to 2 percent less than those with insulated vinyl siding in southwestern climates.

Brick's advantages over other cladding products do not stop at reducing direct energy usage. Because brick does not fade, warp, dent or become brittle, it requires little maintenance or repair compared to other products. It is not compromised by mold, rot, bacteria or termites. It is widely recognized as being both resistant to fire and to water intrusion, both of which can considerably shorten the life of a building. In fact, because of its durability, the National Institute for Standards and Technology has rated brick masonry as having a 100-year lifespan, and there are many examples of far older structures that have retained their usability.

In addition, brick provides a comfortable environment for building users. It reduces noise transmission from the exterior. And it does not emit volatile organic compounds (VOCs), including chlorofluorocarbons, hydro chlorofluorocarbons and other ozone-depleting substances that raise both environmental and health issues.

Green Manufacturing and Construction

As people have become more discerning green consumers, they have discovered that products touted for some environmental advantages often have hidden drawbacks that may outweigh the benefits. Therefore, when pursuing sustainability, it is critical to analyze a product's life cycle from a number of perspectives to understand the environmental consequences of its use.

Several independent ways of assessing sustainability have emerged, such as the Building for Environmental and Economic Sustainability (BEES) software developed by the National Institute of Standards and Technology, which measures 12 environmental impacts, including fossil fuel depletion, indoor air quality, habitat alteration, ozone depletion, water intake, human health and more. Another assessment tool, McDonough Braungart Design Chemistry's Cradle to Cradle certification, measures the beginning-to-end recyclability of products by determining how resources used to make a product are perpetually circulated within a closed loop rather than ending life in a landfill. Two other types of software are particularly well-suited to capture all of the thermal mass implications of brick for accurate energy analysis. These are the Building Loads Analysis and System Thermodynamics (BLAST) program created by the University of Illinois Building Systems Laboratory and EnergyPlus, a program of the U.S. Department of Energy.

In addition, nationally renowned organizations that certify both commercial and residential buildings as constructed in environmentally preferred ways have established rating systems that take into account the sustainability of materials used. These include the U.S. Green Building Council's LEED program and the National Association of Home Builders' National Green Building Standard program.

In all of the various evaluation methods described above, brick's many positive attributes earn it high marks. Those attributes include:

- ***Efficient manufacturing practices.*** Manufacturers have significantly reduced the energy required to mine, manufacture and transport brick. In 2007, on average it required 1,239 BTU per pound, as determined by the BEES software, a sharp reduction from the approximately 4,000 BTU per pound required in the past, according to the Brick Institute of America.

- ***Alternative energy sources.*** Brick plants today make use of non-fossil fuel resources, such as burning methane captured from landfills, sawdust and agricultural waste products. For example, Boral USA uses methane in its Union City, Oklahoma plant and its LEED-certified Terre Haute, Indiana plant. In both cases, the methane not only replaces fossil fuels that the plants would otherwise consume but also removes a pollutant that the landfill operators would otherwise have to deal with.

- ***Recycled content.*** Brick can be made from unwanted materials, such as the mine tailings that constitute brown fields in some communities. In addition, waste products such as sawdust can be incorporated in brick in a burnout process that creates an end product that is lighter than but just as sturdy as regular brick.

- ***Minimized waste.*** Very little waste is produced in manufacturing and building with brick because the materials are inherently recyclable. A pound of clay material yields almost a pound of brick once water is extracted. During the manufacturing process, any materials that are left over after one run of bricks has been fired can simply be re-mixed into the next run. On the construction site, any brick debris can be recycled in a number of ways, including crushing the material for landscaping uses, reusing remaining brick for other projects and adding it to concrete as aggregate.

- ***Efficient transportation.*** Because materials to make brick can be found throughout the United States, manufacturing plants are sited to minimize the distance of transportation, both of the materials to make the brick and of the finished products to major areas for construction activity. The Brick Institute of America reports that most brick is manufactured from materials that are an average of 15 miles away from the plant. In addition, there are two or more plants within 500 miles of 49 of the 50 largest metropolitan areas within the United States, which includes the majority of construction projects in the country. More than 70 percent of the 50 have at least one plant within 200 miles. The energy used to transport brick is further reduced when lighter-weight products are used. For example, the Boral facility in Augusta, Georgia – which sells the largest quantity of brick in the United States – employs a specialized method of manufacturing that combines clay, shale and recycled wood waste to create such a lighter brick.

With today's sophisticated technology, it is possible to accurately evaluate the comparative performance of different building cladding materials. One way to compare materials is to examine the embodied energy. This is the energy required to produce a product, from extraction of materials through manufacturing and distribution. The following chart is provided by Architecture 2030. The first column measures energy density by mass (mega joules per kilogram), while the second measures energy density by size (mega joules per cubic meter). In both cases, lower numbers represent less energy usage.

To give these numbers more meaning, one can divide the embodied energy assessment by the life expectancy of a material. The following chart, which evaluates the kilowatt-hours used per ton, compares the embodied energy of brick with wood, fiber cement, concrete and vinyl. These are materials commonly considered when deciding on building cladding. Because of its long lifespan, brick tops the other materials; even without considering lifespan, it outperforms all materials but wood when it comes to embodied energy.

	EMBODIED ENERGY	
MATERIAL	MJ/kg	MJ/m3
Aggregate	0.10	150
Straw bale	0.24	31
Soil-cement	0.42	819
Stone (local)	0.79	2030
Concrete block	0.94	2350
Concrete (30 Mpa)	1.3	3180
Concrete precast	2.0	2780
Lumber	2.5	1380
Brick	2.5	5170
Cellulose insulation	3.3	112
Gypsum wallboard	6.1	5890
Particle board	8.0	4400
Aluminum (recycled)	8.1	21870
Steel (recycled)	8.9	37210
Shingles (asphalt)	9.0	4930
Plywood	10.4	5720
Mineral wool insulation	14.6	139
Glass	15.9	37550
Fiberglass insulation	30.3	970
Steel	32.0	251200
Zinc	51.0	371280
Brass	62.0	519560
PVC	70.0	93620
Copper	70.6	631164
Paint	93.3	117500
Linoleum	116	150930
Polystyrene Insulation	117	3770
Carpet (synthetic)	148	84900
Aluminum	227	515700

NOTE: Embodied energy values based on several international sources - local values may vary.

EMBODIED ENERGY* ANALYSIS OF BRICK

MATERIAL	WOOD	BRICK	FIBER CEMENT	CONCRETE	VINYL
kWh/PER TON	640	1240	2060	3200	3840
ADDITIONAL ENERGY REQUIREMENTS	REQUIRES REPEATED PAINTING, STAINING AND/OR SEALING OVER LIFE OF STRUCTURE**	OTHER THAN CLEANING, NO MAINTENANCE OR ADDITIONAL TREATMENT IS REQUIRED	REQUIRES REPEATED PAINTING OVER LIFE OF STRUCTURE**	REQUIRES REPEATED PAINTING OVER LIFE OF STRUCTURE**	OTHER THAN CLEANING, NO MAINTENANCE OR ADDITIONAL TREATMENT IS REQUIRED
PRODUCT LIFE	20–25 YEARS***	100 YEARS	50 YEARS	50 YEARS	50 YEARS
EMBODIED ENERGY/LIFETIME****	25.6 kWh PER TON PER YEAR	12.4 kWh PER TON PER YEAR	41.20 kWh PER TON PER YEAR	64.0 kWh PER TON PER YEAR	76.8 kWh PER TON PER YEAR

* Embodied energy refers to the energy required to extract raw materials, manufacture and transport the materials required to build a home, as well as the energy required to assemble and construct the house.

** The manufacturing processes used to produce paint, stain and seal are energy intensive, contributing to the embodied energy in the structure calculated over the life of the structure.

*** Life expectancy depends on quality of maintenance.

**** Embodied energy calculated over the life of the structure.

The National Brick Research Center at Clemson University has looked at embodied energy and other data to conduct a more comprehensive life cycle analysis of materials, including brick, block masonry, fiber cement, vinyl siding and EIFS (a form of stucco). The following chart looks at life span, recycling opportunity, energy usage, air and water pollution potential, energy required during distribution and waste. As the numbers at the bottom of the chart indicate, brick compares very favorably with the other materials.

CLADDING / LIFE CYCLE ANALYSIS

BASIC DATA	BRICK MASONRY	BLOCK MASONRY	FIBER CEMENT	VINYL SIDING	EIFS
WARRANTY WEIGHT / FT^2	100 YEARS 35.5 LB.	50 YEARS 42.8 LB.	50 YEARS 2.3 LB.	50 YEARS 0.5 LB.	5 YEARS 1.24 LB.
ENERGY, MINING AND MANUFACTURING	RECYCLING: BRICK 100% MORTAR 40%	RECYCLING: 80%	RECYCLING: 0%	RECYCLING: 80%	RECYCLING: 0%
RECYCLING AND ENERGY KWH / FT^2 / YR	ENERGY: 0.252	ENERGY: 0.228	ENERGY: 0.328	ENERGY: 0.210	ENERGY: 5.48
POLLUTION WATER AND AIR EMISSIONS LB / FT^2 / YR	0.011	0.005	0.026	0.001	0.023
DISTRIBUTION ENERGY AVG / DISTANCE, MILES AND NET ENERGY KWH / FT^2 / YR	175 MILES 0.004	100 MILES 0.004	365 MILES 0.146	310 MILES 0.001	300 MILES 0.189[3]
WASTE AND DEPLETION LB / FT^2 / YR	0.108	0.203	0.048	0.460[4]	0.828
TOTALS					
ENERGY	0.256	0.232	0.474	0.211	5.669
POLLUTION	0.011	0.005	0.026	0.001	0.023
WASTE AND DEPLETION	0.108	0.203	0.048	0.460	0.828

Research data in chart is generated by the National Brick Research Center, Clemson University.
1 There is no proven method of recycling available for fiber cement siding or EIFS.
2 Used the maximum allowed in this analysis (80%). According to the Vinyl Siding Institute, 100% of vinyl siding is recyclable. Some environmental groups claim recycling of vinyl siding results in dioxin emissions.
3 Low weight per truckload influenced results.
4 Depletion of salt in processing PVC influenced results.

Conclusion

As early mankind moved out of caves and into communities, brick was a preferred building material. Its ingredients were easy to find, the manufacturing process was simple and the results were durable.

With today's increasingly sophisticated approach to construction and people's growing commitment to sustainability, it is comforting to discover that brick remains a leading building material that can be trusted to deliver high performance, low maintenance, long life and a comparatively small footprint on the world our children have loaned us.

From architects who incorporate brick in their designs for its energy efficient qualities, to builders who appreciate its durability and ease of construction, to owners who enjoy its livability, brick is a top choice for building cladding. The fact that it is also sustainable makes it a building material for the ages.