

ROCKIN NATURAL STONE KNOWLEDGE:

What is natural stone?

Natural stones are those which have been harvested from their in-situ position in the earth, then cut and machined into final products without alteration to the natural fabric of the material.

Embodied Carbon and Natural Stone

Using healthier building materials with minimal amounts of processing will reduce the embodied carbon of building projects. Natural stone is a single ingredient, all-natural material with zero VOCs. Since mother nature does most of the manufacturing, its embodied energy is inherently low.



Also, natural stones are fully recyclable throughout its life cycle.

Natural stone can be recycled by being repurposed, reused, or crushed into smaller aggregates for use in various construction and landscaping projects. This process diverts valuable materials from landfills, reduces the demand for newly quarried stone, and saves significant energy compared to sourcing new raw materials. Large, undamaged pieces can be salvaged for new projects, while smaller or damaged stone is often broken down to be used in applications like road construction, patios, or as decorative landscaping fill.

Natural Stone Pavers

- **Main processes:** Quarrying, cutting, surface finishing, and transport.
- **Embodied Energy:**
 - ~0.79–1.20 MJ/kg (per BRE and other LCA sources).
 - Per m² (30–50 mm thick): ~100–150 MJ/m².
- **Key reason:** Very low manufacturing energy. Most energy is in quarrying, sawing, and transportation. No firing or chemical transformation needed.

- **Notes:** Local sourcing significantly reduces embodied energy, they are green and sustainable!
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Man-made landscape pavers are durable, prefabricated units used for outdoor surfaces like patios, walkways, and driveways. These engineered materials may offer greater uniformity and design flexibility than natural stone, and their characteristics vary depending on their composition. However, they have a higher embodied energy in their production.

Concrete pavers

These are manufactured paving stones made from a mixture of cement, sand, aggregates (such as gravel), water, and color pigments.

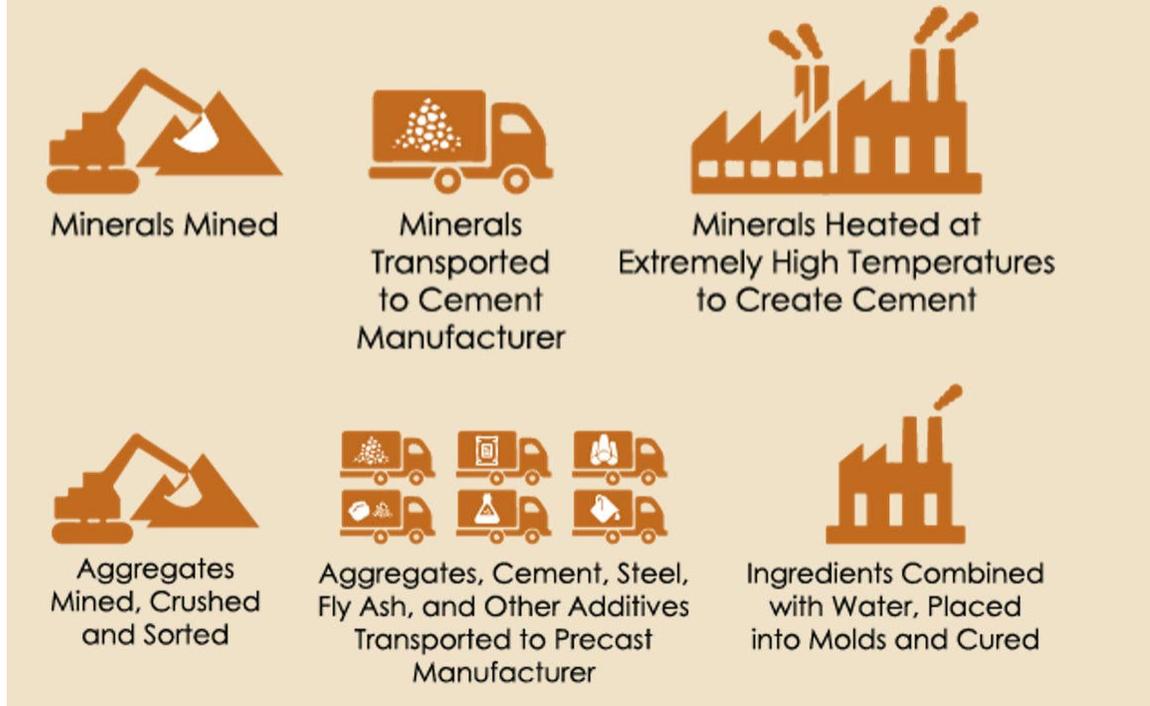
- **Manufacturing:** The mixture is poured into molds, vibrated to increase its density, and then cured to achieve extreme durability. This process makes them stronger than standard poured concrete. Cement production (very energy intensive), mixing with aggregates, molding, and curing.
- **Design and uses:** They are highly versatile and available in numerous colors, shapes, and sizes, with some styles mimicking brick or natural stone. They are widely used for driveways, pool decks, patios, and walkways.
- **Cost and maintenance:** First generation concrete pavers can be more affordable than clay pavers, with newer technologies being more expensive than clay pavers. They can be easily replaced individually if damaged, but newer replacement material may not match the older faded material. Lastly, they may require periodic sealing to maintain their color and prevent staining. Some of their newer technologies may prevent this, but cost more.
- Cement is the source of **about 8% of the world's carbon dioxide (CO₂) emissions**, according to think tank Chatham House. If the cement industry were a country, it would be the third largest emitter in the world - behind China and the US.

Embodied Energy:

- ~1.1–1.7 MJ/kg (can be higher with high cement content).
- Per m² (50–80 mm thick): ~150–250 MJ/m².
- **Key reason:** Cement accounts for ~80–90% of the energy/carbon footprint of concrete.
- **Notes:** Use of supplementary cementitious materials (fly ash, slag) can lower embodied energy.

Manufacturing Impacts

Concrete



Clay pavers

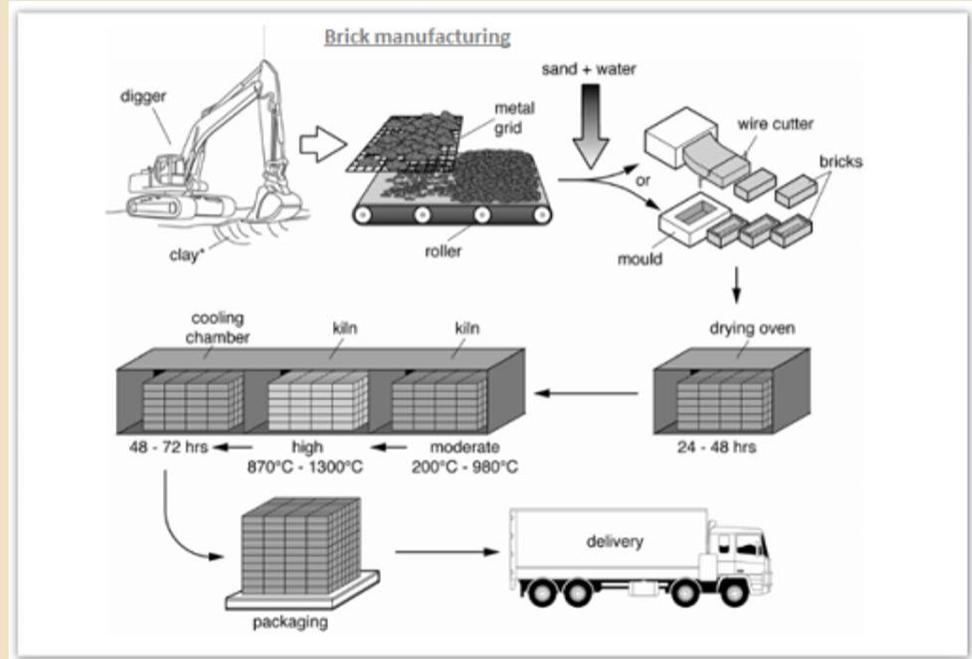
Often called brick pavers, these are made from natural clay or shale that is shaped and then fired in a high-temperature kiln.

- **Manufacturing:** The kiln-firing process creates a very hard, durable, and colorfast paver. The color is inherent throughout the entire paver, so it won't fade over time. Clay extraction, forming, and **firing at $\sim 1,000^{\circ}\text{C}$** .
- **Design and uses:** They are available in a range of earthy tones like reds, browns, and beiges, providing a classic, timeless look. They are suitable for high-traffic areas such as driveways, patios, and walkways.
- **Cost and maintenance:** Clay pavers may be more expensive than first generation concrete pavers but can be less expensive than newer concrete paver technologies. They require less maintenance, as they resist fading and don't need to be sealed. They will continue to look as good as the day that they were installed over their life cycle.
- **Embodied Energy:**
 - $\sim 2.5\text{--}3.5$ MJ/kg.
 - Per m^2 (40–60 mm thick): $\sim 250\text{--}400$ MJ/ m^2 .
- **Key reason:** The firing stage is extremely energy intensive.

- **Notes:** Modern kilns with waste heat recovery can reduce this somewhat, but clay products are still higher than stone and concrete.

Manufacturing Impacts

Clay



Porcelain Pavers

These are a man-made tile made from a mixture of highly refined clay, sand, and other minerals.

- **Manufacturing:** The mixture is fired at extremely high temperatures (>2200°F), which creates a dense, non-porous, and incredibly strong material. High-quality clays, feldspar, silica; pressed and fired at ~1,200–1,400°C for long durations.
- **Design and uses:** Advanced digital printing allows porcelain pavers to faithfully replicate the appearance of natural stone, wood, or concrete. They are very versatile and can be used for patios, walkways, pool decks, and even rooftop terraces due to their lighter weight.
- **Cost and maintenance:** Porcelain pavers are typically the most expensive of the man-made options. However, they are virtually non-porous, making them resistant to stains, mold, and moss, so they require minimal maintenance and do not need to be sealed.
- Since they essentially have no absorption, moisture must surface drain or evaporate off of them. In the winter in freeze thaw regions, this can create slippery surfaces where the moisture has pooled and frozen.
- **Embodied Energy:**
 - ~4.0–5.5 MJ/kg (sometimes higher for dense porcelain).
 - Per m² (20 mm thick typical): ~200–300 MJ/m².

- **Key reason:** Ultra-high firing temperature, longer kiln times, and additional glazing/polishing steps.
- **Notes:** Although thin, the firing makes porcelain the highest embodied energy per kg.

Manufacturing Impacts

Porcelain



Clay, Sand, Feldspar, and Other Minerals are Mined



Raw Materials Transported to Manufacturing Plant



Ink, Glaze and Other Additives are Acquired and/or Manufactured then Transported to Manufacturing Plant



Ingredients Combined with Water, Formed, Dried, and Pressed. Images and Glaze are Applied to Surface, then Fired

Embodied Energy

Here's a comparison of **embodied energy** (the total energy required to extract, process, transport, and install a material) between **natural stone**, **concrete**, **clay**, and **porcelain** pavers. Values vary by source, region, and manufacturing practices, but the relative ranking is consistent.

Relative Ranking (Lowest → Highest embodied energy per kg)

Material	MJ/kg (approx.)	Main Energy Driver
Natural Stone	0.8–1.2	Quarrying & transport
Concrete Pavers	1.1–1.7	Cement production
Clay Pavers	2.5–3.5	Kiln firing
Porcelain Pavers	4.0–5.5	High-temp firing & processing

Takeaways for Design

- **Natural stone** generally has the *lowest embodied energy* because it's largely “ready-made” by geology; only cutting and finishing are needed.
- **Concrete** is higher due to cement but still lower than fired products.
- **Clay and porcelain** are the highest because of energy-intensive firing.
- Transportation distance can shift these values — e.g., imported stone can approach concrete's embodied energy if shipped far.



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