A COMPARATIVE ANALYSIS

OF

EMBODIED CARBON

OF

VALENTIA SLATE

WITH OTHER NATURAL AND MAN-MADE DIMENSION STONES

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CARRIG
conservation international

Atlantis Building, South Cumberland Street, Dublin 2, Ireland **T**: +353 1 5529080 **E**: info@carrig.ie www.carrig.ie

Carrig UK, 70 Cowcross Street, London, EC1M 6EL, England

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COMPARATIVE ANALYSIS

Valentia Slate Company Ltd has requested Carrig Conservation International to carry out a comparative analysis of the embodied carbon of Valentia Slate used in construction in Ireland with other dimension stones commonly used in construction. The following report addresses this request.

1 MATERIALS COMPARED

In compiling this report, the following readily available natural dimensioned materials were compared.

Name	Rock type and age	Quarry location	Years in operation	Production volume p.a.
Valentia Slate	Slate, 385 Ma	Valentia Island, Ireland	204	1,000 m3
Irish Limestone	Limestone, 340 Ma	County Kilkenny, Ireland	150	25,000m^3
Portland Stone	Oolitic limestone, 145 Ma	Dorset, UK	390	7,800-10,400m^3
Spanish Grey	Granite,	Pontevedra, Galicia, Spain	100	9,000m^3
Moca Cream	Limestone,	Alcanede, Portugal	75	10,000m^3
Chinese	Basalt	Various	30	30,000m^3
Stanton Moor	Buff Sandstone, 350 Ma	Matlock, Derbyshire, UK	120	28,300m^3
Locharbriggs	Red Sandstone, 275 Ma	Dumfries, Scotland	130	2,000m^3

In addition, the following readily available man-made materials were compared.

Name	Manufacturer	Location
Dekton	Cosentino	Cantoria, Spain
Silestone	Cosentino	Cantoria, Spain

2 COMPARISON OF EMBODIED CARBON IN NATURAL DIMENSION STONE COMPARED TO OTHER CONSTRUCTION MATERIALS

The following embodied carbon levels for various common building materials are adapted from Crishna et al 2011. As seen, the embodied carbon of the dimension stones is lower than most of the other building materials because of the additional steps in the production and sale of manufactured construction materials.

The life cycle of natural stone product is:

1. Extraction of the base material (stone)
2. Transport to processing facility (in some cases)
3. Processing into intermediate or final product
4. Perhaps further transport and processing stages if processing is multi-site
5. Possible multiple transport stages in sales chain
6. Use in construction
7. Operational phase to the end of the useful life of the material (unlimited)
8. Reuse or recycling

In contrast, the life cycle of manufactured construction material or product has additional high-carbon-intensive stages as underlined below:

1. Extraction of the raw materials such as iron ore or silica sand
2. Transport to processing facility
3. Processing into base material (e.g. steel or glass)
4. Transport to manufacturing plant to convert base material into intermediate or final products
5. Perhaps further transport and processing stages if processing is multi-site
6. Possible multiple transport stages in sales chain
7. Use in construction
8. Operational phase to the end of the useful life of the material (limited to c.40 years)
9. Separation of product components for reuse or recycling

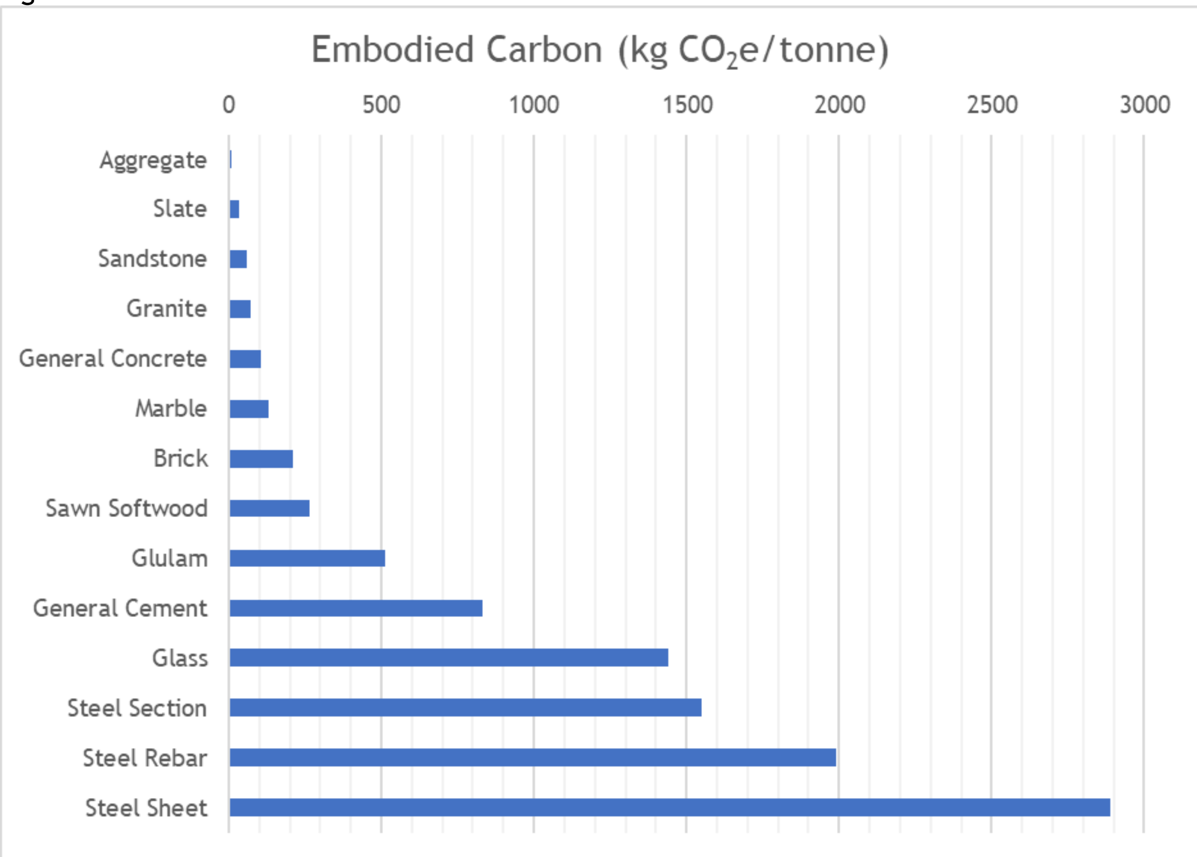
The underlined stages above contribute a significant amount of embodied carbon into the production process for manufactured construction materials. While this is self-evident qualitatively, the quantification of these effects is not straightforward. Life Cycle Analysis (LCA) of construction products is a modelling exercise that is very assumption dependent and it is notoriously difficult to establish the nature of the supply chain for many construction products, including natural stone. For this reason, while we have reviewed the literature for embodied carbon values, we recommend that the reader also considers the qualitative position. This, we would suggest on the basis of the consideration of the production stages noted above, must conclude that manufactured construction products of all types are of considerably higher embodied carbon than natural stone.

Material	Embodied Carbon (kg CO_2e/tonne)[1]
Aggregate[2]	7.5
Slate (no waste)	35
Sandstone	60
Granite	70
General Concrete[3]	103
Marble	130

Brick[4]	210
Sawn Softwood[5]	263 how is this so high when it is just extraction and shaping as with natural stone? Higher than brick in particular seems implausible
Glulam[5]	512
General Cement[6]	832
Glass[7]	1440
Steel Section[8]	1550
Steel Rebar	1990
Steel Sheet[9]	2890

[1] All embodied carbon values are cradle-to-(factory) gate without transport costs?.
[2] General UK aggregate, mixture of land won, marine, secondary and recycled, bulk, loose.
[3] General concrete mix: 200kg CEM I, 95kg GGBS, 15kg fly ash, 1915kg aggregate, 139kg water, 1.55kg admixture.
[4] General common brick with average brick weighing 2.13 kg in UK.
[5] Embodied carbon figures for timber do not account for sequestered carbon.
[6] General cement mix by weight: 86.1% clinker, 0.04% GGBS, 3.4% fly ash, 4.8% gypsum, 5.1% limestone, 0.56% MACs.
[7] General glass: 2.5kg per mm thickness, per m^2.
[8] Steel Section: hot-rolled engineering steel used for I-beams, H-beams, wide-flange beams, etc.
[9] Tin-free, electrolytic chrome coated. Typical thickness between 0.13 to 0.49mm.

Additionally, these embodied carbon values, represented graphically, further portray the significant differences in embodied carbon between various construction materials.



3 COMPARISON OF EMBODIED CARBON IN NATURAL DIMENSION STONES WHEN TRANSPORT IS TAKEN INTO ACCOUNT

It can be assumed that all natural stones have zero embodied carbon "in the ground" and that embodied carbon thereafter arises from processing and from transport. In this regard, it may be plausibly argued that differences in embodied carbon arising from different processing methods are not as significant, given global trading of dimension stones, as the embodied carbon differences that arise from transport.

Stone Type	Total CO2 emissions (kgCO2 for journey)
Irish limestone	63.81
Portland Limestone (UK)	175.43
Valentia Slate	280.02
Irish Limestone (via Bel)	304.07
Spanish Grey Granite	350.85
Moca Cream (Portuguese)	491.19
Chinese Basalt	6831.08

4 NOTE ON WASTE IN THE PRODUCTION PROCESS OF DIMENSION STONES

In some analyses (e.g. Krishna 2011) it is suggested that typical slate quarrying for roofing slate results in a high proportion of waste to final product and thus is less efficient in terms of embodied carbon. While this is true for a traditional roofing slate quarry operation such as was carried on in North Wales, this is clearly not applicable to a slate quarry where dimension stone and other products other than roofing slate are produced. In the case of Valentia Slate, the quarry manufactures slab as well as roofing products and works under a zero-waste protocol which significantly further reduces embodied carbon by excluding any loading in a life cycle analysis that arises from a high proportion of waste in the production process. Using this reasoning, we argue that Valentia Slate should be assigned an embodied carbon value that is at least as low as any other dimension stone and in fact is in principle lower than almost all others due to the ease of working of the material as compared to granite for example. Please see this topic elaborated on in the following section.

5 INTERNATIONAL STANDARDS THAT THESE RESULTS ALLOW COMPLIANCE WITH

Carrig is of the opinion that the results referred to in this document demonstrate, together with our knowledge of Valentia Slate's production practices, that Valentia Slate meets or exceeds the acceptance metrics of all the following international standards:

ANSI/NSC 373	The Natural Stone Council's standard for the *Sustainable* Production of Natural Dimension Stone
BS EN 15978:2011	British Standards Institution's standard for the *Sustainability of construction works—Assessment of environmental performance of buildings—Calculation method*
BREEAM	The *Building Research Establishment Environmental Assessment Method* from the UK's Building Research Establishment (BRE Group).
LEED	The LEED (Leadership in Energy and Environmental Design) v4.1 from the United States Green Building Council (USGBC).

	Valentia Slate could assist projects in compliance with the following LEED v4.1 prerequisites/credits: LEED v4.1 BD+C: New Construction, Core + Shell, Schools, Retail, Healthcare, Data Centres, Hospitality, Warehouses + Distribution Centres Building Life-Cycle Impact Reduction Building Product Disclosure and Optimization – Environmental Product Declarations Building Product Disclosure and Optimization – Sourcing of Raw Materials LEED v4.1 BD+C: Single Family Durability Management Environmentally Preferable Products LEED v4.1 BD+C: Multifamily, Multifamily Core + Shell Building Life Cycle Impact Reduction Environmentally Preferable Products LEED v4.1 ID+C: Commercial Interiors, Retail, Hospitality Interiors Life-Cycle Impact Reduction Building Product Disclosure and Optimization – Environmental Product Declarations Building Product Disclosure and Optimization – Sourcing of Raw Materials LEED v4.1 O+M: Existing Buildings, Schools, Retail, Data Centres, Hospitality, Warehouse + Distribution Centres, Multifamily, Interiors Purchasing
BES 6001	The BES 6001 from Intertek. The standard and guidance may be found at: https://www.intertek.com/sustainability/bes-6001/
ISO 14044	The International Organization for Standardization Standard 14044:2006 *Environmental management – Life cycle assessment – Requirement and guidelines*. The standard may be found at: https://www.iso.org/standard/38498.html.
PAS 2050	The Publicly Accessible Specification 2050 may be downloaded from: https://shop.bsigroup.com/en/forms/PASs/PAS-2050/.

6 PERFORMANCE OF VALENTIA SLATE IN THIS ANALYSIS; COMMENTARY

It is now widely recognised, and implemented in public procurement policies, that natural stone in general has a far lower embodied carbon than manufactured construction materials. This principle is amplified if the natural stone is also local to the construction site. The natural stone quarry can then further increase this advantage by employing green manufacturing methods such as using electric machinery and obtaining its electricity from renewable sources. Natural stone can also be easily recycled by local reuse.

Valentia Slate is one of the lowest embodied carbon natural stone of the representative sample that it is compared to in this analysis. For use within Europe it is significantly lower in embodied carbon than other natural stones for three principal reasons:

1. Despite its high density and strength, Valentia Slate is relatively easy to extract, machine and finish. Other stones, with comparable or inferior physical properties, may nevertheless be more difficult to work.
2. Many popular dimension stones originate in China or India. Embodied carbon arising from transport in getting the stone to a construction site in Europe are obviously significantly higher than for a local stone.
3. Aside from the greater straight-line distance from the source quarry to the construction site in Europe, many stones imported into Europe are quarried, processed, warehoused and distributed by a convoluted supply chain involving several stages of handling. In the case of Valentia Slate, all sourcing and processing is carried out at the quarry and the product is sent directly to the construction site.

Provenance can be defined as terroir+traceability+transparency. This allows the environmental effect of any product to be assessed by the final customer. It is important that all three elements are present. Valentia Slate satisfies these requirements fully because its source in the landscape and geology of Valentia is well-known and it is a long-standing part of the community there (terroir), the recorded production method and simply supply chain is easily demonstrated (traceability) and the location and methods of working are there for all to see at Valentia (traceability). However, in cases where an element is missing, it is difficult for the final customer to assess the environmental effects of the market offering. For example, in some cases, including in Ireland, stone is exported from the original quarry to a processing facility in another country and then reimported and sold as Irish stone. Obviously, such an approach risks an incorrect impression being given to the final customer as to the provenance of the stone. Artisan producers, such as Valentia Slate, tend to carry out all processing at or adjacent to the source quarry and can fulfil the requirements of provenance. This way of supplying construction materials reduces the carbon load of a complicated supply chain and allows this simple supply chain to be clearly demonstrated to the final customer.

Valentia slate employs traceable and recorded sustainable manufacturing methods. This practice is not the norm in the production of imported stone. Valentia Slate's methods are demonstrated in its Factory Production Control System which is part of its CE marking to comply with all relevant regulations (available from the Valentia Slate website). Traceability and provenance are important elements of the general environmental friendliness of any product.

In Life Cycle Analysis (LCA) terms, because it is very durable, the low embodied carbon of production is matched by a very long life. Many Valentia Slate installations of the 1840's are still fully fit for purpose and do not need to be replaced. In effect, this quasi-infinite life cycle saves one or more cycles of replacement, each of which would have had a full LCA carbon load.

The end stage of the LCA is the effect of the end of use of the product. Valentia Slate is completely either reusable or recyclable when the initial use comes to an end. A slab of Valentia Slate 200 years old, when taken from a building, is as usable as a slab of the same dimensions taken from the quarry today. It may be repurposed as is but is also convertible into any of the many uses that freshly quarried material is put to, for example, headstones, kitchen countertops, steppingstones, tiles. As a last resort, it may even be crushed and used as a permanent, non-rotting flowerbed mulch. The material is also non-toxic and even if not repurposed, is not a pollutant.

Environmental Product Declaration (EPD) is a relatively new method of calculating the carbon implications of manufactured products. The application to quarried dimension stone is still problematic for many reasons which include the significant variation in production methods between quarries and the tendency for raw blocks of dimension stone to be traded internationally thereby losing provenance. A quarry-specific Environmental Product Declaration (EPD) will be prepared for Valentia Slate in the near future as part of a PhD project to be carried out at TU Dublin and funded in part by Valentia Slate. Quarry-specific EPDs are uncommon in the dimension stone industry but EuroRoc (www.euroroc.net) has published an averaged EPD for dimension stone from its members European quarries which presents an averaged result for the sector. This published EPD (link available at www.valentiaslate.com) demonstrates that dimension stone outperforms functionally equivalent manufactured construction products in carbon terms. However, because of Valentia Slate's vertically integrated business which keeps quarrying and processing on the same premises, its predominant use of renewable electricity and its use of wood for crating and packaging, Valentia Slate will significantly outperform this European average for dimension stone in terms of carbon performance.

It should also be noted that Valentia Slate is in the process of being confirmed for listing as a Global Heritage Stone Resource. Valentia Slate is also a member of the Irish Green Building Council.

Valentia Slate and Technical University Dublin have begun a collaboration to support a PhD project to investigate the embodied carbon in dimension stones in Ireland with particular reference to Valentia Slate. This project will be active from 2021-2024. Please contact Valentia Slate for further information.

7 SOURCES OF INFORMATION

The information used in this analysis was obtained from the following sources.

Name	Source
General	Adams, M., Burrows, V., & Richardson, S. (2019). Bringing embodied carbon upfront; Coordinated action for the building and construction sector to tackle embodied carbon. World Green Building Council publication. Crishna, N., Banfill, P. F. G., & Goodsir, S. (2011). Embodied energy and CO2 in UK dimension stone. *Resources, Conservation and Recycling*, *55*(12), 1265-1273. Gillespie, M.R. & Tracey, E.A. (2016). Scotland's building stone industry: a review. British Geological Survey Commissioned Report, CR/16/026. I. Bianco, G.A. Blengini / Journal of Cleaner Production 231 (2019) 419-427 Jones, C. (2019). Inventory of Carbon and Energy (ICE) Database, Version 3.0. Circular Ecology, https://circularecology.com/embodied-carbon-footprint-database.html. A Life-Cycle Inventory of Sandstone Quarrying and Processing (Version 2). (2009). A Report Prepared for The Natural Stone Council by the University of Tennessee Center for Clean Products
Valentia Slate	Sandberg LLP testing carried out in 2020, available on the Valentia Slate website.
Irish Limestone	Technical specifications available from Kilkenny Limestone at: www.kilkennylimestone.com
Liscannor	DoP available from Liscannor Flagstone at: www.liscannorflagstone.ie
Portland Stone	DoP available from Albion Stone at: www.albionstone.com Technical Specifications available in report from Global Heritage Stone.
Spanish Grey	Technical specifications available from Diazpa at: www.diazpa.com
Moca Cream	Technical specifications available from Mocapor at: www.mocapor.com
Stanton Moor	Technical specifications available from Cumbrian Stone at: www.cumbrianstone.co.uk Additional quarry details available from Peak District Planning Application.

Locharbriggs	DoP and technical specifications available from Cumbrian Stone at: www.cumbrianstone.co.uk Additional quarry details available from Dumfries and Galloway Council. Additional technical specifications available from Stancliffe Stone.
Dekton	Technical specifications available from Cosentino in the Dekton Technical Datasheet
Silestone	Technical specifications available from Cosentino in the Silestone Technical Datasheet

*Based on Valentia Slate's historical and current status as a slab quarry and not primarily a roofing slate producer, we agree with the approach of Crishna et al (2011) and classify Valentia Slate Quarry as no-waste sandstone quarry equivalent, for the purpose of comparison and interpretation of data from the literature.