BUILDING MATTERS: Mitigating climate change transition risks of the construction sector through building capacity in sustainable building materials

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WP3. Deployment of the Sustainable Building Materials Knowledge Package

A. 3. 1. Development of the Sustainable Building Materials Curricula

HANDBOOK

Release 11.2023

Co-funded by the European Union

BUILDING MATTERS
sustainability in the construction sector

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INTRODUCTION

This document has been developed within the ERASMUS+ project **Building Matters** whose aim is to support awareness raising of key stakeholders in sustainable pathways for mitigating climate change transition risks of the construction sector. The project anticipates developing green sectoral skills and competences in sustainable building materials, through introducing future-oriented and innovative curricula and learning practices tailored to the needs of learners, enabling sustainable behavioral changes in line with the New European Bauhaus initiative.

More in specific, this document structures the proposal training content for the Sustainable Building Materials Curricula, being an integral part of the Building Materials Knowledge Package, consisting of developing and testing the VET- curricula package, i.e. the Building Maters training program that will be performed in a digital e-learning environment, supporting the professional development of VET teachers and trainers through learning opportunities and training offers that meet forward looking sustainable transition pathways.

Structure of the training curricula

Objectives of the course/curricula:

This course provides end users with enhanced green competences for tackling environmental and climate transition challenges that the construction sector faces, through the promotion and providing fundamental knowledge on the use of sustainable building materials. The aim of the course is highlighting the environmental impacts of building materials and the importance of initiatives and aspirations that will drive the necessary shift toward the use of sustainable and environmentally friendly materials and approaches in the construction sector in future.

The training overall impacts to enable behavioral changes and build competences in line with the New European Bauhaus initiative, that calls for reskilling and fostering VET in the affected sectors such as the construction one, for effective use of new materials and relevant tools.

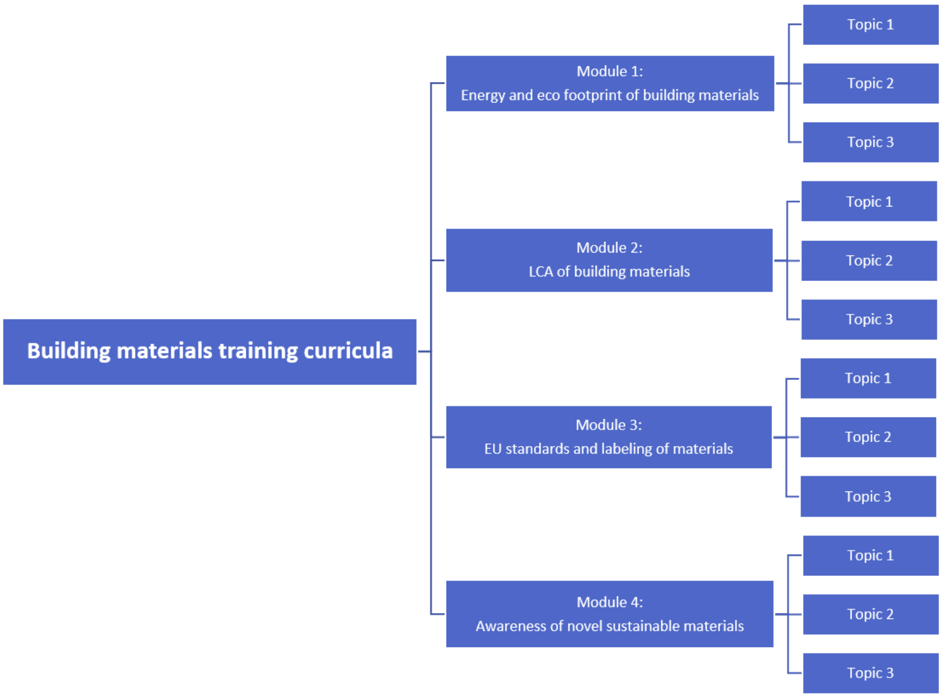
Type of course/curricula: Self-guided microlearning training, enabling consecutive progress through the training content.

Type format of course/curricula: Online through digital e-learning platform

Level: Introductory

Language: English | MK | IT | DE | SI| GR |RO

Structure of the training curricula



Development of learning material (*portfolio*) for the training on Sustainable Building Materials

To provide the learners with enhanced green competences for tackling environmental and climate transition challenges that the construction sector faces, through the promotion and providing fundamental knowledge on the use of sustainable building materials, the training course on Sustainable Building Materials will encompass 4 consecutive modules:

Module 1: Environmental aspects of building materials

Module 2: Life Cycle Assessment of building materials

Module 3: EU standards and labeling of building materials.

Module 4: Awareness of novel sustainable building materials

For each of the modules corresponding learning material is developed, to serve as an input material available through e-learning platform of Building Matters:

Handbook (Reading material)

1 animated video presentation for each module, up to 5 minutes

Library

Self-assessment quiz at the end of each module

MODULE 1: ENVIRONMENTAL ASPECTS OF BUILDING MATERIALS

1. The impact of construction industries. Environmental impact of construction activities

1.1 The impact of construction industries

Most human activities that impact on the environment have backwards or forward linkages to the construction industry and their impact can be mitigated through changes in the practices of the construction industry. The environmental impact of industry is measurable, but its socio-economic impact should not be negated. Sustainable construction in developing countries tends to focus on the relationship between construction and human development, often marginalizing the environmental aspects.

The environmental impact of the construction industry as an industry sector is probably larger in developing countries than it is in developed countries. This is since the developing countries are virtually still under construction and they have a relatively low degree of industrialization, making the construction industry one of the biggest factors impacting on the biophysical environment.

The environment and the construction sector are linked principally by the demands made by the latter on global natural resources, and this assumes huge environmental significance with the rapid growth in global population and the attendant implications for natural resources. This is especially the case with housing and infrastructure, which are very resource intensive. The call and desire for sustainable construction is in realization capacity of the construction industry to make a significant contribution to environmental sustainability because of the enormous demands it exerts on global resources.

The simplest point at which to begin evaluating the impact of the construction industry is to look at its consumption of energy and greenhouse gas emissions. The biggest culprits in terms of climate change are the materials that form the basis of modern construction – concrete and steel. Twice as much concrete is used in formal construction around the world than the total of all other building materials – including wood, steel, plastic and aluminum. Cement production is, after the burning of fossil fuels, the biggest anthropogenic contributor to greenhouse gas emissions. Cement kilns have been identified as a stationary source of nitrogen oxides, releasing more than 25 tons per year. Although cement makes up only 12-14% of the final concrete mix, further embodied energy comes from the transportation and extraction of aggregates and, in the case of reinforced concrete, the manufacturing of steel.

Steel is one of the most energy-intensive materials. Together, the production of iron and steel is responsible for 4.1% of global energy use. The manufacturing and final use of both these materials can also be very water intensive. Construction activities, whether through the manufacturing of construction materials, or through the operational activities of actual construction, also lead to several other environmental problems. These include noise pollution, dust, and hazardous contamination through toxic waste.

Apart from the energy embedded in building materials and products, and the associated greenhouse gas emissions, massive environmental pollution also occurs during processing of the raw materials and manufacturing of the product. Toxic gases and effluents are discharged into the environmental media with devastating effects on aquatic and marine life, as well as contributing to atmospheric pollution. The production of iron, steel, and non-ferrous metals, as well as the production of other construction materials such as cement, glass, lime and bricks, is responsible for 20% of annual dioxin and furan emissions.

This excludes emissions due to the production and use of PVC and other chlorinated substances used in the construction industry such as paints, sealants, plastics, and wood preservatives, for which specific figures are not yet available. Road transport infrastructure, especially road paving with asphalt, contributes a further one percent of annual dioxin emissions. The bulk of dioxin emissions (69%) come from the incineration of municipal waste.

Construction and demolition waste is another important issue, as waste is often dumped illegally in dams, river courses and any available hollow. If left unchecked, dumping sites become breeding grounds for mosquitoes and vermin. High material consumption rates are due to high material wastage, both as waste and as material unnecessarily incorporated in the building. (Material wastage can be defined as the amount of material consumed in addition to the planned amount.) The highest rates of wastage are recorded for Portland cement and concrete and ceramic blocks, all materials which significantly contribute to climate change through their manufacture.

The building materials manufacturing industry is also responsible for the pollution of watercourses and filling up of landfill sites. The raw materials for building materials are often extracted from the rural hinterlands, where they cause degradation of land and ecosystems. The processing and production of these usually take place close to the city, where they produce air and dust pollution and consume a great deal of energy.

Any discussion on the environmental impact of construction would not be complete without the inclusion of the mining and mineral-related industrial sectors. Pollution, land degradation and widespread disruption of natural terrain are direct impacts that are exacerbated by the lack of programmers and regulations regarding the rehabilitation of mining sites.

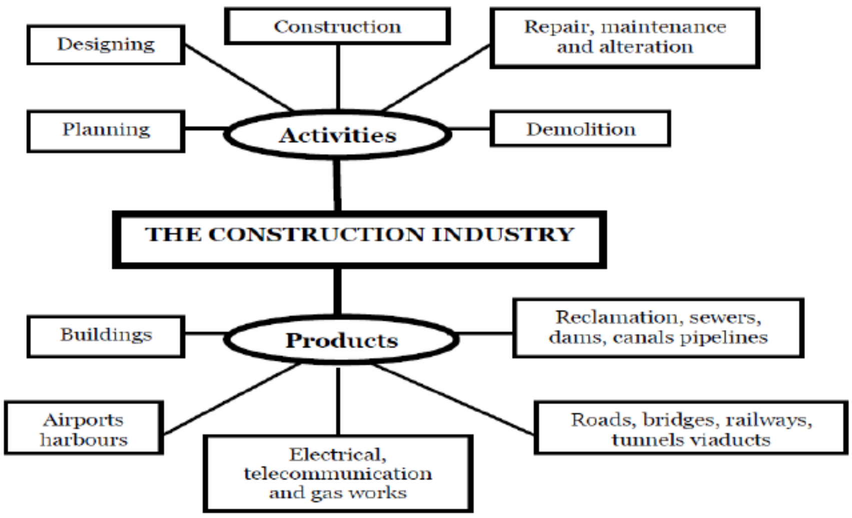


Figure 1. Activity and products of construction industry

The following sections focus primarily on environmental impacts relevant to construction activities.

1.2. Environmental impact of construction activities

Globally, the construction sector is arguably one of the most resource intensive industries. Concern is growing about the impact of building activities on human and environmental health. Actions are needed to make the built environment and construction activities more sustainable. The construction industry and the environment are intrinsically linked, and it has found itself at the center of concerns about environmental impact. Indeed, the construction industry has a significant irreversible impact on the environment across a broad spectrum of its activities during the off-site, on-site and operational activities, which alter ecological integrity. Construction activities affect the environment throughout the life cycle of a construction project. This life-cycle concept refers to all activities from extraction of resources through product manufacture and use and final disposal or recycle.

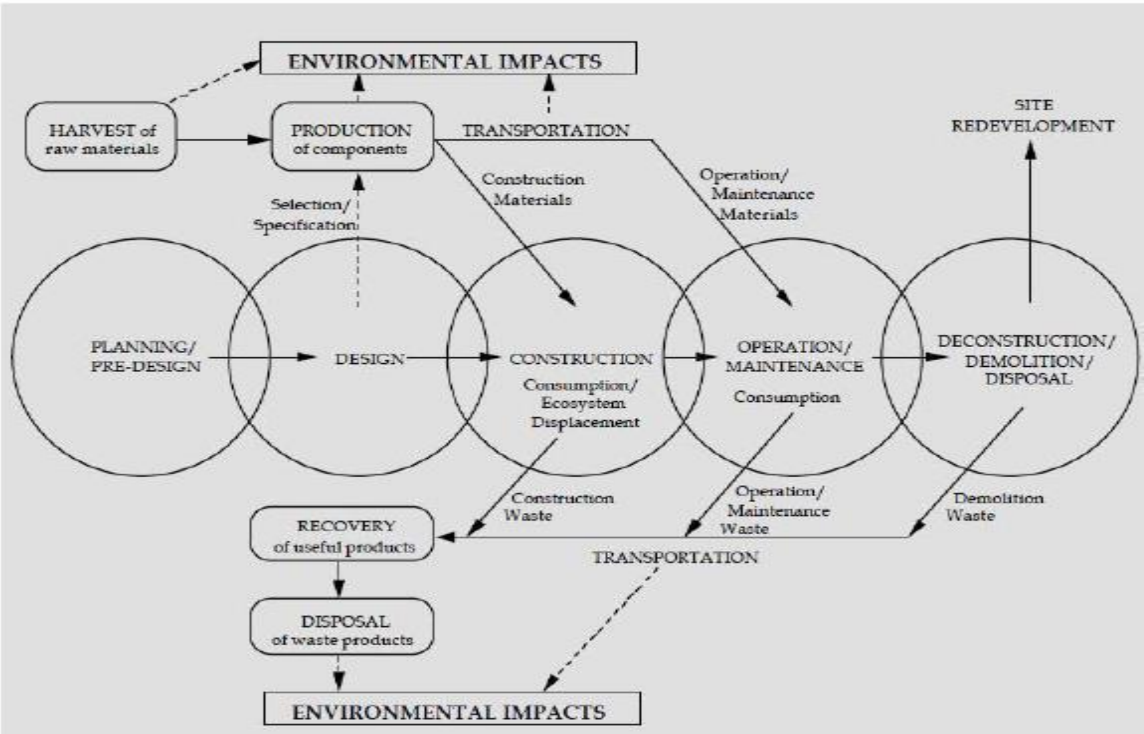


Figure 2. Life Cycle Environmental Impact of building construction

Even though the construction period is comparatively short in relation to the other stages of a building's life, it has various significant effects on the environment.

The aim of circular construction is to create a sustainable, green, circular, and economical construction industry that minimizes the impact on the environment. It is important to realize that optimizing material flows in construction involves efficient resource management, such as recovery, waste recycling, the use of recycled materials (secondary raw materials) and the reuse of existing buildings and components. This reduces the need to source new raw materials, reduces the amount of waste ending up in landfills and achieves more sustainable results. Optimizing material flows is key to reducing the ecological footprint of the construction sector and achieving more sustainable results.

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1.2.1. Environmental impact of Raw material consumption

The construction industry is one of the largest exploiters of renewable and nonrenewable natural resources. The global construction materials market size is expected to grow from 1121100 MUSD in 2022 to 1493810 MUSD by 2028, at Compound Annual Growth Rate (CAGR) of4.9% from 2022 to 2028 (Figure 1). It relies heavily on the natural environment for the supply of raw materials such as timber, sand and aggregates for the building process. This extraction of natural resources causes irreversible changes to the natural environment of the countryside and coastal areas, both from an ecological and a scenic point. The subsequent transfer of these areas into geographically dispersed sites not only leads to further consumption of energy, but also increases the amount of particulate matter in the atmosphere.

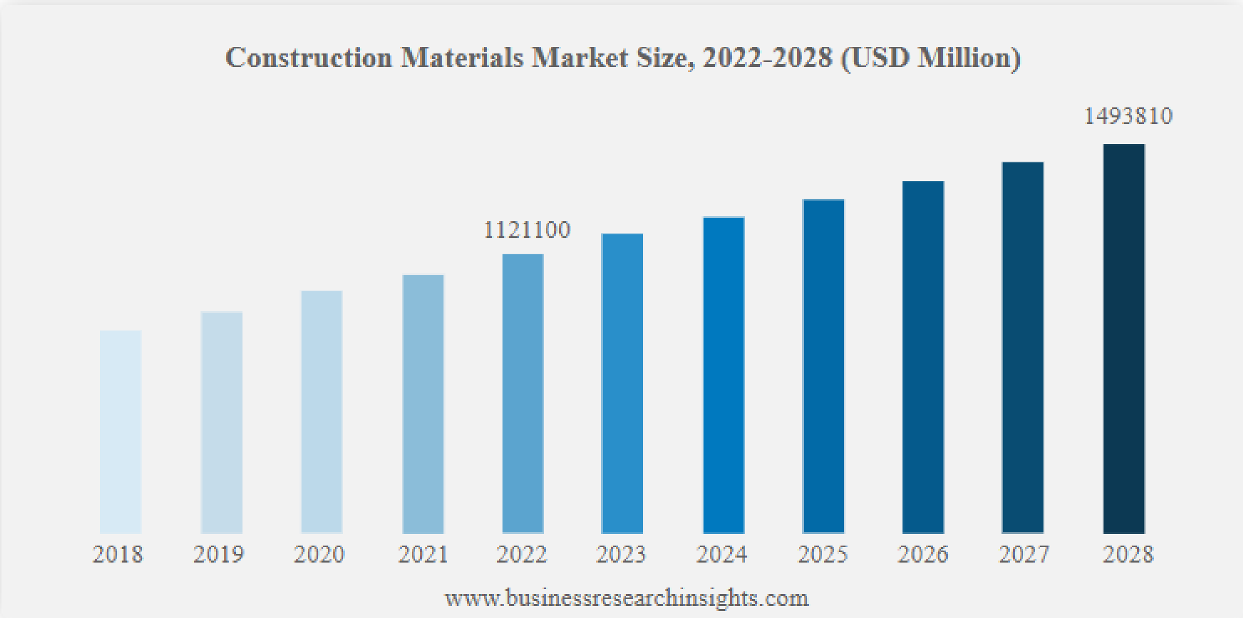

Figure3. Construction Materials Market Size. SOURCE: businessresearchinsights.com

1.2.2. Pollution generation

Raw materials extraction and construction activities also contribute to the accumulation of pollutants in the atmosphere, mostly in the processing of materials for construction. And again, not surprisingly, the construction industry has the biggest effect of all sectors because of the quantity of materials used in construction. The construction sector is responsible for almost 40 % of atmospheric emissions, 20 % of water effluents and 13 % of other releases. Dust and other emissions include some toxic substances such as nitrogen and sulfur oxides. They are released during the production and transportation of materials as well as from site activities and have caused serious threat to the natural environment. Other harmful materials, used in insulation, air conditioning, refrigeration plants and fire-fighting systems and have seriously depleted the ozone layer. Pollutants have also been released into the biosphere causing serious land and water contamination, frequently due to on-site negligence resulting in toxic spillages which are then washed into underground aquatic systems and reservoirs. About one third of the world's land is being degraded and pollutants are depleting environmental quality, interfering with the environment's capacity to provide a naturally balanced ecosystem. Risks should be identified, and steps taken to minimize potential pollution. The construction industry must consider enhancing or at least protecting biodiversity as it considers all things and their habitats and there is an obligation to consider biodiversity in developments in terms of good design and material selection.

1.2.3. Environmental impact of construction waste generation

The construction industry produces an enormous amount of waste. A large volume results from the production, transportation, and use of materials. In the European Union, the construction industry contributes about 40–50 % of waste per year.

The best possible solution for reducing construction waste is by implementing construction waste management plans. The practice of minimizing and diverting waste from disposal to redirecting recyclable resources into the construction process is known as construction waste management.

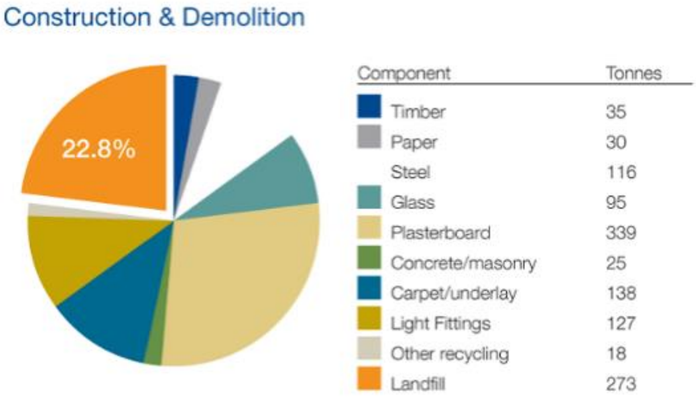

Figure 4. Components in construction waste

Figure 4 describes the share of each component in construction waste. The industry by integrating Construction Waste Management (CWM) creates a win situation both for environment and bottom line. The CWM starts from planning, allocating responsibilities, identification of waste, identifying the way to manage waste and to organize the waste. The CWM plan is a continuous process that should be measured, updated, and regularly reviewed. The architect, by developing CWM plan and reducing activities that result in the creation of waste on site of the project will help in implementing the sustainability goals. The successful CWM framework involves all the parties of the project such as owner, architect, project manager, contractor, etc. By involving parties in the design process, it becomes easier to achieve established goals.

The circular business model therefore involves the sustainable extraction, use and disposal of construction materials and follows a multi-level inverted pyramid (hierarchy) of waste management. This means that, in line with EU waste legislation which establishes a waste hierarchy, it promotes the following circularity strategies, which in English start with the letter "R":

"Reduce, Rethink, Refuse, Refurbish, Repair, Reuse, Reset, Repurpose, Redistribute, Regift, Recover, Remanufacture, Recycling, Rot".

Disposal is ranked last in the hierarchy and should only be used as a last resort when other management options are not possible (in exceptional circumstances - natural disasters and catastrophes, weather events, wars, pandemics, etc.).

Construction waste accounts for a large proportion of all waste generated by the population and the economy. Construction waste is defined as waste generated during construction work. According to the recommendations of the European Commission, construction waste is classified under waste classification group 17 - construction and demolition waste. Waste is divided into non-hazardous and hazardous (explosive, oxidizing, flammable, corrosive, irritant, carcinogenic, corrosive, infectious, mutagenic, ecotoxic, ...) and inert. Construction waste treatment centers collect and treat most of these wastes and landfilling is avoided and discouraged. Some of this waste still ends up in black dumps and in the environment, an illegal and unacceptable practice that could harm our future generations and living beings for centuries to come.

Table 1. Classification of construction and demolition waste (list from the Commission Decision on the European list of wastes - Commission Decision 2000/532/EC)

17 01 CONCRETE, BRICKS, TILES AND CERAMICS	- concrete-based: from dismantling of buildings, civil engineering structures, concrete roads, concrete pipes and blocks, concrete residues from concreting, incorrect formulation, improper application, testing (external, internal control) or testing of new mixes and formulations, etc. - brick-based products: they are the result of demolition and may be contaminated with mortar and plaster. Brick waste is sometimes mixed with other materials such as wood and concrete.
17 02 WOOD, GLASS, AND PLASTICS	- Plastic and petroleum-based waste: Plastic waste is best recycled if collected separately and cleaned. Recycling is difficult if plastic waste is mixed with other plastics or contaminants. Plastic can be recycled and used in products specifically designed to use recycled plastic, such as street furniture, roofing and flooring, noise barriers for PVC windows, cable ducts, panels.

	- Wood-based and wood composites: generated in large quantities during land clearing and preparation for construction.
17 03 BITUMINOUS MIXTURES, COAL TAR AND TAR-CONTAINING PRODUCTS	As in the title
17 04 METALS (INCLUDING ALLOYS)	- ferrous metals: almost entirely recyclable (nails, screws, plumbing, radiators, grilles, fittings, etc.). - Non-ferrous metals: Aluminum, copper, lead, and zinc are examples of non-ferrous waste materials generated on construction sites (from roofing, joinery: windows and doors, etc.). Most of these materials can be recycled.
17 06 INSULATION MATERIALS AND BUILDING MATERIALS CONTAINING ASBESTOS	As in the title
17 09 OTHER CONSTRUCTION AND DEMOLITION WASTES	As in the title

The general conditions in the Waste Regulation are also very demanding, which can make recycling difficult. Such materials must meet the technical specifications needed to obtain certificates and standards, while at the same time being environmentally sound.

Directive 2008/98/EC stipulates that waste ceases to be waste when it has been recovered, including recycling, and meets certain criteria designed in accordance with the following conditions:

- the substance or object is normally used for a specific purpose,
- there is a market or demand for the substance or object,
- the substance or object meets the technical requirements for the specified purpose and the requirements of existing legislation and standards applicable to the products,
- the use of the substance or object will not cause an overall adverse effect on the environment and human health (Directive 2008/98/EC 2008, Article 6).

The EC Recommendations of the EU Protocol for the Management of Construction and Demolition Waste (expected to be updated in 2024) is a Checklist document for EU Member States to:

- Better waste identification,
- better and more appropriate disposal methods - selective demolition,
- better separation and collection at source,

- transparency and tracking of waste,
- optimizing logistics,
- better storage,
- preparation for re-use,
- recovery, reuse, recovery, treatment, recycling of waste
- waste management and quality assurance.

1.2.4. Energy consumption and its associated impacts

Apart from waste generation, the building industry rapidly growing world energy use and the use of finite fossil fuel resources has already raised concerns over supply difficulties, exhaustion of energy resources and heavy environmental impacts. Building material production consumes energy, the construction phase consumes energy, and operating a completed building consumes energy for heating, lighting, power, and ventilation. The existing building stock in European countries accounts for over 40% of final energy consumption in the European Union member states, of which residential use represents 63% of total energy consumption in the buildings sector. The current low levels of energy efficiency in the built environment offer vast scope for improvement in energy performance, which may be achieved through the deployment of an array of techniques ranging from simple plant and insulation upgrades to the deployment of advanced energy monitoring and control.

1.2.5. Land degradation

Fragile eco-zones in many countries are being destabilized because of construction activities. The occurrence of floods, land and mud slides caused by construction on delicate hill slopes and wetlands testify to the vulnerability of the environment to interventions of the construction sector. Physical destruction of land is also caused by extraction of sand and gravel for concrete and extraction of clay to produce bricks. The rate of deforestation is extensive due to lumbering, land clearing for farming and building construction, which has even penetrated restricted areas like forest reserves on hill sided and highlands. This resulted in increased instability of the natural landscape and increased erosion. Rational decision-making and implementation of transparent and effective strategies are needed to solve the conflicts between land use and the construction sector is urgently required and should be given high priority by decision makers.

1.2.6. Sand Mining

For thousands of years, sand and gravel have been used in the construction of roads and buildings. Today, demand for sand and gravel continues to increase. Mining operators, in conjunction with cognizant resource agencies, must work to ensure that sand mining is conducted in a responsible manner.

Excessive in stream sand-and-gravel mining causes the degradation of rivers. In stream mining lowers the stream bottom, which may lead to bank erosion. Depletion of sand in the streambed and along coastal areas causes the deepening of rivers and estuaries, and the enlargement of river mouths and coastal inlets. It may also lead to saline-water intrusion from the nearby sea. The effect of mining is compounded by the effect of sea level rise. Any volume of sand exported from streambeds and coastal areas is a loss to the system.

Excessive instream sand mining is a threat to bridges, riverbanks, and nearby structures. Sand mining also affects the adjoining groundwater system and the uses that local people make of the river.

Instream and mining results in the destruction of aquatic and riparian habitat through large changes in the channel morphology. Impacts include bed degradation, bed coarsening, lowered water tables near the streambed, and channel instability. These physical impacts cause degradation of riparian and aquatic biota and may lead to the undermining of bridges and other structures. Continued extraction may also cause the entire streambed to degrade to the depth of excavation.

Sand mining generates extra vehicle traffic, which negatively impairs the environment. Where access roads cross riparian areas, the local environment may be impacted.

1.2.7. Depletion of non-renewable Resources

The construction industry is a major consumer of natural non-renewable resources such as metals, fossil fuel and non-renewable energy resources. Construction sector activities and the Manufacturing processes of basic building materials such as cement, steel, aluminum, glass, bricks, and lime are highly energy dependent where fossil fuel is a major non-renewable resource requires generating huge amount of energy. The worldwide recognition of the limited supply of fuels and the high degree of dependency on energy by the construction industry has led to regional efforts in search of alternative energy sources and renewable sources. Consequently, as fossil fuel become more and more precious fuel wastage are prevented, and the overall energy efficiency become the overriding criterion in the design and operation of buildings. Energy efficiency is seen as the most attractive factor why stakeholders invested in sustainable building and construction.

SOURCE: Sanket Suresh Petkar, Environmental impact of Construction Materials and Practices, DOI: 10.13140/RG.2.1.2581.0001, 2014

2. Carbon production in building materials manufacturing. Carbon footprint of building materials and databases

2.1 Carbon Emissions of Building Materials

The construction industry is responsible for a large percentage of total global GHG emissions, especially from the carbon footprint (CF) of building materials. They generate embodied and operational emissions in the processing and use. The green building calculator can be used to figure out the emissions of any project. Decarbonization goals estimate that the sector should consider the CF of building materials and reduce its emission levels by at least 50% before 2030 to achieve the Paris Agreement targets.

Globally, the building and construction sectors account for nearly 40% of global energy-related carbon dioxide emissions in constructing and operating buildings (including the impacts of upstream power generation).[1]

Current building codes address operating energy, but do not typically address the impacts 'embodied' in building materials and products. More than half of all GHG emissions is related to materials management, including material extraction and manufacturing, when aggregated across industrial sectors.[2]

As building operations become more efficient, these embodied impacts related to producing building materials become increasingly significant.

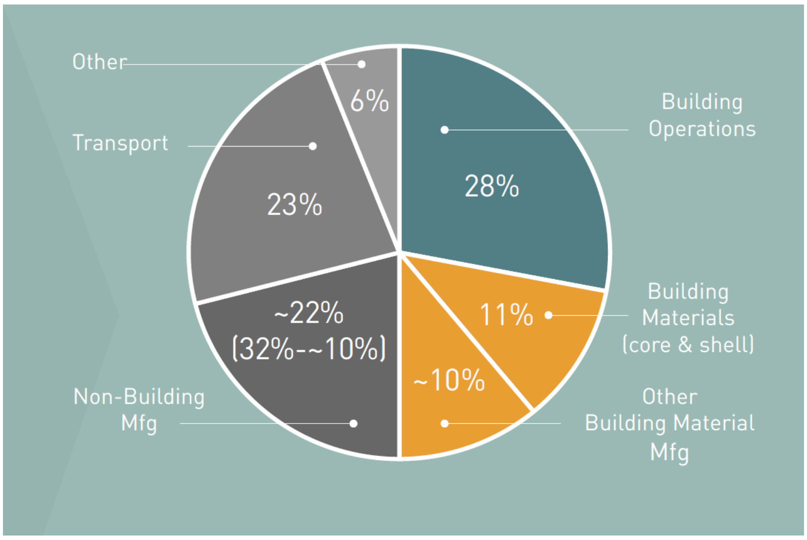

Figure 5. Global CO_2 Emissions in Construction Sector. SOURCE: 2019 Global Status Report, Global Alliance for Building and Construction (GABC) and Architecture 2030.

The building and construction sector has a vital role to play in eliminating carbon, as it is responsible for at least 39% of global carbon emissions. All buildings and facilities have carbon emissions from GHG from construction materials and daily operations. Whether it is an existing or a new/ residential or commercial building, a building's CF is measured usually by the square footage and other factors.

By far the biggest CFs are found in colocation or data centers. These massive facilities utilize massive amounts of energy and water to operate, in addition to the embodied emissions of the building materials.

Some industries have developed ways to reduce buildings' energy usage, but the elusive aspect is embodied energy from construction materials.

The embodied carbon makes up about 11 percent of worldwide GHG emissions, a staggering value that needs immediate addressing.

Construction materials account for about 70% of a building's CF, and the only remedy is to use low-carbon alternatives. For construction projects, a great example is a carbon-neutral concrete, steel, and wood.

2.1.1. Estimation of the Carbon Footprint of Steel

According to the International Energy Agency (IEA), the direct carbon emissions from steel production are around 1.4 tons of CO^{2}e per ton, but the level may be higher, reaching 1.85 tons. The CF of steel is notably higher in countries like China due to the production method.

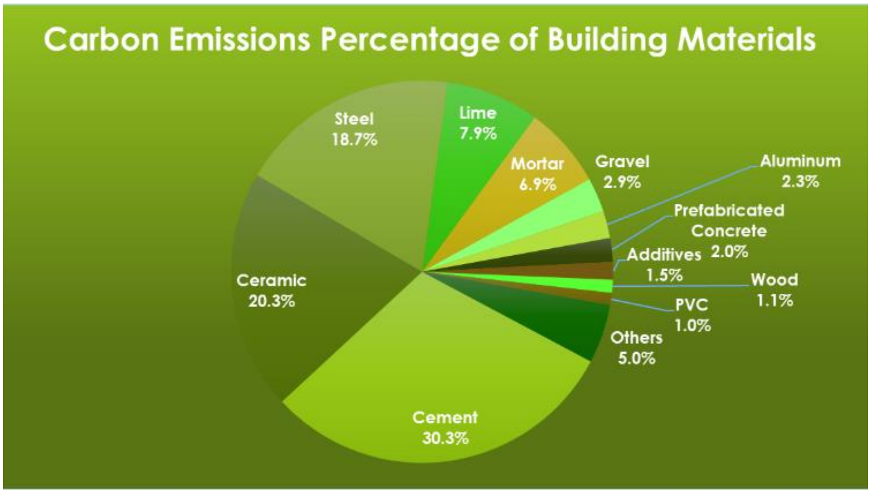

Figure 6. Carbon Emission Percentage of Building materials

China is one of the largest steel manufacturers, and the ratio can rise to three CO_2 tons per ton. They produce the material in furnace ovens where the iron ore heats to 1500 degrees and then blasts oxygen into the liquefied iron to eliminate impurities.

2.1.2. Contributions to Carbon Footprint of a Building

Various factors determine a building carbon footprint (CF), but most people are only aware of the energy consumption, which they reduce by switching to renewable alternatives.

The less obvious contributors to a building CF include the emissions from the transportation of materials to the construction site and their embodied carbon. Experts estimate that embodied carbon accounts for a significant percentage of GHG emissions. Steel, concrete, and aluminum are the worst offenders here since their emissions are almost equal to the GHG from the building sector operations.

China is one of the leading countries in matters of carbon emissions from material production. As a country's economy rises, so does the demand for more commercial and residential buildings, explaining the increased material production. Figure 7 shows that China's carbon emissions from cement production, which as vital in the building sector, is responsible for massive carbon emissions in China industries.

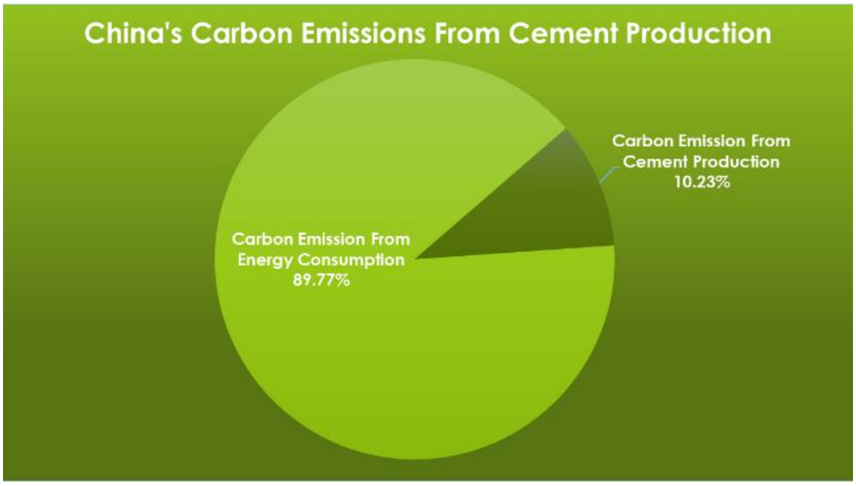

Figure 7. China Carbon Emissions form Cement productions

Concrete is one of the most widely used construction materials, given that it is cheap and durable, and that it can be used for a variety of applications. Unfortunately, the production of cement accounts for approximately 8% of the worldwide CO_2.

On the other hand, steel is an environmentally friendly alternative with lower embodied carbon, unlike concrete. Steel is often used in combination with concrete as reinforcement. Effective ways for construction companies to check their CF are by carefully selecting low-carbon building materials and using energy-efficient equipment. Electric machinery is more sustainable than fuel-powered ones and significantly reduces the construction's energy usage. Firms can also turn to renewable energy sources for building maintenance.

2.1.3. Carbon Emission of Global Construction Sector: Building Sector CO2 Emissions

The carbon emissions from the construction sector increase with the rise in building projects; for instance, they reached a record high in 2019 at 9.95 GtCO2 when contractors undertook more building projects. However, the rate subsided in 2020 when the number of projects plummeted following the pandemic.

In 2040, two-thirds of the buildings today will still exist, and they will keep generating more carbon unless remedies are in place. Without building decarbonization, it will be impossible to achieve the Agreement targets. The first zero-carbon step is to insist on energy efficiency. Occupants consume a lot of energy with their household and office equipment, and this rate will only be minimal if there is a switch to renewable energy.

The building and construction industry is one of the heaviest carbon emitters, responsible for about 11% of the total GHG worldwide. Whether residential or commercial, the embodied carbon from the materials and the pollution from the entire process needs immediate attention.

2.2. Carbon footprint of building materials

The global construction industry is responsible for a massive percentage of all emissions. This level comprises the carbon from operations, the embodied CO2 from the construction materials, and the level emitted from the material manufacture. Some reports indicated that the CF from 6 buildings was 1,800 kg of CO^2e per m^2, with only six materials causing 70% of the embodied emissions. Surprisingly, concrete accounted for about 80% of all of them.

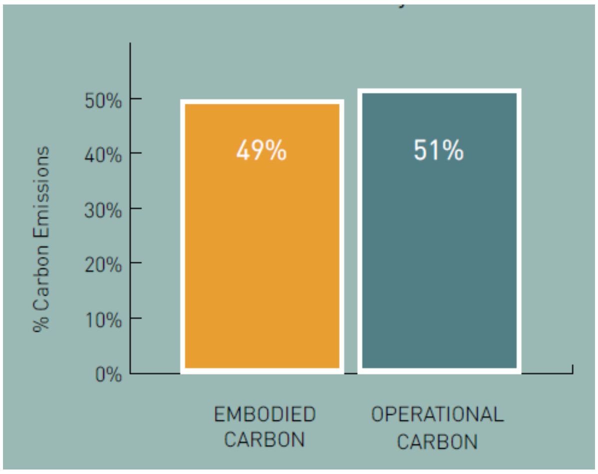

Figure 8. Total Carbon Emissions of Global New Construction from 2020-2050. Embodied Carbon: Manufacture, transport, and installation of construction materials; Operational Carbon: Building energy consumption. SOURCE: © 2018 2030, Inc. / Architecture 2030. All Rights Reserved. Data Sources: UN Environment Global Status Report 2017; EIA International Energy Outlook 2017

The Growing Significance of Embodied Carbon Between now and 2060 the world's population will be doubling the amount of building floor-space, equivalent to building an entire New York City every month for 40 years. Most of the CF of these new buildings will take the form of embodied carbon — the emissions associated with building material manufacturing and construction. Embodied carbon will be responsible for almost half of total new construction emissions between now and 2050.

Unlike operational carbon emissions, which can be reduced over time with building energy efficiency renovations and the use of renewable energy, embodied carbon emissions are locked in place as soon as a building is built.

Most common building materials seriously impact the environment because most humans live, eat, or work in them. It explains why there is a high demand for governments and contractors to build more to accommodate the ever-growing population. These materials need processing from their raw states, which requires a lot of energy. Transporting them after manufacture before reaching the consumer also emits greenhouse gases besides waste production. These factors contribute to the embodied CF of building materials, and after construction, you must account for its emissions, like energy usage. Therefore, building materials need a lot of energy for creation and maintenance.

Bodies like the UN target the construction industry since it accounts for a large percentage of carbon emissions. Managing the sector is critical in helping achieve net zero emissions before 2050 as part of the Paris Agreement.

Humanity depends on built environments, and everyone either sleeps, works, or eats in buildings; therefore, it is an excellent place to start when advocating for climate justice.7 Besides the NGOs, states have laid down regulations for residents to follow in their construction projects.

2.2.1. Highest and Lowest Carbon Footprint Building Materials

Concrete is responsible for the most CF of building materials due to its frequent usage, weight, and energy required for manufacture. However, mixing with fly ash is an effective way to reduce embodied carbon.

Besides concrete, plastic and aluminum are heavy emitters, although contractors do not use them as frequently. On the other end, wood and biomaterials have the lowest CF.

Manufacturers are also devising greener alternatives like low-carbon MDF panels that need less water and energy to produce. Salvaging and recycling materials are also brilliant strategies to help reduce embodied carbon in materials.

2.2.2. Calculation of Carbon Footprint of a Building

A building's CF measures the embodied CF of construction materials, energy usage, and daily activities. These numbers can be bulky and complicated when manually calculating them, but automated calculators online can help. It emits about 18.5 tons per cubic meter, although it is not as green as wood. Various versions have unique designs and use the data from the building's design that you can import from tools like Excel and Revit. After the input, the system will generate reports from the data, and some calculators further help you identify the eco-friendliest carbon reduction methods to implement.

If you find an effective calculator, it will be easier to quantify your green building architecture construction emissions, know the ideal materials to use, and how to minimize pollution from the project.

2.2.3. Effective Ways To Reduce The Carbon Footprint of Building Materials

Stakeholders first need to have crucial conversations before undertaking any construction projects. Clients should understand buildings' environmental impact and the value of critical material choices. Similarly, designers and contractors can join in developing alternative eco-friendly building projects.

The implementation process is the most vital, where you consider aspects like the building's site and public transportation proximity. The equipment and material choices also play a significant role in determining the project's CF.

Instead of heavy emitters like concrete, contractors can switch to low-carbon options like timber and use eco-friendly finishes that are locally produced. Additionally, the building can use renewable, efficient, and affordable energy sources.

2.2.4. Achievement of Zero Embodied Carbon in Buildings

Various stakeholders are relentlessly looking for ways to reduce the CF from all the major sectors, like advocating for carbon offsets credits. Research is also ongoing to find the most effective technologies in the industry to minimize the CF. According to their estimates, the companies can reach carbon neutrality by adopting advanced tech and using renewable energies. If the right policies are implemented, industry carbon emissions will significantly reduce with time. It may be a while before the industry declares zero carbon or achieves the country's carbon goals, but every step counts. It starts from the design stages to picking materials, and soon most new buildings will be green.

Buildings generate almost 40% of the global greenhouse gases if you include other related aspects like energy, water use, and waste. Commercial and residential buildings are heavy emitters, given the number of activities that take place there every day.

Employees travel daily to work and use a lot of energy for their tasks, contributing to the total emissions. Still, it doesn't include the pollution from the construction work while the building was erected. Therefore, there is a dire need to develop green building methods for any project, starting with material choices and using less energy for maintenance.

Companies are also focusing on obtaining green building construction credits as an effective way to save the planet. It is a gradual process but a brilliant idea to help achieve climate goals. The manufacturing industry outdoes other sectors in terms of carbon emissions across various spectrums. For instance, the construction industry for iron and steel manufacture generates 7.2% of energy-related emissions, while the chemical and food sectors account for 3.6 and 1%, respectively. The manufacturing industries use energy-hungry equipment and emit many gases into the atmosphere, hence the high emission levels. On the other hand, residential and commercial buildings generate 10.9 and 6.6% energy usage worldwide.

Here are some strategies contractors can employ to reduce carbon emissions:

Instead of undertaking new projects, you can refurbish or repurpose existing buildings.

Contractors can consider building less, ensuring that the goal is to meet the community's needs.

You can reuse materials or switch to low-carbon options.

Building efficiently helps you maximize material use.

You can ensure that the project emits low waste by recycling materials and improving construction methods.

The built environment, encompassing all constructions, generates almost 50% of global carbon emissions. Out of this, building operations account for 27% yearly, while the embodied carbon, which comprises building materials and the construction process, is responsible for another 20% annually.

2.3. Database of Embodied Carbon Footprint of Building Materials

The embodied carbon of construction materials comes from the consumption of the energy used during extraction, refining, processing, transportation, and fabrication. It is often a quantity from the cradle to the factory, then the site, and finally to the grave. Generally, embodied carbon is how much CO_2 emissions result from producing a material. It entails carbon and other greenhouse gases, plus the emissions from all activities before the materials' consumption.

Figure 9 shows the approximate carbon emission percentage of various building materials that are common. Alternatively, you can go for the more straightforward route where you calculate the building's energy usage, which accounts for most of the CF. If dealing with a massive construction whose CF can be difficult to quantify, you can always seek help from private consultants. There are also various free software options online.

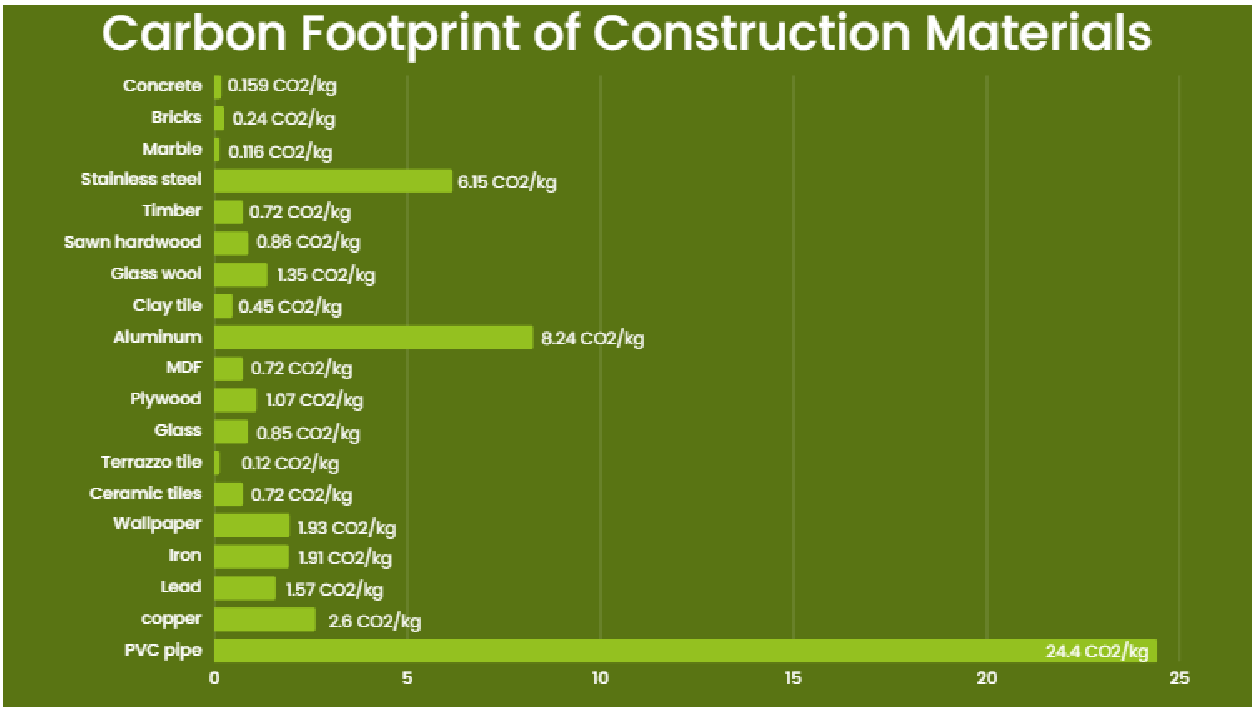

Figure 9. Carbon Footprint of common Construction Materials

Frequently Asked Questions About Carbon Footprint of Building Materials

What Is the Embodied Energy of Construction Materials?

Embodied energy from construction materials estimates the total power that went into their mining, processing, and transportation until they reached the final user. It is how much energy it takes to create the materials that constitute a building.

What Is the Carbon Footprint of Aluminum?

Aluminum is one of the materials with the highest CF and is widely used due to its low maintenance and strength. It generates about 18,000 kg of embodied CO_2 per cubic meter.

What Is the Carbon Footprint of Concrete per M3? What Is the Embodied Carbon of Concrete?

Concrete is a standard construction material for various building stages, but its 635 kg embodied carbon per cubic meter makes it one of the most harmful options to use in projects. Its production is not energy efficient, hence the need for low-carbon concrete alternatives and mixtures.

What Is the Carbon Footprint of Stainless Steel?

Steel produces about 51 million tons of emissions worldwide yearly and averages about 0.49 tons of CO2 per produced ton. However, it is greener than aluminum and concrete and should be the better alternative because it is also durable.

What Is the Carbon Footprint of Steel Per Kg?

50% of the construction industry requires steel because it is flexible, affordable, and highly durable. It is responsible for approximately 12 090 kg of carbon per cubic meter or 1.8- 3.0 tons of emissions per tons of steel produced.

What Are the CO_2 Emissions Per Kg of Plastic?

Plastic is one of the worst offenders in carbon emissions, and construction companies would rather avoid it. You emit about 1.7 -6kg CO_2e for each kilogram you use, depending on several factors.

How Much CO_2 Emissions per Kg of Polypropylene?

The process of manufacturing polypropylene generates massive amounts of carbon, and it helps to find more sustainable materials. It emits an average of 1.95 kg CO_2e per kilogram of polypropylene.

What Is the Embodied Carbon of Timber?

Timber is the best environmentally friendly building material, given that trees lock carbon from the atmosphere and serve as purifiers. Each dry ton you produce from timber accounts for about 1.8 tons of CO_2 absorbed from the air. On average, timber can emit less than 100 kg of embodied CO_2 per cubic meter.

SOURCES:

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Materials CAN Carbon Action Network. materialsCAN.org

3. Embodied energy of building materials. Parameters and analysis of Embodied energy. Databases of Embodied Energy of building materials.

3.1. Embodied energy

Understanding and considering embodied energy when making decisions about building or renovating your home can help to reduce energy use and your environmental footprint.

Embodied energy is a calculation of all the energy that is used to produce a material or product, including mining, manufacture, and transport. To achieve a home that is truly low energy, it is important to consider embodied energy when choosing materials and construction systems. Different types of materials and construction systems will have very different levels of embodied energy. It is not just a matter of choosing low embodied energy materials. A house built with low embodied energy materials may require more operational energy to run the home (for example, for heating and cooling). You therefore need to balance the embodied and operational energy of your home.

The total embodied energy of a building is the total energy needed for:

production of all the materials used in the initial construction (initial embodied energy)

production of all the materials used in repairs or renovations over the life of the building (recurrent embodied energy)

transport of materials to site

energy used on-site during construction, repairs, or renovations.

The choice of materials and construction methods can significantly change the amount of energy embodied in a building, because embodied energy varies enormously between materials. Different materials also have different capacities to be reused or recycled, which can help recover the embodied energy at the end of a building's life.

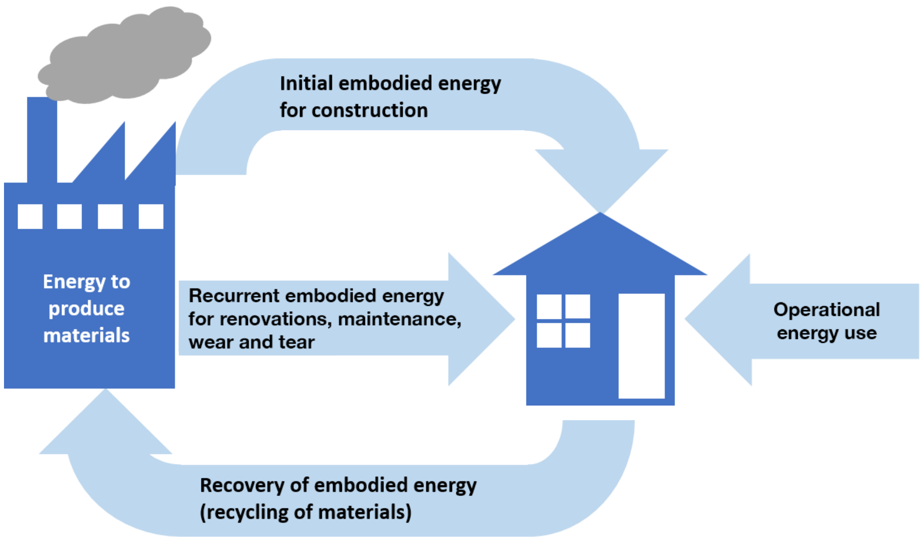

Figure 10. Embodied energy use

3.2. Embodied energy and operational energy

Embodied energy is just one part of the energy use of a building. The other is operational energy – the energy that is used to run the home, including for lighting, appliances, heating, and cooling.

When you are buying, building, or renovating a home, it is worthwhile considering both the embodied energy of the materials and how they affect the operational energy use. Comparing materials based on their lifecycle energy performance will consider initial and recurrent embodied energy as well as their operational energy use. The Low Energy Building Assembly Selector can be used for this purpose.

It is important to remember that choosing materials with low embodied energy may result in higher operational energy use. Conversely, a material with higher embodied energy may result in a building with lower operational energy. For example, large amounts of thermal mass (for example, concrete), which is high in embodied energy, can significantly reduce operational heating and cooling needs in well-designed and insulated passive solar houses.

As buildings become more efficient in operation, the embodied energy proportion of the total energy use increases. This can be even more pronounced where additional materials (for example, insulation, double glazing, thermal mass) are added to the building to achieve operational energy savings. For example, initial and recurrent embodied energy may represent just over 50% of the total life cycle energy of a typical brick veneer house over a life of 50 years – see following graph. The rest of the life cycle energy is taken up by operational energy. By contrast, the embodied energy proportion can approach 100% for zero-operational energy buildings, because less operational energy is required to run the home.

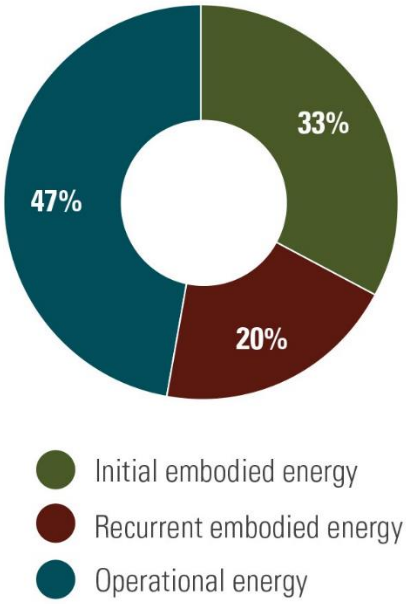

Figure 11. Proportion of operational and embodied energy over the 50-year life of a typical brick veneer house. Source: Operational energy based on Waterings and Tustin (2017) and initial and recurrent embodied energy based on Crawford (2014) (average initial embodied energy of 13.4GJ/m^2, average recurrent embodied energy of 8GJ/m^2 for 50 years) and average floor area based on ABS/CommSec (2018) (new detached housing of 230.8m^2).

3.3. Embodied energy calculation

Assessing the embodied energy of a material, component or whole building is a complex task. Every building is a complex combination of many materials, each with a production history and a contribution to the embodied energy of a building. Embodied energy can also vary for the same type of product because the efficiency of processes, sources of energy, and transport of materials can vary between manufacturers.

International standards have been developed for calculating the embodied energy of products (for example, ISO 14067:2018 Greenhouse gases – Carbon footprint of products – Requirements and guidelines for quantification). However, there are different methods used for the calculation. This means that some caution is required when using embodied energy values from different sources. For example, 'hybrid analysis' combines detailed data on processes used to manufacture products with background data of industry interactions. This method gives more comprehensive estimates of embodied energy than other methods as it captures a larger number of processes.

The calculation of embodied energy is often performed within a lifecycle assessment (LCA) framework (ISO 14040:2006 Environmental management — Life cycle assessment — Principles and framework). LCA considers a range of environmental impacts and is used for developing product labels and Environmental Product Declarations (EPD). International standards are available for developing EPDs of construction materials (refer to References and additional reading). Considering embodied energy means choice of materials should consider both the embodied energy of the materials and how the materials affect the design and operational energy of the building.

In general, to reduce materials with high embodied energy, unless they play a role in reducing operational energy; this may include sourcing local materials to reduce energy for transportation reuse existing materials, reducing the need for new materials choose new materials that have a high proportion of recycled content design for a long building life as well as disassembly for ease of reuse and recycling.

This general guidance may mean different material selections in different climates. Although materials with high thermal mass typically have high embodied energy, they can deliver operational energy savings when used in the right climates with the right passive design principles. However, used in the wrong climates or without regard for passive design principles, high thermal mass can add to the embodied energy of the building. It can also increase operational energy use and reduce thermal comfort. Is important to use materials that have more embodied energy than is required for the intended purpose. For example, there is little point in using a highly durable material with a high embodied energy, for example a floor covering, if the user intends to replace the flooring in a few years.

3.4. Embodied energy of common materials

Generally, the more highly processed a material, the higher its embodied energy. Buildings typically use many materials with relatively low embodied energy (for example, bricks and timber) and smaller amounts of materials with high embodied energy (for example, steel). Because most of the embodied energy of materials results from the manufacturing process, energy efficiency improvements within the manufacturing industries can make the most significant contribution to lowering the embodied energy of materials. Energy sources used to manufacture materials are also important to consider, given the large difference in environmental impact between renewable and fossil fuel-based energy sources.

Embodied energy values for some materials are given in Table 1, expressed as the amount of energy (in megajoules) per kilogram. However, these figures should be used with caution because that the actual embodied energy of a material will vary depending on where and how it is produced materials manufactured with recycled content will have lower embodied energy, and savings will vary depending on the proportion of recycled content and manufacturing processes used materials of high monetary value, such as stainless steel, are almost certain to have been recycled many times, reducing their embodied energy compared with virgin materials.

It is more useful to think in terms of building components and assemblies (for example, walls, floors, roofs) rather than individual materials. The embodied energy per m^2 of construction for different assembly types can then be compared. Table 2 shows the embodied energy values for different types of floors, walls and roofs.

Table1. Embodied energy of common building materials

Material	Embodied energy MJ/kg
Aluminium	358
Carpet – nylon	198
Carpet – wool	140
Ceramic tile	18.9
Clay brick	3.5
Concrete roof tile	4.3
Concrete 25MPa	1.1
Double glazing – flat (4:12:4)	66.8
Fibre cement sheet	18.3
Glass – flat	28.5
Glasswool insulation	57.5
Hardwood – kiln dried	26.9
Laminated veneer lumber (LVL)	34.3
Medium density fibreboard (MDF)	22.0
Paint – solvent-based	124
Paint – water-based	111
Particleboard	18.7
Plasterboard 10mm	15.1

Plywood	42.9
Polystyrene (EPS)	155
Softwood – kiln dried	19.0
Steel – structural	38.8
Steel – corrugated sheet	79.6

*Note: These figures should be used with caution. See text above table. Source: Crawford, Stephan and Prideaux (2019).

Table2. Embodied energy values for different types of floors, walls, and roofs

Embodied energy for assembled floors

Assembly	Embodied energy MJ/m^2
Elevated timber floor	2065
110mm concrete slab on ground, raft	1053
110mm concrete slab on ground, waffle pod	1838

Source: Crawford (2019)

Embodied energy for assembled walls

Assembly	Embodied energy MJ/m^2
Brick veneer wall, timber frame	1292
Brick veneer wall, steel frame	1387
Cavity clay brick wall	1973
Cavity concrete block wall	1276
Concrete block veneer wall, timber frame	965
Corrugated steel wall, timber frame	715
Hardwood weatherboard wall, steel frame	1421
Hardwood weatherboard wall, timber frame	1325
Polystyrene wall, timber frame	591
Reverse brick veneer wall, timber frame	1588
Single-skin autoclaved aerated concrete (AAC) block wall, plasterboard lining	2079

Source: Crawford (2019)

Embodied energy for assembled roofs

Assembly	Embodied energy MJ/m^2
Concrete tile pitched roof, timber frame, plasterboard ceiling	795
Terracotta tile pitched roof, timber frame, plasterboard ceiling	894
Corrugated steel sheet roof, timber frame, plasterboard ceiling	909
Corrugated steel sheet roof, steel frame, plasterboard ceiling	976

Source: Crawford (2019)

3.5. Reuse and recycling

Many building materials can be reused or recycled. Savings from recycling of materials vary considerably, with savings up to 95% for aluminum, but only 20% for glass. Also, some materials may require reprocessing before they are reused which will add to the energy cost, particularly if long transport distances are involved.

Although embodied energy is an important environmental issue, the full range of environmental effects associated with building construction, use, and end-of-life, should be considered when choosing a building material. Environmental effects would include aspects such as water use, land use, raw material depletion, release of pollutants and greenhouse gas emissions, and biodiversity and habitat loss.

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Library on Module 1: Environmental aspects of building materials

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Explore the Energy section to find ways to reduce the operational energy use of your home, Read Passive heating and Passive cooling for tips on the best materials to use in your home, Explore Waste minimisation for more ideas on how to reduce, reuse and recycle when building or renovating, from Embodied energy | YourHome

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4. Self-assessment quiz on Module 1: Environmental aspects of building materials

1. Reduction of emission level to 50% by 2030 is the target of the ______________________.

a. Paris Agreement

b. Kyoto Protocol

c. Intergovernmental Panel on Climate Change

d. Montreal Protocol.

2. The building sector is one of the major sources of greenhouse gas emissions contributing to climate change. The sector heavily uses raw materials, chemical processes, energy, and equipment thereby contributing to ____ of greenhouse gas emissions.

a. 40%

b. 45%

c. 75%

d. 50%

3. Which of the following has the major share in waste generation by the construction sector?

a. landfill

b. steel

c. plasterboard

d. glass

4. There has been ongoing research by academia, industry, and organizations to establish a whole life ____________________ framework for buildings.

a. Product footprint

b. Carbon footprint

c. Partial carbon

d. Carbon guideline

5. Zero Net Carbon concept can be applied to the following building sectors and types:

a. residential and non- residential

b. new or existing

c. buildings in dense urban environments with limited on- site renewable energy capacity

d. All the above

6. The initial ________ energy in buildings represents the non-renewable energy consumed in the acquisition of raw materials, their processing, manufacturing, transportation to site, and construction.

a. Neutral

b. Indirect

c. Sustainable

d. Embodied

7. ____________________________, the leading authority of International Standards, has come out with a suite of standards for sustainability in building construction.

a. International Organization of Standardization (ISO)

b. Environmental Organization of Standardization (EOS)

c. International Organization of Sustainability (IOS)

d. Functional Objectives of Standardization (FOS)

8. The proper selection of building material influence the amount of:

a. embodied energy only

b. operational energy only

c. embodied and recurrent embodied energy.

d. both embodied (including recurrent) and operational energy.

MODULE 2: LIFE CYCLE ASSESSMENT OF BUILDING MATERIALS

1. Life Cycle Thinking for building materials

Often, the term sustainability is only associated with the dimension of the environment or ecological consequences of economic activity. However, the concept of sustainability is defined much more broadly: Sustainability or sustainable development means satisfying the needs of the present in such a way that the possibilities of future generations are not or only insignificantly restricted. The three dimensions of sustainability - economically efficient, socially just, ecologically viable - must be considered on an equal footing. To preserve global resources in the long term, sustainability should be the basis of all, not just political, decisions (analogous definition of the German Federal Ministry for Economic Cooperation and Development).

1.1. Influence Factors on the planning of sustainable building materials

Sustainable action is defined as the simultaneous implementation of environmental, economic, and social objectives to leave an intact environment for future generations and to enable equal opportunities in life. An assessment system has been developed for building based on the model of the three pillars of sustainability: economic, ecological, and social. These three aspects interact with each other and should be considered equally in planning and execution of buildings.

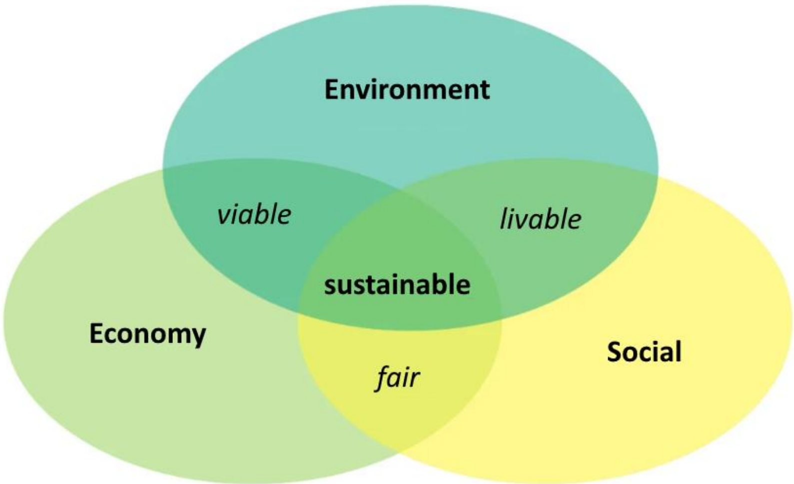


Fig. 1: Aspects of sustainability

(Source: https://www.baunetzwissen.de/boden/fachwissen/einfuehrung/nachhaltigkeit-151602/gallery-1/1)

The three aspects are assigned corresponding protection goals about sustainable construction:

Environment

Conservation of resources through optimized use of building materials and products; low land use; preservation of biodiversity; reduction of energy and water consumption; minimization of environmental pollution at local and global level. The following indicators are currently used to objectively assess the environmental impact of a building:

Land use

Primary energy use (renewable/non-renewable),

Global warming potential (GWP), regarding "global warming."

Ozone Depletion Potential (ODP), regarding the "hole in the ozone layer".

Acidification potential (AP), regarding "acid rain".

Eutrophication potential (EP), regarding water bodies or groundwater

Ozone creation potential (POCP), regarding "summer smog".

Economy

Minimization of life cycle costs; improvement of economic efficiency through efficient use of resources. In addition to the acquisition and construction costs, this dimension also includes the follow-up costs that are incurred during the entire life or useful life of the building. These include the following individual costs, such as the entire construction costs - from land to planning and construction costs to insurance -, the utilization costs - such as energy, water, and waste disposal, but also the cleaning, maintenance, and upkeep of the building – and the deconstruction costs - from demolition and transport to disposal or reuse (recycling).

Social

Preservation of health, safety, and comfort; guarantee of functionality; assurance of design and urban development quality. The social (and in the broadest sense cultural) dimension of sustainability is considered in the areas of aesthetics, design, accessibility and aspects of health protection and comfort. To obtain an objective view in this dimension and, above all, an optimal design already in the planning of a building, protection goals are defined for each aspect. The design and aesthetic characteristics of a building (e.g. spatial geometry, materiality, color scheme, etc.) and the resulting questions of identity and acceptance by the building's users can only be described by qualitative factors. However, it is undisputed that higher user satisfaction and social acceptance of a building lead to a special appreciation and lasting value of the building and thus make it more sustainable.

In addition, accessibility (usability and flexibility of use) as well as health and comfort aspects (thermal, hygienic, acoustic, and visual) are also considered.

However: Problematic substances or environmental influences (e.g. noise, draughts, insufficient lighting) that could endanger the health of the users are excluded from the outset (by legal requirements).

Thoughts for sustainable planning

Next to nature, buildings are among the most used and stressed facilities in human life. Durability, health safety and resilience therefore play a major role in the choice of building materials and construction. Ensuring flexible future use can also promote long building life.

In terms of sustainability criteria, resource-conscious and material-efficient planning is necessary here according to the specific requirements. Aspects of recycling must also be considered in the choice of building materials. For example, the recyclability of multi-layer building components is based on the separability of individual layers (e.g. the façade with a thermal insulation composite system). The energy intensity and water requirements in the production of a building material are also relevant for the life cycle assessment.

In relation to the above-mentioned model of sustainability, the following aspects, among others, thus play a role in the planning of sustainable buildings:

Environment: choice of materials and ingredients (product components from renewable raw materials, reduction of energy-intensive and/or petrochemical substances, recyclability).

Economy: durability, economical and efficient use of materials and resources

Social: guaranteeing healthy living conditions in private homes and public spaces, as well as socially acceptable manufacturing conditions.

Sustainable building can only be realized through thoughtful and foresighted planning. Various institutions help with hints and suggestions for the assessment of building materials with regard to sustainability criteria and their integration into planning and execution.

In Germany, these are, for example, the German Sustainable Building Council (DGNB) with the product database DGNB-Navigator (https://www.dgnb-navigator.de/en/) registration required, the information portal Nachhaltiges Bauen (Sustainable Building) with the Sustainable Building Guidelines of the Federal Ministry for Building and the Interior (https://www.nachhaltigesbauen.de/fileadmin/publikationen/BBSR_LFNB_D_190125.pdf) , the ecological building materials information system WECOBIS (https://www.wecobis.de),Rating system Sustainable building (https://www.bnb-nachhaltigesbauen.de).

In addition, corresponding seals or certifications provide information on the sustainability of certain building materials, such as the **GuT signet** for environmentally friendly floor coverings (https://gut-prodis.eu), the "**Wood from here**" seal as an eco-label of a sustainable regional timber industry (https://www.holz-von-hier.eu/en/) or Information portal **Quality Seal Sustainable Building** (https://www.qng.info).

1.2. Building materials and environmental protection

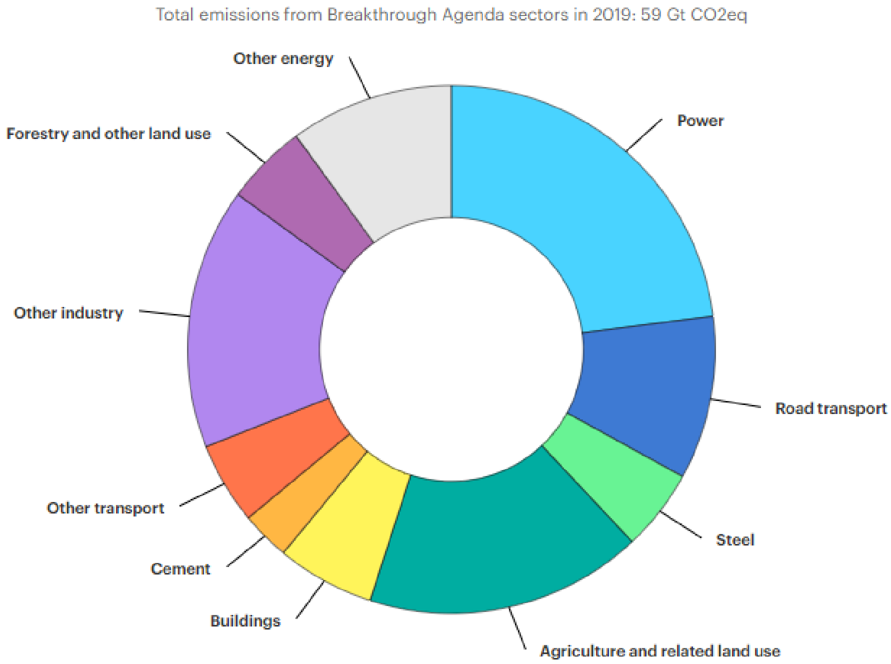


Fig. 2: Greenhouse gas emissions by sector, 2019

(Source: https://www.iea.org/data-and-statistics/charts/greenhouse-gas-emissions-by-sector-2019-2)

More than one third of all final energy worldwide is consumed in and for buildings. Greenhouse gas emissions are an important index of the overall complex of environmental protection.

With reference to Fig. 2, the construction sector appears at first sight to have only a small share of greenhouse gas emissions (Buildings: 6%, Cement 3%). The construction, operation, and maintenance of a building, as well as its deconstruction and recycling, have a significant impact on the other sectors listed (road transport, steel, power).

As a result, approximately 40 % of all greenhouse gases are emitted in the building sector (Global Alliance for Buildings and Construction, International Energy Agency and the United Nations Environment Program 2019, https://www.iea.org/reports/global-status-report-for-buildings-and-construction-2019). This highlights both the enormous importance of the building sector for energy and environmental issues and the opportunities that lie in reducing energy consumption and greenhouse gas intensity. Planners and all those involved in construction therefore bear a great responsibility, which also requires a high level of information.

1.3. What does sustainable building mean?

The consideration of sustainable development principles becomes an integral part of all planning and decision-making processes over the life cycle of a building. This includes the formulation of objectives as well as the review and evaluation of the achievement of objectives. Specific requirements, procedures and tools are available to support the actors, depending on the area of work, responsibility and influence and the life cycle phase. The complexity of planning, building, and operating in general as well as the sustainability assessment embedded in the usual decision-making processes must be considered. At the same time, manageable solutions must be developed at a reasonable cost and time.

Sustainable building is primarily about the planning and realization of a building that follows the basic idea of sustainability. The objective is to minimize the consumption of energy and resources. To achieve this objective, all life cycle phases of a building must be considered. It is also important to optimize all factors influencing the life cycle. This refers to the process of raw material extraction, construction, and deconstruction.

The following factors must be considered when building a sustainable house:

- Reduction of energy consumption
- Reduction of the consumption of operating materials
- Lowest possible transport costs/routes of the building components
- Safe recycling of all materials used.
- Possibility of subsequent use
- Protection of natural areas (through area-saving construction)

Other aspects that do not originally appear in the definition of sustainability are, for example.

- protection against radon entering the building.
- electromagnetic radiation (electro smog)
- Possible heat island effects
- Risk considerations / worst-case scenarios
- Rebound effects.

If the new building is to be environmentally friendly and energy efficient, several questions must also be answered.

Which building materials should be used?

How can electricity be produced sustainably and how can one be particularly energy-efficient?

What is the best way to use water?

How do I keep my house warm without heating it too much?

These are all questions that need to be considered when building a sustainable house. Numerous strategies and technologies have been established and developed in recent years to ensure that the home meets its own environmental protection requirements.

Answering these questions is generally difficult because the construction of a building initially consumes many resources. Also, the use of "environmentally friendly" materials only pays off after a few years, since especially at the beginning of the construction process the corresponding materials first must be transported to the desired location, which is already associated with emissions and environmental impacts. The location itself also influences the environmental friendliness of the home. Here, a distinction must be made not only between urban and rural areas, but also between the spatial conditions that the location entails. This refers, for example, to the availability of wind or solar energy, which can vary between urban and rural locations. In a built-up city, the generation and availability of wind energy will be more difficult than in the countryside. Living in the countryside can be more advantageous in this respect, but the longer distances to the centers must be considered here.

However, once a suitable location for the building has been found where energy generation can be made sustainable, the next step is to procure the building materials. Here, not only the type of material is important, but also its origin and production. The building materials should be made of renewable, long-lasting, and recyclable raw materials. To be able to measure the environmental impact of building materials, so-called Environmental Product Declarations (EPDs) have been developed. An EPD describes building materials, building products, or building components regarding their environmental impacts based on life cycle assessments as well as their functional and technical properties. This quantitative, objective and verified information relates to the entire life cycle of the building product (https://ibu-epd.com/en/epd-programme/). These contain life cycle assessment-based indicators that describe the effects of the individual products regarding various criteria such as the greenhouse effect or the consumption of grey energy. Resource efficiency plays an important role in product declaration. This refers to the use of products that have been produced using locally available resources. This means that they have a shorter transport route and therefore have a lower pollutant load. When using a building component, its maintenance (maintenance, cleaning, repair) should ideally always be considered.

The life cycle of a building material also influences its sustainability. For this reason, building materials should be used that have a similar lifespan. In this way, it can be avoided that building materials/parts have to be removed or disposed of before the end of their actual life cycle. Simple, uncomplicated constructions and well recyclable and easily replaceable building materials are preferable.

1.4. The role of building materials in the overall life cycle of buildings

The above-mentioned number of greenhouse gas emissions is composed of the production of building materials and for the construction of buildings and building operation, as well as for deconstruction and disposal.

(Global Alliance for Buildings and Construction, International Energy Agency, and the United Nations Environment Program 2019).

For classification purposes, the life cycle of a building can be illustrated. This approach is laid down in various standards, for example DIN 15978 (standard DIN EN 15978:2012-10), which divides it into three main phases: Production and construction, use, and disposal (Figure 3). In addition, there is phase D: Credits and debits outside the system boundaries.

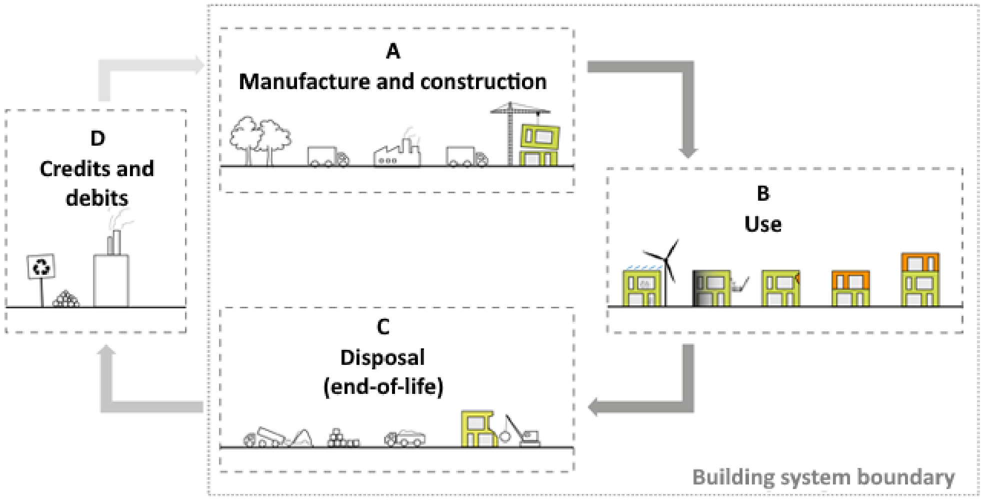


Fig. 3: Overview: Life cycle of a building

source: https://www.wecobis.de/en/service/sonderthemen-info/gesamttext-baustoffe-klimaschutz-info/rolle-baustoffe.html

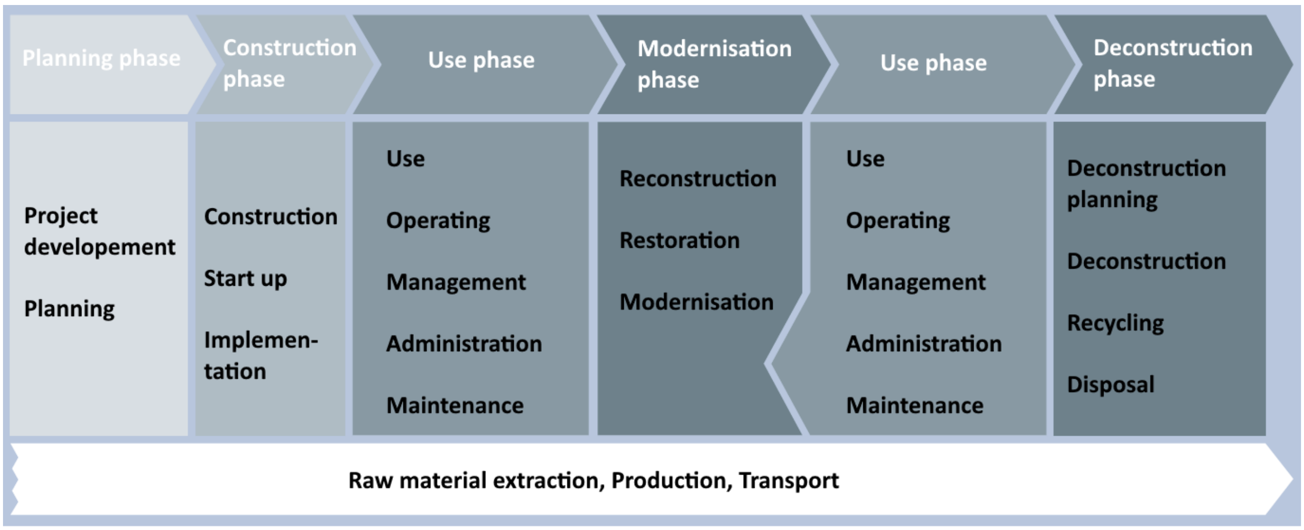


Fig. 4: Life cycle phases

Source: https://www.nachhaltigesbauen.de/fileadmin/publikationen/BBSR_LFNB_D_190125.pdf

In addition to energy as a resource, many materials are consumed in all phases of the life cycle. Raw materials for building materials are not inexhaustible and the mining and processing of raw materials increasingly leads to environmental problems. Considering the resource problem, sufficiency, i.e. the economical use of resources, is becoming more important. In the design and detailing of buildings, materials that occur in large quantities are particularly important from this point of view. These are especially the supporting structure material (reinforced concrete, steel, wood, masonry), and claddings such as plasterboard or façade panels. Possibilities for resource conservation are offered by recycled building materials (e.g. recycled aggregates or steel) and the use of renewable raw materials if these come from sustainable agriculture and forestry. However, the use of recycled building materials is often restricted by law, especially when structural aspects must be considered (hazard potential).

In summary, the following objectives can be summarized for the construction trade:

Building material resources

Extending the useful life of products, building structures and buildings

Use of reusable or recyclable building products / building materials

Safe recycling of materials into the technical cycle or, where appropriate, into the natural material cycle

Reduction of resource requirements in the construction and operation of buildings

Use of sustainably produced renewable raw materials (also under the aspect of preserving biological diversity)

Non-building material resources

Use of rainwater or grey water and reduction of drinking water consumption

Energy resources

Reduction of transport costs for building materials and components

Minimization of energy demand in the utilization phase

Use of renewable energy

Biologically diverse land resources

Minimization of land use by the building Implementation of compensatory measures

2. Life Cycle Costing approaches

The economic quality of a building is reflected in the degree to which the following protection goals are implemented:

- Minimization of life cycle costs
- Improvement of economic efficiency
- Preservation of capital and (building) value

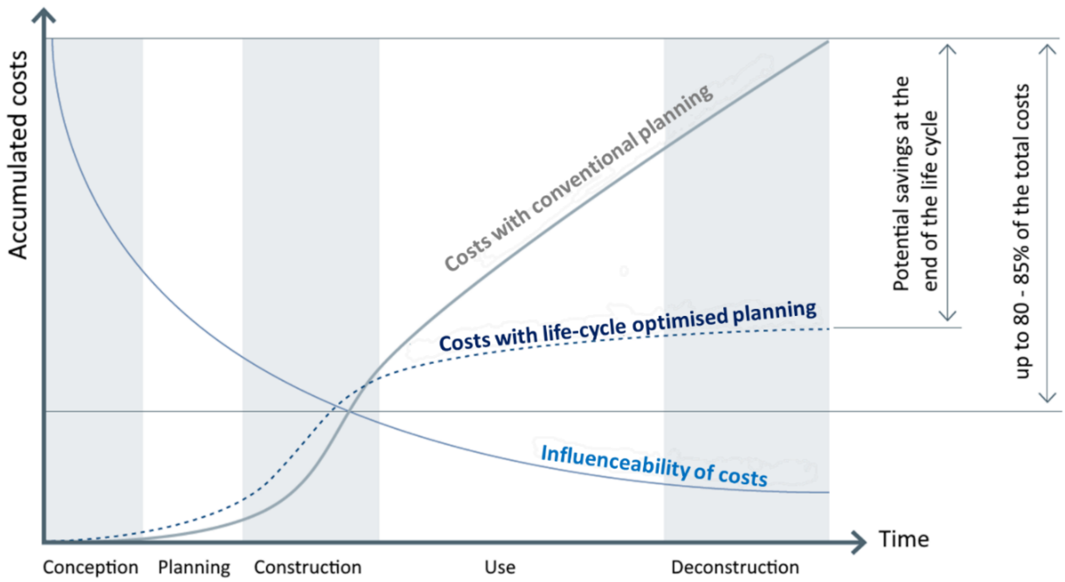
In terms of sustainability assessment, life cycle costs break down as follows (rough classification):

- Production costs (construction costs)
- Use of building costs (costs for cleaning, care, and maintenance; replacement investment)
- Demolition costs, costs for deconstruction and disposal

In this context, the planning phase is of considerable importance.

2.1. Importance of planning

Fig. 5: Influenceability of costs depending on the life cycle.



Source: https://www.nachhaltigesbauen.de/fileadmin/publikationen/BBSR_LFNB_D_190125.pdf

Since the decisions made in the early planning stage have a great influence on the later quality of the building, the quality of the planning is of particular importance. The possibilities for influencing the structural properties and costs of a measure are greatest at the beginning of the measure, see Figures 5 and 6.

Decisions that have a high impact on costs are already made during the program definition (demand planning) and in the initial concept phase. This also applies to the associated environmental impacts.

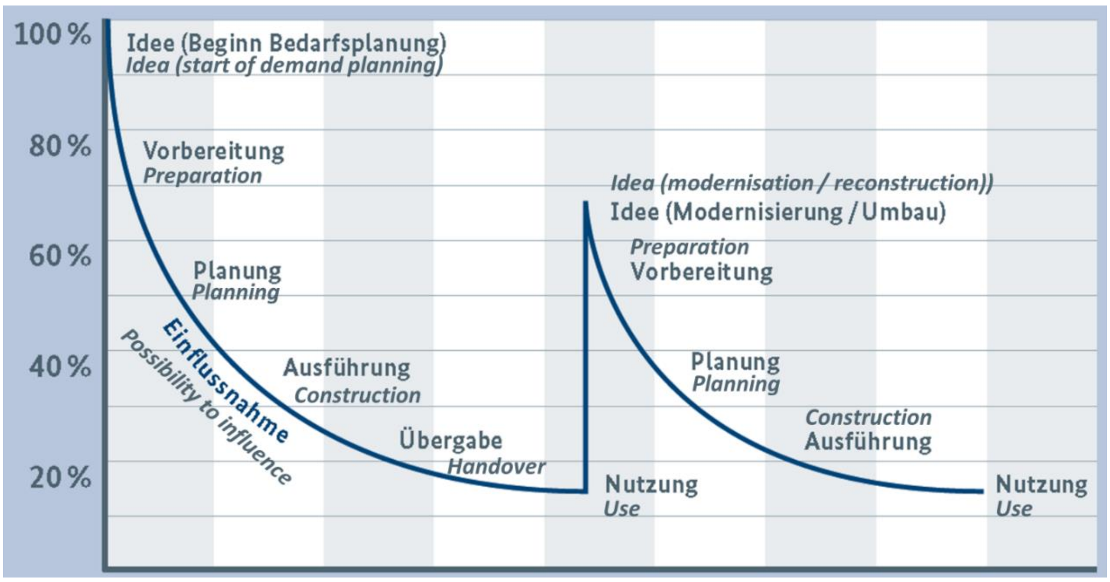


Fig. 6: Influenceability of properties of the building

Source: https://www.nachhaltigesbauen.de/fileadmin/publikationen/BBSR_LFNB_D_190125.pdf

Questions such as development and planning law, functional aspects, urban development, architectural and building regulations (stability and fire protection) must be considered at an early planning and in the process of architectural and engineering competitions and optimized in terms of sustainability.

In the conception and planning phase, the possibility to influence costs is highest. Decisions are made here on the aspects of

- Economic efficiency,
- Value stability
- Functionality
- Design quality (public acceptance)
- Technical quality (fire protection, sound insulation, heat and moisture protection, ease of use, cleaning and maintenance, deconstruction)
- Health, comfort, and user satisfaction

2.2. Quality of construction

The execution of construction work must also be controlled regarding the goal of protecting the environment and resources. At the same time, the health of all those involved must be protected. In addition to the quality of the construction site process, attention must therefore be paid to the implementation of the agreed sustainability qualities in the construction process in the sense of goal-oriented planning. Comprehensive quality controls must be carried out in this process to avoid defects and damage to the building on the one hand and to ensure the achievement of the agreed goals on the other. The realization of the design must be monitored and the materials and building products used must be precisely documented. Practical experience confirms that due to faulty construction schedules, regularly occurring but unforeseeable delays or unclear specifications, the execution on the building is changed at short notice and thus considerable deviations from the planned quality can result.

The overall design determines the life cycle costs to a significant extent. The approach to costing can vary.

2.3. 1st approach: Comparison of construction costs and construction time

The architect and professor of planning and building economics at the Brandenburg University of Technology Cottbus-Senftenberg, Wolfdietrich Kalusche chooses a different approach when considering the issue. He takes an exemplary look at the construction costs per m² and the average construction time, comparing a solid construction and a timber construction (medium equipment standard). The comparison was carried out on a type of building for which numerous comparable objects are available: kindergartens without basements. The data are empirical and based on several thousand billed properties documented in the Building Cost Information Centre of the German Chambers of Architects (BKI), status 2022.

Sources: https://www.dabonline.de/2023/01/25/holzbau-massivbau-guenstiger-vergleich-baukosten-kindergaerten/ and https://bki.de

Construction	Cost in €/m²
Kindergarten in timber construction, no basement, medium standard	2.610 €/m²
Kindergarten, solid construction, no basement, medium standard	2380 €/m²

Fig. 7: Production costs for kindergartens

Construction	Construction time in weeks
Kindergarten in timber construction, no basement, medium standard	42
Kindergarten, solid construction, no basement, medium standard	58

Fig. 8: Construction time until completion

Regardless of the construction, almost every building is partly made of concrete. These are basement walls, floor slabs and foundations. This also applies to timber structures. On the other hand, roof supporting structures, even those of solid buildings, are made of wood. In this respect, load-bearing structures - especially buildings - consist of only one material only in exceptional cases. In summary, W. Kalusche has found that timber buildings are about 6% more expensive to build than solid buildings, but the construction time is only about 70% of that of a solid building.

2.3. 2nd approach: Comparison of maintenance costs

An exemplary cost analysis for a period of 80 years has been prepared by the engineering office Konrad Fischer (**Hint**: Costs as of 2020; more up-to-date figures are currently not available. The list therefore has a comparative character).

Source: http://www.konrad-fischer-info.de/7waefe26.htm

From a purely cost perspective, double-shell masonry appears to be the most sustainable because maintenance and upkeep costs are the lowest. In terms of sustainability, however, the construction costs as well as the deconstruction and disposal costs must also be considered. Nor does it consider the costs of repairing any environmental damage.

x = Action required

Fig. 9: Repair intervals and repair costs of selected building components in residential buildings

Component, type of service	Maintenance interval	Costs	Durability in years																Costs after 80 years (incl. ancillary costs + VAT, inflation 2%)	Costs in Annual average
Exterior walls	[Jahre/years]	[EUR/m²]	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	[EUR/m²]	[EUR/m²]
Exterior wall with facing brickwork																			**284,73**	**3,56**
Repair jointing	20	7,67	.	.	.	x	.	.	.	x	.	.	.	x	.	.	.	x	89,10	1,11
Scaffolding supply	20	7,67	.	.	.	x	.	.	.	x	.	.	.	x	.	.	.	x	**89,10**	**1,11**
Cleaning masonry	40	15,34	.	.	.	.	.	.	.	x	.	.	.	.	.	.	.	x	106,53	1,33
Exterior wall with standard plaster (and paint)																			**566,36**	**7,08**
New paint	15	25,56	.	.	x	.	.	x	.	.	x	.	.	x	.	.	x	.	333,09	4,16
Plaster repair	15	10,23	.	.	x	.	.	x	.	.	x	.	.	x	.	.	x	.	133,32	1,67
Scaffolding supply	15	7,67	.	.	x	.	.	x	.	.	x	.	.	x	.	.	x	.	99,95	1,25
	[Jahre/years]	[EUR/m²]	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	[EUR/m²]	[EUR/m²]

Component, type of service	Maintenance interval	Costs	Durability in years																Costs after 80 years (incl. ancillary costs + VAT, inflation 2%)	Costs in Annual average
Exterior wall made of timber studs with timber boarding																			**650,47**	**8,13**
Painting / Coating	5	5,11	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	205,92	2,57
Scaffolding supply	5	7,67	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	309,63	3,87
New wooden boarding	50	51,13	.	.	.	.	.	.	.	.	.	x	.	.	.	.	.	.	134,92	1,69
Exterior wall with thermal insulation composite system																			**1.314,05**	**16,43**
Cleaning and maintenance	5	7,67	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	309,63	3,87
Scaffolding supply	5	7,67	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	309,63	3,87
Plaster repair	10	7,67	.	x	.	x	.	x	.	x	.	x	.	x	.	x	.	x	162,21	2,03
New thermal insulation composite system	40	76,69	.	.	.	.	.	.	.	x	.	.	.	.	.	.	.	x	532,58	6,66

2.3. 3rd approach: Lifetime of building components

Another method for assessing sustainable building materials or constructions is to examine the statistical lifetime of building components (status 2017).

The (somewhat abbreviated) table refers to office and administrative buildings and provides an overview.

Explanation:

- Code no. = internal designation of the rating system
- Sustainable building
- Column A = statistical life span in years
- Column B = renewal frequency in 50 years

Source: https://www.nachhaltigesbauen.de/fileadmin/pdf/baustoff_gebauededaten/BNB_Nutzungsdauern_von_Bauteilen__2011-11-03.pdf

Code no.	**Assembly**	**Component**	**A**	**B**
320 Foundation				
320 Foundation	**322 Shallow foundations**			
		Single / strip foundations	≥ 50	0
		Foundation slabs	≥ 50	0
320 Foundation	**323 Deep foundations**			
		Bored piles, pressed piles, driven piles, pile walls, diaphragm walls, sheet pile walls, soldier pile walls	≥ 50	0
320 Foundation	**324 Subfloors and floor slabs**			

Code no.	Assembly	Component	A	B
		Base plate	≥ 50	0
320 Foundation	**326 Building waterproofing**			
		Sealing against non-pressing water	35	1
330 Exterior walls				
330 Exterior walls	**331 Load-bearing exterior walls**			
		Masonry wall	≥ 50	0
		Concrete wall	≥ 50	0
		Wooden wall	≥ 50	0
		Steel construction wall	≥ 50	0
		Clay wall	≥ 50	0
		Molded bricks with concrete filling	≥ 50	0
330 Exterior walls	**333 External supports**			
		Masonry column	≥ 50	0
		Concrete column	≥ 50	0
		Wooden column	≥ 50	0
		Steel column	≥ 50	0

Code no.	Assembly	Component	A	B
330 Exterior walls	**334 Exterior doors and windows**			
330 Exterior walls	**334 Exterior doors and windows**	**Exterior doors**		
		Standard doors: Hardwood	≥ 50	0
		Standard doors: Metal	≥ 50	0
		Standard doors: derived timber product	40	1
		Standard doors: plastic	40	1
		Standard doors: softwood	35	1
		Fire doors	≥ 50	0
		Special doors: soundproof doors, glass doors	≥ 50	0
		Special doors: Automatic doors	20	2
		Special doors: sliding doors, revolving doors	30	1
330 Exterior walls	**334 Exterior doors and windows**	**Exterior windows**		
		Windows (frame and sash): Aluminum, aluminum-wood composite, aluminum-plastic composite, hardwood treated, steel	≥ 50	0
		Windows (frame and sash): Plastic, softwood treated	40	1
330 Exterior walls	**334 Exterior doors and windows**	**other**		
		Fittings: simple fittings, sliding fittings	30	1

Code no.	Assembly	Component	A	B
		Fittings: Tilt and turn fittings, swing sash fittings, lift and tilt fittings	25	1
		Door locks, door stop dampers, panic locks	25	1
		Door closer	20	2
		Door operators	15	3
		Glazing: Safety insulating glass, 3-pane thermal insulation glass, 2-pane thermal insulation glass, fire protection insulating glass, sound insulation glass, attack-resistant insulating glass, solar control insulating glass	30	1
		Sealing profiles	20	2
		Sealants	12	4
		Roller shutters	40	1
330 Exterior walls	**335 External wall cladding, exterior**			
330 Exterior walls	**335 External wall cladding, exterior**	**Waterproofing and insulation in contact with the ground**		
		Waterproofing in contact with the ground, against pressing water: Waterproofing membranes	≥ 50	0
		Waterproofing in contact with the ground, against pressing water: Bentonite	40	1
		Waterproofing in contact with the ground: Structures made of water-impermeable concrete	≥ 50	0

Code no.	Assembly	Component	A	B
		Waterproofing in contact with the ground, against non-pressing water: Bitumen waterproofing membranes, levelling compound	40	1
		Waterproofing in contact with the ground, against non-pressing water: Coatings and paints	30	1
		Waterproofing in contact with the ground retrofit: cross-sectional waterproofing against rising damp by mechanical injection	40	1
		Waterproofing in contact with the ground retrospectively: sealing, veil injection	20	2
		Waterproofing in contact with the ground: Waterproofing protection from protective walls (concrete, brick, hard-fired clinker)	≥ 50	0
		Waterproofing in contact with the ground: Waterproofing protection made of rigid polystyrene foam sheets, dimpled sheets (polyethylene polypropylene), corrugated sheets fiber-reinforced on a cement base.	40	1
		Waterproofing in contact with the ground: Waterproofing protection made of granulate mats, corrugated sheets	30	1
		Thermal insulation of building components in contact with the ground: Perimeter insulation foam glass	≥ 50	0
		Thermal insulation of building components in contact with the ground: Perimeter insulation Extruded polystyrene	40	1
330 Exterior walls	**335 External wall cladding, exterior**	**Coatings / Surface treatment**		
		Exterior coatings, mineral substrate: emulsion paint, emulsion silicate paint, white cement paint, plastic coatings on concrete, silicone resin paint, silicate paint, polymer resin paints.	15	3

Code no.	Assembly	Component	A	B
		Exterior coatings, mineral substrate: Lime paint	8	6
		Exterior coatings, mineral substrate: Impregnation on brickwork	15	3
		Exterior coatings, mineral substrate: Glaze	15	3
		Wood protective coatings, exterior: Wood varnishes	8	6
		Wood protective coatings, exterior: Wood stains	4	12
		Wood protective coatings, exterior: Wood oils/waxes	2	24
		Graffiti protection: short-term effective products (sugar-based)	1	49
		Graffiti protection: semi-permanent systems (hydrophobic coating with "sacrificial layer")	10	4
		Graffiti protection: permanent systems (thick film)	20	2
330 Exterior walls	**335 External wall cladding, exterior**	**Plaster**		
		Plaster on monolithic base course: highly hydraulic lime mortar, mortar with plaster and masonry binder, lime cement mortar, cement mortar with addition of air lime, cement mortar, air lime mortar, hydraulic lime mortar, water lime mortar.	45	1
		Render on monolithic base course: Renovation render systems, mineral lightweight render systems on porous base course	40	1
		Plaster on monolithic base layer: silicate plasters, silicone resin plasters, synthetic resin plasters	30	1

Code no.	Assembly	Component	A	B
		Plaster on thermal insulation: mineral plaster systems, silicate plaster systems, synthetic resin plaster systems, silicone resin plaster systems	30	1
330 Exterior walls	**335 External wall cladding, exterior**	**Masonry**		
		Cladding: Clinker, sand-lime brick, fair-faced concrete	≥ 50	0
330 Exterior walls	**335 External wall cladding, exterior**	**Plates, stone**		
		Cladding: Natural stone, artificial stone, concrete slabs, fiber cement slabs, synthetic resin stone, brick slabs, ceramic tiles and slabs, porcelain stoneware, stoneware, and split tiles	≥ 50	0
		Grouting compounds	30	1
		Claddings: hard covering materials on thermal insulation	30	1
330 Exterior walls	**335 External wall cladding, exterior**	**Insulation**		
		Insulation layer as core insulation: mineral wool insulation boards, polyurethane insulation boards, polystyrene, expanded slate granulate, expanded glass granulate, expanded clay granulate	≥ 50	0
		Insulation layer behind facing layer back ventilated: Mineral foam boards, foam glass boards	≥ 50	0
		Insulation layer behind facing shell: Vacuum insulation panels	30	1
		External thermal insulation composite system: Mineral wool insulation boards, polystyrene insulation boards, polyurethane insulation boards, wood fiber insulation boards, wood wool lightweight boards, cork boards	40	1

Code no.	Assembly	Component	A	B
		Thermal insulation composite system transparent	20	2
330 Exterior walls	**335 External wall cladding, exterior**	**Wood**		
		Wood cladding: Softwood treated, Hardwood, Wood-based panel systems	40	1
		Wood cladding: Coniferous wood untreated	30	1
		Wood cladding: Wood shingles	≥ 50	0
330 Exterior walls	**335 External wall cladding, exterior**	**Metal**		
		Metal cladding: Zinc, copper, anodized aluminum, painted aluminum, stainless steel	≥ 50	0
		Metal cladding: Galvanized steel	40	1
		Facing shell ventilated: copper sheeting	≥ 50	0
		Facing shell ventilated: zinc, stainless steel	45	1
		Facing shell ventilated: corrosion-reduced steel, steel galvanized and coated	30	1
		Facing shell ventilated: aluminum composite panels	≥ 50	0
330 Exterior walls	**335 External wall cladding, exterior**	**other**		
		Facing, rear-ventilated: Glass	≥ 50	0
		Transparent plastic web sheets: Acrylic glass sheets	40	1
		Plastic multiwall sheets transparent: Polycarbonate sheets	30	1

Code no.	Assembly	Component	A	B
		Facing, rear-ventilated: fiber-reinforced resin composite panels	30	1
		Wall cladding (systems): Plastic, multilayer lightweight boards	40	1
		Facing: joint and compression tape, jointing, expansion joint, profile	40	1
		Facing shell: Substructure	≥ 50	0
330 Exterior walls	**336 Exterior wall cladding, interior**			
		Insulation panel cladding: mineral foam insulation panels, calcium silicate panels	≥ 50	0
330 Exterior walls	**338 Sun protection**			
		Blinds: plastic, aluminum	25	1
		Awnings	15	3
		Sunshade, fixed: aluminum	≥ 50	0
330 Exterior walls	**339 Exterior walls, other**			
330 Exterior walls	**339 Exterior walls, other**	**Balconies**		
		Free-standing construction: masonry, reinforced concrete, stainless steel, hot-dip galvanized steel (piece-galvanized), coated aluminum, hardwood, plastic composite.	≥ 50	0
		Free-standing construction: softwood, treated	45	1

Code no.	Assembly	Component	A	B
		Parapet: Steel lattice construction hot-dip galvanized (piece-galvanized), glass, masonry, reinforced concrete	≥ 50	0
		Parapet made of wooden construction	30	1
		Parapet cladding made of aluminum panels, glass panels	≥ 50	0
		Parapet cladding made of plastic panels	40	1
340 Interior walls				
340 Interior walls	**341 Load-bearing interior walls**			
		Masonry wall	≥ 50	0
		Concrete wall	≥ 50	0
		Wooden wall	≥ 50	0
340 Interior walls	**342 Non-load-bearing interior walls**			
		Masonry wall	≥ 50	0
		Concrete wall	≥ 50	0
		Wooden wall	≥ 50	0
		Stand systems	≥ 50	0
		Gypsum wallboards	≥ 50	0
340 Interior walls	**343 Interior supports**			

Code no.	Assembly	Component	A	B
		Masonry column	≥ 50	0
		Concrete column	≥ 50	0
		Wooden column	≥ 50	0
		Steel column	≥ 50	0
340 Interior walls	**344 Interior doors and windows**			
340 Interior walls	**344 Interior doors and windows**	**Interior doors**		
		Standard doors: wooden doors, wood-based material doors, aluminum doors, plastic doors, wood-based material doors, steel doors and stainless-steel doors	≥ 50	0
		Special doors: glass doors, smoke protection doors, sound insulation doors	≥ 50	0
		Fire doors	≥ 50	0
		Special doors: Damp room doors	40	1
		Special doors: sliding doors, revolving doors	30	1
		Special doors: Automatic doors	20	2
		Doors: Fire protection doors	30	1
340 Interior walls	**344 Interior doors and windows**	**Inner window**		
		Windows (frame and sash)	≥ 50	0

Code no.	Assembly	Component	A	B
340 Interior walls	**344 Interior doors and windows**	**other**		
		Fittings: simple fittings	≥ 50	0
		Fittings: Swing door fittings, folding door fittings, sliding door fittings, turn-tilt fittings, lift-turn-tilt fittings	30	1
		Door closers, door locks, window locks	30	1
		Panic locks	25	1
		Door operators	15	3
		Door stops damper	20	2
		Window and door glazing: Single glazing	≥ 50	0
		Window and door glazing: attack-resistant insulating glass, safety insulating glass, fire protection insulating glass, sound insulation insulating glass	40	1
		Sealing profiles	30	1
		Sealants	20	2
340 Interior walls	**345 Interior wall cladding**			
340 Interior walls	**345 Interior wall cladding**	**Coatings / Surface treatment**		
		Interior coatings: Wet abrasion class 1	15	3
		Interior coatings: Wet abrasion class 2	10	4
		Interior coatings: Wet abrasion class ≥ 3	5	9

Code no.	Assembly	Component	A	B
		Interior paints: Glaze	18	2
340 Interior walls	**345 Interior wall cladding**	**Plaster**		
		Standard interior plasters: gypsum plaster, anhydrite plaster, lime plaster, lime-gypsum plaster, lime-cement plaster, synthetic resin plaster, clay plaster	≥ 50	0
		Mineral finishing plasters: Cement plaster, trass lime plaster, trass cement plaster	≥ 50	0
		Special plasters: Restoration plaster/systems	15	3
		Special plasters: Acoustic plaster, radiation protection plaster	≥ 50	0
		Plaster profiles: Plastic, steel, glass fiber	≥ 50	0
		Plaster base: steel wire mesh, ribbed expanded metal, plastic fabric	≥ 50	0
340 Interior walls	**345 Interior wall cladding**	**Clothing**		
		Cladding: Wood, derived timber products and multi-layer lightweight boards, aluminum, steel, copper, zinc, natural stone, artificial stone, ceramic tiles and slabs, porcelain stoneware, stoneware, earthenware and split tiles, glass mosaic	≥ 50	0
		Cladding (systems): Plasterboard, plasterboard composite panels	≥ 50	0
		Cladding: Plastic (PVC, PE, PP)	40	1
		Cladding: Special constructions made of glass	≥ 50	0
		Special claddings: Fire protection, sound insulation, thermal insulation (interior insulation), moisture-resistant claddings	≥ 50	0

Code no.	Assembly	Component	A	B
340 Interior walls	**345 Interior wall cladding**	**Wallpapers**		
		Wallpapers: Paper, plastic, wallpaper not paintable, wallpaper paintable	10	4
		Wallpapers: Textile, woven fabric	15	3
340 Interior walls	**346 Paneled interior walls**			
		Sanitary partitions: toilette partitions, urinal partitions	30	1
		Sanitary partitions: Shower partitions	25	1
		Changing rooms	30	1
340 Interior walls	**349 Interior walls, other**			
		Stair railings: Handrails made of aluminum, hardwood, steel	≥ 50	0
		Stair railings: Handrails made of plastic, softwood	30	1
350 blankets				
350 blankets	**351 Ceiling constructions**			
		Concrete ceilings: solid concrete ceiling, STB cavity ceiling, aerated concrete ceiling	≥ 50	0
		Prefabricated ceilings: lattice girder ceiling, ribbed ceiling	≥ 50	0
		Metal ceilings: steel composite ceiling, steel girder ceiling	≥ 50	0

Code no.	Assembly	Component	A	B
		Wooden ceilings: Solid wood ceiling, wooden beam ceiling, prefabricated wooden elements, wood-concrete composite ceiling	≥ 50	0
		Staircase: supporting structure made of reinforced concrete, steel, wood, aluminum	≥ 50	0
350 blankets	**352 Ceiling coverings**			
		Flowing screeds: Cement screed, mastic asphalt screed, anhydrite screed, magnesia screed	≥ 50	0
		Dry screeds (systems): Wood-based panels, gypsum fiberboards, gypsum plasterboards	≥ 50	0
		Screeds as wearing floors	≥ 50	0
		Impact sound insulation	≥ 50	0
		Floor insulation, incl. insulation of the top floor ceiling	≥ 50	0
		Natural stone coverings	≥ 50	0
		Artificial stone coverings	≥ 50	0
		Ceramic tiles and slabs: Fine stoneware, stoneware, stoneware, split tiles, glass mosaic	≥ 50	0
		Cast floors: Synthetic resin	30	1
		Cast floors: Terrazzo	≥ 50	0
		textile coverings: Cotton, wool, synthetic fiber, sisal, natural fiber blend, jute, natural fiber blend, coconut	10	4

Code no.	Assembly	Component	A	B
		Linoleum, laminate, PVC, synthetic parquet, cork, rubber, sports hall flooring	20	2
		Solid wood parquet, wooden floorboards, wooden plasters	≥ 50	0
		Wood multilayer parquet	40	1
		Wood coating for floor coverings: Wood varnishes, wood sealants	15	3
		Wood protection coatings for floor coverings: Wood oils/waxes	4	12
350 blankets	**352 Ceiling coverings**	**other**		
		Raised floors and cavity floors	≥ 50	0
		Raised floor props and cavity floor props: Steel	≥ 50	0
		Sprung floors: wood, plastic	45	1
		Skirting boards: natural stone, artificial stone, clinker, ceramic, wood	≥ 50	0
		Dirt trap coverings: Synthetic fiber, plastic, cotton, sisal, jute, coconut	8	6
		Surface treatment: Sealing	12	4
		Surface treatment: Plastic-based coating	10	4
		Surface treatment: wax or oil-based coating	8	6
350 blankets	**353 Ceiling linings**			
		Plasterboard cladding	≥ 50	0
		Metal cladding: Aluminum, steel, copper, zinc	≥ 50	0

Code no.	Assembly	Component	A	B
		Wood cladding: Wood, wood-based material and multi-layer lightweight panels	≥ 50	0
		Special constructions incl. fastening: Mineral fiber panels, plastic panels, glass panels	≥ 50	0
		Special constructions incl. fastening: Fire protection suspended ceilings	40	1
		Special constructions incl. fastening: Acoustic ceilings, acoustic elements, acoustic foam, sound absorbers	40	1
		Special constructions incl. fastening: Light ceilings	25	1
		Insulation of the basement ceiling	≥ 50	0
		Wallpapers: paintable	20	2
		Wallpapers: Plastic, textile, woven fabric, paper cannot be painted over	10	4
		Substructures: Drywall profiles (steel, wood)	≥ 50	0
		Interior coatings: Wet abrasion class 1	15	3
		Interior coatings: Wet abrasion class 2	10	4
		Interior coatings: Wet abrasion class ≥ 3	5	9
		Interior coatings: Wood stain	18	2
350 blankets	**359 Ceilings, other**			
		Railings, gratings, grates, ladders: steel, aluminum, wood, derived timber products, cast iron	≥ 50	0
		Grids and grates: Plastic	40	1

Code no.	Assembly	Component	A	B
360 Roofs				
360 Roofs	**361 Roof construction**			
		Support structure: pitched roof	≥ 50	0
		Support structure: Flat roof	≥ 50	0
360 Roofs	**362 Skylights, roof openings, canopies**			
		Roof windows (frame): Aluminum, plastic, aluminum-wood composite	≥ 50	0
		Skylight (frame): Aluminum-plastic composite	35	1
		Skylight (frame): Hardwood, treated	40	1
		Skylight (frame): Coniferous wood, treated	25	1
		Light domes	25	1
		Strip lighting	20	2
		Roof exits and hatches: hot-dip galvanized steel (piece-galvanized)	40	1
		Roof exits and hatches: plastic	30	1
		Drives for openings: Manual drive	35	1
		Drives for openings: electric drive	25	1
		Drives for openings: pneumatic drive	20	2

Code no.	Assembly	Component	A	B
360 Roofs	**363 Roof coverings**			
360 Roofs	**363 Roof coverings**	**Flat roof waterproofing**		
		Waterproofing membranes: Elastomeric membranes, plastic membranes underneath the insulation	40	1
		Waterproofing membranes: Bitumen membranes underneath the insulation	30	1
		Waterproofing membranes: Bitumen membranes, elastomeric membranes, plastic membranes above insulation with heavy protective layer	30	1
		Waterproofing membranes: Bitumen membranes, elastomeric membranes, plastic membranes above insulation with light protective layer	20	2
		Waterproofing compounds: Asphalt mastic, liquid waterproofing, mastic asphalt underneath insulation	40	1
		Waterproofing compounds: Asphalt mastic, liquid waterproofing, mastic asphalt above insulation with heavy protective layer	30	1
		Waterproofing compounds: Asphalt mastic, liquid waterproofing, mastic asphalt above insulation with light protective layer	20	2
		Waterproofing compounds: Liquid waterproofing above insulation without protective layer	20	2
		Heavy protective layer: Extensive greening	40	1
		Heavy protective layer: graveling, laying slabs, intensive greening	30	1

Code no.	Assembly	Component	A	B
		Light protective layer: splintering on site, factory sprinkling	15	3
		Coatings: Metal coating	12	4
360 Roofs	**363 Roof coverings**	**Roofing**		
		Coverings: Slate	≥ 50	0
		Coverings: Brick	≥ 50	0
		Coverings: Concrete, fiber cement	≥ 50	0
		Coverings: Zinc, copper sheet, aluminum, stainless steel	≥ 50	0
		Coverings: Wood shingles	≥ 50	0
		Coverings: Galvanized and coated steel	45	1
		Coverings: Galvanized steel	40	1
		Coverings: Glass	30	1
		Coverings: Bitumen shingles, corrugated bitumen sheets	25	1
		Metal strip covers: Stainless steel, copper, aluminum sheeting	≥ 50	0
		Metal strip covers: Galvanized and coated sheet steel	45	1
		Metal strip covers: Galvanized sheet steel	40	1
		Coverings: Reet	30	1
		Insulation layer as above and between rafter insulation: foam glass panels, mineral wool panels, extruded polystyrene panels, expanded polystyrene panels, polyurethane panels, fiber panels made of wood, hemp, cellulose.	≥ 50	0

Code no.	Assembly	Component	A	B
360 Roofs	**363 Roof coverings**	**Attica cover**		
		Parapet covers: Natural stone, artificial stone, precast concrete, concrete block slabs, ceramic tiles and slabs, porcelain stoneware, stoneware, split tiles, copper, aluminum, steel, stainless steel, zinc.	≥ 50	0
		Parapet covers: Fiber cement	40	1
		Parapet covers: Galvanized steel	30	1
		Parapet covers: Plastic	20	2
360 Roofs	**363 Roof coverings**	**Drainage**		
		Drainage (gutters, downpipes, roof drains): Stainless steel, copper, zinc, aluminum	≥ 50	0
		Drainage (gutters, downpipes, roof drains): Galvanized and coated steel	40	1
		Drainage (gutters, downpipes, roof drains): Galvanized steel	30	1
		Drainage (gutters, downpipes, roof drains): Plastic	20	2
360 Roofs	**364 Roof claddings**			
		Sub-roof: Bitumen wood fiber boards	≥ 50	0
		Sub-roof: Impregnated fiber boards made of wood, hemp, cellulose	30	1
		Sub-roof: vapor-diffusion-open plastic sheeting	30	1

Code no.	Assembly	Component	A	B
		Intermediate, above and below rafter insulation: mineral wool, polystyrene, polyurethane, expanded granules, renewable insulation materials (e.g. wood insulation materials, cellulose, cork, light clay mixture, flax, meadow grass, hemp).	≥ 50	0
360 Roofs	**369 Roofs, other**			
360 Roofs	**369 Roofs, other**	**Roofing**		
		Entrance roofing: steel construction, steel-glass construction, reinforced concrete construction, prestressed concrete construction, timber construction (clad)	≥ 50	0
		Entrance roofing: wooden construction (uncovered), wood-glass construction, glass construction (load bearing)	40	1
		Courtyard roofing: steel-glass constructions	≥ 50	0
		Courtyard roofing: wood-glass constructions, rope net constructions	40	1
		Courtyard roofing: Textile constructions	8	6
360 Roofs	**369 Roofs, other**	**Railings, gratings, ladders**		
		Stainless steel, hot-dip galvanized steel (piece galvanized)	≥ 50	0
		Aluminum, hardwood treated	45	1
		Hardwood untreated, softwood treated, wood material coated	30	1
		Coniferous wood untreated	20	2

Code no.	Assembly	Component	A	B
360 Roofs	**369 Roofs, other**	**other**		
		Fall protection, steps, treads, leaf and snow guards, lightning protection systems: hot-dip galvanized steel (piece-galvanized), stainless steel	≥ 50	0
		Roof ventilation Steel, galvanized	25	1
		Vent pipes plastic	25	1

In summary, solid components have a higher statistical service life than wooden or plastic components. From all three approaches described, it can be concluded that the sustainability of solid building materials is good. Of course, the lifespan of the components and the building also depends largely on usage behavior, responsible handling of the building substance and maintenance and repair behavior.

2.3. Recycling

About the recycling of demolition material, statistics are currently available almost only for mineral waste. According to these statistics, about 90% of recycled mineral waste can be reused as road construction materials (https://www.umweltwirtschaft.com/news/abfallwirtschaft-und-recycling/Kreislaufwirtschaft-Bau-13-Prozent-Recyclingquote-bei-mineralischen-Bauabfaellen-28398The construction sector in Europe consumes about 10 million tons of **plastic** per year. That is about 20% of European plastic consumption. Much of this can be recycled and used in road construction products such as beacons and erection devices, posts or traffic cones (https://www.kunststoff-cluster.at/news-presse/detail/news/wie-kunststoff-auch-am-bau-im-kreislauf-bleibt).

Wood is a renewable resource, and its use as a building material is considered sustainable. For an average single-family house, about 60 m³ of wood is needed, which corresponds to about 35 to 40 trees, depending on the type of wood chosen (https://www.bruno-kaiser.de/faq). To replace the environmental performance of an old tree, about 400 young trees are needed. This is what the Dresden forest scientist Prof. Andreas Roloff found out during his research on the so-called "methuselah trees" (trees with a diameter of about 100 centimeters or more) (https://tu-dresden.de/tu-dresden/newsportal/news/400-jungbaeume-sind-ein-alter-baum-dresdner-forstexperte-andreas-roloff-fordert-mehr-achtung-fuer-die-grossen-gehoelze) .

Unlike other inorganic raw materials, wood is part of the natural cycle. Wood is a recyclable material (processed into wood-based panels), thermal (combustion), and biologically (soil improvement, mulch). In addition, it can be downgraded and used for other, non-load bearing building components, e.g. cladding. The prerequisite for this is the healthy condition of the wood, it must be free of fungal and other biological infestation and may only contain small amounts of wood preservatives.

2.4. CO2-emissions, the unquantifiable costs

A completely different approach to sustainability can be found in a study can of The **Ministry of Economic Affairs, Energy, Climate Protection, and the Environment in Saxony-Anhalt** used the "LENA Model House". The target is to investigate the ecological footprint of conventionally and ecologically constructed buildings (see fig. 10 – 15).

Source: https://www.sachsen-anhalt-energie.de/de/modellhaus-baustoffe-bauteile.html

Fig. 10: Ecological footprints: Solid exterior wall

Solid exterior wall (U=0,20 W/m²K)				
Conventional building materials (e.g. bricks, metals, glass) are characterised by high temperatures and energy consumption during production and should therefore achieve the longest possible lifetime.				
Construction method	**Conventional**		**Ecological**	
Building materials	Concrete, brick, lime, plastics, foamed plastic, rock and mineral wool		Natural building materials, wood, clay, cork, hemp, sheep's wool, reed, straw	
Examples		External thermal insulation composite system, synthetic resin plaster, 14 cm polystyrene board, 36 cm vertically perforated brick, 15 mm lime plaster		External thermal insulation composite system, adhesive mortar, 18 cm wood fibre board, 36 cm clay blocks, wooden pillars, clay plaster
Reference value	**Component 1 m²**	**Model house 100 m²**	**Component 1 m²**	**Model house 100 m²**
Primary energy	474 kWh/m²	47.400 kWh	334 kWh/m²	33.400 kWh
Global warming potential	147 kg CO_2 Äqv./m²	14.700 kg CO_2 Äqv.	6 kg CO_2 Äqv./m²	600 kg CO_2 Äqv.
Heat loss / year	16 kWh/m²	1.600 kWh	16 kWh/m²	1.600 kWh
Recycling	Recyclable through industrial reprocessing		Reusable, recyclable through industrial processes, thermally recyclable (incineration)	

Fig. 11: Ecological footprints: Exterior wall, lightweight construction

Exterior wall, lightweight construction (U=0,20 W/m²K)				
Metal stud structures with synthetic petroleum-based insulating materials (polystyrene, polyurethane) versus wooden stud structures with mineral and natural insulating materials				
Construction method	**Conventional**		**Ecological**	
Building materials	Metal framework, mineral fibre mats, plasterboard, plastics		Natural building materials, wood, clay, cork, hemp, sheep's wool, reed, straw	
Examples		External board fibre cement, 24 cm rock wool, metal framework, vapour barrier, gypsum plasterboard		Exterior plaster, wood fibre board, 20 cm timber frame, 8 cm cellulose, 6 cm wood fibre board, gypsum fibreboard
Reference value	**Component 1 m²**	**Model house 100 m²**	**Component 1 m²**	**Model house 100 m²**
Primary energy	157 kWh/m²	15.700 kWh	79 kWh	7.900 kWh
Global warming potential	40 kg CO_2 Äqv./m²	4.000 kg CO_2 Äqv.	-34 kg CO_2 Äqv./m²	-3.400 kg CO_2 Äqv.
Heat loss / year	16 kWh/m²	1.600 kWh/Jahr	16 kWh/m²	1.600 kWh/Jahr
Recycling	Raw material recycling, thermal recovery (combustion)		Recycable, thermal recovery (incineration), landfillable	

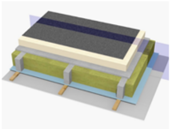
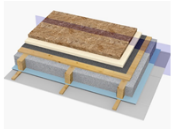
Flat roof (U=0,20 W/m²K)				
Construction method	**Conventinal**		**Ecological**	
Building materials	Reinforced concrete, rigid foam panels, mineral wool, roof sealing (bituminous, polymer)		Wooden construction, natural insulating materials, vegetation on roof	
Examples		Bitumen waterproofing membrane, 10 cm rigid foam panels, reinforced concrete beams, 20 cm mineral wool, wooden battens, gypsum plasterboard		Humus soil with vegetation, Bitumen waterproofing membranes, 10 cm rigid foam panels, wooden beams & boarding, 16 cm cellulose, vapour barrier, wooden battens, OSB boards
Reference value	**Component 1 m²**	**Model house 60 m²**	**Component 1 m²**	**Model house 60 m²**
Primary energy	165 kWh/m²	9.900 kWh	125 kWh/m²	7.500 kWh
Global warming potential	36 kg CO_2Äqv./m²	2.160 kg CO_2Äqv.	-30 kg CO_2Äqv./m²	-1.800 kg CO_2Äqv.
Heat loss / year	16 kWh/m²	960 kWh	16 kWh/m²	960 kWh
Recycling	Raw material recycling, thermal recovery (combustion)		Recycable, thermal recovery (incineration), landfillable	

Fig. 12: Ecological footprints: Flat roof

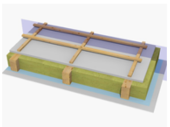
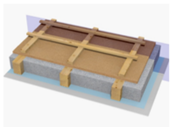
Pitched roof (U=0,20 W/m²K)				
The production of roof tiles is energy-intensive and generates many greenhouse gases. Alternatives are green roofs or integrated solar roofs.				
Construction method	**Conventinal**		**Ecological**	
Building materials	Concrete or clay roof tiles, wooden rafters with mineral wool, aluminium foil, gypsum plaster boards		Clay tiles, wooden rafters with wood fibre or cellulose insulation, gypsum plaster boards	
Examples		Roof tiles, battens, aluminium foil, Wood rafters, 22 cm mineral wool 035, vapour barrier, Gypsum plasterboard		Roof tiles, battens, wood fibre insulation board, Wood rafters, 20 cm cellulose 040 vapour barrier, gypsum plasterboard
Reference value	**Component 1 m²**	**Model house 80 m²**	**Component 1 m²**	**Model house 80 m²**
Primary energy	3.850 kWh/m²	308.000 kWh	120 kWh/m²	9.600 kWh
Global warming potential	1.075 kg CO_2Äqv./m²	86.000 kg CO_2Äqv.	-27 kg CO_2Äqv./m²	-2.160kg CO_2Äqv.
Heat loss / year	16 kWh/m²	1.280 kWh	16 kWh/m²	1.280 kWh
Recycling	Raw material recycling through industrial processes; thermal recovery (combustion)		Raw material recycling through industrial processes; thermal recovery (incineration), landfillable	

Fig. 13: Ecological footprints: Pitched roof

Fig. 14:. Ecological footprints: Floor against ground

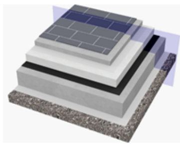
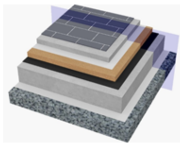
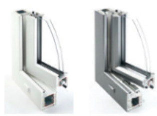
Floor against ground (U=0,35 W/m²K)				
High energy input in concrete production; new energy-efficient technologies are under development (certification)				
Construction method	**Conventional**		**Ecological**	
Building materials	Concrete, reinforced concrete, foam polymers, bitumen, ceramic tiles		Foam glass, concrete, reinforced concrete, natural insulating materials, bitumen, ceramic tiles	
Examples		Tiles, cement screed, PE foil, hard foam boards, bitumen sheeting, reinforced concrete, gravel fill		Tiles, cement screed, PE foil, wood fibre boards, bitumen sheeting, reinforced concrete, foam glass grave
Reference value	**Component 1 m²**	**Model house 60 m²**	**Component 1 m²**	**Model house 60 m²**
Primary energy	305 kWh/m²	18.300 kWh	302 kWh/m²	18.120 kWh
Global warming potential	85 kg CO_2Äqv./m²	5.100 kg CO_2Äqv.	70 kg CO_2Äqv./m²	4.200 kg CO_2Äqv.
Heat loss / year	< 25 kWh/m²	< 1.500 kWh	< 25 kWh	< 1.500 kWh
Recycling	Raw material recycling, thermal recovery (combustion)		Recycable, thermal recovery (incineration), landfillable	

Fig. 15:. Ecological footprints: Window frames

Window frames (U=0,95 W/m²K)				
Glass production is energy- and CO2-intensive. Triple glazing significantly reduces heat loss. Wooden frame windows have better eco-balances than PVC or aluminium windows.				
Construction method	**Conventional**		**Ecological**	
Building materials	Double or multiple glazed windows with frames made of wood, PVC, aluminium or other metals		Double or multiple glazed windows with frames made of local woods	
Examples		Aluminium profiles, polymer profiles, multi-chamber hollow profiles made of polymer, steel profiles		Domestic woods from sustainable cultivation (pine, spruce, larch)
Reference value	**Window 1,6 x 1,3 m**	**Model house 14 pieces (30 m²)**	**Window 1,6 x 1,3 m**	**Model house 14 pieces (30 m²)**
Global warming potential	520 kg CO_2Äqv./m²	15.600 kg CO_2Äqv.	440 kg CO_2Äqv./m²	13.200 kg CO_2Äqv.
Heat loss / year	80 kWh/m²	2.300 kWh	80 kWh/m²	2.300 kWh
Recycling	Household waste, partly hazardous waste; thermal recovery (combustion), partly re-usable (used glass)		Material separation, partially re-usable, thermal recovery	

In summary, it can be said that each approach has a different focus (construction costs - maintenance costs - life cycle consideration and replacement frequency - CO2 emissions). Depending on the approach, one or the other aspect is considered primarily. The "ideal" sustainable building will therefore always be a compromise and reflect the preferences of the client as the actual decision-maker. In all the approaches listed, the so-called "eternity costs", i.e. the costs of environmental pollution, are not considered. These are often thrown into the discussion from a higher (moral) perspective. Whether and how these can be integrated and quantified in the sustainability assessment is disputed among experts.

3. Building design and material selection

3.1. Energetic structural basics

Currently, the use phase accounts for the lion's share of energy consumption, i.e. heating and cooling buildings consume many times the energy needed to construct them. How large this share is depending on the energy standard of the building and on how the users deal with the building - wastefully or energy-savingly. Overall, our buildings are becoming more and more energy-efficient in the operating phase; since the new Building Energy Act, they are even supposed to be "nearly zero energy buildings" (NZEB), i.e. have an energy demand close to zero. In this view, the energy demand to produce building products and for building processes also comes more into focus.

Not only production and construction are relevant, but also demolition and disposal or the possible further use of building components and materials. In addition, every time parts of the building are replaced, for example floor coverings or windows, the same processes (removal and disposal of the old parts and production and installation of new parts) take place for the affected parts of the building, so that energy is consumed. Considering the resource problem, sufficiency, i.e. the economical use of resources, is becoming more important. In the design and detailing of buildings, materials that occur in large quantities are particularly important from this point of view. These are especially the supporting structure material (reinforced concrete, steel, wood, masonry), and claddings such as plasterboard or façade panels. Opportunities to conserve resources are offered by recycled building materials (recycled crushed stone, steel, plastics) and the use of renewable raw materials if they come from sustainable agriculture and forestry.

Another indication of how high the material consumption of the construction industry is the amount of waste: approx. 57% of the waste in Germany is demolition material (source: Federal Environment Agency / construction, demolition, commercial and mining waste). Much of this is recycled, but little is used in building construction. Gypsum waste, for example, is used for backfilling in mining and landfill construction instead of being processed into new building materials.

The energy consumption of a building is also determined by a multitude of influences in the design as well as the structural and technical planning, in the construction and in the use of the building.

The main influencing factors are:

- Compactness of the building design,
- Thermal insulation of the building shell,
- avoidance of thermal bridges,
- Air tightness of the building shell,
- type and method of ventilation,
- Passive use of solar energy through windows and storage-capable masses of the interior components,
- Zoning of the building through north orientation of the rooms with temporarily or permanently lowered indoor temperature,
- Energy efficiency of heat generation,
- Losses during heat storage and distribution,

Behavior of the people living in the building about room temperatures, air exchange, hot water consumption, passive solar energy use, size of internal heat gains, operating mode of the system technology.

The **thermal insulation** of building envelope (exterior walls, roof, basement) is ensured for decades with only low maintenance costs (depending on the type of construction, 30 - 50 years); so it is the safest and most sustainable measure of energy-saving construction (RWE-Handbuch Energiesparendes Bauen, 15. Auflage).

An essential prerequisite for the effectiveness of thermal insulation is the **airtightness** of the building envelope. The attention of the experts responsible for energy-saving experts is therefore increasingly focused on reducing heat losses through air ventilation. In addition to technical solutions (e.g. fan-assisted ventilation with heat recovery), a tighter construction method is also of importance. But also, among building experts the subject of airtightness is also gaining interest among building faults in the airtight building envelope are often the cause of mold damage or annoying draughts, and thus ultimately also cause legal disputes about building defects.

The avoidance of **thermal bridges** or the reduction of their effectiveness remains indispensable in energy-saving construction. The effect of thermal bridges on transmission heat losses can be very high.

In addition to the thermal insulation of the individual components, the **size of the heat-emitting surface** of a building has a very large influence on the energy demand. This is because the transmission heat loss increases proportionally with the surfaces of the heat-transferring enclosure components. A building of compact design, which has a small heat-transferring enclosure surface in relation to its heated building volume, has low transmission heat losses and is thus particularly efficient in terms of energy.

Passive solar energy use: Important aspects are among others.

- the orientation, size, and total energy transmittance of the windows,
- Heat storage capacity of building components and building materials.
- Arrangement of rooms with different uses (zoning)

For passive solar energy use, a high heat storage capacity of the interior components as well as the room-side layers of the exterior components is advantageous: Heavy room-side component layers up to a depth of 8 to 10 cm contribute to heat storage.

3.2. Sustainable building materials

As illustrated in the previous sections, sustainability does not only refer to the choice of building materials. Not all building materials that are considered sustainable are so when looked at in more detail. However, the consideration should not be limited to the exterior walls and the façade or the roof; attention must also be paid to the materials used for insulation and interior finishing.

The construction of permanent dwellings only came about when people settled down and moved from caves and tents into huts and houses. For a long time, whatever nature offered was used as building material: Wood, hewn stones or clay for the walls and reeds for the roofing. Around 5,000 years ago, people succeeded for the first time in firing bricks from clay in charcoal kilns - a building material that was more durable and stable than the previous mud bricks, wood, or straw.

If there were far fewer people compared to today and industrial building material production did not yet exist, building was sustainable: natural building materials were used that could be found in the immediate vicinity, and due to the low population density, resource consumption was low.

It was only with industrialization in the late 18th and 19th centuries that the mass production of energy-intensive building materials began. Brickworks fired by coal or natural gas burned bricks by the millions, and with the invention of reinforced concrete in 1867, skyscrapers and soon skyscrapers began to rise into the sky. Due to the high demand for fossil fuels in the industrial production of bricks and concrete, however, these building materials can no longer be called sustainable.

Fun fact Recycled houses: from car tires to homes of your own.

Resourceful builders are experimenting with waste as a building material for new houses. For example, old car tires filled with earth can be stacked to form stable walls, old bottles can be used for semi-transparent interior walls, or discarded materials from trade fair construction can be used for interior finishing. The pioneer of the recycled building method is the American architect Michael Reynolds, who founded the "Earthship" movement, which has meanwhile erected around 3,000 buildings worldwide, mainly from waste materials (https://utopia.de/autark-earthship-deutschland-41862/).

3.3. Check: Which building materials are sustainable?

To determine the sustainability of a building material, a holistic life cycle assessment is required. This ranges from the availability of raw materials and energy consumption during production to insulation properties, service life and subsequent recyclability.

Bricks

The production of bricks requires a lot of energy. Optimized production can reduce the amount of material required and at the same time optimize thermal insulation, so that fewer additional insulating materials are needed when building a house. On the other hand, the long service life speaks in favor of brick.

Concrete

Due to the high energy requirements for burning the cement and producing the steel reinforcement that is often needed, as well as the poor thermal insulation, concrete was long considered to be harmful to the environment. Measures such as reducing the cement content through additives, e.g. rock flour or fly ash, or increasing the recycling rate can improve sustainability. What speaks in favor of concrete is its durability and stability.

Wood

The wooden house is considered sustainable because wood is a renewable resource and can be processed with little energy input. However, the prerequisite is that the wood used comes from sustainably managed forests and is not contaminated with poisons for pest control. Wood is often not available regionally in sufficient quantity and quality, so that long transport routes are sometimes required, for example from Scandinavia or Ukraine. The amount of wood required for a house can be enormous, and the medium- and long-term maintenance of the building components against fungal and other biological infestations can also be very high. The durability of load-bearing building components is roughly equivalent to that of solid building components.

Sustainable insulation materials

Conventional building materials such as rigid foam or mineral wool have an unfavorable ecological footprint because a lot of energy is needed for their production, or their subsequent disposal is problematic. There is now a wide range of alternative natural insulation materials. The spectrum ranges from blow-in insulation with cellulose to cork, straw, or wood fiber insulation materials.

Ecological paints and varnishes

Exterior and interior paints should not only look good, but also protect the building fabric from moisture penetration. Ecological products are not only free of solvents, but also contain as few petroleum-based ingredients as possible. Instead, mineral and plant-based basic materials are used.

Materials for the floor

Ecology and sustainability also play an important role in interior design - not least because ecological materials have a positive effect on healthy living. Floor coverings made of cork or solid wood flooring are far ahead in the sustainability ranking, but carpets made of natural textiles also have good sustainability properties.

3.4. Overview: Sustainability of single building materials (examples)

Exterior Walls

Building material	Positive	Negative
Concrete	- Long life span - good heat storage - Partly recyclable	Poor thermal insulation High primary energy content due to energy-intensive production
Bricks	- Long life span - Partly recyclable - partly good thermal insulation with appropriate construction - partly good heat storage - partly recyclable	High primary energy content due to energy-intensive production
Aerated concrete, lightweight concrete	- Long life span - Good thermal insulation	High primary energy content due to energy-intensive production
Wood	- Renewable raw material - Low energy consumption during production and processing	- Environmental damage from the use of wood from non-sustainable forestry - Partly long transport routes - Partially high maintenance and care requirements
Composite building materials	Good thermal insulation depending on the structure	- Partly high primary energy content due to energy-intensive production - Often not recyclable

Insulating materials

Building material	Positive	Negative
Petroleum-based insulation, e.g. polystyrene	Good to very good insulating properties	- Energy-intensive production - problematic disposal - release of toxic substances in case of fire

Building material	Positive	Negative
Mineral and glass wool	- Good to very good insulating properties - incombustible	High primary energy content due to energy-intensive production
Wood and cellulose-based insulation materials	- Renewable raw material - Good insulating properties	Environmental damage from the use of wood from non-sustainable forestry
Hemp and straw	- Renewable raw material - Good insulating properties	No ecological disadvantages, but often additional costs for purchase and processing

3.5. Other features of sustainable building

Land consumption: A sustainable house should consume as little floor space per user as possible. A reduction in land sealing is also possible in an indirect way, for example by providing residential buildings with green roofs that relieve the burden on the sewage system by delaying rain runoff.

Transport routes: The choice of regional building materials and craftsmen can shorten the transport routes associated with house construction and thus indirectly contributes to saving energy and protecting the environment.

Flexible architecture: Even at the planning stage, builders should consider how the home can be adapted to new living circumstances if necessary - for example, by dividing it into two separate units when the children have moved out. This is also part of sustainability, because it avoids costly conversion work that involves a lot of building waste.

Library on Module 2: Life Cycle Assessment of building materials

Leitfaden Nachhaltiges Bauen, Bundesministerium des Innern, für Bau und Heimat, Auflage 2019
(Guide to Sustainable Building, Federal Ministry of the Interior, for Building and Home Affairs, edition 2019)
https://www.nachhaltigesbauen.de/fileadmin/publikationen/BBSR_LFNB_D_190125.pdf

Non Profit Initiative: Holz von hier – Low Carbon Timber;

https://www.holz-von-hier.eu/en/

WECOBIS - Ecological Building Materials Information System

What role do building materials play in the overall life cycle of buildings?

https://www.wecobis.de/en/service/sonderthemen-info/gesamttext-baustoffe-klimaschutz-info/rolle-baustoffe.html

Aachener Stiftung Kathy Beys – Wandel ganzheitlich denken
(Aachen Foundation Kathy Beys - Thinking change holistically)

Encyclopaedia of Sustainability

https://www.nachhaltigkeit.info/artikel/nachhaltiger_hausbau_1947.htm

Ecobuildproject

The EcoBuild Project focuses on young students between 12 and 16 years old and provides them with the necessary awareness and knowledge about new concepts, such as the carbon footprint, the recyclability of construction materials and all materials in general, the consumption of water or the acidification of the land.

https://ecobuildproject.com/uncategorized/animated-video-about-the-sustainable/

https://ecobuildproject.com/resources/

Bee VET Project
"Transforming VET in Construction – Innovative Materials for Building and Energy Efficiency" (BEE-VET)

https://beevet.eu/about-bee-vet-project/

Speicherpotenzial von mineralischen Baustoffen
(Storage potential of mineral building materials)

https://www.baulinks.de/webplugin/2023/0180.php4

4. Self-assessment quiz on Module 2: Life Cycle Assessment of building materials

1. Sustainability is based on three pillars. Which is *NOT ONE* of them?

a. Environment

b. Individuality

c. Economy

d. Social

2. What is one of the social aspects of sustainability?

a. Preservation of health and safety

b. Utilization costs

c. Deconstruction costs

d. Durability

3. What are the intellectual basics for sustainable building?

a. Completion of the building as quickly as possible

b. As few renewable raw materials as possible

c. The transport routes of the building material should be as long as possible.

d. Thoughtful and foresighted planning

4. What is the approximate percentage contribution of the construction trade to greenhouse gas emissions?

a. nearly 0 %

b. approx. 10 %

c. approx. 20 %

d. approx. 40 %

5. Some questions need to be considered when building a sustainable house. Which one does not belong to them?

a. Which building materials should be used?

b. How do I keep my house warm without heating it too much?

c. Which craftsmen work cheapest?

d. What is the best way to use water?

6. In which life cycle phase of a building are Reconstruction and Restoration located?

a. Use phase

b. Modernization phase

c. Deconstruction phase

d. Planning phase

7. In which life cycle phase of a building is the possibility to influence the accumulated costs particularly high?

a. Conception and planning

b. Selection of building materials

c. Building the foundations.

d. Erection of exterior walls

8. Which statement regarding lifespan of Load-bearing exterior walls is correct?

a. A wooden wall has a shorter lifespan than a concrete wall.

b. Masonry walls and wooden walls have a lifespan of more than 50 years.

c. Reinforced concrete walls have a very short lifespan because of the risk of rusting.

d. A wooden wall must be renewed twice in 50 years.

9. Which statement regarding the selection of sustainable building materials is correct?

a. Sustainable building materials are only necessary for exterior walls.

b. Sustainable building materials are only necessary for roofs.

c. Sustainability is fundamentally necessary for all building materials, including cladding and floor coverings.

d. Sustainable building materials consist almost exclusively of concrete.

10. Which statement regarding the building design is wrong?

a. Energy consumption is influenced by the compactness of the building.

b. An essential prerequisite for the effectiveness of thermal insulation is the airtightness.

c. the orientation, size and total energy transmittance of the windows is important for passive energy use.

d. Thermal bridges play no role in sustainable buildings.

MODULE 3: EU STANDARDS AND LABELLING OF BUILDING MATERIALS.

1. The role of green building materials in green procurement processes

Green Public Procurement (GPP) is defined in the Communication (COM -2008- 400) "Public procurement for a better environment" as "a process whereby public authorities seek to procure goods, services and works with a reduced environmental impact throughout their life cycle when compared to goods, services and works with the same primary function that would otherwise be procured."

While GPP is a voluntary instruments and Members States are able to determine the extent to which policies or criteria are applied, it plays a key role in the EU's efforts to boosting a resource-efficient economy.

GPP is within the framework of Strategic Public Procurement, together with Socially Responsible Public Procurement (SRPP) and Innovation Procurement. The basic concept of GPP relies on having clear, verifiable, justifiable, and ambitious environmental criteria for products and services, based on a life-cycle approach and scientific evidence base.

The European Commission (EC) has been developing voluntary GPP criteria for several product groups. Furthermore, following the adoption of the 2020 Circular Economy Action Plan, the Commission is proposing minimum mandatory GPP criteria and targets in sectoral legislation and phase in compulsory reporting to monitor its uptake.

EU Ecolabels: Labels can play a particular role in developing technical specifications and award criteria, and in verifying compliance helping public buyers to save time in accordance with Art. 43 of Directive 2014/24/EU.

Green construction procurement is a part of the sustainable development goals (SDGs) that influence economic growth on a strategic level. Adopting green technologies and practices has no longer been an option but a well-worth route for gaining a competitive advantage in the construction sector. The emergent concepts of green procurement and sustainability have raised the need to measure the financial performance in supply chain practices.

Green procurement is now gaining importance in the construction industry and supply chain practices for a safer tomorrow. Construction procurement is partially associated with green logistic services management, which thoroughly determines the sustainable economic development goals. Furthermore, construction procurement has a significant impact on green innovation practices that partially predict the SDGs, and the mediation of green logistic services and innovation practices are partially mediated to the construction procurement and sustainable goals. The implication of green procurement and logistic services offers many challenges in the long run for attaining SDGs; however, in the short run, it gives operational efficiency and less hazardous environmental emissions.

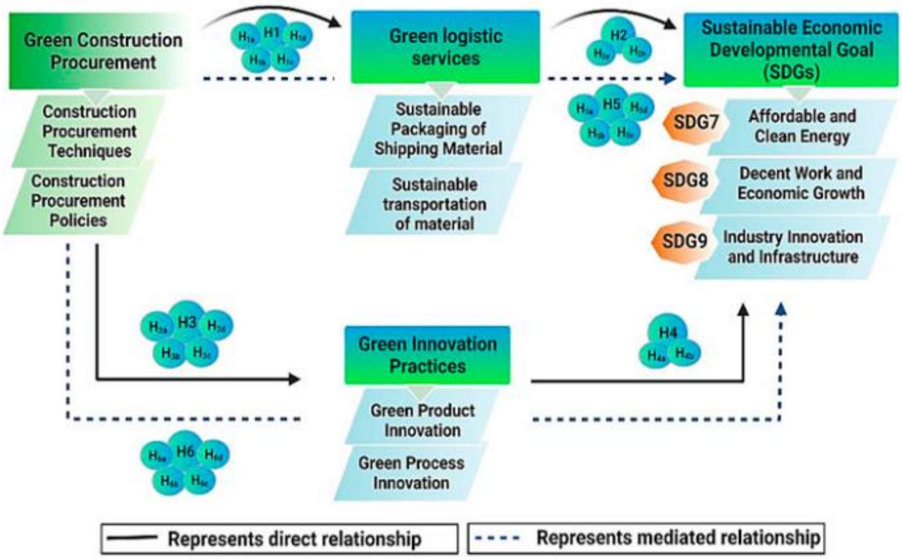


Figure1. Relationship between Green Construction Procurement and SDGs

SOURCE: https://www.frontiersin.org/articles/10.3389/fenvs.2021.815928/full

2. ECO Labelling concept and types of ecolabels

Labels, endorsements, and accolades provide critical third-party review of the worth of manufacturers' claims made on behalf of their products. Labels abound and reflect a spectrum of environmental concerns from the general to the specific. The world-wide proliferation of 'eco labels' is testament to the utility of third-party certification.

Given the complex data that they are based upon, labels provide simple confirmation for non-experts that products bearing a label meet with a range of environmental standards. Through encouraging consumer awareness, labels can exert a significant beneficial impact upon the market in environmentally preferential products and materials. Also, though there are many certificates, relatively few relate to building products and materials. Labels that include construction usually do so as one of many categories.

Ecolabels, though mostly having developed nationally, can apply internationally. Hence some North American labels might be in use in Europe - and vice-versa. Other labels have been developed specifically for international application - the FSC label is a good example.

ISO 14024 Type I ecolabels continue to be uncommon in the UK where the BRE's Green Guide to Specification accepts certification only from the BRE's own Eco Profiling program.

2.1. Types of ecolabels

2.1.1. The three types of ecolabels

To standardize eco-label principles, practices, and characteristics, the ISO (International Organization for Standardization) has created three distinct eco-label categories. They are as follows:

Type I – The 'classic' ecolabel

- By design is consumer-friendly and easily understood
- Awarded by a third-party organization.
- Based on a standardized set of criteria, determined by independent experts, available to be evaluated by the public
- Certification is time limited, with the need for periodic recertification.
- Facilitates the ability to contrast different products easily.

Type II – Self-declaration claims

- Self-declared
- Specific focus on one area, e.g., recyclable
- Not necessarily independently verified.
- If unverified, raises the question of validity.

Type III – Environmental declarations (report cards/information labels)

- Can be third party certified, but not always.
- Is not a certification on any specific product.
- Provides the ability for independently researched conclusions on overall sustainability when compared to other products.

As you can guess from the above information, Type I is generally considered the 'gold standard' of ecolabeling, due to its independent verification, comprehensive approach, and widespread use. By choosing Type I you are guaranteed a product that has passed certain strict environmental requirements, however you don't get the quantitative information. Two products that are Type I ecolabel can't really be compared, you will not know which one is best, you will just know that both passed a certain threshold. Some examples of Type I ecolabels that can be found in the furniture industry include the EU Ecolabel and Möbelfakta.

Types II & III should not be discounted though, especially not the third-party verified (as for instance Type III EPD – Environmental Product Declaration), as they can display transparent and quantitative information on performance. Lack of third-party verification and specific as opposed to holistic measurement of environmental impact leaves the door open for greenwashing. Making a bold claim about one aspect of their design may leave an impression of positivity, whilst masking serious deficiencies in other areas. Therefore, you should always read closely as to what a company or product is claiming and carry out your own investigation. When executed properly these are usually good tools for indication though.

2.1.2. Public, multi-criteria ecolabels (Type I, ISO 14024)

A "Type I" label is a third-party assessment of a product based on several criteria / issues involved in the environmental impact of a product or material throughout its life cycle. These labels are the ones most used by "Type I environmental labelling" is defined by ISO as "a voluntary, multiple criteria based, third party program that awards a license which authorizes the use of environmental labels on products indicating overall environmental preferability of a product within a particular product category based on life cycle considerations”.

Type I labelling is in use today in many parts of the world. Ecolabelling programs that meet the requirements of ISO 14024 include:

- The European Ecolabel: ec.europa.eu/environment/ecolabel/
- The Nordic Swan, Scandinavia: www.svanen.se/en/
- The Blue Angel (Blauer Engel), Germany: https://www.blauer-engel.de/en/our-label-environment
- Umweltzeichen, Austria: www.umweltzeichen.at
- Ecomark, Japan: www.ecomark.jp/english/
- EcoLogo, Canada: http://bit.ly/1gDbu4p

Key guiding principles of Type I labels are:

- Voluntary.
- A third party sets the criteria and grants license to use the label.
- Verifiable.
- Criteria are set to enable products to be distinguished by measurable environmental impact(s).
- Consistent with the requirements of ISO 14020.
- Criteria are set with reference to product life cycle.
- Transparent process.
- A product's fitness for purpose and general performance are considered.
- Certificate subject to regular review

Public, single-issue labels

Three types of publics, single-issue labels:

- **“Pass or fail” type label linked to a specific issue**. The product either meets with the standard or doesn't like EU Energy Star labelling the energy efficiency of office equipment: www.eu-energystar.org/en/index.html.
- **“Graded' labels”**. Products are graded according to their environmental performance on the issue in question like EU 'Energy label' which grades white goods according to their energy efficiency from A++ down to G: www.energylabels.org.uk/eulabel.html.
- **Statement of performance**. The label is non-judgmental but illustrates the measure of the issue of concern like Carbon Reduction Label records a products carbon footprint: www.carbon-label.com

Private labels

Private labels are run by NGOs, industry groups or stakeholders. The examples include:

- Forest Stewardship Council (FSC): www.fsc-uk.org/
- British Allergy Foundation Seal of Approval : www.allergyuk.org
- CertiPUR - foam block manufacturers' label: www.europur.com/index.php?page=certipur

2.2. Type I Ecolabel commonly used in Europe.

Table1. The list of commonly used Ecolabels in Europe

Label	Certification	Description
	Blue Angel	The Blue Angel was initiated by the German government and awarded by an independent Jury to products that are environmentally friendlier than others serving the same use. Each label specifies that the product or service focuses on one of four different protection goals: health, climate, water, and resources. The Blue Angel Standard is managed by four entities: The Environmental Label Jury is an independent decision-making body composed of representatives from environmental and consumer associations, trade unions, industry, trade, crafts, local authorities, science, media, churches and federal states. The Federal Ministry for the Environment Nature Conservation and Nuclear Safety is the owner of the label. It regularly informs the public about the decisions of the Environmental Label Jury. The Federal Environment Agency with its “Eco-labelling, Eco-declaration and Eco-procurement” department acts as office of the Environmental Label Jury and develops the technical criteria of the Basic Award Criteria for the Blue Angel. RAL gGmbH is the label-awarding agency. The Blue Angel promotes the concerns of both environmental protection and consumer protection. Therefore, it is awarded to products and services which are particularly beneficial for the environment in an all-round consideration and which also fulfill high standards of occupational health and safety and fitness for use.
	BRE Certified Enviromental Profile	The UK's only construction materials certification scheme. International.
	British Allergy Foundation Seal of Approval	Endorsement scheme for a wide range of products (from air conditioners and bedding to cars and cleaning products) which specifically restrict or remove high levels of named allergens from the environment.

	Carbon Reduction Label	The Carbon Reduction Label is a public commitment that the carbon footprint of a product or service has been measured and certified and the owner of the product or service has committed to reduce that footprint over the following two years. The footprint that has been calculated will have been rigorously measured and be comparable based on the PAS2050 standard and Footprint Expert™. This will have a been full life cycle assessment including production, use and disposal. The certification must be undertaken again after two years and prove that real reductions have been made.
	CertiPUR label	PUR industry-created label. Certifies the content of PUR used in construction and furniture. Origin: Belgium. Use area: EU
	Climatop	The aim of climatop is to label the most climate friendly products and services (best-in-class). Similar products of a product family (functional unit) are compared with respect to their environmental emissions. Products that cause CO2-eq emissions that are generally 20% lower, receive the label. Only products that have an environmental balance, which is at least equal to or better than the one of the non-successful competitors, can be labelled. Independent organizations calculate life cycle assessments (LCA) of the products according to the standard ISO 14040. The label is valid for two years. Origin: Switzerland. Use area: Switzerland.
	Cradle to Cradle Certified(CM) Products Program	The Cradle to Cradle Certified(CM) Products Program provides a company with a means to demonstrate efforts in eco-intelligent design. Cradle to Cradle Certification is a third-party sustainability label that requires achievement across multiple attributes: use materials that are safe for human health and the environment through all use phases. product and system design for material reutilization, such as recycling or composting. use of renewable energy efficient use of water, and maximum water quality associated with production. company strategies for social responsibility. Cradle to Cradle certification is a four-tiered approach consisting of Basic, Silver, Gold, and Platinum levels. This certification program applies to materials, sub-assemblies and finished products.

	eco-INSTITUT-Label	With substantial emission and toxicological testing living up to more than just the legal specifications, eco-Institute supplies clients with a reliable and significant label for building products and textiles without any health hazards. Origin: Germany. Use: International.
	Energy Saving Recommended	Energy saving products use less energy and therefore have less of an environmental impact as well as being cheaper to run. The Energy Saving Recommended logo is a quick and easy way to spot the most energy efficient products on the market. Origin: UK. Use: International.
	Environmentally Friendly: Croatia	National label certifying low environmental impacts. Products including construction materials. Origin: Croatia Use: Croatia.
	Environmentally Friendly: Czech Republic	National label certifying low environmental impacts. Products including construction materials. Origin: Czech Republic. Use: Czech Republic.
	EU Ecolabel	A voluntary scheme designed to encourage businesses to market products and services that are kinder to the environment and for European consumers - including public and private purchasers - to easily identify them. Origin: EU. Use: International.
	EU Energy Label	By law, the European Community Energy Label must be displayed on all new household products displayed for sale, hire or hire-purchase. The Directive applies to the following types of household appliances, even where these are sold for non-household uses: refrigerators, freezers and their combinations; washing machines, dryers and their combinations; dishwashers; ovens; water heaters and hot-water storage appliances; lighting sources; air-conditioning appliances. Household appliances offered for sale, hire or hire-purchase must be accompanied by a fiche and a label providing information relating to their consumption of energy (electrical or other) or of other essential resources. Products are generally rated from ‘A’ to ’G’, with ‘A’ being the most efficient (‘A+’ and ‘A++’ for the most efficient fridges and freezers).

		The supplier must establish technical documentation sufficient to enable the accuracy of the information contained in the label and the fiche to be assessed. Council Directive 92/75/EEC. Origin: EU. Use: International.
INDOOR AIR COMFORT eurofins GOLD CERTIFIED PRODUCT	Eurofins Indoor Air Comfort	Certifies low VOC emissions. Construction products and furniture. Origin: Germany. Use: Europe.
FSC	Forest Stewardship Council (FSC) Chain of Custody Certification	The Forest Stewardship Council® (FSC) promotes environmentally appropriate, socially beneficial, and economically viable management of the world's forests. FSC® chain of custody (CoC) tracks FSC certified material through the production process - from the forest to the consumer, including all successive stages of processing, transformation, manufacturing, and distribution. Only FSC CoC certified operations are allowed to label products with the FSC trademarks. The FSC label thus provides the link between responsible production and consumption and thereby enables the consumer to make socially and environmentally responsible purchasing decisions. FSC on-product labels: 100% Products only contain material from FSC certified forest that meet the environmental and social standards of FSC. Mix Products with material from FSC certified forests, recycled material or other controlled sources. Recycled Products contain post-consumer material and may include some pre-consumer material content. Origin: International. Use: International.
орган екологічної сертифікації ЖИВА ПЛАНЕТА	Green Crane: Ukraine	National label certifying low environmental impacts. Products including construction materials. Origin: Ukraine. Use: Ukraine
GREENGUARD	Gre Green Craneen Guard	Gre Green Crane is a voluntary, multiple specifications based environmental labelling program that operates to international standards and principles. It is awarded to products with relatively less environmental impact compared to similar products, during their entire life cycle,

		from extracting and collecting the product materials, to the manufacturing, distribution, use and consumption, disposal, and recycling. Founded in 2002 Green Crane is the only Ukrainian environmental standard and certification mark. The Green Crane Program has been successfully audited by the Global EcoLabelling Network (GEN) as meeting ISO 14024 standards for eco-labelling in 2004. Origin: USA. Use: International
	GREENGUARD	Acquired in 2011, GREENGUARD Certification is now provided by UL Environment, a division of UL (Underwriters Laboratories). GREENGUARD Certification helps manufacturers create -- and helps buyers identify -- interior products and materials that have low chemical emissions into indoor air during product usage. All certified products must meet stringent emissions standards based on established chemical exposure criteria. Products that earn GREENGUARD Certification have been scientifically proven to meet some of the world's most rigorous, third-party chemical emissions standards, helping to reduce indoor air pollution and the potential health risks of chemical exposure.
	Environmentally Friendly: Hungary	National label certifying low environmental impacts. Products including construction materials. Origin: Hungary. Use: Hungary.
	Environmentally Friendly: Slovak Republic	National label certifying low environmental impacts. Products including construction materials. Origin: Slovak Republic. Use: Slovak Republic.
	natureplus	Natureplus is an international label of quality for sustainable building and accommodation products, tested for health, environmental-friendliness, and functionality. The label's primary aim is to provide consumers as well as architects, tradesmen, building companies and all those involved in construction, with a reliable orientation aid towards sustainable products i.e. environmentally friendly and not posing any health risks. The natureplus®-seal of quality embodies health-awareness, environmentally friendly production, the protection of our limited resources and their suitability of application. Products with this label are made predominantly from renewable/sustainable sources of raw materials. Test

		procedures relating to the health aspects of the chosen materials guarantee the integrity of the products certified. Origin: Germany. Use EU
	NF-Environnement Mark	National label certifying low environmental impacts. Primarily aimed at consumers but can include construction products. Origin: France. Use: France.
	Nordic 'Swan' Ecolabel	Certifies reduced Carbon emissions. Consumer products and some construction materials. Origin: Scandanavia. Use: Scandanavia.
	ÖkoControl	Certifies use of sustainable materials Furniture, bedding etc Origin: Germany Use: Austria, Germany.
	Programme for the Endorsement of Forest Certification schemes (PEFC)	The timber industry's own endorsement of national certification schemes Timber. Origin: Switzerland. Use: International.
	SCS FloorScore®	FloorScore® is a certification for commercial and residential hard-surface flooring products and flooring adhesives. Developed in conjunction with the Resilient Floor Covering Institute, products must comply with indoor air quality and VOC emission requirements set by California Section 01350, and meet rigorous quality management standards in manufacturing. Certification and documentation help products qualify for credits within the LEED rating systems. Origin: USA. Use: International.
	Waterwise	Certification of efficient water appliances. Water appliances. Origin: UK, Use: UK.

	AENOR Medio Ambiente	Type I ecolabel system aimed at recognizing environmentally friendly products or services. Certification procedure based on auditing and labs test. The program will mark those products with less environmental impacts. It is mainly oriented to consumer products.
	BASF Eco-Efficiency	BASF SE has developed a label for products that have been evaluated by an Eco-Efficiency Analysis. The awarding of the label is dependent on demanding requirements: After conclusion of the analysis a third-party evaluation (peer review) is requested. Furthermore, publication of the results of the analysis will be undertaken via internet. The label can be carried on for three years. After that period, a revision of the analysis is required due to cover market developments and product diversity. Requirements Accomplished Eco-Efficiency Analysis according to the methodology certified by TÜV Rheinland/ Berlin-Brandenburg (Germany) and NSF International (USA).
	BASS (Product inventory for the construction industry)	BASS is an online tool to help companies to meet regulatory requirements associated with the use of chemicals in the workplace/projects. Since its establishment in 2001, BASS developed to become the industry standard in the construction industry in Norway. Since 2009, BASS includes the auto industry. Development of the BASS is done in close cooperation with business, and provides users with a tool for: Receipt of Material Safety Data Sheets Control of Material Safety Data Sheets Creation of records on project / merchant Overview of all chemicals used in your business Distribution between actors Material Tracking Identification of all products is on the government's priority list Risk and substitution Ratings From 2013 the system will be replaced by a European system www.ChemXchange.com which is supported by leading European associations.
	BASTA	The BASTA system focuses on hazardous substances in construction and building products. Products are assessed according to their chemical ingredients. Suppliers are responsible for the assessment, and are required to: Declare contents - The supplier must have detailed knowledge of the product´s chemical composition;

		Provide supporting documentation - The supplier must be able to provide documentation to support the assessment that the product meets the properties criteria; Demonstrate Competence - those who undertake the product assessment must demonstrate necessary competence in environmental and health assessments; and BASTA undertakes regular controls to ensure that participating suppliers follow the BASTA terms of qualification. Following an assessment, products are designated in either the BASTA or BETA register. The BASTA register has more comprehensive requirements; and the BETA register has those products meeting more basic requirements. BASTA is run as a non-profit owned jointly by IVL Swedish Environmental Research Institute and The Swedish Construction Federation. BASTA is developed for use in the Swedish market, and the database is only available in Swedish.
BRE GLOBAL LISTED	BRE Global Certified Environmental Profile	Environmental profiles measure the impacts of a construction material, product or building system throughout its life – not only during its manufacture, but also its use in a building over a typical building lifetime. This includes its extraction, processing, use and maintenance and its eventual disposal. The Environmental Profiles Methodology assesses environmental indicators that reflect impacts occurring globally, regionally and locally - in the air, in water and on the land, impacting humans and the environment. These impacts are assessed under a range of issue categories and normalized by reference to European data. They are weighted to generate a measure of environmental impact as a proportion of the annual impact of a European citizen.
BYGGVARUBEDÖMNINGEN	Byggvarubedömningen	Byggvarubedömningen, or BVB, is a building materials assessment tool. It evaluates, proactively and systematically, the contents of a product and of the production process. BVB also provides a common criterion and an evaluation standard based on seven factors: • Chemical content (declaration of contents) • Input materials (raw materials) • The construction phase • The management phase • Demolition • Residual and waste products • Indoor environment These are weighted to come up with a final score: either "recommended", "accepted" or "to be avoided". In the online database, products have a final score and a product card containing the declaration of contents and the evolution outcome. The product cards are adapted for

		inclusion in the supporting documentation for product procurement and in the documentation of the construction project. All companies affiliated to BVB insist on the use of environmentally approved products in their construction and management projects.
	Certipur	CertiPUR® is a voluntary standard to advance the safety, health and environmental (SHE) performance of flexible polyurethane foams used in bedding and upholstered furniture. The scheme considers existing standards and scientific studies related to emanations from foams, product criteria and risk assessments.
	DUBOkeur	In 2004 NIBE developed a quality label to compare the environmental friendliness of multiple building products. The DUBOkeur® label is meant to certify the best choices of a product in the fields of environmental and health. To do this, the environmental impact of a product in relationship to other products is tested through NIBE's Twin-model. The most eco-friendly product is classified in environmental class 1a, the environmental reference. The other product's class is related to reference, with class 7 as the biggest polluters. In principle the products in the classes 1 and 2 are considered for a DUBOkeur®.
	Danish Indoor Climate Label	The Danish Indoor Climate label is a tool for development and selection of indoor air quality friendly products and better understanding of the impact of products and materials on the indoor air quality in buildings.
	ECOLOGO	The ECOLOGO Certification Program was acquired by UL Environment, a division of UL (Underwriters Laboratories) in 2010. ECOLOGO Certification is based on several attributes, life cycle–based standards. All products certified to an ECOLOGO standard must meet or exceed each of the listed criteria before receiving the mark. ECOLOGO Certification is classified as an ISO (International Organization for Standardization) Type 1 ecolabel and has been successfully assessed by the Global Ecolabeling Network, further demonstrating its credibility. Since its establishment in 1988, ECOLOGO has been recognized or referenced in more than 350 specifications and standards, and UL Environment has public affairs and outreach teams dedicated to continuing to enhance market adoption.

ECOproduct	ECOproduct	ECOproduct is a Norwegian method to choose environmentally friendly building materials and chemicals based on information in an Environmental Product Declaration (EPD) or a safety data sheet. The method has been developed in collaboration with several building industry organizations and contractors in Norway. Each product has a character for Indoor Environment, Health and Environmental Hazardous Substances, Global Warming Potential and Resource Consumption. The environmental profile is presented visually in a simple manner by showing a green, white or a red symbol for the above-mentioned areas (for chemicals; Health and Environmental Hazardous Substances only). The specific environmental data can also be studied more carefully at an expanded level, in addition to the actual EPD/Safety Data Sheet for every product. ECOproduct database is operated by Norsk Byggtjeneste (Norwegian Building Centre).
environment health safety ecomaterial	EcoMaterial	EcoMaterial certification provides independent, third-party verification that a material was manufactured using strategies aimed at achieving high performance in human and environmental safety and indoor environmental quality, functional characteristics, water efficiency, energy efficiency, raw materials selection. The principle of the standard is an individual approach to each material, depending on its functional purpose. The audit for compliance with the standard is carried out based on laboratory investigations, the company's environmental documentation analysis, and the evaluation of the manufacturer. If the material complies with Mandatory Requirements of the Standard and achieves a minimum 65 points it receives the certificate of compliance and right to use the EcoMaterial ecolabel. Each year the manufacturer confirms compliance with the Standard via documentation or audit.
Effinature Certification de la Biodiversité	Effinature	Effinature certification was designed to reverse the trend of biodiversity deterioration in the construction sector and raise awareness among town planners about this major issue. Determine the value of the site and the ecological potential of the project. Preserve the existing natural heritage and existing landscape. Control the impacts of the project on biodiversity and well-being of residents.

		Unlock the ecological potential of the project through responsible and sustainable management of biodiversity. Train those involved in the project and raise awareness. Effinature certification was conceived to be part of the design, construction and operation of the project. Effinature certification has over 100 biodiversity control points determined by a concerted scientific approach: organization, design, realization and operation.
	Ekologicky setrny vyrobek / Environmentally Friendly Product	The ecolabel "Ekologicky setrny vyrobek" is the official registered label of The Czech ecolabelling program (National Program for Labelling Environmentally Friendly Products). It was launched on 14. April 1994. The program is administered by CENIA, Czech Environmental Information Agency. The guarantor of the program is the Ministry of the Environment. In 2004 the program the scope of the program was extended by the opportunity to certify services, beginning with tourist accommodation services. At the same time, a new version of the ecolabel (Ekologicky setrna sluzba / Enviromentally Friendly Service) was introduced. At present, the Czech ecolabel can be acquired at 41 categories of products and two categories of services about 400 products and services bearing the label on the market from about 100 companies.
	Environmental Product Declaration	The overall goal of an Environmental Product Declaration, EPD, is to provide relevant, verified, and comparable information to meet various customer and market needs. The International EPD® System has the ambition to help and support organizations to communicate the environmental performance of their products (goods and services) in a credible and understandable way.
	Environmentally Friendly Label: Croatia	The main objective of awarding the Environmental Label is the promotion of products with a reduced adverse environmental impact as compared to other equivalent products. Awarding of the Environmental Label was established to promote development of new (eg. low waste) technologies, production and consumption of products less adverse to the environment, pollution reduction and a more economical management of raw materials and energy. It promotes concern for environmental and consumer protection. It has mostly been used for products, but now we are introducing it for services too.

GEV-EMICODE EC1 very low emission	GEV-Emicode	Flooring installation materials labelled with the GEV sign EMICODE EC1; very low emission; grant the greatest possible protection against indoor air pollution.
No logo provided yet.	Greenspec PASS	GreenSpec PASS identifies and endorses green building materials, products, and equipment. The PASS label indicates that a product has been selected and endorsed for its superior environmental qualities. PASS is organized and run by architects and specifiers for the benefit of fellow building designers.
KÖRNYEZETBARÁT TERMÉK	Hungarian Ecolabel / Környezetbarát Termék Védjegy	Hungarian national ecolabel developed by the Ministry of Environment in 1994. Goals and procedures meet the requirements of ISO 14024 standard.
Institut Bauen und Umwelt e.V.		IBU Type III Environmental Declaration (IBU Environmental Product Declaration) This is a Type III declaration for building products. It is based on ISO 14025 as well as ISO 21930 and EN 15804 and declares environmental information on a pass/fail basis. It is meant to identify properties of building products that are relevant to the environmental performance of buildings, and it is based on a Life Cycle Assessment. There are currently 96 declaration holders that together have 230 Environmental Product Declarations (EPD), as they can obtain multiple EPDs for different products. All EPDs are based on a so-called Product Category Rules (PCR), which define the rules for a specific group (category) of building products. The PCRs are based on general program rules ("General Principles") and their underlying norms (ISO 14025, ISO 21930, EN 15804).
INDOOR AIR COMFORT eurofins GOLD CERTIFIED PRODUCT	Indoor Air Comfort	Eurofins "Indoor Air Comfort" product certification is an innovative tool for showing compliance with low VOC emission requirements from construction products and furniture of all relevant European specifications on two levels: Standard level "Indoor Air Comfort - certified product" shows compliance of product emissions with all legal specifications issued by authorities in the European Union. Higher level "Indoor Air Comfort GOLD - certified product" shows compliance of product emissions with the voluntary specifications issued by all relevant ecolabels and similar specifications in the EU.

	M1 Emission Classification of Building Materials	EMISSION CLASSIFICATION OF BUILDING MATERIALS (M1) The aim of the classification is to enhance the development and use of low-emitting building materials so that material emissions do not increase the requirement for ventilation. The classification presents requirements for the materials used in ordinary workspaces and residences. For air-handling components there is a separate Cleanliness Classification of Air-handling Components.
	Minergie-ECO	MINERGIE ECO is a label for new and refurbished low-energy-consumption buildings that addresses ecological and social requirements. It can be combined with MINERGIE, MINERGIE-P, and MINERGIE-A, which are standards that focus more on energy consumption. Health requirements: high percentage use of daylight instead of electricity sound insulation indoor air quality (minimization of pollutant emissions from building materials, limitation of ionizing (radon gas) and non-ionizing radiations) Ecological requirements: readily available raw materials high proportion of recycled building materials building materials with low environmental impact (rely on other ecolabels) environmentally friendly disposable building materials long lifetime, flexibility, dismantling ability
	National Programme of Environmental Assessment and Ecolabelling in the Slovak Republik (NPEHOV)	National environmental labelling scheme - Environmentally friendly product- is adapted by Act No.469/2002 on environmental labelling of products as amended by later provisions. Its aim is to promote development of production and consumption of products that have impact on lowering of negative impacts on environment, energy consumption and consumption of raw material and hazardous substances, to improve among public, producers, suppliers, sellers' better knowledge about environmental performance of products, to lower pollution of environment.
	Nordic Ecolabel or "Swan"	Demonstrates that a product is a good environmental choice. The "Swan" symbol, as it is known in Nordic countries, is available for 65 product groups. The Swan checks that products fulfill certain criteria using methods such as samples from independent laboratories, certificates, and control visits.

		Each Nordic country has local offices with the responsibility for criteria development, control visits, licensing, and marketing. In Denmark Nordic Ecolabel is administered by Ecolabelling Denmark at Danish Standards Foundation, in Sweden by Ecolabelling Sweden AB, in Finland by Finnish Standards, in Norway by The Foundation for Ecolabelling, and in Iceland by the Environment Agency that operates under the direction of the Ministry for the Environment.
No logo provided yet.	OK Compost	Packaging or products featuring the OK Compost label (based on European standard EN 13432: 2000) are guaranteed as biodegradable & compostable in an industrial composting plant and applies to all components, inks, and additives. Any product featuring the OK compost logo complies with the requirements of the EU Packaging Directive (94/62/EEC).
No logo provided yet.	OK Compost HOME	OK compost HOME guarantees complete biodegradability in the light of specific requirements, in home garden compost heaps.
No logo provided yet.	OK biobased	OK biobased label offers a comprehensive guarantee about the origin of your products. On a basis of the determined percentage of renewable raw materials (% Bio-based carbon), your product can be certified as one-star-bio-based, two-star-bio-based, three-star-bio-based, or four-star-bio-based.
No logo provided yet.	OK biodegradable SOIL	The OK biodegradable SOIL label is a guarantee a product will completely biodegrade in the soil without adversely affecting the environment.
No logo provided yet.	OK biodegradable WATER	Products certified for OK Biodegradable WATER guarantee biodegradation in a natural freshwater environment, and thus substantially contribute to the reduction of waste in rivers, lakes or any natural fresh water. Note that this does not automatically guarantee biodegradation in marine waters.
	Passivhaus	PassivHaus is a certification for super-energy efficient buildings meeting the code developed by the PassivHaus Institute in Germany, and administered in Canada, Germany, UK and US. A Passive House is a very well-insulated, virtually air-tight building that is primarily heated by passive solar gain and by internal gains from people, electrical equipment, etc. Energy

		losses are minimized. Any remaining heat demand is provided by an extremely small source. Avoidance of heat gain through shading and window orientation also helps to limit any cooling load, which is similarly minimized. An energy recovery ventilator provides a constant, balanced fresh air supply. The result is an impressive system that not only saves up to 90% of space heating costs, but also provides a uniquely terrific indoor air quality.
PEFC™ PEFC/01-00-01	Programme for the Endorsement of Forest Certification (PEFC) schemes	The Program for the Endorsement of Forest Certification (PEFC) is an international non-profit, non-governmental organization dedicated to promoting Sustainable Forest Management (SFM) through independent third-party certification. It works throughout the entire forest supply chain to promote good practice in the forest and to ensure that timber and non-timber forest products are produced with respect for ecological, social, and ethical standards. PEFC is an umbrella organization. It works by endorsing national forest certification schemes developed through multi-stakeholder processes and tailored to local priorities and conditions. Each national forest certification scheme undergoes rigorous third-party assessment against PEFC's unique Sustainability Benchmark. Today, PEFC includes over 35 national certification schemes among its membership. Together these account for over 220 million hectares of certified forests.
SCScertified™ RECYCLED CONTENT	SCS Recycled Content	SCS Recycled Content Certification recognizes products made either in whole or part from recycled waste material in place of virgin raw materials. The percentage of post-consumer or pre-consumer recycled content is reported in compliance with Federal Trade Commission guidelines and ISO standards. The certification process includes company auditing and supply chain verification. Certification and documentation help products qualify for credits within the LEED rating systems.
SEE what you are buying into.com	SEE What You Are Buying Into	SEE What You Are Buying Into is a labelling scheme for businesses that are open and honest about their Social, Environmental and Ethical (SEE) policies and practices. To use the SEE Logo, a company completes the SEE Questionnaire, developed in collaboration with leading NGOs. Businesses guarantee the accuracy and veracity of their responses and publish them on the SEE What You Are Buying Into website for scrutiny, monitoring, and comment by the public. Using Web 2.0 technology, the scheme is developing into a social movement. Companies and citizens work together to drive improvement in SEE business responsibility.

		SMaRT Consensus Sustainable Product Standards Sustainable Materials Rating Technology or SMaRT, is the consensus sustainable products standard and label for building products, fabric, apparel, textile & flooring, covering over 80% of the world's products with environmental, social, & economic criteria. It is the result of 17 years of standardization with six national votes of consensus approvals involving thousands of professionals. SMaRT is the Leadership Sustainable Product Standard recognized by LEED Green Building Standard and the Leadership Standards Campaign of leading environmental groups, purchasers, governments, and companies. SMaRT requires 28 points for the entry level of certification and 156 maximums achievable for Platinum, with 15 points from prerequisites. SMaRT covers all product stages, is ISO compliant LCA, and incorporates over 40 single attribute standards. It has been adopted by 20 leading entities including the US Green Building Council and 11 Fortune 500 companies with over $100B in annual sales. SMaRT incorporates and builds on other well-known sustainable standards and practices.
	Singapore Green Label Scheme (SGLS)	The Singapore Green Labeling Scheme (SGLS) aims to help the public identify environment-friendly products that meet certain eco-standards specified by the scheme and seeks to encourage the level of eco-consumerism in Singapore as well as to identify the growing demand for greener products in the market. The scheme hopes to encourage manufacturers to design and manufacture with the environment in mind. It was launched in May 1992 by the Ministry of the Environment. It was handed over to the Singapore Environment Council (SEC) on 5 June 1999 and is currently under the authority of the SEC.
	SundaHus Miljödata	SundaHus Environmental Data is an environmental assessment of products used in construction and buildings. The core of the system is a database of substances, materials and products. The product assessment is based on the provider's documentation of the product together with the rules of the Swedish Chemical Inspectorate's PRIO criteria and EU REACH Directives. The assessment is based a combination of the following: Constituent materials and substances as well as the raw materials Building product health and environmental hazard under: Manufacturing stage Construction phase Use phase

		Waste phase Demolition and waste materials Documentation. Products are assessed and awarded one of the letters A, B, C or D where A is the best.
	Sustainable Forestry Initiative (SFI)	The SFI program has on-product labels to help customers and consumers identify exactly what they are buying: three SFI chain of custody labels and one SFI certified sourcing label. SFI chain of custody labels allow the use of fiber from certified forests, certified sourcing, and post-consumer recycled material. All of these terms are defined in the SFI Definitions (Section 13 of the SFI 2010-2014 Standard Requirements). Certified forest content can include fiber certified under the SFI 2010-2014 Standard (objectives for land management), Canadian Standards Association (CAN/CSA-Z809) and/or the American Tree Farm System (ATFS) individual and group certification. The SFI certified sourcing label and claim do not make claims about certified forest content. Certified sourcing can include fiber sourced from a company that conforms with objectives 8-20 of Section 2 - SFI 2010-2014 Standard's fiber sourcing requirements, from pre or post-consumer recycled content, or from a certified forest, and fiber sourced from non-controversial sources. Certified sourcing is a defined term in the SFI Definitions (Section 13 of the SFI 2010-2014 Standard Requirements). A note on label usage: Organizations that want to use SFI program labels must contact the SFI Office of Label Use and Licensing, which must approve the use of all SFI labels and claims.
	SustentaX	SustentaX is a Brazilian ecolabel that assists consumers to identify sustainable products, materials, equipment's and services. Products with the SustentaX Seal are evaluated for their quality and human safety. Manufacturers must prove their social, environmental, and marketing responsibilities. The independent verification process for the SustentaX Seal is based on ISO 14024.
	Vitality Leaf	"Vitality Leaf" was developed by the Russian NGO Non-profit partnership Ecological Union in 2001, is officially registered, open and clear for all potential participants. Member of the Global Ecolabelling Network since 2007. Certified member of the Global Ecolabelling Network's Internationally Coordinated Ecolabelling System (GENICES) since 2011.

		Criteria for certification are developed using a lifecycle approach, according to ISO 14024 standard. Main objectives are: Encourage the demand for and supply of environmentally preferable products and services. Contribute to reduction of environmental impact of producers. Improve the quality of the environment and encourage sustainable resource management. 25 standards for assessing environmental safety are being developed for building and construction materials, electronics, detergents, lighting, food products, offices, shops, hotels.
waterwise AWARD WINNING WATER SAVER	Waterwise Marque	The Marque is awarded annually to products which reduce water wastage or raise the awareness of water efficiency in the U.K.
WINDMADE™	WindMade	Windmade™ is a consumer label identifying products and companies using wind energy. WindMade™ is dedicated to increasing corporate investments in wind power by informing consumers about companies' use of wind energy, and increasing demand for products that embrace this clean and renewable energy source. To use the WindMade label for their communications or products, WindMade members must undergo a certification process to verify their wind energy procurement. The aim is to drive the development of new wind power plants, over and above what would be developed anyway. Windmade is managed by an independent non-profit, and is supported by a consortium including WWF, the UN Global Compact, the Global Wind Energy Council, the LEGO Group, Vestas Wind Systems, PricewaterhouseCoopers, and Bloomberg.
level®	level	The level® brand identifies that a furniture product has been evaluated to the multi-attribute ANSI/BIFMA e3 Furniture Sustainability Standard by an independent, third-party certifier. level has three conformance thresholds. Products can be awarded a level 1, level 2, or level 3 conformance mark based on the combined score achieved in their sustainability evaluation. level® was created to deliver an open and holistic means of evaluating and communicating the environmental and social impacts of furniture products in the built environment.

		Considering a company's social actions, energy usage, material selection and human and ecosystem health impacts, level addresses how a product is sustainable from multiple perspectives.

SOURCES:

https://www.greenspec.co.uk/ecolabels/

https://www.greenspec.co.uk/ecolabels-used-in-europe/

3. EU standards for ECO Labeling and legal framework and EU Ecolabel

3.1. About EU Ecolabel

The EU Ecolabel helps consumers, retailers and business make truly sustainable choices.

Launched in 1992, the EU Ecolabel logo has become a byword for quality while meeting the highest environmental standards. It means products (goods and services) displaying the iconic "EU flower" symbol meet all the criteria and have earned the right to join the growing EU Ecolabel Community!

The EU Ecolabel is a world-renowned, voluntary scheme promoting goods and services that clearly demonstrate environmental excellence, based on standardized processes and scientific evidence.

How the EU Ecolabel works is set out in the official Regulation of the European Parliament and of the Council. It is managed by the European Commission and Member States according to the priorities established in the Strategic Working Plan for the EU Ecolabel.

Figure2. The logo of EU Ecolabel

EU Ecolabel is the only EU-wide ISO 14024 Type I ecolabelling scheme. Recognized throughout Europe, it is multi-criteria and tackles the main environmental impacts of products along their full lifecycle, from extraction of raw material to disposal.

The EU Ecolabel is third-party verified, which means independent experts are responsible for checking compliance with the EU Ecolabel criteria.

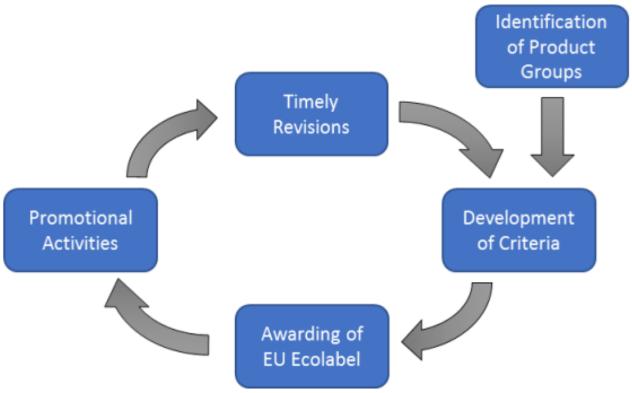
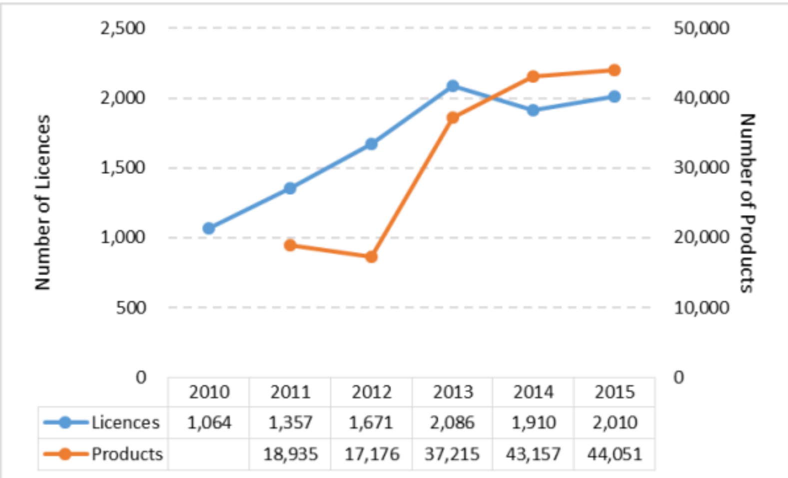


Figure3. The EU Ecolabel delivery cycle

Launched more than 30 years ago as the 'Community Eco-label', it has become the biggest and best-known scheme in many EU countries. Consumers increasingly look for the 'EU flower' on products to guide them towards more sustainable choices.

With a wide scope of product categories and increasing uptake, the EU Ecolabel attracts more and more manufacturers and retailers to the scheme, which today covers [diverse categories and a growing list of product groups](). Independent experts help to verify that EU Ecolabel products use sustainable ingredients and avoid hazardous, toxic or otherwise harmful substances. Successful applicants also prove they use minimal, recycled and/or easily to recycle packaging.



	2010	2011	2012	2013	2014	2015
Licences	1,064	1,357	1,671	2,086	1,910	2,010
Products		18,935	17,176	37,215	43,157	44,051

Figure4. Number of EU Ecolabel licences and products

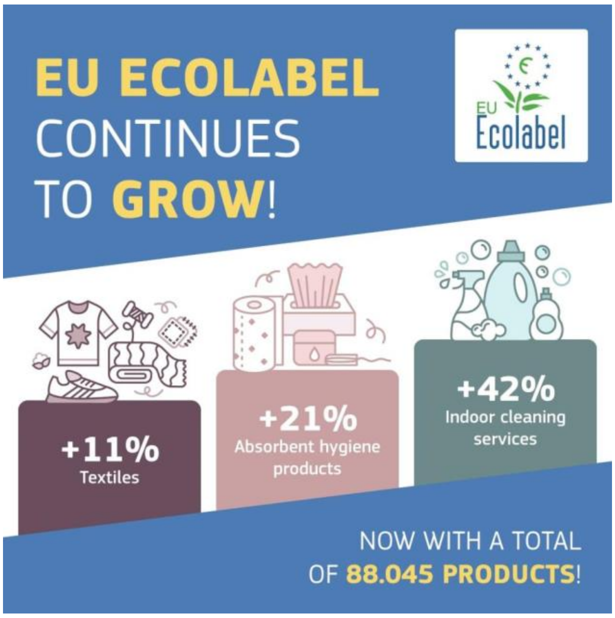


Figure5. March 2023 Statistics Release about the number of EU Ecolabel licenses and products, as for March 2023

3.2. EU Ecolabel structure

3.2.1. The European Commission

The European Commission manages the EU Ecolabel at the EU level to ensure that the EU Ecolabel Regulation is implemented correctly.

The Commission is responsible for preparing the final draft of the criteria documents, considering comments from the EU Ecolabelling Board (EUEB) (see below). The development or the revision of EU Ecolabel criteria can be initiated and led by parties other than the European Commission (Member States, Competent Bodies and other stakeholders).

The Commission adopts EU Ecolabel criteria for each product group as "Commission Decisions" after the EU Ecolabel Regulatory Committee vote of the criteria by a qualified majority.

3.2.2. European Union Ecolabelling Board

The European Union Ecolabelling Board (EUEB) is composed of representatives of the Competent Bodies of the European Union, Iceland, Liechtenstein and Norway, and the representatives of the following organizations:

13 Stakeholder organizations (Type C Members)

- The European Consumer Organization (BEUC)
- European Environmental Bureau (EEB)
- EuroCommerce
- Eurochambres
- Collaborating Centre on Sustainable Consumption and Production (CSCP)
- Plastic Recyclers Europe
- European Chemical Industry Council (CEFIC)

- World Wide Fund for Nature (WWF)
- Better Finance - the European Federation of Investors and Financial Services Users
- European Fund and Asset Management Association (EFAMA)
- European Savings and Retail Banking Group (ESBG)
- Insurance Europe
- European Banking Federation (EBF)

3 EU /UN Bodies (3 Type E Members)

- European Chemical Agency (ECHA)
- European Investment Bank (EIB)
- International Labour Organization (ILO)

The EUEB contributes to the development and revision of EU Ecolabel criteria and to any review of the implementation of the EU Ecolabel scheme. It also provides the Commission with advice and assistance in these areas and issues recommendations on minimum environmental performance requirements.

3.2.3. National Competent Bodies

National Competent Bodies are independent and impartial organizations designated by states of the European Economic Area within or outside government ministries. They are responsible for implementing the EU Ecolabel scheme at the national level and should be the first point of contact for any questions from applicants.

They receive and assess applications and award the EU Ecolabel to products that meet the criteria set for them. As such, they are responsible for ensuring that the verification process is carried out in a consistent, neutral and reliable manner by a party independent from the operator being verified, based on international, European or national standards and procedures concerning bodies operating product-certification schemes.

The Competent Bodies meet regularly at the Competent Body Forum to exchange experiences and ensure a consistent implementation of the scheme in different countries.

3.2.4. Stakeholders

In the development of the criteria, a balanced participation of all relevant stakeholders (interested parties) concerned with a particular product group, such as industry and service providers, including SMEs, and their business organizations, trade unions, traders, retailers, importers, environmental protection groups and consumer organizations must be guaranteed.

3.3. Correspondence between EU Ecolabeling and national labeling schemes

In order to harmonize the criteria of European ecolabelling schemes, Article 11 of the EU Ecolabel Regulation1 states that where EU Ecolabel criteria exist for a given product group, other nationally or regionally officially recognized EN ISO 14024 type I labels that do not cover that product group at the time of the publication of the EU Ecolabel criteria, may be extended to that product group only where the criteria developed under those schemes are at least as strict as the EU Ecolabel criteria. Furthermore, Article 11 of the EU Ecolabel Regulation establishes that the EU Ecolabel criteria shall also consider existing criteria developed in officially recognized (EN ISO 14024 type I) ecolabelling schemes in the Member States.

Type I Ecolabels which, according to the definition above, are officially recognized at national/ regional level, and therefore are affected by Article 11, are:

- Österreichisches Umweltzeichen (AUSTRIA)
- Ekologicky Setrny Vyrobek (CZECH REPUBLIC)
- Nordic Ecolabel (DENMARK, NORWAY; SWEDEN, ICELAND, FINLAND)
- Blue Angel (GERMANY)
- Hungarian Ecolabel (HUNGARY)
- Polish Ecolabel (POLAND)
- NL Milieukeur (NETHERLANDS)
- National Programme of Environmental Assessment and Ecolabelling in the Slovak
- Republik NPEHOW (SLOVAKIA)
- Catalan Environmental Quality Guarantee Award (SPAIN, CATALONIA)
- TCO certification (IT products) (SWEDEN)

The coverage of the different Ecolabels for the selected product groups is detailed in Table 2 below. From this sample of all these product groups sets, only a part of them have been analyzed due to resources limitation, trying to cover all ecolabels and products groups. As summary, 33 criteria set corresponding to 12 Type I Ecolabels and 9 product groups have been analyzed and results are presented in this deliverable.

Table2. The matrix of coverage of different Ecolabel schemes and product groups analyzed.

<table>
<tr><th></th><th>Hung</th><th>AT</th><th>CZ</th><th>Nordic</th><th>Blue Angel</th><th>Mil (NL)</th><th>Slovak (SK)</th><th>Cat. Award</th><th>TCO</th><th>NF *</th><th>Good Choice*</th><th>Green Mark *</th></tr>
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Referring to construction materials, EU Ecolabeling includes only one category of products: Paints and varnishes.

3.4. EU Ecolabel criteria

As stated in the Regulation (EC) No 66/2010 on the EU Ecolabel, EU Ecolabel criteria are based on the best products available on the EEA market in terms of environmental performance throughout the life cycle and correspond indicatively to the best 10- 20 % of the products available on the EEA market in terms of environmental performance at the moment of their adoption. The criteria are based on scientific data and information considering the whole life cycle of products. They cover the main environmental impacts of the product and their technical performance, including health, safety, social and ethical aspects, where appropriate. The criteria favor substitution of hazardous substances with safer ones and support durability, reusability, recyclability and recycled content of products. They include fitness for use requirements and guarantee compliance with existing EU legislation. The EU Ecolabel criteria are regularly revised to follow the technological evolution and are adopted as Commission Decisions. An overview of the existing product and service groups and the associated criteria can be found on the Product Groups and Criteria website. Implementation of Article 11 under the EU Ecolabel Regulation- Final Report

EU Ecolabel criteria development/revision is a multi-step and multi-stakeholder process carried out according to the Annex I of the EU Ecolabel Regulation (No 66/2010).

The EU Ecolabel criteria development is managed by the Joint Research Centre (JRC). Every set of criteria undergoes several rounds of discussion. Criteria are finally adopted through a Decision of the European Commission. Please consult the section on the criteria development and revision process for more information.

Table3. EU Ecolabel's importance

Pan-European:	As the only pan-European Type I ecolabel, it is recognized throughout Europe, thus supporting the Single Market for green products.
Transparent and reliable:	The label is a mark of green excellence and professional discipline thanks to strict criteria developed by the European Commission and Member States with industry, consumer organizations and environmental NGOs.
Vast choice:	Whether paper, cleaning products, cosmetics, clothes, do-it-yourself materials or hotels, there is a growing list of green product groups now open to certification.
Good for people and planet:	Retailers and consumers can trust that labelled goods and services have a lower environmental footprint, generate less waste and CO_2 during manufacturing, contain less hazardous chemicals, and they are designed to last longer and be easier to repair.
Measurable and marketable:	For businesses, displaying 'the flower' logo on their products and in their promotional materials has a measurable impact on returns, especially when targets (on circularity, emissions, waste…) are integrated into a company's sustainability strategy.
Independently verified:	An independent third party ('Competent Body') ensures that products fully comply with the relevant EU Ecolabel criteria.
Strict criteria:	Awarded products comply with strict criteria for reducing their environmental impact, from the extraction of raw

	materials to distribution and end-of-life. They must comply with quality requirements and often also respect relevant social criteria.
ISO 14024 compliant:	EU Ecolabel is an ISO 14024 Type 1 ecolabel, which means it is reliable, multi-criteria and third-party verified. Criteria are set with a lifecycle approach through an open, transparent, multi-stakeholder process.

The EU Ecolabel promotes Europe's transition to a circular economy, supporting both sustainable production and consumption. Thanks to transparent ecological criteria, consumers can make conscious choices without compromising on the quality of the products. Similarly, the EU Ecolabel rewards those manufacturers who choose to design products that are durable and repairable, promoting innovation and saving resources. Any products that have been awarded the EU Ecolabel meet a set of high environmental and performance standards. The EU Ecolabel is a component of the European Commission's action plan on Sustainable Consumption and Production and Sustainable Industrial Policy and is referred to in the new Circular Economy Action Plan. The Action Plan foresees that the review of the Ecodesign Directive as well as further work on specific product groups, will build, among others and where appropriate, on criteria and rules established under the EU Ecolabel Regulation.

The EU Ecolabel has in fact acted as a pioneer in promoting the circular economy, as the criteria are based on the main principles of the circular economy concept. The EU Ecolabel supports products and services that have a lower environmental impact and contribute to sustainable development along their life cycle, are energy efficient, durable, and repairable.

SOURCE: https://environment.ec.europa.eu/topics/circular-economy/eu-ecolabel-home/about-eu-ecolabel_en

Library on Module 3: EU standards and labelling of building materials.

https://www.ecolabelindex.com/ecolabels/?st=category,building_products

REFIT Report, from < https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM%3A2017%3A355%3AFIN>

Evaluation of the Implementation of the EU Ecolabel Regulation - Synthesis Report, from < https://environment.ec.europa.eu/document/053cc47b-c1c9-4590-af61-fe37888ae75f_en>

Implementation of Article 11 under the EU Ecolabel Regulation- Final Report, from < https://environment.ec.europa.eu/document/6acdb550-074c-40ee-9040-eaf99930f001_en>

Commission Decision establishing the European Union Ecolabelling Board and its rules of procedure, from < https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32010D0709>

European Union Ecolabelling Board and its rules of procedure (June 2020), from < https://circabc.europa.eu/ui/group/6e9b7f79-da96-4a53-956f-e8f62c9d7fed/library/6e484c8f-83e2-4ffc-b4d0-5f083f0ece21/details?download=true>

4. Self-assessment quiz on Module 3: EU standards and labelling of building materials

1. Ecolabels allow an organization to:

a. publishes the environmental qualities of their products and services.

b. also improves the image of the organization.

c. both a. and b.

d. none of the above

2. When is EU Ecolabeling scheme established?

a. 1990

b. 1992

c. 2002

d. 2010

3. EU Ecolabel is standardized ecolabelling scheme with the following standard:

a. ISO 14028

b. ISO 14024

c. Regulation (EC) No 66/2010

d. ISO 14020

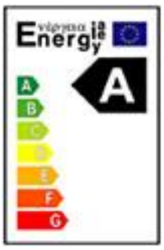
4. The following label sign is referring to:

a. carbon footprint of the product

b. color of emitted light

c. environmental effect

d. energy consumption of the product



5. Which type of ecolabeling is considered as the 'gold standard' of ecolabeling?

a. Type I

b. Type II

c. Type III

d. BREEM

6. Which categories of construction materials are included in EU ecolabeling?

a. glass

b. steel

c. paints and varnishes

d. PVC

7. To which extent is EU ecolabeling mandatory scheme?

a. mandatory for all products in EU countries

b. voluntary scheme

c. mandatory only for products imported in EU

d. recommended for hazardous materials.

8. How are the EU ecolabels awarded?

a. voluntary

b. based on the specific criteria.

c. following equal geographical distribution.

d. based on the product popularity.

MODULE 4: AWARENESS OF NOVEL SUSTAINABLE BUILDING MATERIALS

1. The concept of sustainable construction. Building materials and sustainability. The role of the LCA concept and application in construction. Novel sustainable building materials

1.1 The concept of sustainable construction

In general, by sustainability we mean the ability of a human society to exist and develop without deeply affecting, respectively without depleting the natural resources for the future. According to the United Nations' Brundtland Report in 1987, sustainable development is the kind of advancement that meets current demands without lacking future generations' ability to meet theirs.

With the built environment being accountable for almost half of the world's resources consumption, emitting 40% of carbon emissions, and utilizing over 30% of energy, reducing energy consumption, waste production, and material use should be our ultimate environmental objectives.

Sustainability, an essential aspect of construction, is closely tied to sustainable development. The pillars of sustainability - the fundamental principles identified by the World Summit on Social Development - lay the foundation for this concept. The 3 pillars of sustainability:

Environment: This relates to preserving and restoring ecosystems, habitats, and natural resources.

Social: Involves promoting equality, well-being, and social justice as well as respecting moral social obligations.

Economic: Entails ensuring a just and equitable allocation of economic resources.

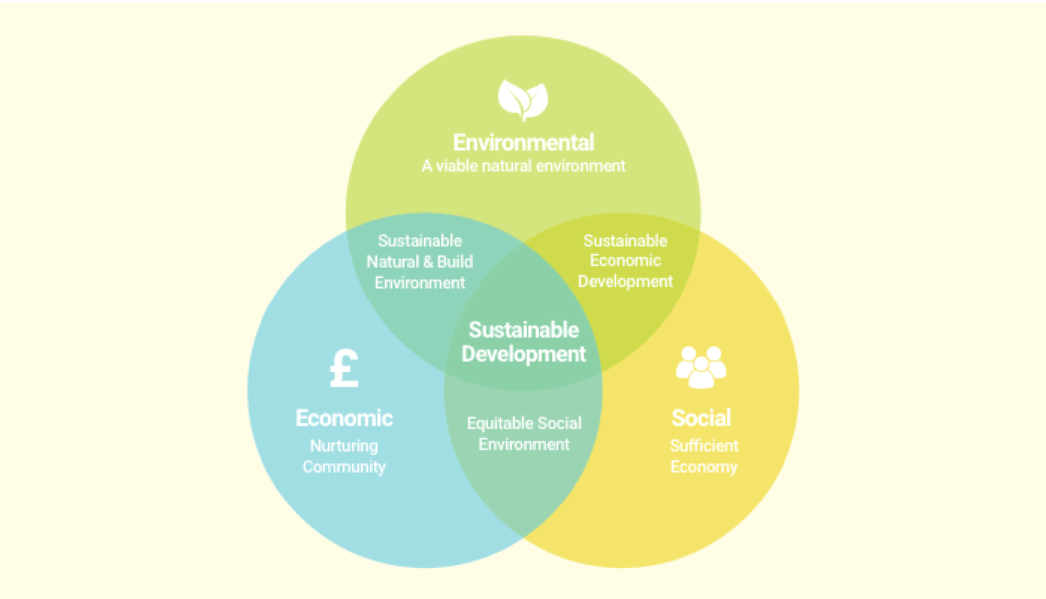


Figure 1. The 3 pillars of sustainability [1]

[1] Source: https://juta.co.uk/juta-news/sustainable-construction-development/

Sustainable construction involves multiple facets, these include conserving water, reducing waste generation, optimizing energy use, selecting eco- materials, ensuring superior indoor air quality, and achieving green building certification through accredited programs like BREEAM or LEED. To successfully pursue sustainability in construction, one must utilize energy-efficient technologies and materials, integrate water-saving fixtures, reduce waste during both construction and operation phases, choose eco-friendly materials with minimal environmental impact, establish healthy indoor environments without pollutants, and earn recognition by meeting rigorous sustainability criteria. Indeed, sustainable construction aims to use renewable and recyclable materials while minimizing both energy consumption and waste production. By prioritizing these objectives, the sustainable construction method seeks to minimize its impact on the environment.

Sustainable construction involves the planning and design of a building project to ensure that the final structure has an impact on the environment. Moreover, sustainable construction requires the use of materials and components that have effects on the environment. Solar panels, energy roof access hatches and insulation that saves energy are all part of sustainability in construction. Sustainable construction methods encompass:

Choosing recyclable materials

- Minimizing the amount of energy used in constructing materials.
- Reducing energy consumption in the completed building
- Minimizing waste generated at the construction site.
- Preserving habitats throughout and, after the construction process

Various aspects can benefit from sustainable construction in numerous ways:

- Construction can make a positive impact on the environment by endorsing sustainable practices that effectively utilize resources and minimize waste and pollution.
- Valuable Training and Employment Opportunities: Sustainable construction practices contribute to improved economic and social conditions by offering employment opportunities and vital training in related industries and communities.
- In the face of environmental threats and climate change, sustainable construction practices are crucial factors in improving the resilience of buildings and infrastructure.
- According to research, the indoor air quality and natural light can be improved with sustainable construction practices, leading to better health and well-being for building occupants, according to research.
- Construction technology is always advancing, and sustainability often plays a key role in driving this innovation forward.
- Enhanced Construction Management is achieved through the integration of sustainable practices. By promoting efficient methods and materials, as well as improving communication and coordination among construction professionals, sustainable practices foster better management in the construction industry.
- Sustainable construction methods enhance the performance of buildings, leading to reduced resource consumption (e.g. energy and water) and minimized pollution. This results in improved building functionality while promoting environmental consciousness.
- Reduced Lifecycle Costs: Buildings designed and constructed using sustainable principles have lower operating costs compared to conventional structures. This is primarily due to their improved energy and water efficiency.

1.2 Building materials and sustainability

Circular approaches necessitate a collaborative and holistic effort involving a wide spectrum of stakeholders, including clients (investors, developers, property firms, home builders, and significant occupants), as well as advisors (architects, engineers, consultants), contractors, product manufacturers, and end-users like us.

In the past, the critical factors that influenced the choice of construction materials were predominantly based on cost, availability, and aesthetics. However, with the increasing emphasis on being sustainable, it is important to consider the wider impacts of selected materials on various sustainability indicators.

Building material options play a significant role in determining the sustainability of a structure. Environment-friendly elements are those produced and employed in ways that minimize their ecological impact. Selecting greener substances is an important aspect of eco-conscious construction. They can be made from renewable resources, recycled materials, or waste products. Using materials that are available locally is another way to promote environmental sustainability. This not only saves money but also reduces the energy needed and pollution produced.

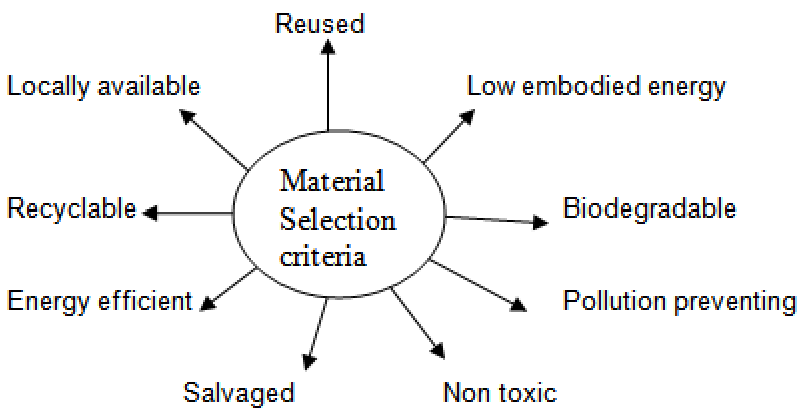


Figure 2: Selection criteria related to sustainability. [2]

Environmentally friendly materials, often referred to as green building materials, are those used in construction that have undergone processes with minimal environmental impact during their production, installation, and maintenance phases. These materials should possess certain characteristics such as durability, reusability, or recyclability. Additionally, they should incorporate recycled components in their composition and originate from local resources, making them regionally sourced materials.

The importance of sustainable building materials is undeniable, especially in the face of rising global temperatures and the growing impact of climate change. To address these challenges, adopting sustainable construction practices has become essential.

Sustainable construction materials play a crucial role in reducing the environmental impact of construction projects. They affect everything from the resources used in their production to the energy required for

[2] Source: https://theconstructor.org/building/low-cost-building-materials/5352/

transportation and installation. Choosing sustainable materials is a proactive way to minimize these environmental effects and create eco-friendly structures.

Additionally, sustainable building materials offer economic benefits. They typically require less maintenance and last longer, leading to lower overall costs for building owners. Many of these materials are competitively priced, making them an attractive choice for budget-conscious builders.

Moreover, sustainability and durability are closely intertwined when it comes to these materials. They often surpass the lifespan of alternatives resulting in reduced maintenance and replacement needs for buildings. This translates into savings in terms of time and costs. Essentially opting for building materials does not demonstrate environmental responsibility but also offers financial benefits to both builders and property owners.

There are examples of building materials, such as:

1. Wood; Wood is a resource that can be responsibly harvested. Additionally, its insulating properties contribute to energy expenses.

2. Concrete; Recycled materials like fly ash and slag can be used in the production of concrete making it an ecofriendly choice. Furthermore, concrete is known for its lasting nature.

3. Steel; Steel can be recycled repeatedly without losing its strength properties. It is a durable material for various applications.

4. Glass; Glass can be manufactured using recycled materials.

Apart from being maintenance it also boasts a lifespan. One of the most effective ways for a building to be both economically and environmentally sustainable is for it to be energy efficient. This means that it should be designed to use as little power as is necessary, lowering the building's energy costs.

Why use sustainable building materials in construction?

Using sustainable building materials in construction offers a wide range of environmental, economic, and social benefits.

Environmental Benefits - Sustainable materials contribute significantly to environmental preservation. They curtail the consumption of finite natural resources such as timber, minerals, and fossil fuels, fostering resource conservation. By necessitating less energy during their production, these materials reduce carbon emissions, thereby lowering the carbon footprint associated with construction. Furthermore, they facilitate waste reduction, generating less construction waste, and often being recyclable, which in turn lessens landfill usage. Opting for sustainable materials also translates into lower emissions, diminishing greenhouse gases and air pollutants during production and transportation.

Energy Efficiency - Sustainable materials enhance energy efficiency in construction. Certain materials, like straw bales or hempcrete, provide exceptional insulation, reducing the energy needed for heating and cooling. Sustainable building designs can seamlessly incorporate renewable energy sources, such as solar panels, and leverage passive solar strategies to harness the power of the sun.

Durability and Longevity - Sustainable materials often surpass their traditional counterparts in terms of durability, leading to extended building lifespans. This, in turn, reduces the need for frequent repairs or replacements, ultimately saving both time and money over a building's life cycle.

Cost Savings - Sustainability and cost-effectiveness go hand in hand. Energy-efficient materials and designs can lead to lower utility bills over time. Moreover, in certain regions, financial incentives or tax benefits may be available for those using sustainable materials and energy-efficient technologies.

Market Value and Appeal - Sustainable buildings tend to command higher property values and are appealing to environmentally conscious buyers or tenants. They also bolster a company's reputation, potentially attracting more clients or investors.

Regulatory Compliance - Sustainable construction practices align with local building codes and environmental regulations, ensuring compliance and futureproofing against stricter requirements.

1.3 The role of the LCA concept and application in construction

The environment is directly influenced by buildings, this can be seen in the extraction of resources during construction, as well as maintenance and renovation activities, leading to the release of harmful substances throughout the building's entire lifecycle.

Life Cycle Assessment (LCA) is a technique that evaluates environmental impacts linked to a product, process or activity from the beginning to the end. This covers sourcing and processing of raw materials, production procedures, use of the item and its disposal or reuse. Life Cycle Assessment forms a crucial tool in reducing overall ecological burdens.

Environmental impacts comprise all extractions from the environment and emissions generated. The guidelines for conducting a Life Cycle Assessment are derived from the International Organization for Standardization, the relevant standards being ISO 14040 and ISO 14044. The LCA process is governed under ISO 14000, the series of international standards addressing environmental management. According to International Standard ISO 14040, LCA is a "compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle."

Cornerstone standards	Construction works specific standards	EPD standards
ISO 14040 (fundamentals for LCA)	EN 15978 – LCA standard for construction projects (European standard, basis for all EU regulations)	ISO 14025 – cornerstone standard for all kinds of EPDs
ISO 14044 (fundamentals for LCA)	ISO 21929-1 and ISO 21931-1 (less used LCA standards)	EN 15804 (EPD data) and EN 15942 (EPD format) (European standard, basis for all EU regulations) ISO 21930

Figure 2. Standards for LCA in Buildings. Source: OneClick LCA.

LCA is a systematic approach used to assess the environmental performance of a product, process, or building over its entire lifecycle. It considers all stages, from raw material extraction and manufacturing to construction, operation, and eventual demolition or disposal. LCA helps in quantifying the environmental impacts, such as energy consumption, resource depletion, and greenhouse gas emissions.

Figure 3. The LCA concept[3]

Life Cycle Assessment (LCA) is a tool in construction with several significant benefits. Firstly, it actively contributes to environmental impact reduction by guiding informed decisions at every stage of a building's lifecycle, promoting resource efficiency and responsible practices. Secondly, LCA can yield substantial cost savings over a building's lifespan by optimizing material usage, enhancing energy efficiency, and streamlining maintenance efforts. Lastly, LCA ensures compliance with sustainability standards and green building certifications like LEED or BREEAM, reinforcing the commitment to creating environmentally responsible and efficient structures.

The LCA process can be divided into four primary stages:

Setting goals and defining scope – In this phase, the aims of the LCA, the object under investigation, and the functional unit are determined. The functional unit is a quantitative metric for gauging the performance of a product or procedure, like measuring the number of miles driven by an automobile or calculating the amount of illumination generated by a light bulb.

Inventory assessment - At this stage, all inputs and outputs associated with a specific product or process are identified and quantified. This includes aspects such as energy consumption, material usage as well as emissions to the surroundings.

Evaluation - This step assesses the environmental implications of what was identified in the inventory evaluation. The evaluation can be done employing various techniques including Life Cycle Impact Assessment (LCIA), which was developed by International Organization for Standardization (ISO).

[3] Source: https://pre-sustainability.com/articles/life-cycle-assessment-lca-basics/

Interpretation - Lastly, we interpret impact assessment results to draw conclusions about how sustainable a particular product or process is environmentally.

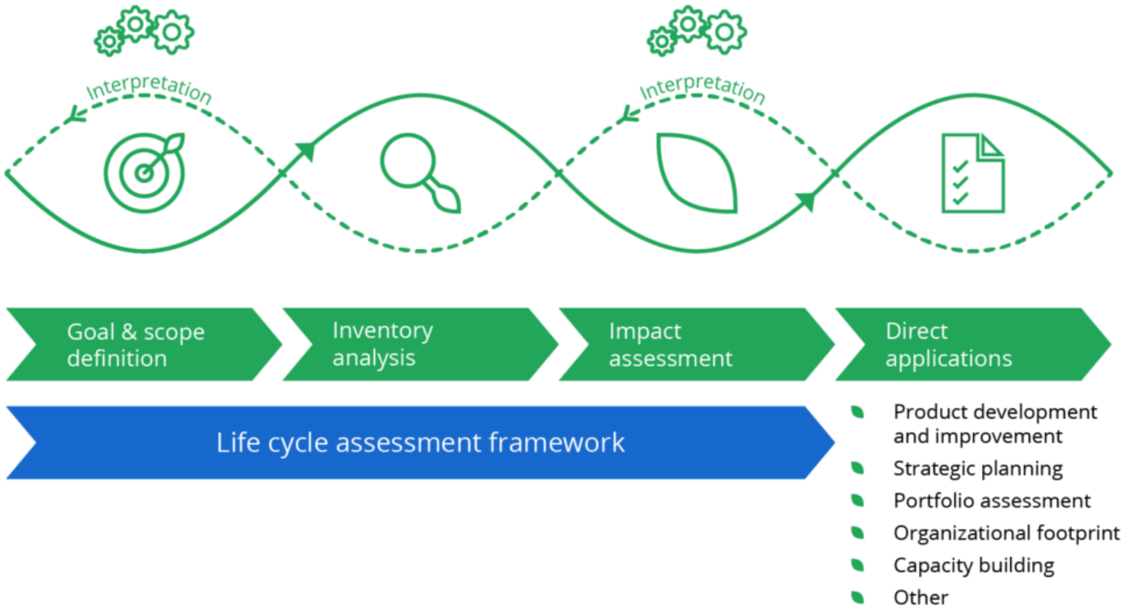


Figure 4. Four steps of life cycle assessment[4]

Life cycle analysis (LCA) is a tool in construction that has several significant advantages. First, it actively contributes to reducing environmental impact by guiding informed decisions at every stage of a building's life cycle, promoting resource efficiency and responsible practices. Second, LCA can generate significant savings over the life of a building by optimizing material use, improving energy efficiency, and streamlining maintenance efforts. Finally, LCA ensures compliance with sustainability standards and green building certifications such as LEED or BREEAM, reinforcing its commitment to creating efficient and environmentally friendly buildings.

Advantages of performing LCA of a building:

- Minimize impact on the environment: Evaluate different construction options to choose the most environmentally friendly option and compare the ecological impact of renovation versus demolishing and rebuilding from scratch. Also, can evaluate design options to select the option with the least impact on the environment.
- Target environmental areas that need attention: Identify and resolve specific environmental issues within a construction project and implement measures to mitigate identified environmental hotspots.
- Optimal Material and Product Selection: This can happen by determining the long-term environmental impact of construction materials and products and facilitating the decision-making process to choose the most sustainable options.

[4] Source: https://pre-sustainability.com/articles/life-cycle-assessment-lca-basics/

1.4 Novel sustainable building materials

The traditional materials used in construction, such as concrete and steel, have substantial environmental impacts. As a response to growing concerns about sustainability, researchers and engineers are actively developing novel sustainable building materials. We will delve into some of these innovative materials that can help reduce the environmental footprint of construction projects. There are several novel sustainable building materials that are being developed and used. These materials include Biomass-based materials which are made from renewable resources, such as wood, straw, and agricultural waste. Recycled materials are made from waste products, such as plastic bottles and tires. Natural materials, materials are extracted from the earth, such as stone, clay, and sand. Advanced materials that have unique properties that make them well-suited for use in buildings, such as self-cleaning materials and energy-absorbing materials.

Some of the most novel sustainable building materials are:

Bamboo is a rapidly renewable resource that has gained popularity as a sustainable building material. It grows quickly, requires minimal maintenance, and can be harvested without harming the plant's root system. Bamboo also boasts impressive strength and durability, making it a viable alternative to traditional wood. Bamboo can be used for a variety of construction purposes, including flooring, roofing and even as a structural element in some cases.

Figure 5. Bamboo[5]

Recycled wood, salvaged from old buildings or furniture, and engineered wood products offer sustainable alternatives to traditional lumber. These materials maximize the use of existing resources and reduce the need for cutting down new trees.

[5] Source: https://www.conserve-energy-future.com/sustainable-construction-materials.php

Figure 6. Recycled wood[6]

Rammed earth construction involves compressing layers of earth, chalk, lime, or gravel to create sturdy walls. This ancient building technique has experienced a resurgence due to its sustainability and thermal mass properties.

Figure 7. Rammed Earth Wall[7]

Cork: Harvested from the bark of cork oak trees, cork is a renewable material used for flooring, wall coverings, and insulation, with the advantage of regrowth after harvesting.

[6]Source: https://www.newscientist.com/article/2321116-waste-wood-chemically-recycled-to-produce-material-stronger-than-steel/
[7] Source: https://en.wikipedia.org/wiki/Rammed_earth

Figure 7. Cork Building Material[8]

Straw Bales: Utilized within walls, straw bales function as an outstanding natural insulator while simultaneously providing structural support, contributing to energy-efficient construction.

Figure 8. Straw Bales Building Material[9]

Hempcrete is a mixture of hemp fibers, lime, and water. It is a lightweight, insulating material that is gaining traction in sustainable construction due to its low environmental impact. Hemp grows quickly and absorbs carbon dioxide during its growth, making it a carbon-negative material.

[8] Source: https://www.molinas.it/en/green-building-material

[9] Source: https://www.buildingwithawareness.com/the-pros-and-cons-of-straw-bale-wall-construction-in-green-building/

Figure 9. Hempcrete Building Material[10]

The adoption of novel sustainable building materials represents a significant step toward more eco-friendly and responsible construction practices. These materials offer the potential to reduce resource consumption, lower carbon emissions, and minimize environmental impact.

These novel sustainable building materials offer a variety of potential benefits, including:

Reduced environmental impact: These materials can help to reduce the environmental impact of buildings by using less energy and resources.

Improved performance: These materials can improve the performance of buildings in terms of energy efficiency, durability, and comfort.

Increased innovation: The development of novel sustainable building materials can help to drive innovation in the construction industry.

There are many types of sustainable construction materials, often referred to as green building products. Lumber, stone, metal and paper are materials that can be recycled and re-used as building products. Bamboo, cork, straw and even coconut are examples of construction products that can be renewed quickly.

Sources:

OneClick LCA. (2023). Standards for LCA in Buildings.

ISO 14040 (2006). Environmental management: life cycle assessment – Principles and framework. International Organisation for Standardisation.

https://sbcgreece.org/en/homepage/

https://www.unep.org/explore-topics/resource-efficiency/what-we-do/cities/sustainable-buildings

[10] Source: https://hempfoundation.net/lookout-for-these-10-hempcrete-and-hemp-building-companies/

2. Environmental management and strategies for building material reuse and recycle. Construction waste impacts. Low-cost and reusable building materials.

2.1 Environmental management and strategies for building material reuse and recycle.

Environmental management refers to the systematic planning, implementation, monitoring, and control of activities, processes, and policies within an organization or industry to ensure that they are conducted in an environmentally responsible and sustainable manner. It involves assessing, mitigating, and managing the environmental impacts of operations, products, and services to minimize harm to the environment and promote conservation. Environmental management is crucial in the construction industry.

80% of the buildings that will exist in 2050 exist today. The most significant quantifiable impact of the building sector is emissions due to energy consumption. In construction works, reuse is the use of materials that come from demolition works and are in good condition. These materials are reused without further processing, e.g. masonry, roof tiles, wooden beams, etc. They can be sold on the second-hand market.

The waste management hierarchy is as follows: Reduce, Reuse, Recycle, Dispose. The waste hierarchy tells us that the best way to deal with waste is to stop it from happening in the first place "reduce". This is the most important step for facility managers who want to be eco-friendly. But if there's already waste, they should know that throwing it away is the worst choice for the environment. Instead, they should aim to use things again and then recycle them. The aim of the waste management hierarchy is to achieve optimal environmental outcomes and is accepted nationally and internationally as a guide for prioritizing waste management practices. The Waste Management Hierarchy was established by the Environmental Protection Agency (EPA) as a guide for prioritizing waste management practices in line with the smallest environmental impact.

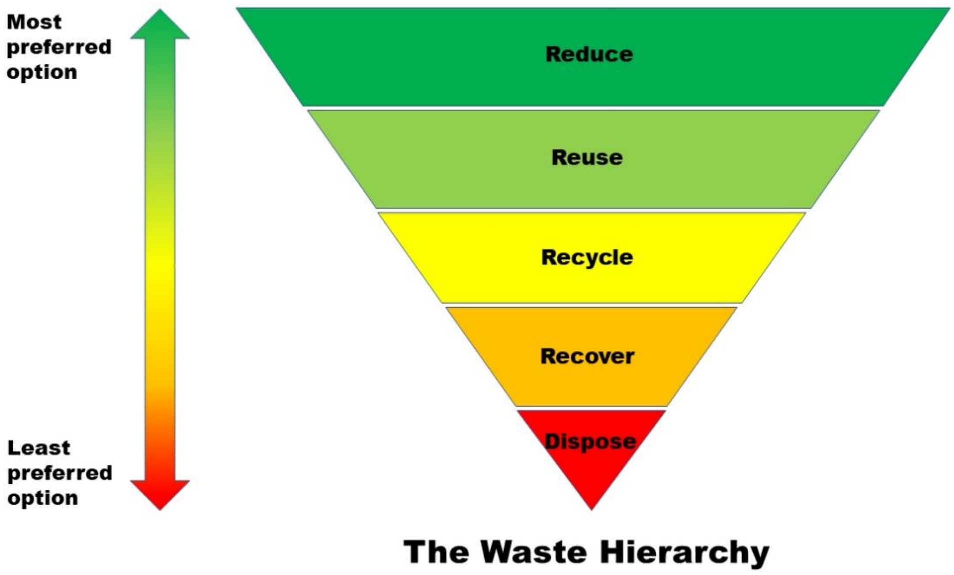


Figure 10. The waste Hierarchy[11]

[11] Source: https://www.fmlink.com/articles/missing-link-sustainable-reuse-recycling-building-products/

Construction waste is the waste generated from the construction, renovation, and demolition of buildings and infrastructure. It is a major environmental problem, as it contributes to pollution, greenhouse gas emissions, and the depletion of natural resources. This waste includes materials such as concrete, wood, metal, plastic, and glass. Activities at construction sites can result in the discharge of polluted water that detrimentally affects local watercourses or the marine or potential health impacts, the escape of litter from the site, or excavation or importation of unsuitable fill materials.

Waste management in construction activities has been promoted with the aim of protecting the environment in line with the recognition that waste from construction works contributes significantly to environmental pollution. Various approaches to construction waste management have been developed in research work and, concomitantly, in existing practices. These project works can be broadly grouped into three areas namely:

- waste classification.
- waste management strategies.
- waste disposal technologies

Construction and demolition waste (C&DW) represents the most significant waste category in the European Union (EU), characterized by consistently produced quantities over time and a considerable portion being recovered. In the European Union (EU), construction and demolition waste (CDW) constitute over one-third of the total waste generated. This category of waste encompasses a diverse range of materials, including concrete, bricks, wood, glass, metals, and plastics. It encompasses all waste generated during the construction and dismantling of structures and infrastructure, as well as activities related to road construction and upkeep. The level of recycling and material recovery of construction and demolition waste varies greatly across the EU, ranging from less than 10% to over 90%. EU countries apply different definitions of construction and demolition waste, which makes cross-country comparisons difficult.

The Construction and demolition waste (C&DW) is based in Waste Framework Directive 2008/98/EC. This directive establishes a legal framework for waste management and sets out key principles and objectives for managing waste within the EU. The objectives for managing construction waste encompass several key aspects. First, the focus is on promoting selective demolition techniques that serve multiple purposes. These techniques enable the safe removal and handling of hazardous substances, facilitating their proper disposal. Additionally, selective demolition supports the goal of enhancing re-use opportunities for various materials, while also enabling high-quality recycling through the careful removal and sorting of materials. Overall, these strategies aim to significantly reduce waste generation in the construction industry while promoting responsible and sustainable waste management practices.

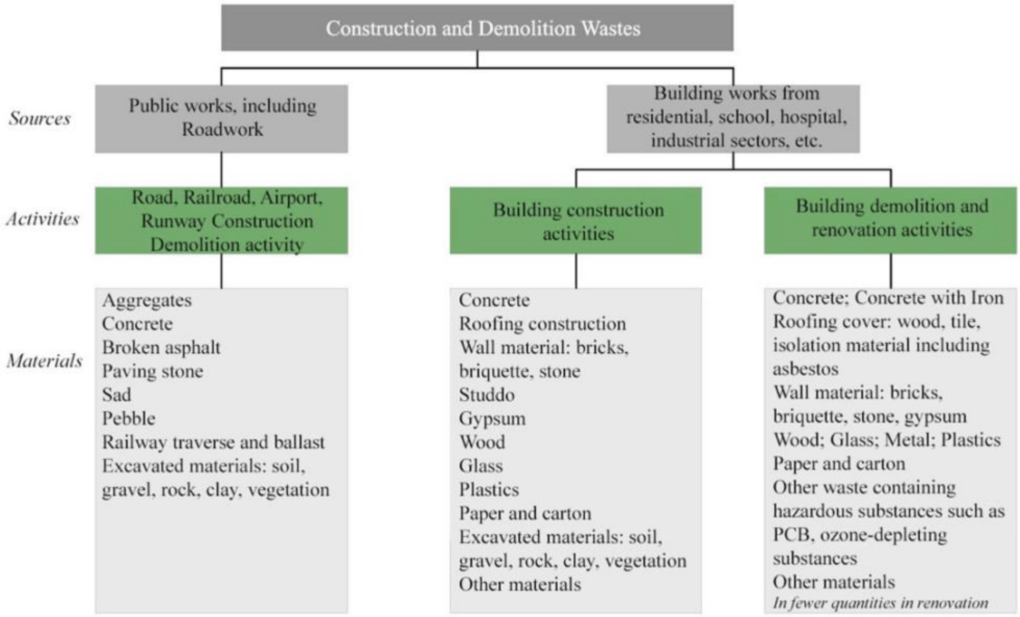


Figure 11. Construction and demolition waste per activity[12]

Various methods are available for managing construction waste, including landfilling, incineration, and recycling. Among these options, recycling is the most favored approach as it reduces waste sent to landfills and the demand for new materials. Construction waste recycling involves sorting and processing materials like wood, concrete, metals, and plastics to create new products. This not only preserves natural resources but also contributes to a reduction in greenhouse gas emissions.

Managing construction waste is not only vital for environmental reasons but also makes economic sense. By implementing waste reduction strategies like source reduction, effective materials management, and waste diversion, construction companies can cut down on material and disposal expenses. Moreover, by opting for waste material recycling, companies can generate income by selling these materials and reducing costs associated with landfills.

Strategies to reduce waste during construction:

- Designing for Material Optimization
- Material Selection
- Waste Management Planning On-Site

Efforts to minimize construction waste can be categorized into three main approaches. Firstly, there's the optimization of design for material efficiency, which entails designing buildings to reduce both the quantity of materials used in construction and the waste generated during the building process. This approach also involves planning for the eventual deconstruction and reuse of materials and components at the end of their lifespan. Secondly, there's the thoughtful selection of materials, promoting a circular economy by prioritizing the reuse of materials and components and specifying construction materials with recycled content. This sustainable approach helps minimize the demand for new resources. Lastly, on-site waste management planning is crucial, involving the implementation of effective waste management practices at the construction site, ensuring the

[12] Sönmez, N. and Kalfa, S.M., 2023. Investigation of Construction and Demolition Wastes in the European Union Member States According to their Directives. Contemporary Journal of Economics and Finance, 1(2), pp.7-26.

proper segregation and recycling of waste materials. These three strategies collectively contribute to reducing the environmental impact of construction activities.

Waste management practices:

- Using modern technology to produce parts and products off-site or using prefabricated parts to save construction waste.
- Effective project planning, design, and construction phase coordination between the consultant, client, contractors, and other stakeholders.
- Establish effective worksite management procedures and raise awareness among the workers in the construction industry.
- Making use of and recycling waste from construction sites
- Provide rewards and bid premiums for waste management.
- Greater use of green building guidelines and requirements
- Establishing sanctions for building companies with subpar waste management procedures
- An increase in landfill fees
- The inclusion of a policy for material waste avoidance in building contracts
- Providing scheduled training on material waste minimization strategies for construction workers

2.2. Construction waste impacts

Construction waste can have a range of negative impacts on the environment, public health, and the economy. There are various strategies, approaches, and measures of construction waste management practiced in the public and private sectors. The impacts of construction waste can be categorized in 3 major categories: economic, environmental, and social.

When looking at the environmental impacts of the construction industry, it becomes clear that it accounts for more than 37% of all waste generated in the European Union, as reported by Eurostat in 2021.

- Overcrowded landfills, which occur when construction waste is not treated properly and is sent to landfills. This can lead to the release of harmful pollutants into the air and water, as well as the production of methane, a greenhouse gas that contributes to climate change.

- Resource depletion, since the production of construction materials requires the exploitation of natural resources such as sand, gravel, and wood, which can lead to environmental degradation such as deforestation and soil erosion.

- Water pollution: Waste from construction sites can often contaminate water sources if not treated properly. This can lead to health problems, such as infections.

- Air pollution. Burning construction waste can release harmful pollutants, such as dioxins, into the air. These pollutants can cause respiratory problems, cancer, and other health problems.

- Noise pollution. Construction can be noisy, disturbing wildlife and people living nearby.

- Security risks. Construction waste can create safety hazards, such as tripping hazards and fire hazards.

These are only some of the impacts of construction waste, as a result it is crucial for the construction industry to follow management waste strategies and promote the use of recycled and reusable construction materials.

2.3. Low-cost and reusable building materials.

Environmental initiatives within the construction sector have emphasized the operational phase and the reduction of energy consumption by building occupants. Nonetheless, it is crucial to recognize that a significant portion, roughly half, of a building's environmental footprint throughout its entire life cycle originates from the materials used in its construction, especially during the manufacturing process. This underscores the growing importance of reuse, which has become a significant point, aligning with principles of the circular economy, and holding substantial implications for the construction industry.

All materials from construction sites used for reuse are recycled construction materials. This includes wood, brick, insulation, plastic, glass, building blocks, wall coverings.

Many materials can be recycled or reused, including:

Concrete: Can be used as aggregate in future projects.

Wood: Can be repurposed for furniture or landscaping.

Metals: Can be melted and made into new metal products.

Plastics: Can be processed into new materials such as plastic lumber or insulation.

Sources:

Sönmez, N. and Kalfa, S.M., 2023. Investigation of Construction and Demolition Wastes in the European Union Member States According to their Directives. Contemporary Journal of Economics and Finance, 1(2), pp.7-26.

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3. Energy efficient buildings: Energy performance of buildings directive, Long-term renovation strategies, nearly zero-energy buildings. Certificates and inspections. Green building concept.

3.1. Energy efficient buildings: Energy performance of buildings directive, Long-term renovation strategies, nearly zero-energy buildings

The Energy Performance of Buildings Directive (EPBD) is a European Union directive that aims to improve the energy performance of buildings within the EU. The directive sets minimum energy performance requirements for new buildings and requires existing buildings to be renovated to meet certain energy efficiency standards. The Energy Performance of Buildings Directive is a crucial tool for achieving energy efficiency and sustainability in the European construction sector. The Energy Performance of Buildings Directive (EPBD) is a significant policy framework in the European Union (EU), aimed at enhancing the energy efficiency of buildings. It plays a vital role in addressing climate change and promoting sustainability in the construction sector.

What is EPBD?

The Energy Performance of Buildings Directive, commonly known as EPBD, is an EU initiative established in 2002 and subsequently revised in 2010 and 2018. The Energy Performance of Buildings Directive (2018/844/EU) which is currently in force, introduced new elements to the former 2010/31/EU Directive. Its primary objective is to reduce energy consumption in buildings, which account for a substantial portion of energy use and greenhouse gas emissions in the EU. The EPBD is a set of regulations and guidelines established by the European Union to improve the energy efficiency of buildings. Its primary objectives are:

Reducing Energy Consumption: EPBD aims to reduce the energy consumption of buildings by setting minimum energy performance standards for both new and existing buildings.

Promoting Renewable Energy: It encourages the use of renewable energy sources in buildings, such as solar panels and wind turbines.

Enhancing Market Transparency: EPBD requires energy performance certificates for buildings, which provide information about a building's energy efficiency. This helps property buyers and renters make informed decisions.

Several new measures to further improve the energy performance of buildings. These measures include:

Minimum Energy Performance Standards: EPBD establishes minimum energy performance standards that all new buildings must meet. These standards ensure that new constructions are designed to be energy-efficient from the beginning.

Renovation Requirements: The directive also applies to existing buildings undergoing major renovations. These buildings must be brought up to a certain energy performance level, making them more energy-efficient during the renovation process.

Energy Performance Certificates: EPBD mandates the issuance of energy performance certificates, which provide an energy efficiency rating for buildings. These certificates are essential for property transactions, as they inform buyers and renters about the energy performance of the building.

Here are some additional things that can learn about the EPBD:

- The EPBD is implemented in each EU Member State through national legislation.
- There are several financial incentives available to help building owners improve the energy performance of their buildings.
- The EPBD is also supported by several voluntary initiatives, such as the Energy Efficiency in Buildings Directive.

Renovation Wave and Long-Term Renovation Strategies

Renovation Wave is an EU initiative that aims to accelerate the refurbishment of buildings across Europe, with a focus on improving their energy efficiency and sustainability. The main objectives of the renovation wave are to increase the energy efficiency of EU buildings, reduce greenhouse gas emissions and create jobs in the construction and renovation sector. For the building sector to contribute to the climate target of reducing greenhouse gas (GHG) emissions by at least 55% by 2030 (compared to 1990), the retrofit wave strategy sets a clear target: a 60% reduction in greenhouse gas emissions from buildings. %, reducing final energy consumption by 14% (by 2030 compared to 2015) and at least doubling the annual renovation rate. The Renovation Wave addresses three main priorities:

- Addressing energy poverty and improving the efficiency of the least energy-efficient buildings.
- Enhancing the sustainability of public buildings and social infrastructure.
- Transitioning towards more environmentally friendly heating and cooling systems.

Figure 12. Priorities of Renovation Wave [13]

According to the European Commission, Long-term Renovation Strategies are essential for facilitating the economic shift required to meet broader sustainability objectives and align with the ultimate aim outlined in the Paris Agreement. This goal entails keeping the rise in the worldwide average temperature significantly below 2°C above pre-industrial levels and striving to restrict it to a 1.5°C increase. The long-term strategies must be related to the national energy and climate plans of Member States covering the period from 2021 to 2030.

The national long-term strategies, as well as the EU's strategy, must encompass a time horizon of at least 30 years. These strategies should address various key aspects, including the reduction of total greenhouse gas emissions and the enhancement of removals through sinks. Furthermore, they must outline emission reduction and removal enhancement targets for specific sectors such as electricity, industry, transport, heating and

[13] Source: https://energy.ec.europa.eu/topics/energy-efficiency/energy-efficient-buildings/renovation-wave_en#a-renovation-wave-for-europe

cooling, buildings (both residential and tertiary), agriculture, waste, and land use, land-use change, and forestry (LULUCF). Additionally, these strategies should provide insights into the expected progress toward transitioning to a low greenhouse gas emission economy, including metrics like greenhouse gas intensity and CO2 intensity of gross domestic product, along with long-term investment estimates and plans for research, development, and innovation in this context. Whenever possible, the anticipated socio-economic impacts of decarbonization measures, encompassing macro-economic and social development, health implications, environmental protection, and other factors, should be considered. Moreover, these strategies should be harmonized with other national long-term objectives, planning efforts, policies, measures, and investment initiatives.

These strategies are comprehensive plans that focus on the renovation of existing buildings to enhance their energy efficiency and reduce environmental impact. These strategies plan for improving the energy performance of buildings. Long-Term Renovation Strategies are crucial for several reasons. Firstly, they promote sustainability by reducing the necessity for new construction, which conserves valuable resources and minimizes waste, aligning with broader sustainability objectives and prolonging the life of existing structures. Additionally, these strategies enhance energy efficiency through the upgrading of insulation, windows, HVAC systems, and lighting during renovations, ultimately decreasing operational costs. Moreover, they prioritize the comfort and functionality of buildings, ensuring they adapt to the changing needs of occupants and evolving environmental conditions, thereby enhancing the overall quality and longevity of the built environment.

These strategies typically focus on the following goals:

- Reducing energy consumption
- Improving indoor air quality
- Increasing comfort and livability
- Reducing greenhouse gas emissions
- Creating jobs and stimulating economic growth

Nearly zero-energy buildings

The recast of the Energy Performance of Buildings Directive (EPBD) introduced, in Article 9, "nearly Zero-Energy Buildings" (nZEB). The EU has proposed to move from the current nearly zero-energy buildings to zero-emission buildings by 2030. Nearly zero-energy buildings (NZEB) are buildings that have a very high energy performance.

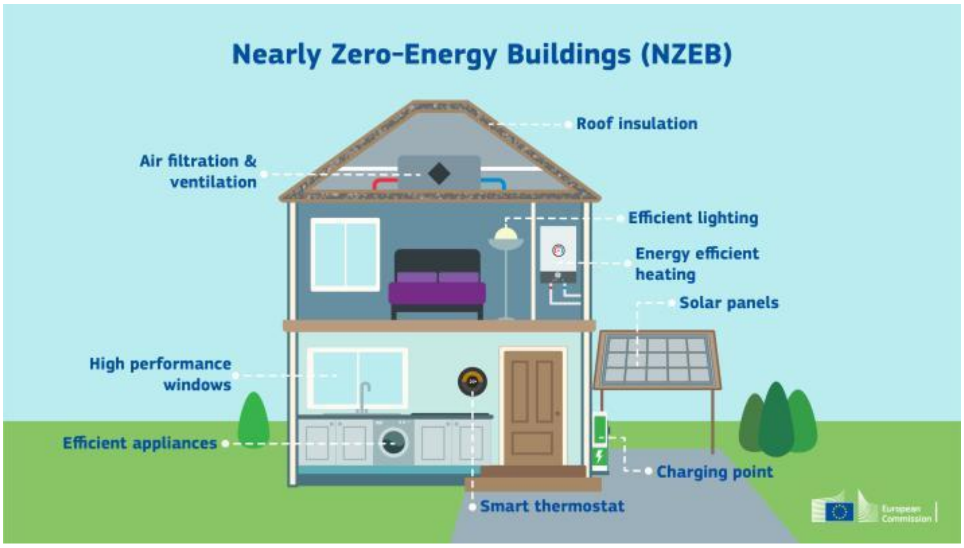

Figure 13. NZEB building [14]

[14] Source: https://energy.ec.europa.eu/topics/energy-efficiency/energy-efficient-buildings/nearly-zero-energy-buildings_en

They require very little energy to heat, cool, and light, and they generate or procure a significant amount of their energy from renewable sources.

Designing and constructing Nearly Zero-Energy Buildings (NZEBs) involves various effective strategies. These approaches include the use of highly insulated materials, which significantly curbs heat loss and gain, ensuring superior thermal performance. Additionally, NZEBs incorporate energy-efficient heating, cooling, and lighting systems to optimize energy consumption. Employing daylighting and passive solar design principles further reduces the reliance on artificial lighting and heating, enhancing overall efficiency. Furthermore, the integration of solar panels and other renewable energy systems provides a sustainable means to generate electricity, enabling NZEBs to achieve their ambitious energy goals while minimizing environmental impact.

First nZEB Principle: **Energy demand**	**Second nZEB Principle:** **Renewable energy share**	**Third nZEB Principle:** **Primary energy and CO_2 emissions**
There should be a clearly defined boundary in the energy flow related to the operation of the building that defines the energy quality of the energy demand with clear guidance on how to assess corresponding values.	There should be a clearly defined boundary in the energy flow related to the operation of the building where the share of renewable energy is calculated or measured with clear guidance on how to assess this share.	There should be a clearly defined boundary in the energy flow related to the operation of the building where the overarching primary energy demand and CO_2 emissions are calculated with clear guidance on how to assess these values.

Figure 14. The 3 principles of NZEB Building[15]

Benefits of NZEBs:

Net Zero Energy Buildings (NZEBs) offer a range of compelling benefits. While the upfront construction costs may be higher, they bring substantial economic advantages in the long run due to their significantly reduced energy consumption. This translates into substantial cost savings over time, making them a financially sound investment. Moreover, NZEBs prioritize occupant comfort through high-quality insulation, efficient HVAC systems, and passive design principles, ensuring consistent and pleasant indoor temperatures throughout the year.

In addition to economic benefits, NZEBs are inherently resilient. They have the capacity to generate their own power from renewable sources and often incorporate energy storage solutions. This self-sufficiency makes them more robust in the face of energy supply interruptions and enhances their reliability, contributing to a more sustainable and resilient built environment.

Erasmus+ BUNG Program Example:

The Erasmus+ BUNG program's game-based learning approach is an excellent way to educate students about NZEB principles and technologies. Hands-on experience with materials, lighting, insulation, and HVAC systems helps students understand the practical aspects of designing and constructing these energy-efficient buildings. This type of experiential learning can be a valuable tool in preparing the future workforce for sustainable construction practices and meeting energy efficiency goals.

[15] Source: https://www.bpie.eu/wp-content/uploads/2015/10/HR_nZEB-study.pdf

3.2. Certificates and inspections. Green building concept.

The green building concept, also known as sustainable building or eco-friendly construction, is an approach to designing, constructing, and operating buildings with a focus on minimizing their environmental impact, conserving resources, enhancing health and well-being, and promoting sustainability. This concept covers various principles and strategies aimed at more energy-efficient, with lower environmental impact buildings. Green building practices prioritize sustainability, energy efficiency, and environmental responsibility in construction and operation. Certificates and inspections are integral components of the green building concept. Certificates, such as LEED or BREEAM, serve as official recognition that a building meets stringent green standards. These certificates are awarded based on a building's adherence to criteria related to energy efficiency, water conservation, materials use, indoor air quality, and more.

Most common green building certification programs:

LEED (Leadership in Energy and Environmental Design): is one of the most widely recognized green building certifications in the world. It is administered by the U.S. Green Building Council. LEED is a green building rating system that helps make buildings more efficient and more cost-effective. It is available for all types of buildings and offers a variety of benefits, including environmental, social, and economic benefits. LEED certification is globally recognized for sustainability achievement, and it is supported by a large community of organizations and individuals who are committed to making the world a more sustainable place. LEED certification not only promotes the use of sustainable building practices but also rewards and acknowledges projects that demonstrate exceptional environmental management, setting a standard for sustainable building practices worldwide.

BREEAM (Building Research Establishment Environmental Assessment Method): is one of the most widely used green building rating systems in the world, with over 500,000 certified buildings in over 70 countries. It is administered by the Building Research Establishment. Developed by the Building Research Establishment (BRE) in the United Kingdom, BREEAM assesses various aspects of a building's sustainability, including energy efficiency, water usage, materials selection, waste management, and the overall environmental impact. It provides a robust framework for designers, developers, and building owners to improve the sustainability of their projects by setting clear standards and benchmarks. BREEAM certification signifies a commitment to creating environmentally responsible and resource-efficient buildings, promoting better practices in construction and operation, and enhancing the overall quality of the built environment.

The DGNB framework, known as the German Sustainable Building Council (Deutsche Gesellschaft für Nachhaltiges Bauen), is a comprehensive system for assessing and certifying the sustainability of buildings and urban developments in Germany and internationally. This framework evaluates various dimensions of sustainability, including environmental, economic, and social aspects, to ensure that construction projects are environmentally responsible, resource-efficient, and considerate of human well-being. The DGNB framework covers a wide range of criteria, such as energy efficiency, materials selection, water management, indoor comfort, and adaptability to future needs. It encourages sustainable practices at all stages of a building's life cycle, from planning and design to construction, operation, and even deconstruction. DGNB certification signifies a commitment to sustainable building practices and demonstrates a project's dedication to minimizing its environmental impact while creating healthier, spaces for people.

The newly introduced E+C- certification label signifies adherence to best practices in constructing buildings that exhibit exceptional energy efficiency and environmental performance. This certification system comprises two fundamental components: an Energy factor and a Carbon factor, evaluated through the "Carbon" indicator. To accommodate the diverse characteristics of different building types, locations, and associated costs, there are four potential performance levels for Energy and two for Carbon.

LEVELs is a new building sustainability assessment framework developed by the European Commission. It is designed to be a simple and flexible tool that can be used to assess the sustainability of buildings of all types and sizes.

Certifications	Requirements
BREEAM International (Similar to BREEAM Sweden, Norway and Spain)	Perform a high-quality whole building LCA analysis.
LEED	Complete a whole building LCA. Additional credits are awarded based on the demonstrated impact reductions and by incorporating building reuse and/or salvage materials into the project's scope of work.
DGNB DE, DGNB International and DK	Perform a whole building LCA and demonstrate impact reductions.
Energie Carbone	Undertake a whole life-cycle assessment for the building permit and post construction. The assessment accounts for materials, construction site, energy, and water impacts. The results are then benchmarked against carbon level thresholds.
Level(s)	Measure GHG across a building's life cycle, demonstrate resource-efficient and circular material life-cycles, optimize life-cycle cost and value.

Figure 15. List of green building certifications Source: OneClickLCA

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4. Self-assessment quiz on Module 4: Awareness of novel sustainable building materials

1. What is the primary goal of using novel sustainable building materials in construction?

(a) To reduce construction costs

(b) To increase the lifespan of buildings

(c) To minimize environmental impact

(d) To improve interior aesthetics

Which of the following are keys to sustainable use of building materials?

(a) Capacity to be recycled at the end of the building lifecycle

(b) Low toxicity towards humans

(c) Low embodied energy

(d) Local manufacturing or acquisition

(**e) All of the above**

3. What are the main steps of the LCA methodology?

(a) **Definition of objectives and scope - Inventory analysis - Impact assessment - Interpretation**

(b) Definition of objectives - Definition of scope - Impact assessment - Interpretation

(c) Definition of objectives - Definition of scope - Inventory analysis - Impact assessment

4. What is the primary objective of the Energy Performance of Buildings Directive (EPBD)?

(a) Reducing energy consumption in industrial processes

(b) Promoting renewable energy use in transportation

(c) Reducing energy consumption in buildings

(d) Promoting energy-intensive technologies

5. Why are Long-Term Renovation Strategies crucial in the context of sustainability and climate goals?

(a) They promote new construction over renovations

(b) They reduce the lifespan of existing buildings

(c) They focus on the renovation of existing buildings to enhance energy efficiency

(d) They have no impact on sustainability goals

6. What are some potential benefits of using novel sustainable building materials?

(a) Increased resource consumption and higher carbon emissions

(b) Reduce environmental impact and increase innovation in construction

(c) Decreased durability and higher construction costs

(d) Limited availability and lack of aesthetic appeal

7. What is a nearly zero-energy building (NZEB)?

(a) A building that requires very little energy to heat, cool, and light, and generates or procures a significant amount of its energy from renewable sources.

(b) A building that produces zero greenhouse gas emissions.

(c) A building that meets the minimum energy performance standards set by the Energy Performance of Buildings Directive.

8. What are some benefits of green building certifications like LEED and BREEAM?

(a) **They promote the use of sustainable building practices and acknowledge projects that demonstrate successful environmental management.**

(b) They lower construction costs and increase profits for building owners.

(c) They increase energy consumption and waste during the construction process