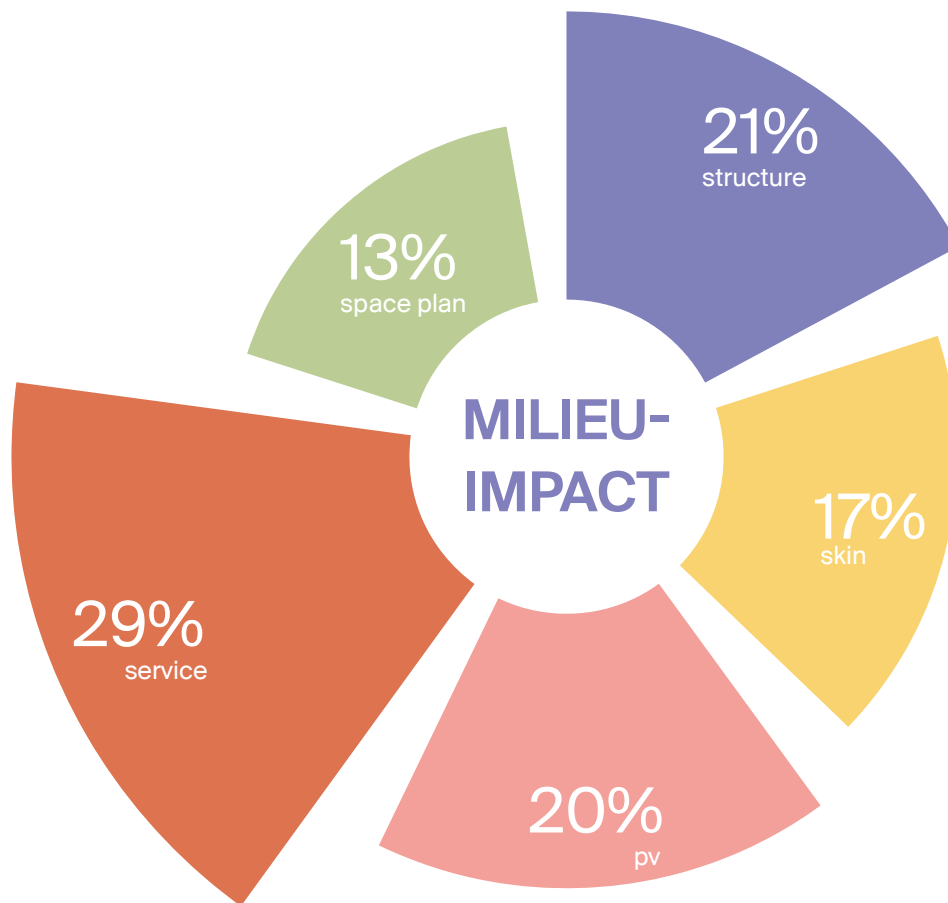


CARBON-BASED DESIGN

Design principles for CO₂ - reduction in residential construction

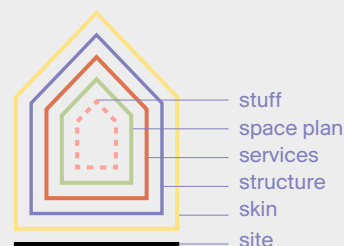
The increasing concentration of CO₂ in the atmosphere contributes to global warming. The construction sector is accountable for approximately 38% of global CO₂ emissions. Material usage alone accounts for 11% of these emissions.¹



To reduce CO₂ emissions in construction, we differentiate between **embodied emissions** (emitted during the production and processing of building materials) and **operational emissions** (emitted by the daily energy consumption to operate the building). While we have been working for years on reducing operational emissions, there is still significant potential for emission reduction in embodied emissions.

The chart shows the proportions of embodied emissions, categorised based on the layers of Brand, **Structure, Skin, Services, Space Plan, and Stuff**.²

Each of these layers has a different lifespan and therefore requires distinct approaches. By distinguishing among these layers, targeted modifications can be made without affecting other layers.
























1. United nations (2020). United Nations Environment Programme. Emissions Gap Report 2020, Nairobi.
2. S. Brand (1994). How buildings learn. What happens after they're built. PV panels play such a large role in the environmental impact of buildings, and they can be applied very differently per building. That is why PV panels have been given their own category in the diagram.

This publication is based on the research 'Carbon Based Design (2022)' by Cityföörster and RVO. For the full research, please visit cityfoerster.net.

















STRUCTURE

The load-bearing structure has the longest lifespan and the largest construction mass, and therefore has great potential for CO₂ reduction. One layer above is the **SITE**. By concentrating housing in urban areas, existing facilities and infrastructure can be utilised, resulting in significantly lower CO₂ emissions.

MEASURES	PRINCIPLE	IMPACT
Renovation vs. new construction - renovation emits up to 75% less embodied emissions compared to new construction ³ .	 	   
Flexible floorplans - Open floor plans and high stories accommodate various uses, extending the building's lifespan as it can be easily adapted for new purposes and different life phases.	 	  
Timber structure - It provides viable alternatives to steel and concrete. Timber is a renewable material that can temporarily store CO ₂ .		 
Reuse existing components - Through reuse, the lifespan is extended, preventing new CO ₂ emissions.	 	 
Design for disassembly - This is useful for complete reuse, but also for small-scale renovations and adjustments to the building.	 	

SKIN

The façade and roof form the building skin, facilitating the exchange of heat, air, moisture, light, and sound between interior and exterior. The shape (compactness), orientation, surface, and physical properties significantly impact operational emissions.

MEASURES	PRINCIPLE	IMPACT
Compact design - A more compact building reduces costs, material usage, and operational emissions.		   
Reduce glass surface - Glass has the largest CO ₂ emissions of the building envelope ⁴ . Reducing glass surface also limits operational emissions.		  
Demountable façade elements - The facade requires maintenance and elements to be replaced. Demountable elements ensure that only what is necessary needs to be replaced and encourage reuse.	 	 
Biobased materials - These materials are renewable and reduce embodied emissions. It is important not only to look at CO ₂ emissions, but to consider the entire environmental impact (such as toxicity).		 



Reduce

By using products and buildings more intelligently, production can be reduced or prevented. The building with the least emissions is the building that does not need to be built.



Reuse

Through reuse, the lifespan of buildings and products can be extended, avoiding emissions from new production.












Recycle

Use recycled materials now practically or enable easy future recycling through design.










SERVICES

While building services are currently used to reduce operational emissions, the embodied emissions of these installations also have a significant impact

MEASURES	PRINCIPLE	IMPACT
<p>Passive design - This means that installations are minimally required for the indoor climate (sun orientation, thermal mass, etc.). These applications do have embodied emissions but no operational emissions.</p>		
<p>Adaptable installations - Installation components have low embodied emissions but can help to make the building layout more flexible (see also „structure“ and „space plan“).</p>	 	
<p>PV panels - In an MPG calculation, the PV panels that are included are necessary to meet the BENG requirements. An energy-efficient installation concept pays off. The rest can be supplemented with renewable energy with a low environmental impact.</p>		
<p>Local energy networks - High-rise buildings may lack sufficient roof area for PV panels. Local energy networks where multiple buildings generate and share energy can be beneficial.</p>		

SPACE PLAN

The space plan includes all non-structural elements (floor finishes, ceilings, interior walls). This layer has the smallest impact, but enables certain uses. Good design can also prevent additional purchases of personal items (**STUFF**), for example by encouraging sharing (such as washing machines or fitness equipment).

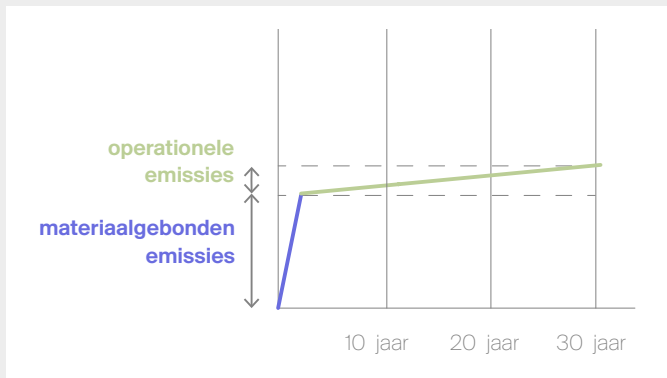
MEASURES	PRINCIPLE	IMPACT
<p>Efficient use of space - By phasing or combining use, the floor plan is better utilized (less m²/person) and the building can be more compact.</p>		
<p>Flexibility of use - Lightweight, demountable interior parts and with a long lifespan support flexible use of space (see also “structure”).⁵</p>	 	
<p>Biobased interior - Make interior elements from biobased materials that replace steel and concrete and are renewable (timber construction, plant-based insulation materials, see also “structure”).</p>		
<p>Avoid cement screeds - Cement screeds make the floor non-demountable, and in combination with underfloor heating the floor plan is no longer adaptable. Alternative products are leveling granules in combination with a dry (not casted) screed.</p>		

3. King, B. (2017) The New Carbon Architecture: Building to cool the climate, p. 35

4. More than 16% of embodied emissions. Sobota, M., Driessen, I., & Holländer, M. (2022). Carbon-based Design: Onderzoek naar de milieupact van de woningbouw, p. 45.

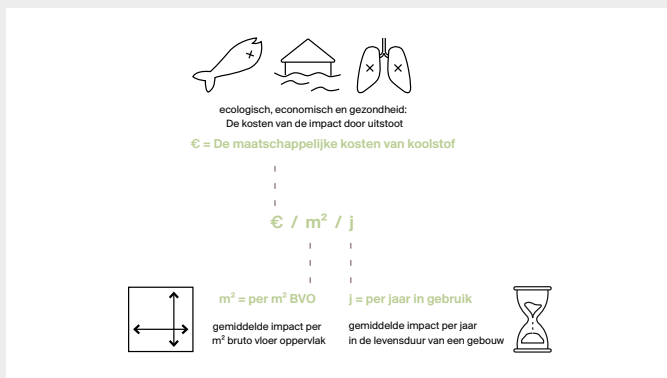
5. Alba Concepts has developed a so-called demountability index, and MAT8 from BREEAM also highlights various aspects.

EMBODIED & OPERATIONAL EMISSIONS



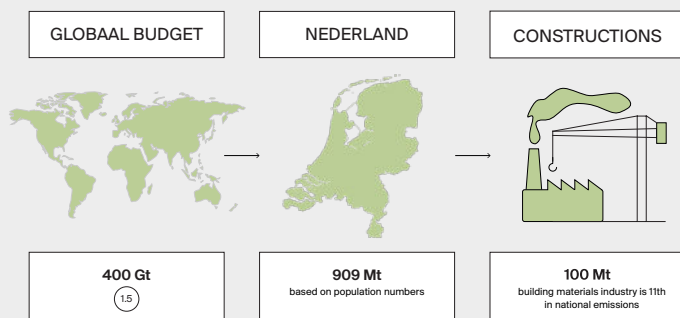
Embodied emissions are released during the production of materials and on the construction site. Operational emissions are caused during the use of a building (electricity, gas, water, heating). Embodied emissions are emitted once, while operational emissions are continuously emitted. As a result, the operationally emitted CO₂ accumulates in the atmosphere. We call this the time value of CO₂. Embodied emissions remain in the air for longer and therefore have a greater climate effect.

ENVIRONMENTAL PERFORMANCE (MPG)



The MPG indicates the environmental impact that arises during the various life phases of a building, with the exception of the usage phase. This calculation is made with life cycle analyses (LCA) per construction product, registered with an environmental declaration in the National Environmental Database (NMD). The MPG is expressed in shadow costs: a fictitious price (€) for which the various environmental effects (normalized via assumed social costs) are added and divided by the GFA (m²) and the lifespan (standard 75 years).

PARIS PROOF CO₂ BUDGET



The Netherlands has signed the Paris Agreement to limit global warming to 1.5 degrees. The Dutch Green Building Council has translated this into a CO₂ budget for the construction sector. By calculating how much CO₂ a building emits, it is determined whether it is „Paris Proof“. This “Paris Proof Score” includes embodied CO₂ emissions per square meter over a period of 30 years. This score is expressed in CO₂ equivalents per square meter GFA (kgCO₂e/m²).

FRAMEWORKS FOR EVALUATION

Milieu-impact & materiaalgebruik	Milieu-impact (MPG)	Milieu-Prestatie Gebouwen (€/ m ² BVO / jaar)
	Embodied Carbon (MPG-2)	Paris Proof Protocol (kg CO ₂ -eq / m ² BVO)
	Construction Stored Carbon	Construction Stored Carbon (kg CO ₂ -eq)
Gebouwflexibiliteit	Materiaalgebruik	Hernieuwbaar / Hergebruikt / Gerecycled (%massa)
	Hergebruikpotentie	Totaal (%massa)
	Adaptief vermogen	Methode Adaptief Vermogen Gebouw (%)
Omgang restmateriaal	Loosmaakbaarheid	Meetmethodiek Loosmaakbaarheid 2.0 (%)
	Omgang restmateriaal (sloop)	Totaal (%massa)
	Omgang restmateriaal (bouw)	Totaal (%massa)
Gezonde materialen	Toxiciteit	# Certificaten (C2C, REACH, Living Building)

The MPG considers 11 aspects of environmental impact, focusing on embodied emissions. However, a good MPG score does not immediately mean low CO₂ emissions. The New Normal is a guideline for circular construction that takes multiple methods into account⁶.

The indicators of the guideline can be used to request circular performance for a project. Many measures from this brochure fit into the topics of the guideline and can be approached with design principles of Carbon Based Design.

6. Leidraad HNN Gebouw 0.5, the final guidelines will be published towards the end of 2023. <https://www.hetnieuwenormaal.nl/>