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NATÜRLICH. NACHHALTIG.

NATURAL STONE FOR SUSTAINABLE CONSTRUCTIO N

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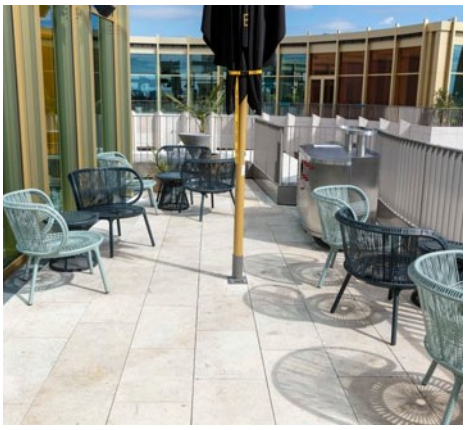

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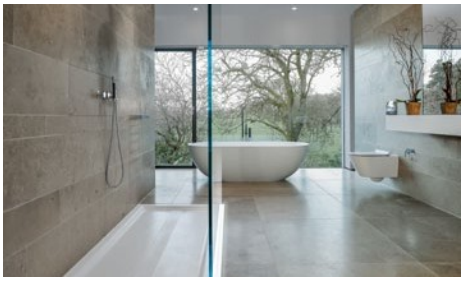


4

Sustainable building with natural stone

The reduction of carbon dioxide emissions (CO_2) is one of the most important environmental policy goals of the German Federal Government and the European Commission. Targets for this were agreed worldwide within the framework of the Paris Climate Agreement of 2015. In Germany and worldwide, the building sector has a significant share in CO_2 emissions. In recent years, political and scientific interest has focused on the assessment of the operation of buildings and the associated emissions, but now the question of the assessment of the buildings themselves is increasingly being raised.

According to the UN Environment Programme's report "2020 Global Status Report for Buildings and Construction - Towards a zero-emissions, efficient and resilient buildings and construction sector" presented on 16 December 2020, the construction sector is at record levels of greenhouse gas emissions worldwide and threatens to exceed the limit set in the Paris Climate Agreement of COP21 ("well below 2 degrees"). The sector now accounts for 38 per cent (9.95 Gt CO_2) of global CO_2 emissions. "Overall, the buildings and construction sector has not moved towards, but away from, the Paris Agreement target of keeping global average warming well below two degrees Celsius," the report says.

(Quelle: www.solarify.eu/2020/12/17/331-0-rekord-co_2 -outputs-in-the-building-sector/)

According to business as usual scenarios, the energy consumed by buildings worldwide could double or even triple by 2050, partly because billions of people will gain access to adequate housing and electricity.

(Source: The Fifth Assessment Report (AR5) of the UN Intergovernmental Panel on Climate Change (IPCC)).

In addition to energy for heating, cooling (glass facades), cooking and power supply, the energy required for the building materials used in their production, use and disposal also plays a significant role.
As part of a study, the German Sustainable Building Council - DGNB e.V. evaluated 50 certified buildings with regard to their CO_2 footprint. A key result: a good third of all greenhouse gas emissions from a building occur before it is actually used - during production and construction. The levers for reducing these CO_2 emissions lie, among other things, in the construction method, the high-mass building components and the useful life of the building materials.

"We have a clear mandate from climate researchers to halve CO_2 emissions from buildings every decade in order to keep the climate crisis at a bearable level," says Dr Anna Braune, Head of Research and Development at the DGNB.

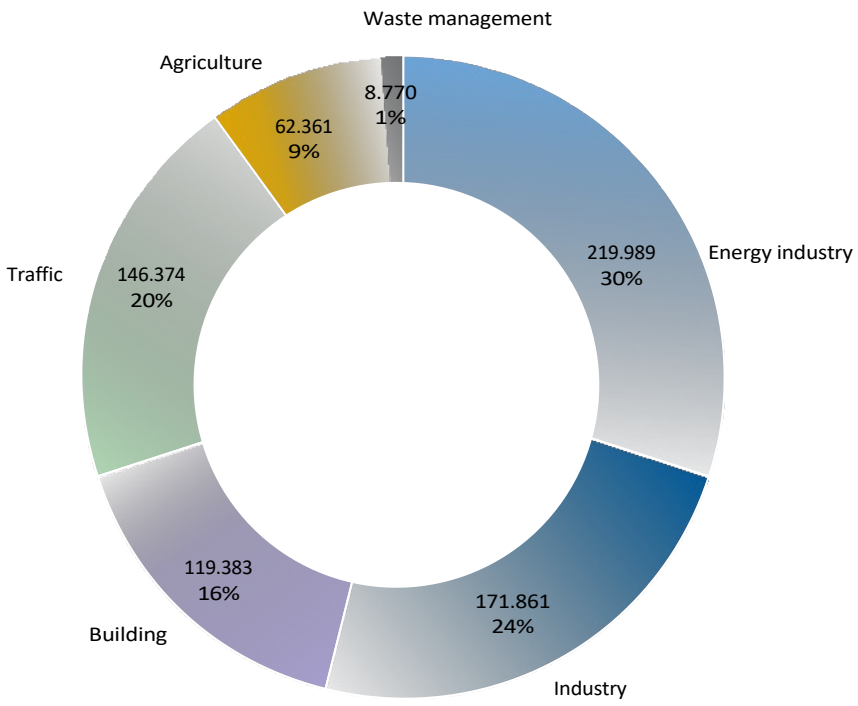
"In the energy efficiency of new buildings, we have made progress in recent years. Looking ahead to the next few years, we now urgently need to put additional focus on the greenhouse gas emissions of the building. They account for a good third of total building emissions and can even be 50 percent or more for buildings with a very low CO_2 footprint."

(Source: www.dgnb.de/de/aktuell/pressemitteilungen/2021/study-co$_2$ -emissions-buildings)

Climate-friendly building with natural stone

Natural stone occupies a special position among all building materials. Since natural stone is already available as a finished product and only a small amount of energy is required for its extraction and processing, natural stone has an excellent ecological balance. In addition, natural stone is an extremely durable building material and can be reused at the end of the building's life or processed into chippings and gravel. In contrast to other building materials, the usable quantity of natural stone produced from the raw material extracted from our planet is very high, and natural stone deposits in Germany and worldwide are virtually inexhaustible. Our entire planet is made up of natural stone, most of which, like granite, is formed by the cooling of magma in the earth's interior. Modern mining methods avoid environmental pollution such as the formation of fine dust.

CO_2 emission in thousand tonnes CO_2 equivalent



ACCORDING TO THE FEDERAL ENVIRONMENT AGENCY, THE FOLLOWING CO_2 EMISSIONS WERE GENERATED IN THE RESPECTIVE SECTORS IN 2020:

"WE HAVE A CLEAR MANDATE FROM CLIMATE SCIENTISTS TO HALVE CO2 EMISSIONS FROM BUILDINGS EVERY DECADE IN ORDER TO KEEP THE CLIMATE CRISIS WITHIN TOLERABLE LEVELS.
HOLD."

Dr. Anna Braune, Head of Research and Development at the DGNB

5

6

Sustainable quarrying in the quarry

A large proportion of the raw materials required in Germany each year, especially stone and earth raw materials, are extracted from domestic deposits. The extraction of natural stone in Germany usually takes place in relatively small quarries and in harmony with nature. According to information from the Federal Government as of 2016, quarries cover 3.55 square kilometres, or 0.001 per cent of the area of the Federal Republic of Germany. It should be taken into account that, according to the Federal Institute for Geosciences and Natural Resources (BGR), a total of 217 million tonnes of quarried natural stone, 55 million tonnes of limestone, dolomite and marlstone for industrial processing and only 1.4 million tonnes of natural building stone were extracted in Germany in 2019. The land consumption in Germany for natural stone quarries is therefore extremely low.

The residues resulting from quarrying and processing are natural rock and can be used directly to backfill quarried parts of the quarry
or economically used, for example, in gardening and landscaping, for masonry, for hydraulic engineering and for the production of crushed stone.

The actual extraction in the quarry is preceded by intensive exploration. This involves assessing whether the largest possible blocks of core rock of unweathered, crack-free quality with a good appearance and good technical properties can be extracted in sufficient quantities. The various environmental, landscape and water protection requirements are taken into account in the planning and use of the quarries, and the impact on nature is kept to a minimum.

Already during the quarrying phases, quarries are special habitats with high biodiversity. Rare plant and animal species find a habitat here that is only created by the operation of the quarry and is otherwise rarely found in our cultural landscape.

Cycle of the natural stone industry

If the usable deposit is exhausted, further use of the quarry can follow in a variety of forms. There is evidence of the use of former quarries as recreational areas and lakes, for example; in addition, complete recultivation and return of the site to agriculture and forestry are possible.
Even in new construction and restoration, old components made of natural stone can often be reworked and reused after the demolition of an existing building. In earlier years, it was a matter of course that natural stones from old castles and churches were reused for the construction of new buildings. Nothing is lost in the entire cycle of natural stone extraction, processing and recycling. Over the millennia of its use, natural stone has a special position ahead of other building materials.

Sustainable natural stone architecture

There are many outstanding examples of high-quality and ecological architecture using natural stone. The German Natural Stone Association (DNV) honours some particularly successful projects by awarding the German Natural Stone Award. The German Natural Stone Award focuses on natural stone as a building material that is exemplary in terms of its durability, natural material properties and the associated processing methods appropriate to the material in interaction with other building materials. The award is given to outstanding achievements in architecture and urban development whose quality is characterised by the design and constructional possibilities of natural stone as a building material, which, through the individual treatment of details and surfaces, becomes a space-creating element in smaller projects and an urban element in larger projects like hardly any other building material.

FAÇADES MADE OF NATURAL STONE ARE CHARACTERISED BY LOW CO_2 EMISSIONS DURING PRODUCTION AND USE.

THE USEFUL LIFE OF FACADES MADE OF NATURAL STONE IS OFTEN WELL OVER 100 YEARS.

9

Advantages of natural stone in construction

Natural stone offers the following advantages with regard to the essential criteria for sustainable building methods:

1 Reduction of energy demand and consumption of operating resources

- No energy is required for the production of natural stone - it is provided to us by nature. Natural stone is available as a finished product in the quarry and does not have to be assembled from various raw materials and fired, as is the case with ceramics, for example.
- Only the extraction in the quarry and subsequent processing in the natural stone plant requires a relatively small amount of energy to manufacture the products from natural stone.
- Natural stone makes a significant contribution to reducing primary energy consumption. The building's construction is a major step forward.

2 Avoidance of transport of building materials

- Germany has large quantities of quarryable natural stone. Due to the great variety of domestic granites, sandstones, limestones, slates, etc., the greatest demand for ashlars can be met from domestic deposits.
- The use of local natural stone helps to avoid unnecessary transport and promotes landscape-bound construction methods.
- Even with longer transport distances, the CO_2 balance of natural stones is favourable compared to other building materials.
- The use of regional and European Natural stone deposits are to be preferred.

3

Use of reusable/recyclable building products

- Natural stone products can be reused in many ways after the use phase of a building. Many building products made of natural stone, such as window sills, paving stones and masonry blocks, can be used directly for new structures.
- Likewise, a reuse as an aggregate for other materials possible.
- Natural stone products that can no longer be used are processed into crushed stone and chippings.

12

4

Extending the service life of building products and structures

- Natural stones have unusually long periods of use of up to thousands of years.
- Natural stone coverings with heavy traces of wear can simply be ground down to create coverings that are virtually as good as new again.
- The life cycle of well-designed natural stone façades is designed to last for centuries.
- Care must be taken to ensure that buildings are constructed with long-life details, so that building elements made of other materials with a shorter life cycle (e.g. windows) can be easily replaced.

11

5

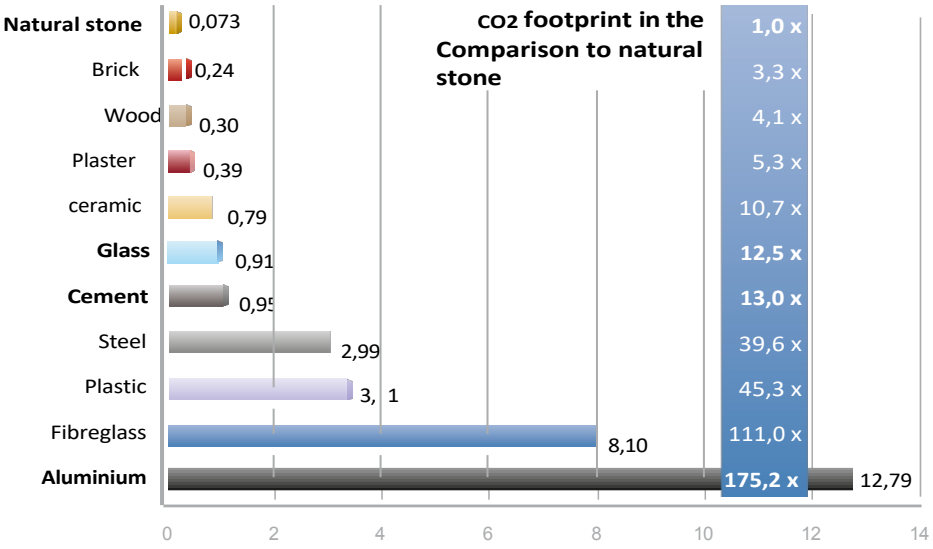
Safe return of the building materials

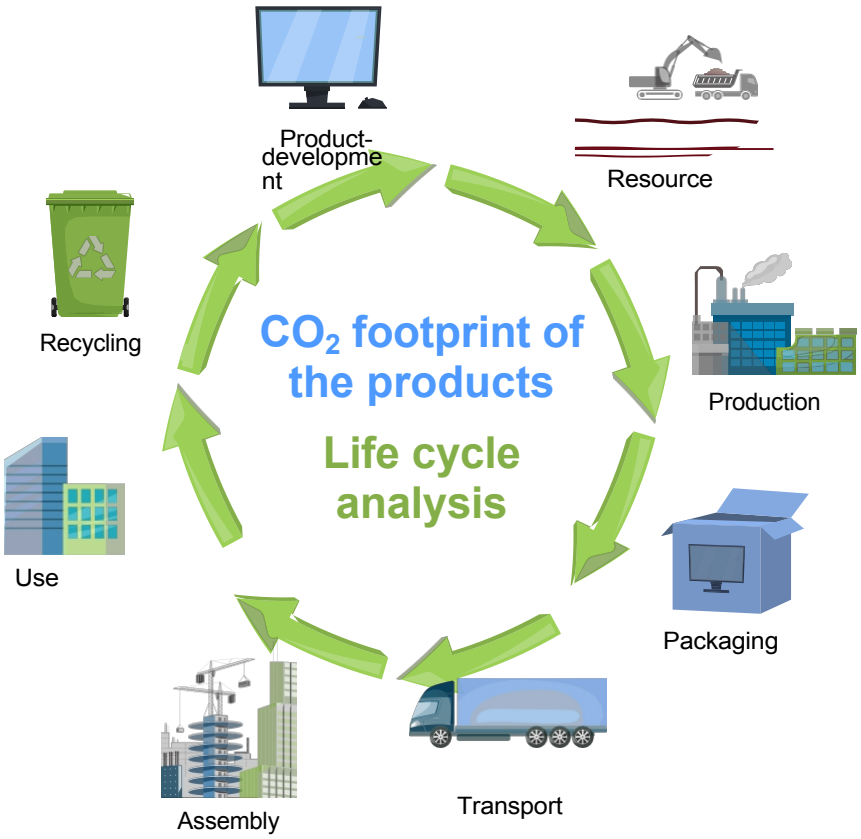
- Natural stones do not contain any pollutants and can be reintroduced into the natural material cycle without any problems.
- Separation by type is possible without any problems in natural stone applications, such as ventilated exterior wall cladding.

Sustainability studies for building materials

As a British study shows, natural stone has the lowest global warming potential of all building materials. Compared to natural stone, other building materials have much higher CO_2 footprints:

CO2 emissions caused (embodied carbon) **by common building materials**





THERE ARE NO WASTE MATERIALS IN THE NATURAL STONE CYCLE - THE RESIDUAL MATERIAL THAT IS PRODUCED WHEN THE STONE SLABS AND BLOCKS ARE CUT OR SPLIT IS NOT SIMPLY LOST, BUT CAN BE USED IN A VARIETY OF WAYS.

BE USED IN A VARIETY OF WAYS

DNV sustainability studies

The Deutscher Naturwerkstein-Verband e. V. (DNV) has commissioned sustainability studies for several areas of application of natural stone, which are based on life cycle assessments of the building materials used. These sustainability studies were carried out on the basis of the LCA method (LCA - Life Cycle Assessment). This is a systematic analysis of the environmental impact of products during their entire life cycle ("from the cradle to the grave"). This includes all environmental impacts during production, the use phase and disposal of the product, as well as the associated upstream and downstream processes (e.g. production of raw materials, consumables and supplies).

The following indicators are determined within the framework of the sustainability studies:

- Primary energy (renewable and non-renewable) in MJ
- Global Warming Potential (GWP) in kg carbon dioxide equivalent (CO_2 -eq.)
- Ozone Depletion Potential (ODP) in kg reference HCFC equivalents (R11 eq.)
- Acidification Potential (AP) in kg in sulphur dioxide equivalent (SO_2 -eq.)
- Eutrophication potential (EP) in kg phosphate equivalent (PO_4 -eq.)
- Photochemical Ozone Creation Potential (POCP) in kg ethene equivalent (C_2 H4-eq.)

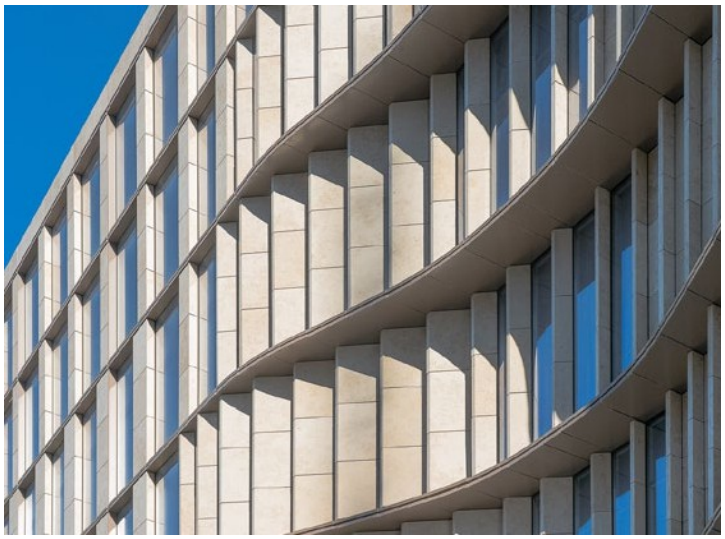
Of particular importance is the effect of the anthropogenic greenhouse effect, which leads to global warming. The cause is greenhouse gases such as CO_2 , nitrous oxide (N_2 O) and methane (CH_4); reflect long-wave radiation and prevent it from overcoming the atmosphere. Emissions are expressed as global warming potential (GWP) in kg of carbon dioxide equivalent (CO_2 -eq.).

NATURAL STONE FAÇADES REQUIRE LITTLE PRIMARY ENERGY AND HAVE ONLY LOW VALUES FOR THE INDICATORS MENTIONED.

Sustainability study façade systems

The results of the sustainability study show that façade constructions with natural stone have considerable ecological and economic advantages over glass constructions, for example.
In the first part of the study prepared by PE International, a typical natural stone façade construction according to DIN 18516-3 is compared with a glass façade construction on the basis of one square metre of façade area.
Over a period of 100 years, the natural stone façade shows clear ecological advantages over a glass façade. In summary, it can be said that natural stone façades require considerably less primary energy than glass elements, both in the production and in the use phase, so that over the entire life cycle, glass façades require more than three times as much energy as glass façades.
of primary energy must be expended.
If the production is considered separately, it becomes apparent that the glass façade requires about twice as much energy resources as the natural stone façade.

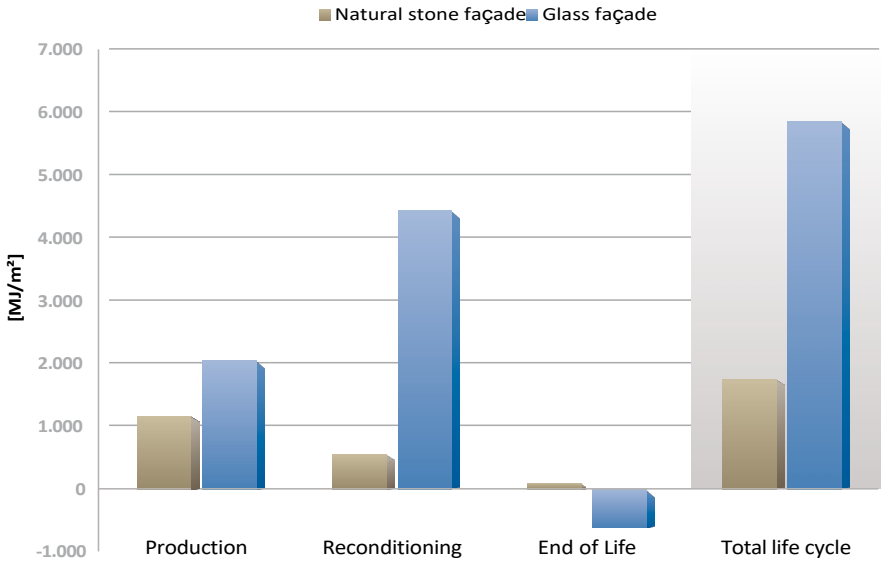
THE NATURAL STONE FLAST ALSO SHOWS SIGNIFICANT ECOLOGICAL ADVANTAGES IN FURTHER ENVIRONMENTAL CHARACTERISTICS (e.g. GREENHOUSE GAS EMISSIONS).



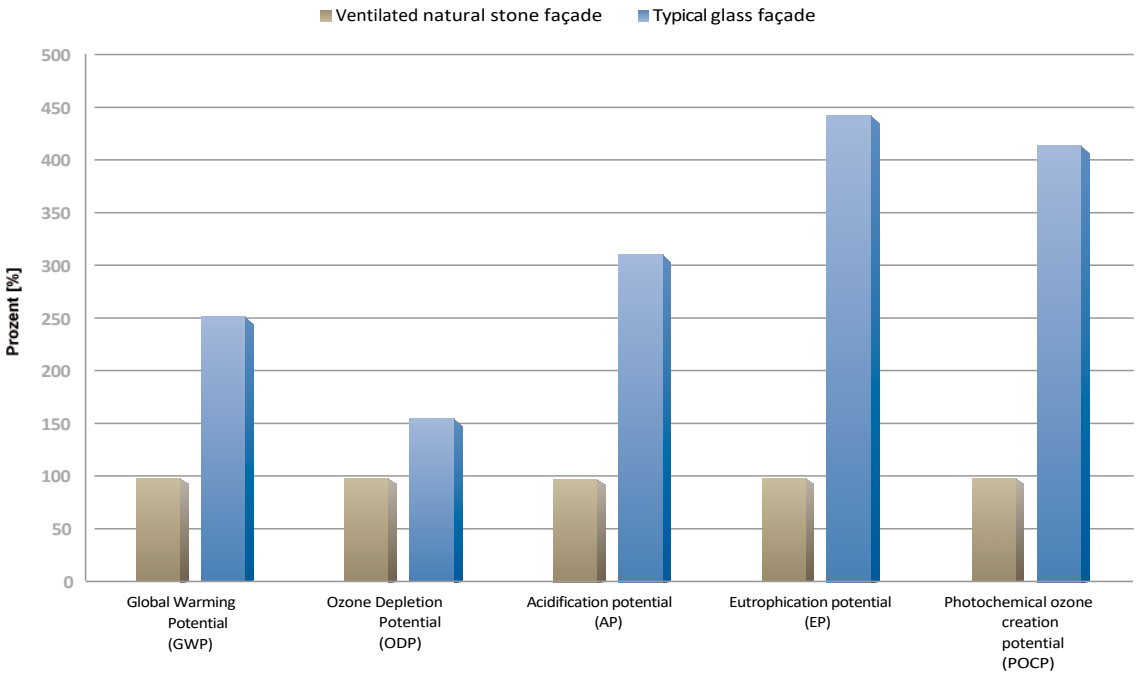
15

In the further course of the life cycle, the use phase is dominated by the maintenance measures depending on the replacement cycles of the components used. While the natural stone façade, with its relatively long-lasting components, manages with about 50% of the energy resources for this phase compared to production, the more replacement-intensive maintenance of the glass façade is the most relevant ecological phase during the entire life cycle.
Calculated over 100 years, individual components are completely replaced up to three times. Although cleaning with water is an important aspect of economic considerations, it is negligible from an ecological point of view. The U-value of 0.32 W/m²K, which is important for thermal insulation, is considerably lower for the natural stone façade than for the glass façade with 1.25 W/m²K. This means that the transmission heat losses and thus the heat demand of the building are significantly lower with the natural stone façade. The economic effects of the heat losses in winter and the cooling requirements in summer are also taken into account in the study.

Primary energy demand over the life cycle of the natural stone façade and the glass façade in [MJ/m²].



Evaluation of environmental impacts over the life cycle (100 years)



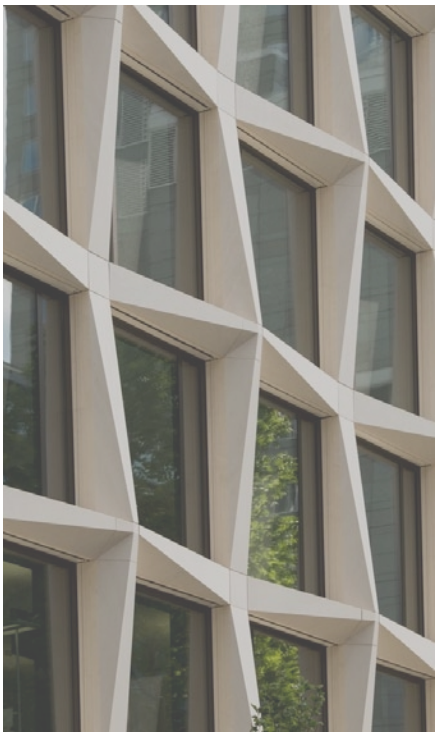
After the utilisation phase, it becomes apparent that the natural stone façade causes low ecological burdens (resource requirements and emissions) in relation to the overall life cycle. When looking at the end of life, it can be seen that in the case of the glass façade, the materials used, such as aluminium and plastic, receive ecological credits, as the recycling of these materials results in a reduction in the environmental impact. into the material cycle, costly primary production (GF) can be avoided.

The considered environmental impacts of the glass façade (GF) are between 60% and around 360% higher than those of the natural stone façade (NSTF):

Environmental impacts

	NSTF : GF
Global warming potential (CO_2 equivalent; GWP)	1 : 2,5
Ozone depletion potential (R11; ODP)	1 : 1,6
Acidification potential (SO_2 -equivalent; AP)	1 : 3,1
Eutrophication potential (PO_2 equivalent; EP)	1 : 4,4
Summer smog potential (C H_{22} equivalent; POCP)	1 : 4,3

NATURAL STONE CAN BE INDIVIDUALLY SHAPED WITH MODERN PROCESSING TECHNOLOGY AND THREE-DIMENSIONAL



In the second part of the study, the ecological performance of the executed façade (façade variant 1) at the Opera Tower in Frankfurt is compared with two theoretical façade constructions (façade variants 2 and 3):

- **Façade variant 1:**
  Façade realised at the OpernTurm in Frankfurt, consisting of an elemental, rear-ventilated natural stone façade (17 %), a rear-ventilated natural stone façade according to DIN 18516-3 (33 %), as well as glass elements (50 %).
- **Façade variant 2:**
  Ventilated natural stone façade according to DIN 18516-3 with a window proportion of 50 %.
- **Façade variant 3:**
  Adequate glass façade consisting of glass elements (90 %) and rear-ventilated natural stone façade according to DIN 18516-3 (10 %).

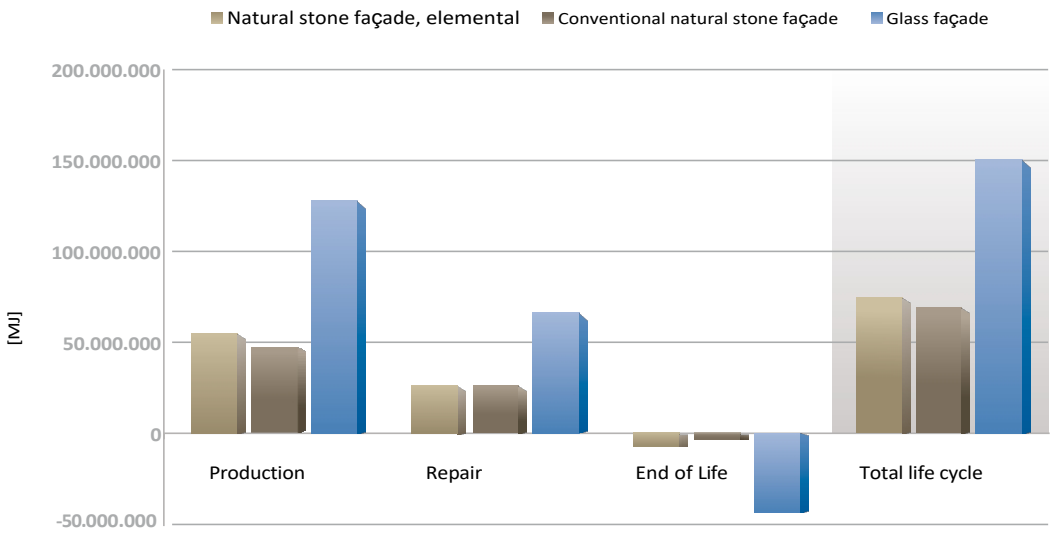
The ecological analysis of the façade variants dealt with in the study is carried out on the basis of assumptions on methodology and data described in the façade study of DNV for an observation period of the façade life cycles of 50 years, in accordance with the guideline "Sustainable Building".

The figure below shows the primary energy demand over the life cycle of the three façade variants. It can be seen that the natural stone façade requires about 50 % less primary energy than the glass façade.

Over the period under consideration, the two natural stone façades under consideration also have clear ecological advantages over the glass façade in all the environmental parameters considered. Depending on the environmental parameters, the emissions and energy resource consumption of the natural stone façades are about one third to two thirds of the environmental impacts and resource consumption of the glass façade.

If the manufacturing phase is considered separately, it becomes apparent that the glass façade requires about twice as much energy resources as the natural stone façade. The production phase of the natural stone façades also shows clear ecological advantages in other environmental parameters (e.g. greenhouse gas emissions).

Primary energy demand [MJ] over the life cycle of the executed, elemental natural stone façade, the optional glass façade and the optional conventional natural stone façade in [MJ] using the example of the Opera Tower.



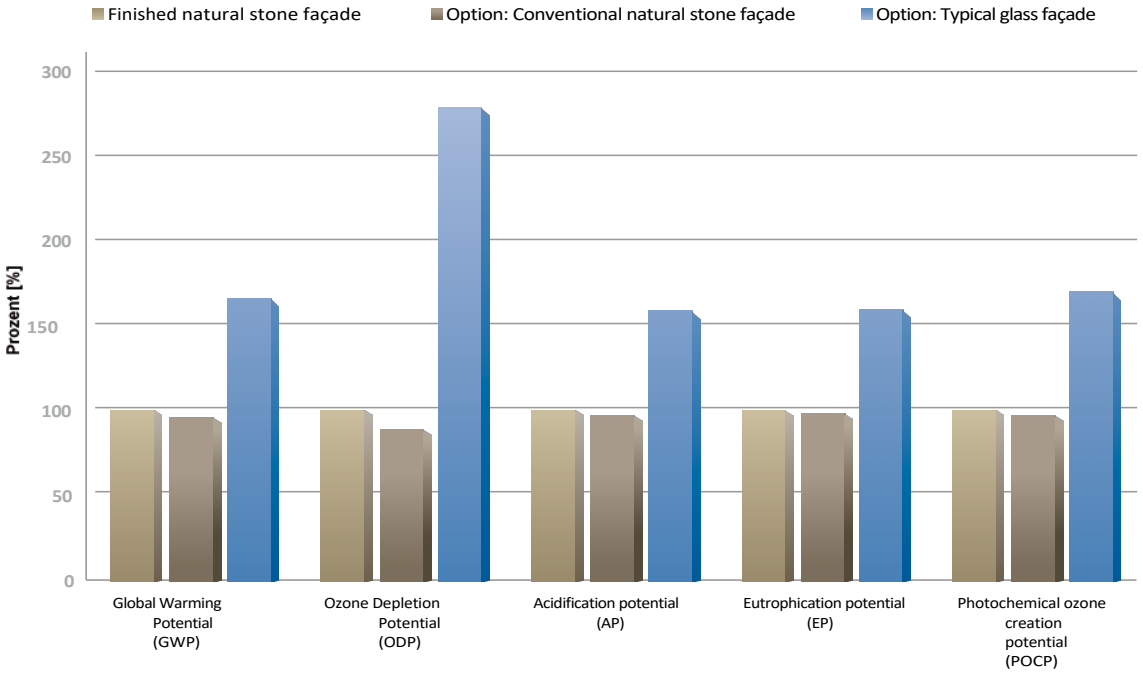
THE NATURAL STONE FAÇADE REQUIRES APPROX. 50 % LESS PRIMARY ENERGY DEMAND THAN THE GLASS FAÇADE UNDER CONSIDERATION.

Sustainability study - Life cycle assessments of façade constructions with natural stone and glass, DNV

17

In the further course of the life cycle, the use phase is dominated by the maintenance measures depending on the replacement cycles of the components used. While the natural stone façades with their relatively long-lasting components manage with about 50 % of the energy resources for this phase compared to production, the share of maintenance for the glass façade is about 80 % compared to production. During the 50 years under consideration, individual components are completely replaced up to three times. The results of the life cycle assessment are negligible for cleaning with water overall, although this is an important aspect of economic considerations.

Evaluation of the environmental impacts of the three scenarios over 50 years: The reference value is the façade that was constructed.



When considering the end of life, it can be seen that the materials used in the glass façade, such as aluminium and plastic, receive ecological credits, since by returning these materials to the material cycle, costly primary production can be avoided.

The considered environmental impacts of the glass façade (GF) are between 60 % and 175 % higher than those of the executed natural stone façade (NSTF executed):

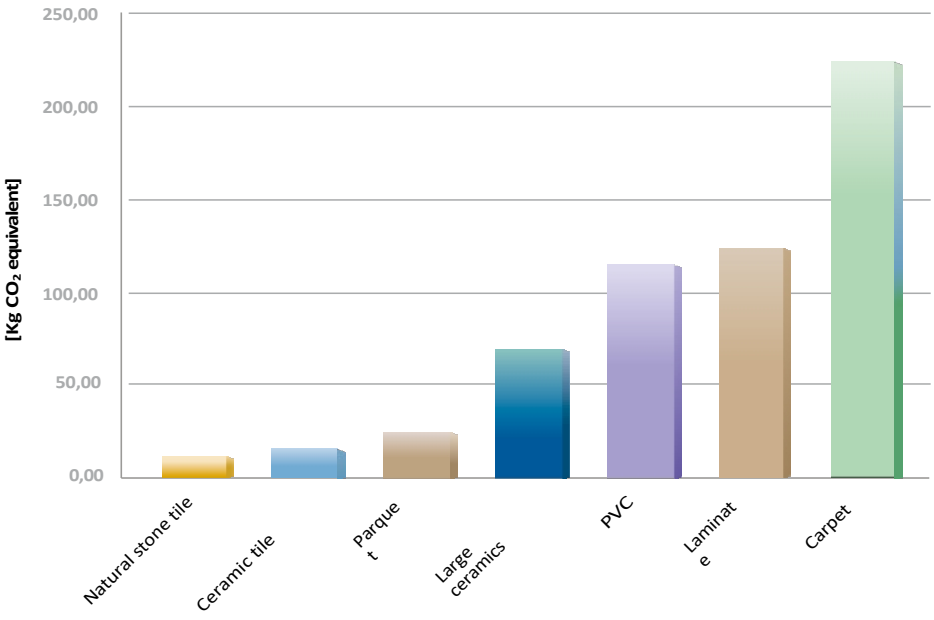
Environmental impacts

	NSTF ed. : GF
Global warming potential (CO_2 equivalent; GWP)	1 : 1,7
Ozone depletion potential (R11; ODP)	1 : 2,8
Acidification potential (SO_2 equivalent; AP)	1 : 1,6
Eutrophication potential (PO_2 equivalent; EP)	1 : 1,6
Summer smog potential (C H_{22} equivalent; POCP)	1 : 1,7

Sustainability study flooring system (interior)

The object of the sustainability study is to determine the ecological performance of different floor coverings used for various applications in public and commercial indoor areas.
The ecological impacts of the supporting structure with concrete ceiling, insulation layers, screed as well as the different floor coverings including their installation mortars were also considered in a screening process over the entire life cycle. The data collection is based on existing environmental product declarations (EPD) of the various building material manufacturers.

GWP in kg CO_2 equivalent for different floor coverings over the entire life cycle



As was to be expected due to the low primary energy demand of natural stone, floor coverings made of natural stone achieve very good results in the life cycle assessment. According to the Bundesverband Baustoffe - Steine und Erden (German Federal Association of Building Materials - Stone and Earth), the cost of energy consumption for working and processing natural stone is only 3.3 % of the production value.

A comparison of all floor coverings showed that coverings made of natural stone have a significantly lower overall environmental impact from production, installation and use than large ceramics, carpet, PVC, laminate and parquet.

In the particularly important impact category of global warming potential (GWP), the production and use of floor coverings with natural stone tiles have significantly lower CO_2 equivalents than are produced in the production and use of the other covering materials. At 10.9 kilograms CO_2 -eqv., the GWP of the natural stone tile together with the associated adhesive mortar are the lowest emissions. The GWP of the carpet is higher than that of the natural stone tile with a value of approx. 223 kilograms CO_2 -eqv. (cf. Figure 1) is more than 20 times higher.

19

NATURAL STONE FLOOR COVERINGS
HAVE EXTREMELY LONG SERVICE LIVES
AND LOW MAINTENANCE COSTS.

20

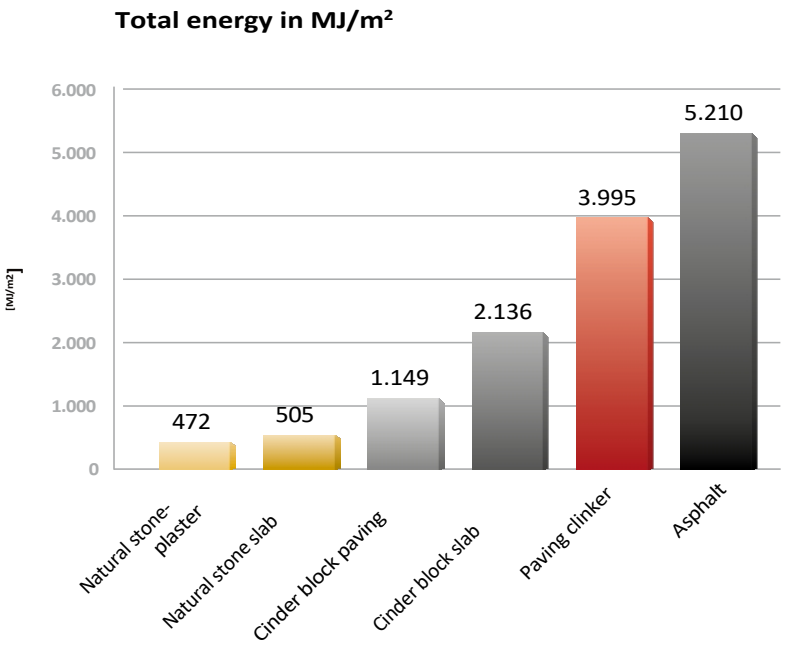
Sustainability study outdoor coverings

NATURAL STONE FLOOR COVERINGS FOR OUTDOOR USE HAVE LOST NONE OF THEIR FASCINATION OVER THE CENTURIES.

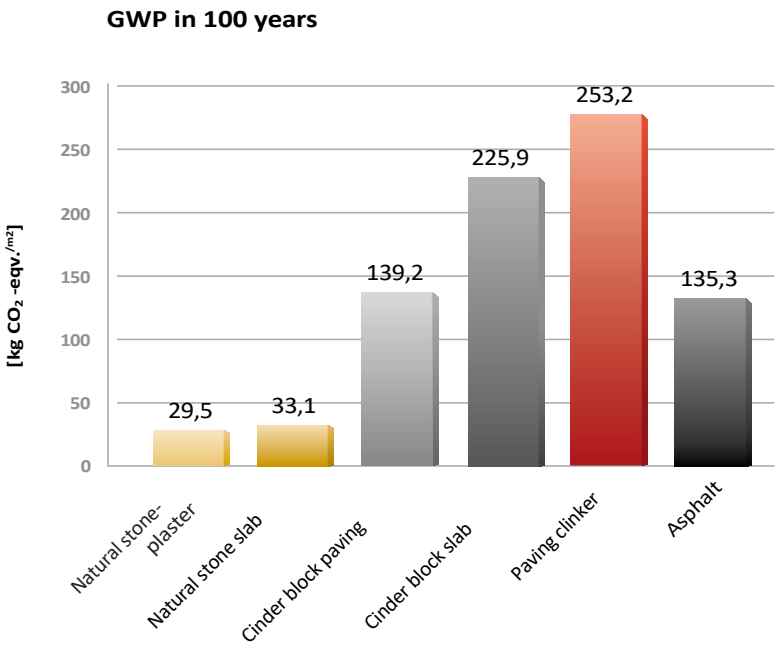
The object of the sustainability study is to determine the ecological performance of different pavements for traffic routes in the
Exterior used in public and private areas.
The ecological impacts of the base courses, beddings and surface courses of the different pavement constructions were considered in a screening procedure over the entire life cycle.
The data collection is based on public environmental product declarations (EPD) of the various building material manufacturers and data from the ÖKOBAUDAT platform of the Federal Ministry of the Interior, for Construction and Home Affairs (BMI).

A comparison of the examined pavement constructions for a service life of 100 years, which is quite common for granite paving stones, for example, illustrates the low energy consumption of outdoor pavements made of natural stone. The energy demand of outdoor pavements with paving stones made of natural stone amounts to approx. 470 MJ/m², which is only about 1/10 of the energy demand of paving clinker (4,000 MJ/m²) and asphalt pavements (5,210 MJ/m²).
The primary energy demand for the use of natural stone slabs for a traffic area of 1,000 m², for example, is only approx. 505,000 MJ over an observation period of 100 years. In comparison, the same area with concrete slabs requires approx. 2,136,000 MJ of primary energy. Based on a guideline value for the electricity consumption of an average two-person household of 2700 kilowatt hours per year, the saved energy could supply approx. 170 two-person households with electricity for one year. Compared to paving bricks, the primary energy saved could supply approx. 360 two-person households with electricity for one year, and approx. 480 two-person households with asphalt.

TERRACE COVERINGS MADE OF
NATURAL STONE ARE USED
FOR THE HIGH-QUALITY
DESIGN OF OUTDOOR SPACES.

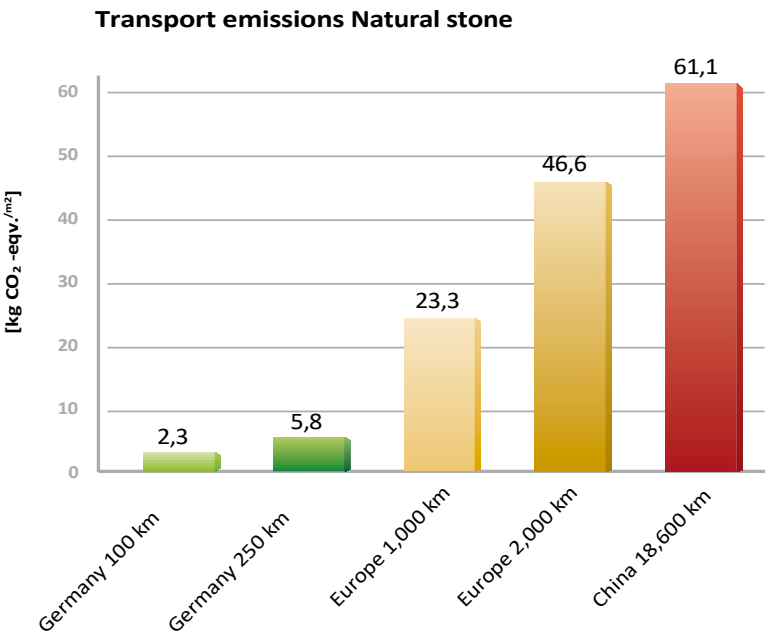


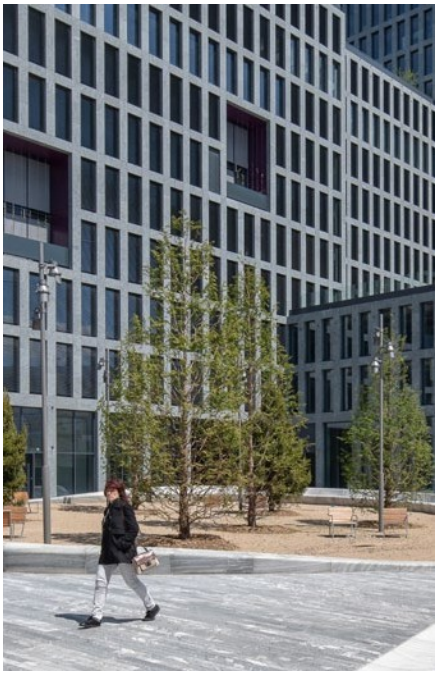
THE DESIGN OF OUTDOOR SPACES WITH NATURAL STONE OFTEN FOLLOWS A LONG TRADITION



In the particularly important impact category of global warming potential (GWP), the floor constructions with paving stones and slabs made of natural stone have significantly lower CO_2 equivalents in production and use than the other surfacing materials. With 29.5 kilograms of CO_2 eqv., the lowest emissions are attributable to the GWP of paving stones made of natural stone during production.

Another important aspect of the use of natural stone is the influence of transport. Whereas the use of local natural stone with 100 km truck transport produces only 2.33 kilogrammes of CO_2 -eqv. per square metre of floor covering or 5.83 kilogrammes of CO_2 -eqv./m² with 250 km truck transport, the figure is 23.32 kilogrammes of CO_2 -eqv./m² for transport within Europe with 1,000 km truck transport.
2,000 km by truck 46.64 kilograms CO_2 -eqv./m² and for natural stone from China (18,600 km by ship, 750 km by truck) 61.07 kilograms CO_2 -eqv. per square metre of flooring.





23

CONCLUSION

DNV's sustainability studies show that the use of natural stone can make a significant contribution to reducing carbon dioxide emissions in the construction industry. Natural stone is already available as a finished product and only a small amount of energy is required for its extraction and processing. Natural stone occupies a special position among all building materials. Moreover, natural stone is an extremely durable building material and can be reused at the end of the building's life or processed into chippings and gravel. In contrast to other building materials, the usable quantity produced from the raw material extracted from our planet is very high and the natural stone deposits in Germany and also worldwide are virtually inexhaustible.

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