CONSTRUCTION BLUEPRINT

Module 5

Building Materials & Systems

Circular Economy in Construction

MODULAR BUILDINGS

24 partners

12 countries

Date of Event

*Author/ **Institute***

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Building Materials and Systems | Summary

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To equip the learner with the relevant knowledge required to understand the impact of material and systems selection and installation for circular buildings.

Building Materials and Systems | Objectives

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1. Explain the **impact that material and system selection** can have on the building and operational carbon emissions
2. Understand the importance of providing a circular building taking into consideration the **occupant's health and wellbeing**, and the building life in the future.
3. Outline **challenges in maintaining the value of materials and products in the economy** for as long as possible, reducing resource use and preventing waste on site.
4. Outline the **use of construction techniques that promote the durability of buildings** and the resilience of the materials
5. Outline the **use of construction techniques that promote the adaptability of buildings**

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Topic 1 – Circular materials and systems in buildings

Topic 2 – Circular construction techniques

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1. Circular materials and systems in buildings

Circular economy principles in materials and buildings

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How do we apply Circular economy principles in materials and buildings?

It is a process that involves long-term thinking and a whole life-cycle approach in order to optimise performance, value and longevity of a building project.

- Circular economy can be applied across the entire building lifecycle from **design, construction, and operation through to disassembly and re-purposing or reuse**.

- It addresses
  - **resource efficiency,** ensuring properties are **designed for longevity**
  - efficiency and **flexibility in the use of space**.

Embodied carbon

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When reusing a product or a building, you are also **saving on embodied carbon.**

- This is the carbon dioxide emitted during the manufacture, transport and construction of new building materials, together with end of life emissions.

Image source: IGBC

Buildings

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- A building consists of a number of elements, such as
  - the **structure and fit-out** (materials in core, shell, internal partitions, fit-out),
  - its **systems** (equipment, HVAC, water and waste)

  and
  - its **occupants** (people).

Question: How can we better design in order to use fewer resources?

- There is also **ground works** required to construct a building, such as foundations, parking spaces, outdoor areas, etc., all of which require a significant amount of energy and resources

Materials

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In a traditional building cycle, virgin, raw materials are extracted, used and thrown away after demolition.

But not anymore.

- **Clients** are increasingly viewing material procurement and waste as a high risk to their businesses.
- **Product manufacturers** are also shifting to a circular economy model, placing production (based on recycled or renewable resources), repair, reuse and recycling at the heart of a cyclical process.
- **The building industry is shifting** from ‘product’ to ‘service’ by leasing, maintaining, repairing and reselling products.

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Zero waste = Maximise resources!

Source: 'Building Revolutions', David Cheshire, 2016, RIBA Publishing

Construction Waste

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- In Ireland it is estimated in a report from 2019 by the Irish Concrete Federation that the current demand for construction aggregates in Ireland **is twice the average demand in the EU.**

- An estimated 400 tonnes of aggregate is required for a typical Irish home. 4.75 million tonnes of construction and demolition waste were produced in Ireland in 2019 with over 80% comprising of soil and stones

- Whilst no comparable figures exist for Ireland, in the UK the construction industry accounts for approximately **60% of materials used**

- Therefore, there is huge **opportunity in the construction industry** to re-think the input to output process and **to implement circular economy principles to reduce waste and increase materials reuse**

Construction Waste

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- A goal of circular economy is to develop a supportive system that enables the building industry to **reuse surplus materials** (from demolition or construction waste) **in other projects.**
- This process has a potential cost saving and embodied carbon reduction
- A **material banking** platform can be used so that materials can continue to be in use after their first cycle of life.

Further reading- examples of CE

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Read about how to reuse glass from one building project to another one, here for the **Building Glass into Circular Economy How-to guide**!

learn about the reuse of steel tubes while ensuring traceability through a pipe numbering system, read here.

the **Oisín House** case study, a five-storey 1970's office block in Dublin City centre (read here), shows that processed concrete arising on site from demolition can be used for other purposes

learn about the **Materials Passports Platform prototype** for materials banking here.

Existing buildings

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- Buildings are currently under-utilised. According to the GeoView Commercial Vacancy Report in Ireland it is estimated that 13.3% of all commercial property is vacant varying from 18% in Sligo to 10% in Meath.

- **Efficient use of existing stock** avoids the need for new resources and reduces the embodied carbon of the built environment.

- This circularity may have **environmental, economic and social impacts** via the regeneration of existing urban areas, the reduction of construction noise, traffic and pollution, and the saving of raw resources

Renovation is Circular

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Constructing Healthy Buildings

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We already spend about 90% of our time inside buildings. This statistic must encourage us to ensure we design **sustainable buildings with healthy indoor environments**, operate them efficiently and ensure they last for a long time.

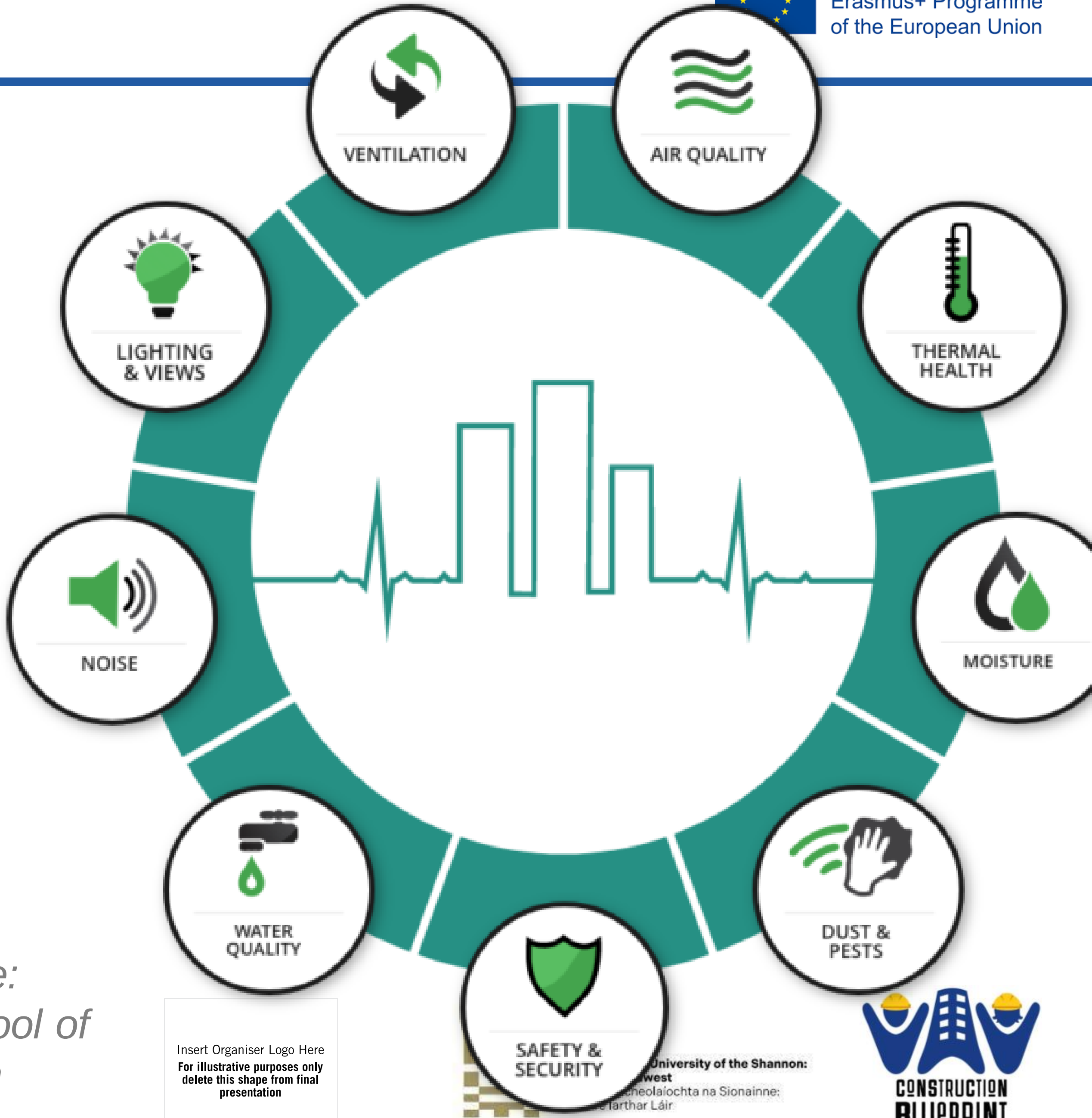

Image source: Harvard School of Public Health

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2. Circular construction techniques

Circular construction

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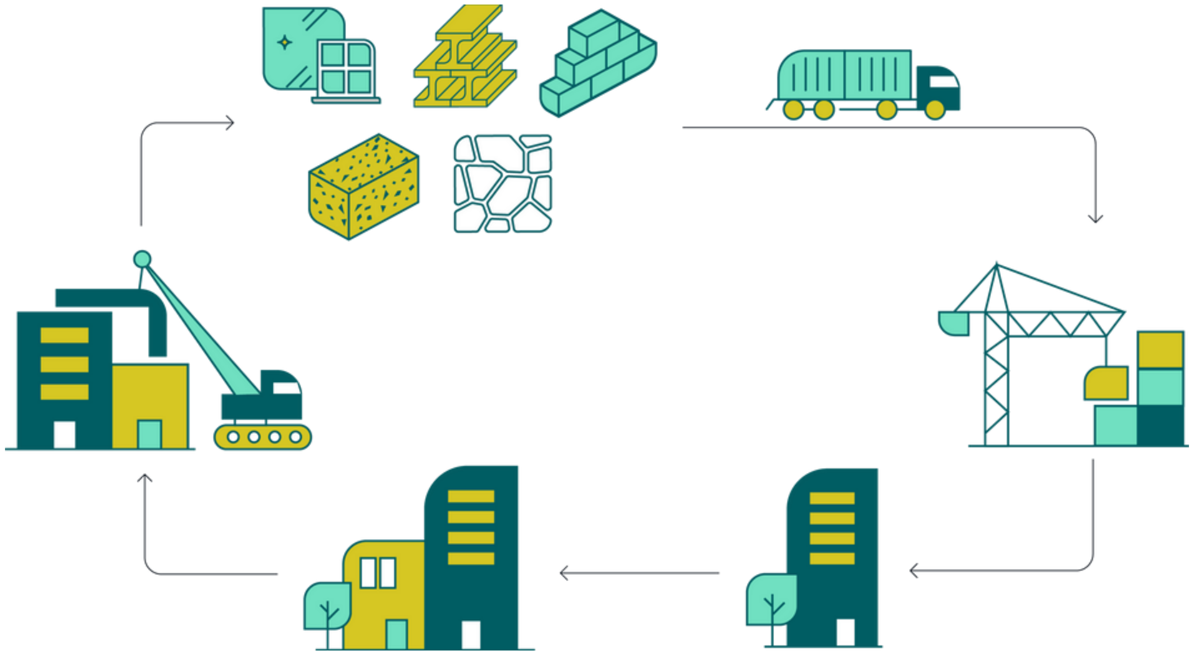
- Circular construction aims to close building material loops by **reusing, sharing, leasing, repairing, refurbishing, upcycling or recycling** rather than continuing the traditional take-make-consume-dispose process.
- It involves **considering how to maximise the lifespan and reusability of entire buildings or materials at the very start of the design process.**
- Many techniques, tools and approaches related to circular construction have been developed and tested around Europe.



Circular economy in construction

Image source: Circuit-project.eu

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On-site, prefabrication and modular

ON-SITE CONSTRUCTION

- Structure built on site
- Longer construction time
- Creates more mixed waste
- Uses more material

PREFAB + ASSEMBLY

- Elements made in factory and assembled on site.
- Shorter site time
- Less site wastage.
- Saves material in case of concrete.

MODULAR BUILDINGS

- Large building blocks made in factory and lifted on place
- Short site time
- Material efficiency varies
- Can be moveable

Construction methods and materials

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ON-SITE CONSTRUCTION

Wood: stick frame
Material efficient, may need weather protection.

Concrete: cast-in-place
uses lot of concrete, may need heat. No reuse later.

Stone/brick/rammed earth
on site built structures, typically for low-rise

PREFAB + ASSEMBLY

Wood: clt / lvl / elements
may use more material, fast to build

Concrete: prefabricated
uses less concrete, initial curing in the factory

Steel: steel frame factory made structure, with enclosure assembled

Light weight ext. Walls
factory made structure, and a lighter enclosure

MODULAR BUILDINGS

Modular wood buildings
low carbon footprint, but may damage easier if moved

3d printed buildings
other 3d printed buildings

Modular steel buildings
factory made structure, with enclosure assembled

Design for Disassembly

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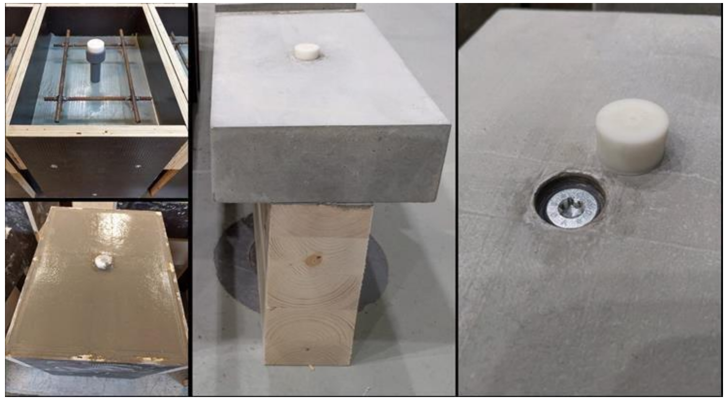
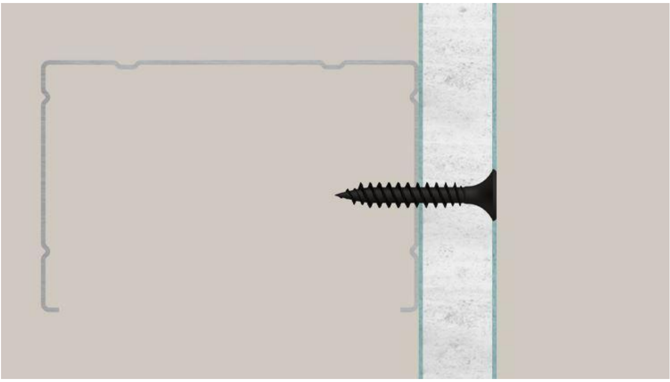
Most construction methods allow for deconstruction, **if designed for disassembly**

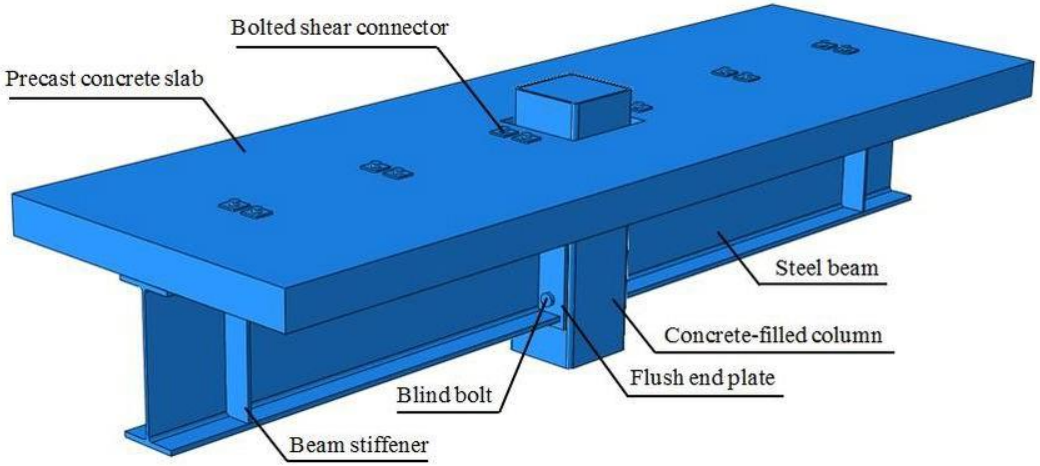
UN-DOABLE CONNECTIONS



NO NAILS, NO CHEMICALS



CONNECTION DESIGN



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Salvage and Deconstruct

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Materials can then be salvaged and deconstructed for reuse (partial or full)

FOR REUSE ELSEWHERE

FOR REUSE ON SITE

Construction materials: carbon emissions

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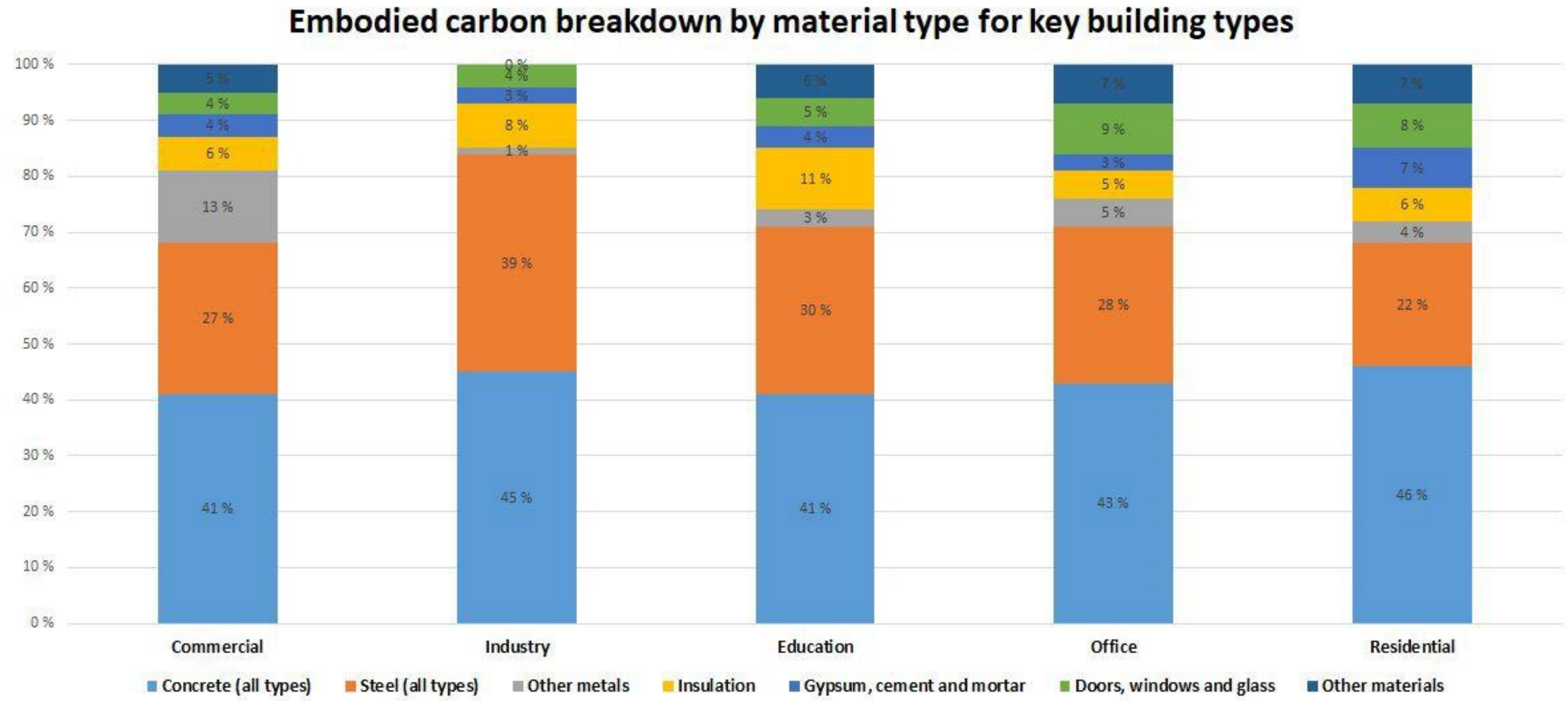

https://www.oneclicklca.com/eu-embodied-carbon-benchmarks/

Construction material types

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MINERAL-BASED

METAL-BASED

+ COMPOSITES & ASSEMBLIES

CHEMICAL-BASED

BIO-BASED

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Main construction product value chains

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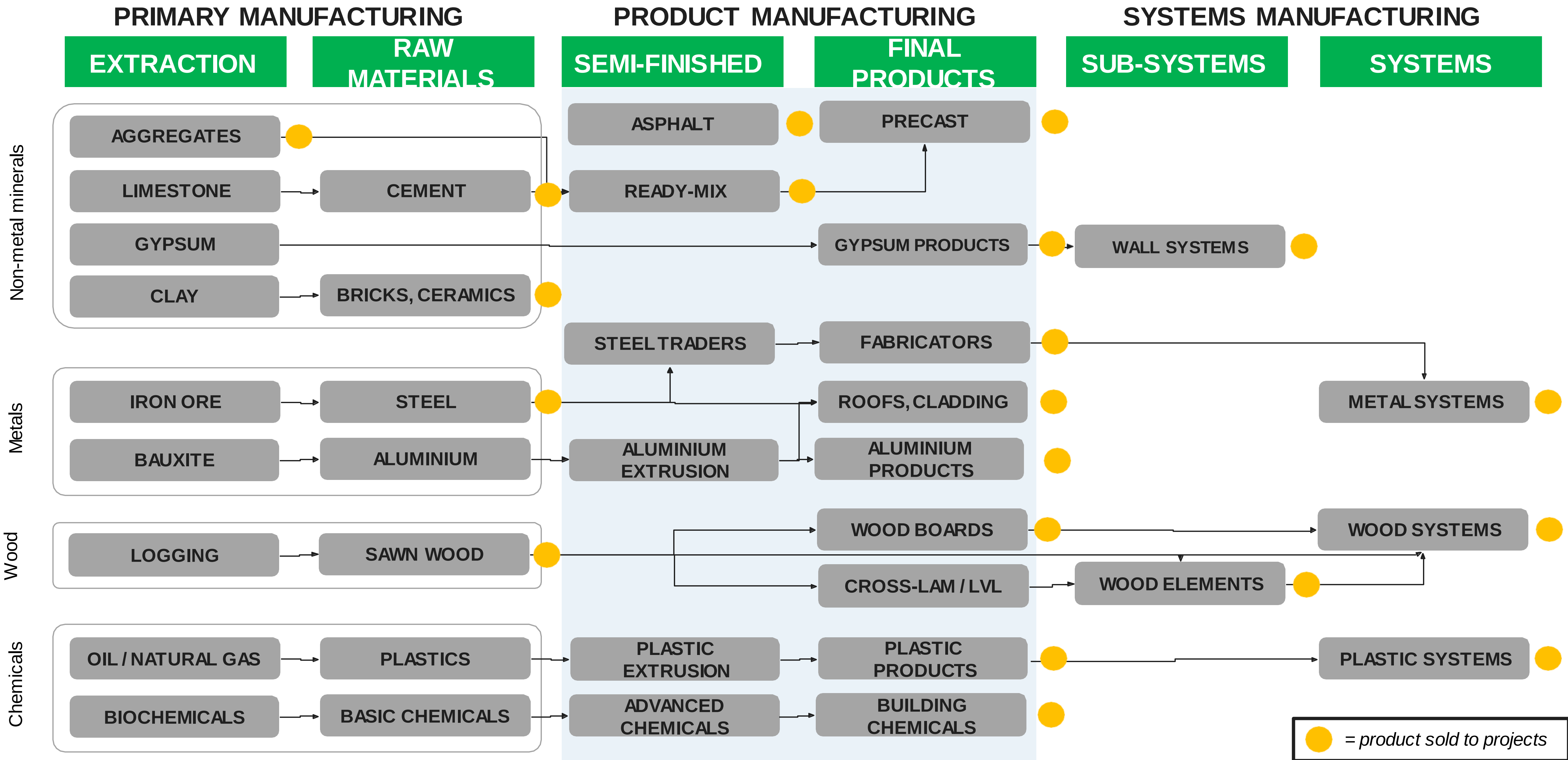

Material processing

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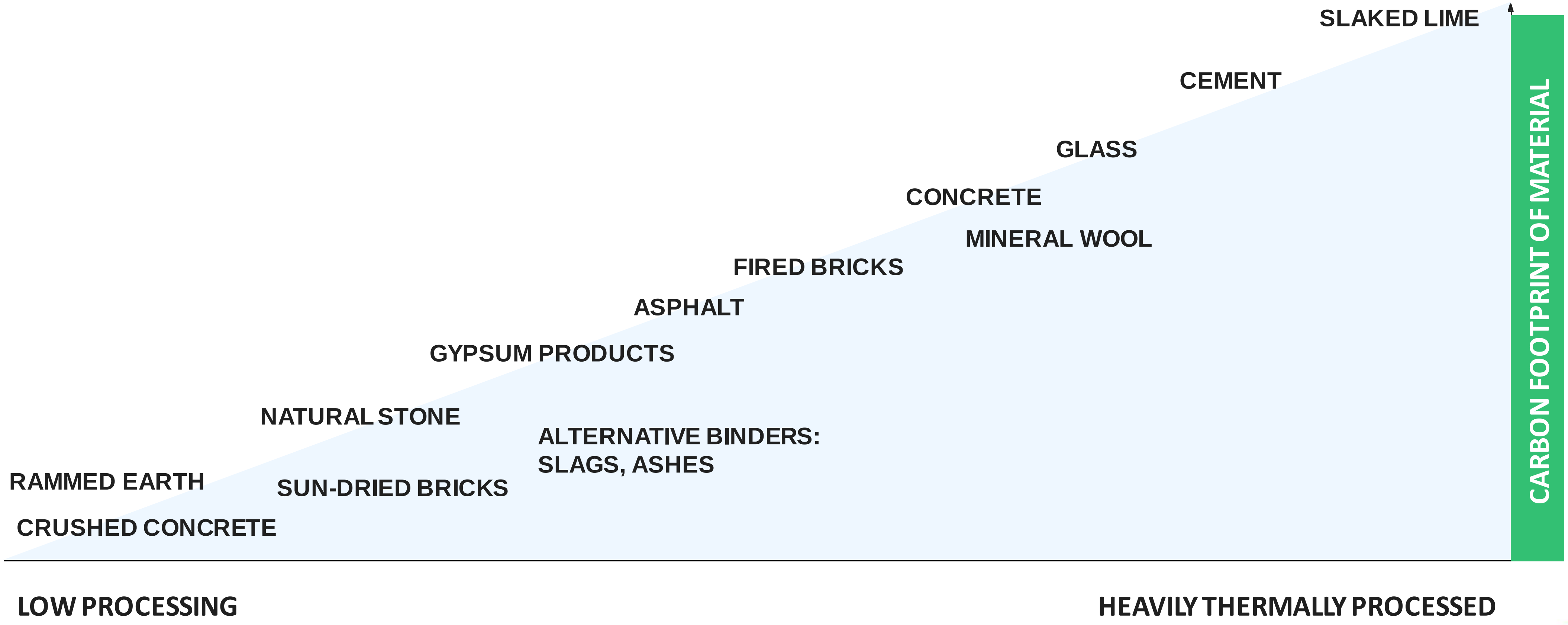
Mineral-based construction materials from the least processed to heavily thermally processed and their carbon impact



Environmental impacts of materials

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	Mineral-based	Metal-based	Chemical-based	Bio-based	Composites / assemblies
Raw material	**Easily extracted, typically local material**	Energy intensive to extract, often imported	Oil-, natural gas- or bio-based chemicals. Upstream emissions	Wood or plant fibre, or wool or fungi. Stores bio-based carbon.	Any mix or combination of the previous
Manufa-ct uring	**Thermal & chemical carbon impacts for limestone, gypsum**	Very energy intensive primary manufacturing, also process emissions	Mostly in precursor manufacturing, less in final manufacturing	Often relatively low impact even if treated	Limited for assemblies, often higher for composites
Transport	**Often local but very massive materials**	Commodities – trans-ported long distances	Depending on material – limited	Can be also very long – light materials	Depends on product mass and value
Use	**Lasts very long. May carbonate in use. Has thermal mass.**	Lasts very long.	Lifetime depends on application(s) and exposure(s)	Often is treated (but it is a choice), increases maintenance	Depends on product
End of life	**If deconstructible, can be reused, or alternatively crushed**	Easy to disassemble, recycles, forever, commercially salvaged	Currently, landfilled or incinerated but more and more raw material recycling	Currently, often incinerated/landfilled, but could be salvaged for new applications	Hard to recover for composites but assemblies can be used as they are

Cement and concrete

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- **New construction methods** that avoid the use of concrete, which constitutes the largest component of CDW, have a high impact on the reduction of waste.
- The **off-site manufacturing** of 3-D modules, like roofs, block work or external insulation, the substitution of concrete frames with timber or steel, pre-cast or composite panels have a waste reduction potential of up to 90%
- The resource-efficient use of concrete and the possibility to **deconstruct it and reuse it,** besides from being economical and reducing costs, is also important because of concrete production's environmental impact.

Image source: RTE

Cement and concrete

- The production of concrete depends on the extraction of sand and gravel, which has negative environmental impacts as it **destabilises riverbeds, putting farming land at higher risk of flooding and leaving coastal communities more vulnerable to storm damage.**
- With sand becoming scarcer and more expensive, illegal sand extraction is taking place, destroying ecosystems. Up to 10% of sand in concrete can be replaced by plastic, without affecting the structural integrity of the material.

Cement

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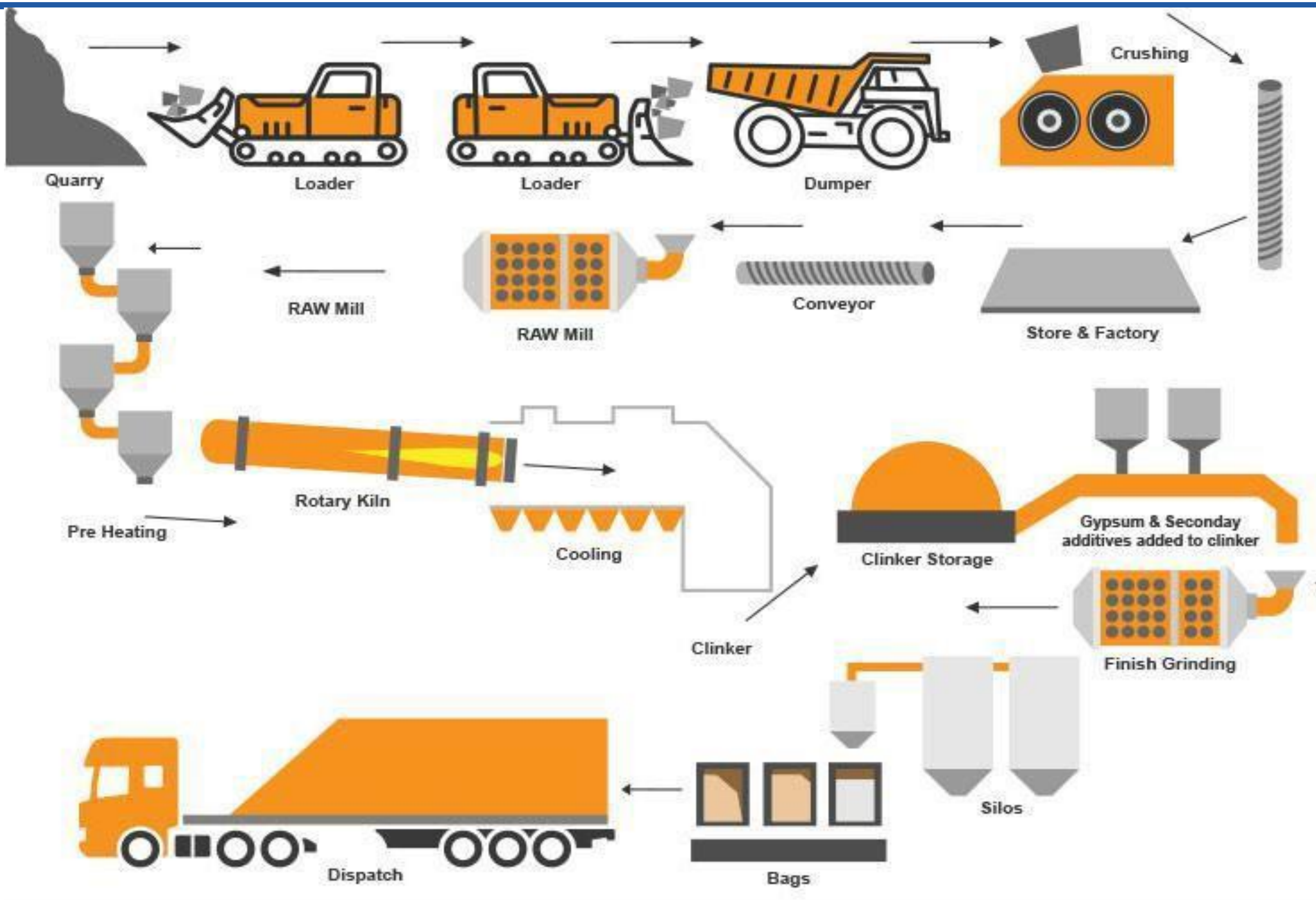
Cement is made by heating crushed limestone in a kiln to 1400 °C (2500 °F) to create clinker



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Cement climate impacts arise due to the calcination process and process fuel use.

TYPICAL IMPACT	LOWER CARBON OPTIONS
In EU, around 700 kg co2e / ton, of which more than one half due to calcination in the process. Varies by region and supplier	Alternative binders: blast furnace slag & other geopolymers, fly ash, rice husk ash and other pozzolans & gypsum and range of innovative technologies*

*https://gccassociation.org/cement-and-concrete-innovation/alternative-binders/

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https://www.cemnet.com/News/story/169720/climate-change-a-bigger-threat-than-recession-for-us-cement-producers.html?source=fb4828b5776b76c92eb98d65021ce5c1

The cement industry is extremely sensitive to climate change regulations and taxes


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CEMNET.COM » CEMENT NEWS » CLIMATE CHANGE A BIGGER THREAT THAN RECESSION FOR US CEMENT PRODUCERS

Climate change a bigger threat than recession for US cement producers

21 October 2020

Ed Sullivan, PCA senior vice-president and chief economist, gave an economic outlook for the USA and a cement business forecast on the opening day of the IEEE East Coast meeting yesterday. He advised

Ready mix concrete

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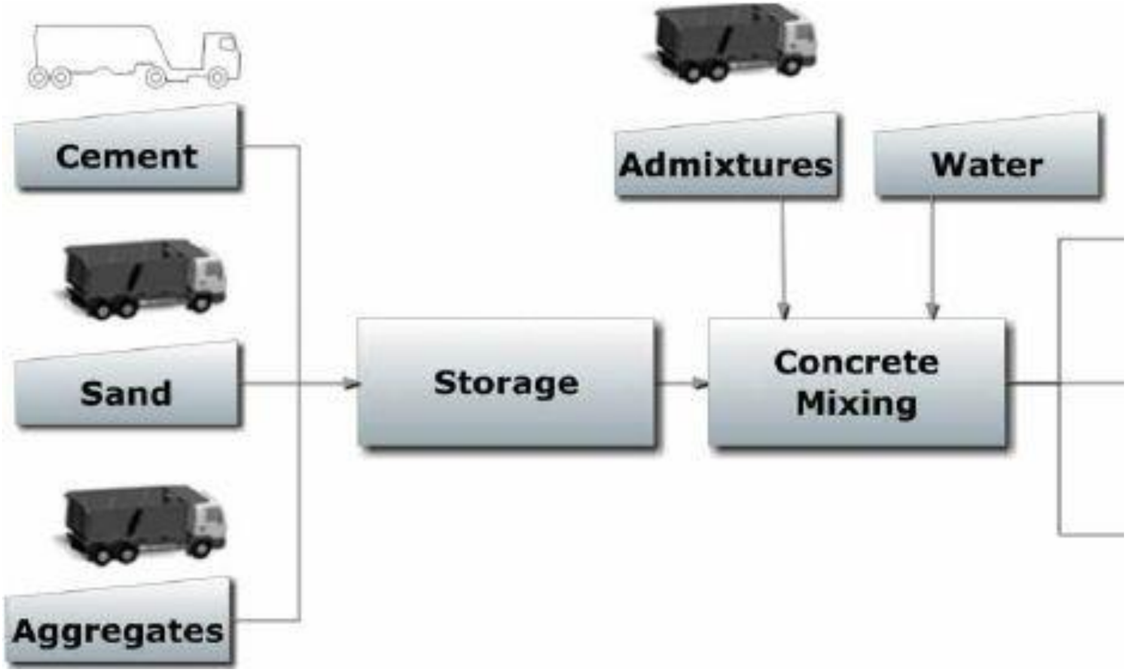
Ready mix concrete is made by mixing cement, water, aggregates & admixtures. Curing happens in formwork on site.



Ready mix concrete

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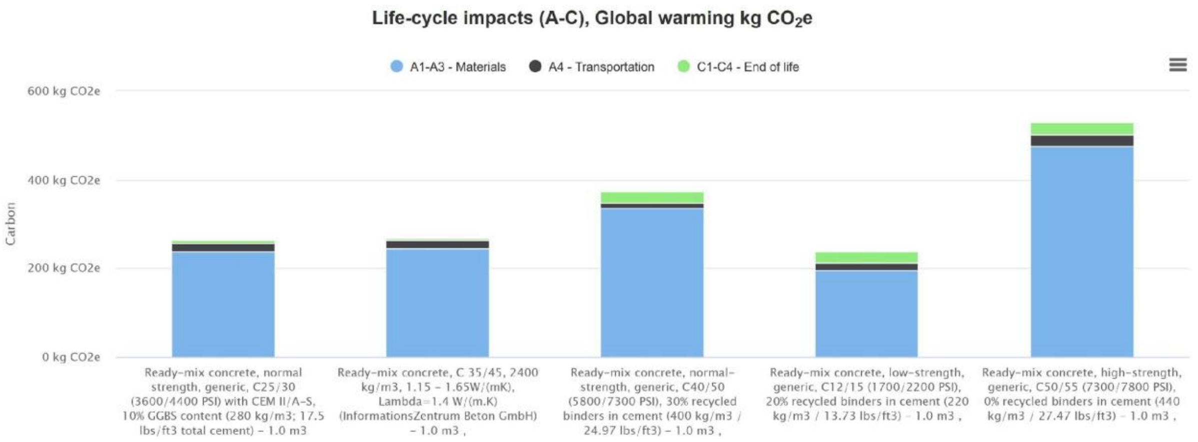
Ready mix concrete climate impact is mostly due to cement it’s using

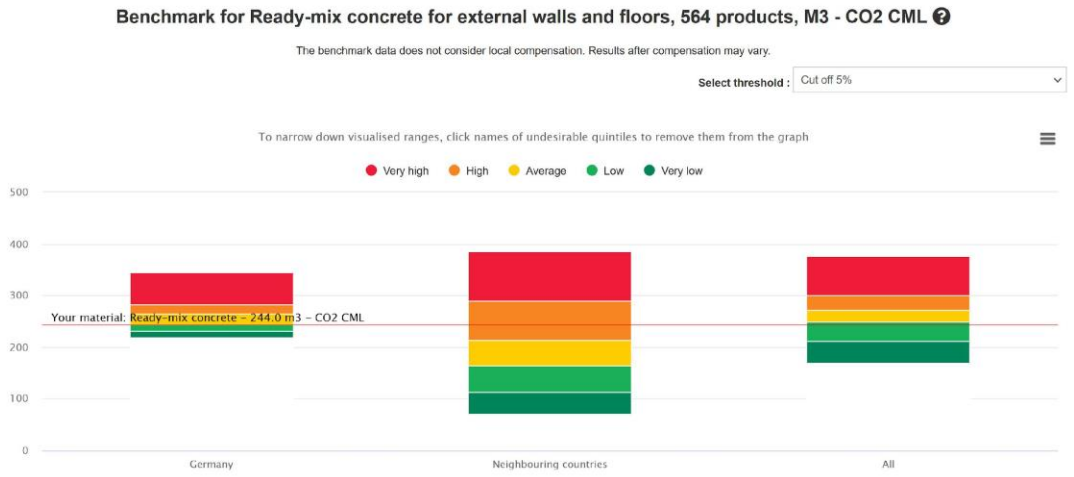
TYPICAL IMPACT

Depending on strength class, ca 200-500 kg co2e / m3 (or 100 kg per ton). Varies by region & exposure class.

LOWER CARBON OPTIONS

Substitute cement with alternative binders, longer curing time (e.g. 90 or 60d instead of 28d)





Precast concrete

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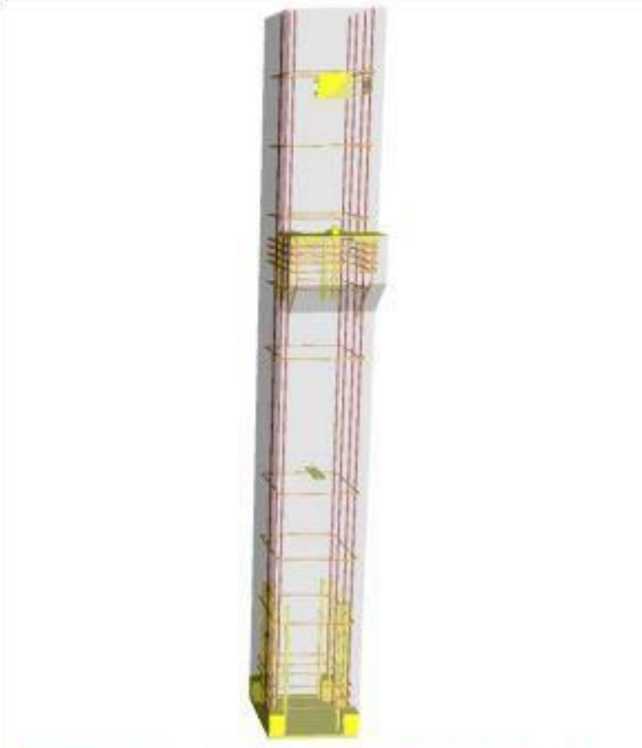
Precast concrete is made by preparing reinforcement with connections in a mould. Concrete is then poured in a factory for curing.



22 B1010.10 - LOD 400 Precast Structural Column (Concrete)

Precast concrete

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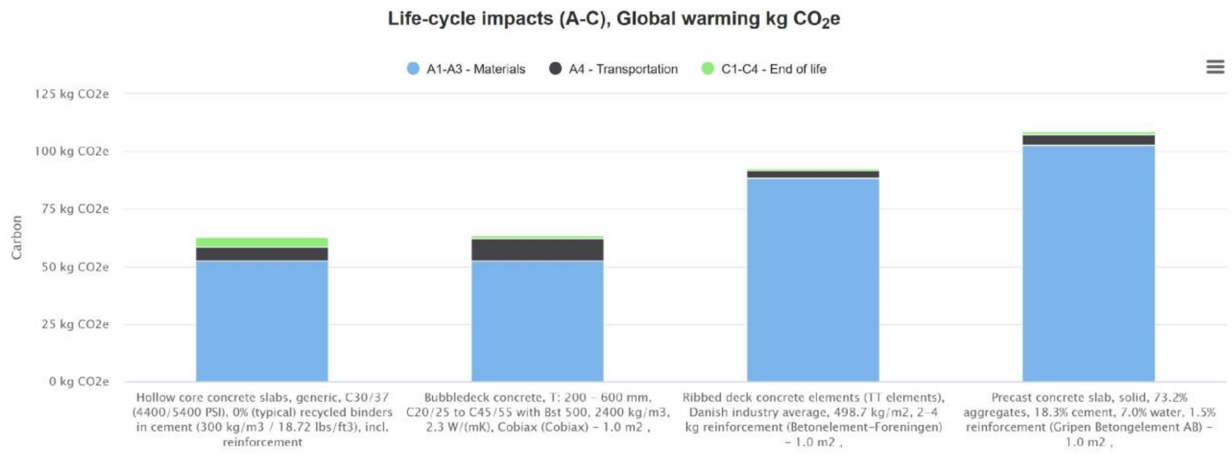
Precast environmental impact is mostly due to cement and rebar, and possible insulation

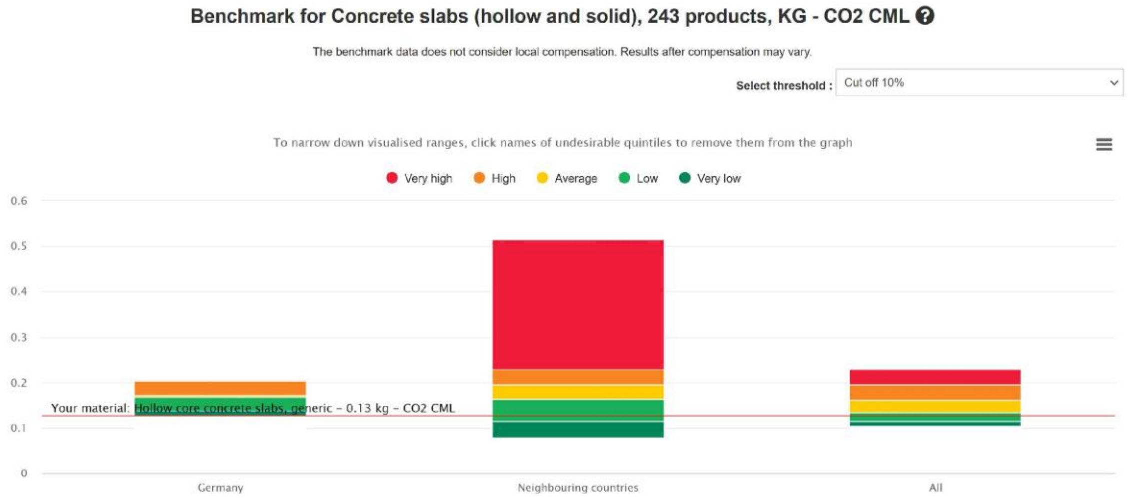
TYPICAL IMPACT

Depends completely on the function of the product in question, as strength and amount of reinforcement is based on function.

LOWER CARBON OPTIONS

Substitute cement with alternative binders, use hollow core products, consider bubbledeck, or other element design strategies





Cement blocks

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Concrete blocks are massive, having both high material use and high structural load. They are laid either with mortar or reinforcement, or use both

SOLID BLOCKS

High load bearing ability & co2 impact

HOLLOW BLOCKWORK

Much lighter, hence lower impacts, also very limited load bearing ability

ALTERNATIVE MATERIALS

Leca blocks, cinderblocks, autoclaved aerated concrete - lighter but limited load bearing

Cement and concrete

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One Click LCA

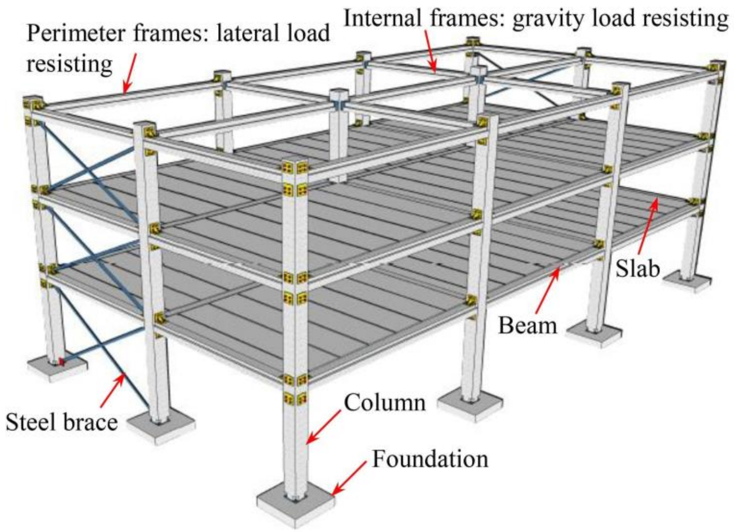
Not even 1 % of the world's concrete buildings are deconstructed at end of life…

HIGH CARBON MATERIALS

CEMENT
4 gigatons ~8 % of global GHGs

STEEL
3 gigatons ~6 % of global GHGs

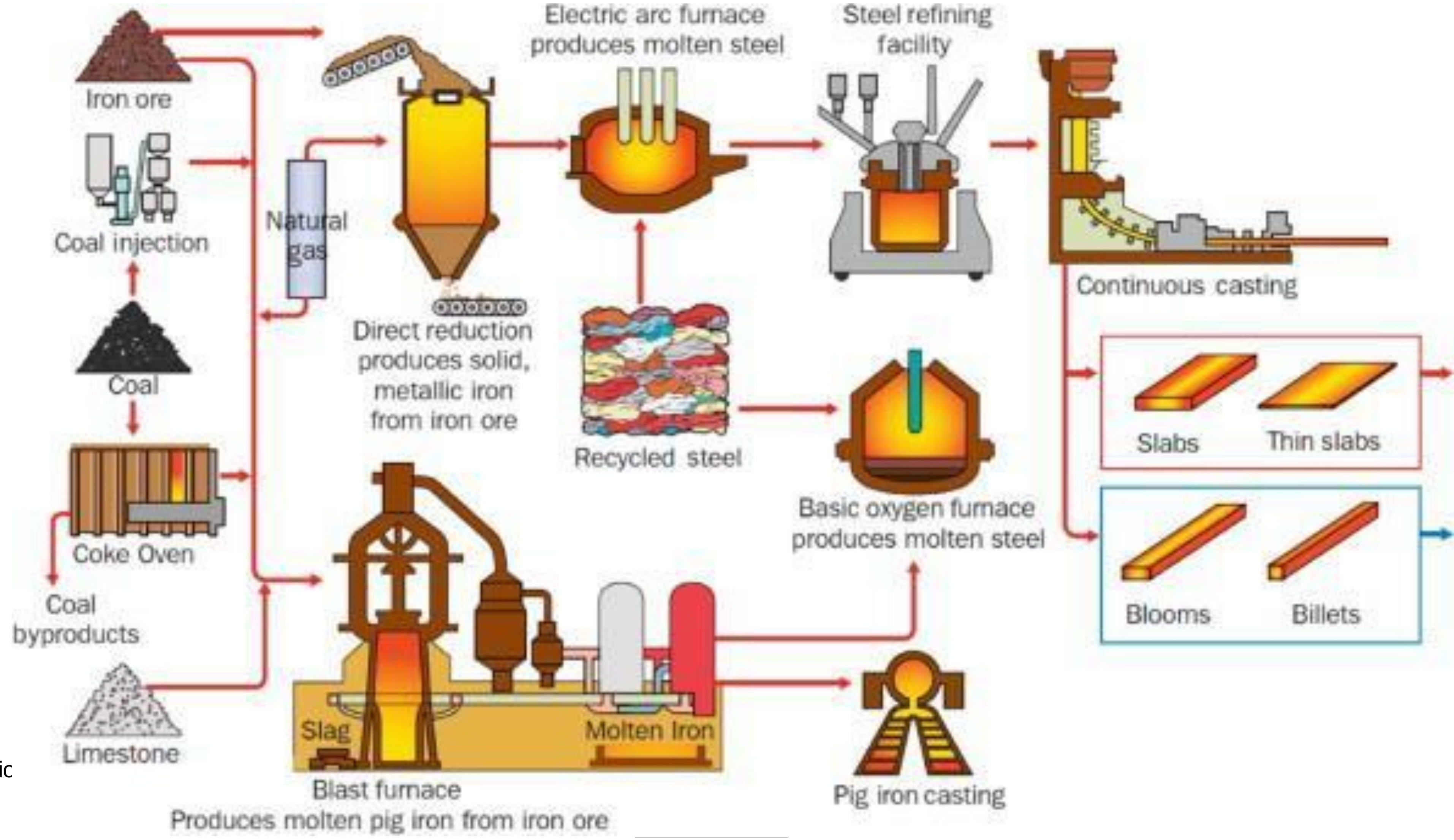
DURABLE PRECAST PRODUCTS



HIGH CARBON WASTE

Steel and aluminium

Steel is made by Electric Arc Furnace & Basic Oxygen Furnace processes at 1800/1600°C, with preliminary iron reduction to remove oxygen from ore



Steel and aluminium

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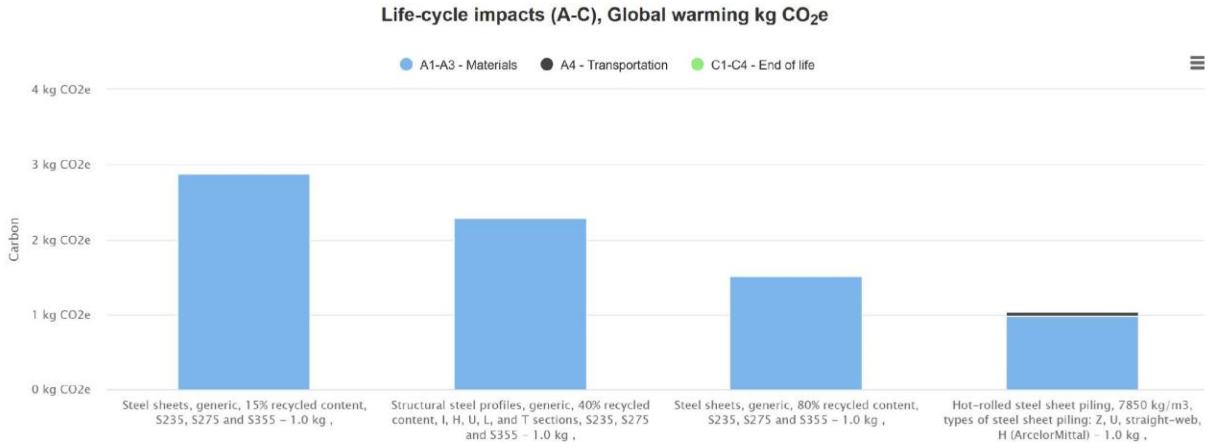
Steel manufacturing impacts are driven by fossil fuels & energy use in primary steel making

TYPICAL IMPACT

Steel carbon footprint is directly proportional to the recycled content, but also heavily influenced by manufacturing energy mix and process energy efficiency (and feedstocks)



LOWER CARBON OPTIONS

Most important at global/policy level is to favour low carbon primary steel (as scrap only covers 25% of global demand), but for project results the recycling rates make a big difference too

Aluminium

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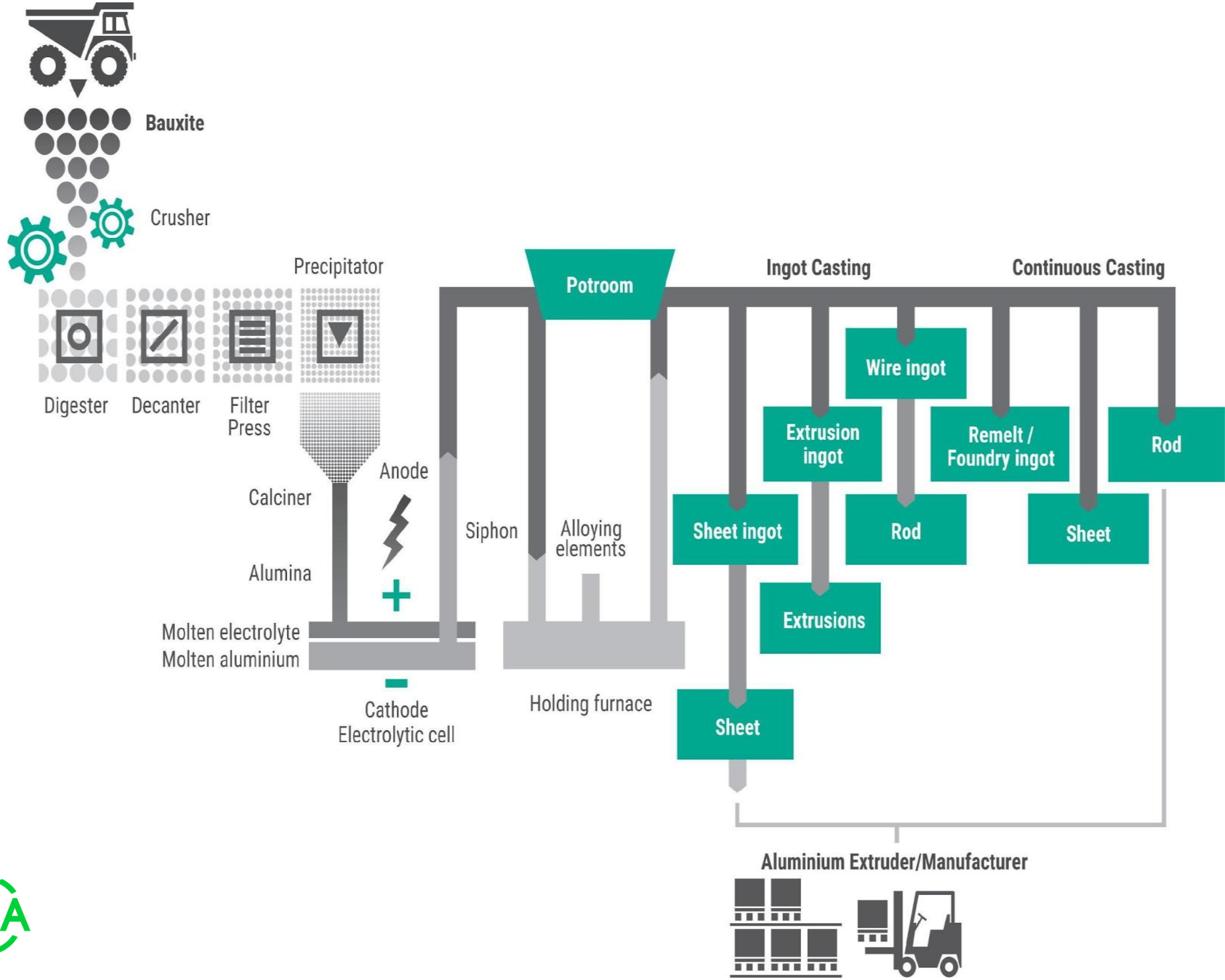
Aluminium is made by chemically & thermally processing bauxite to alumina which is then electrolyzed at temperature of 950°C



Aluminium

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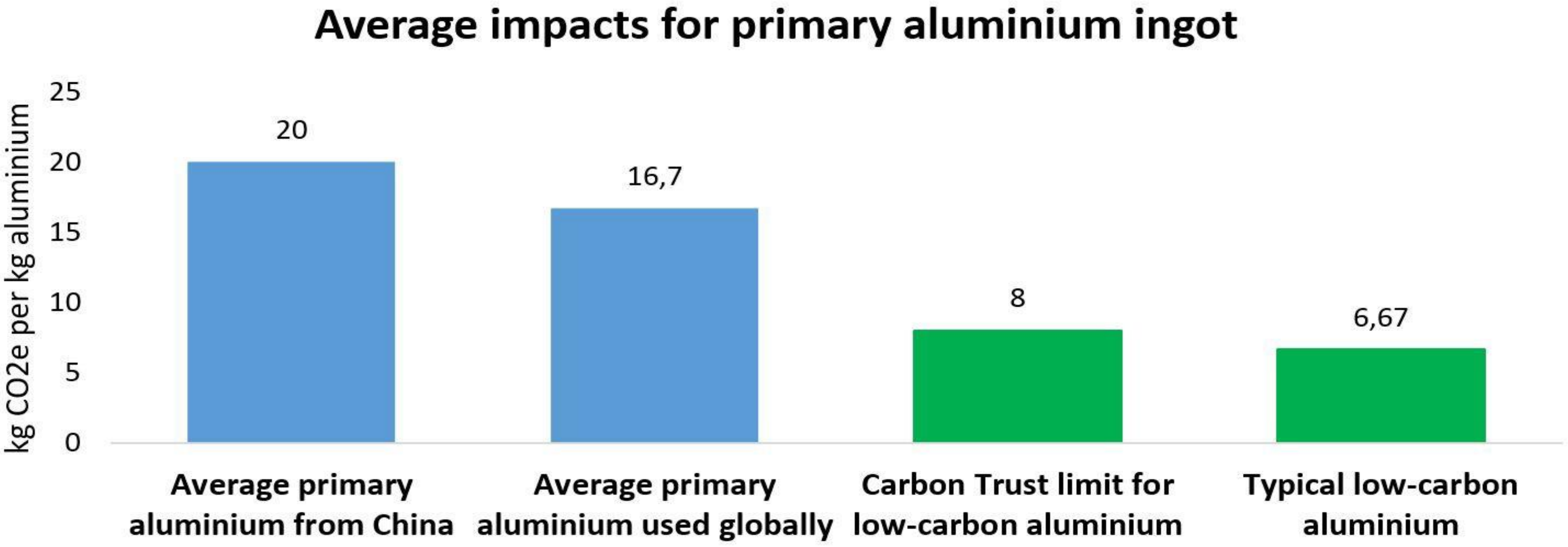
Typical impacts for primary aluminium



Aluminium

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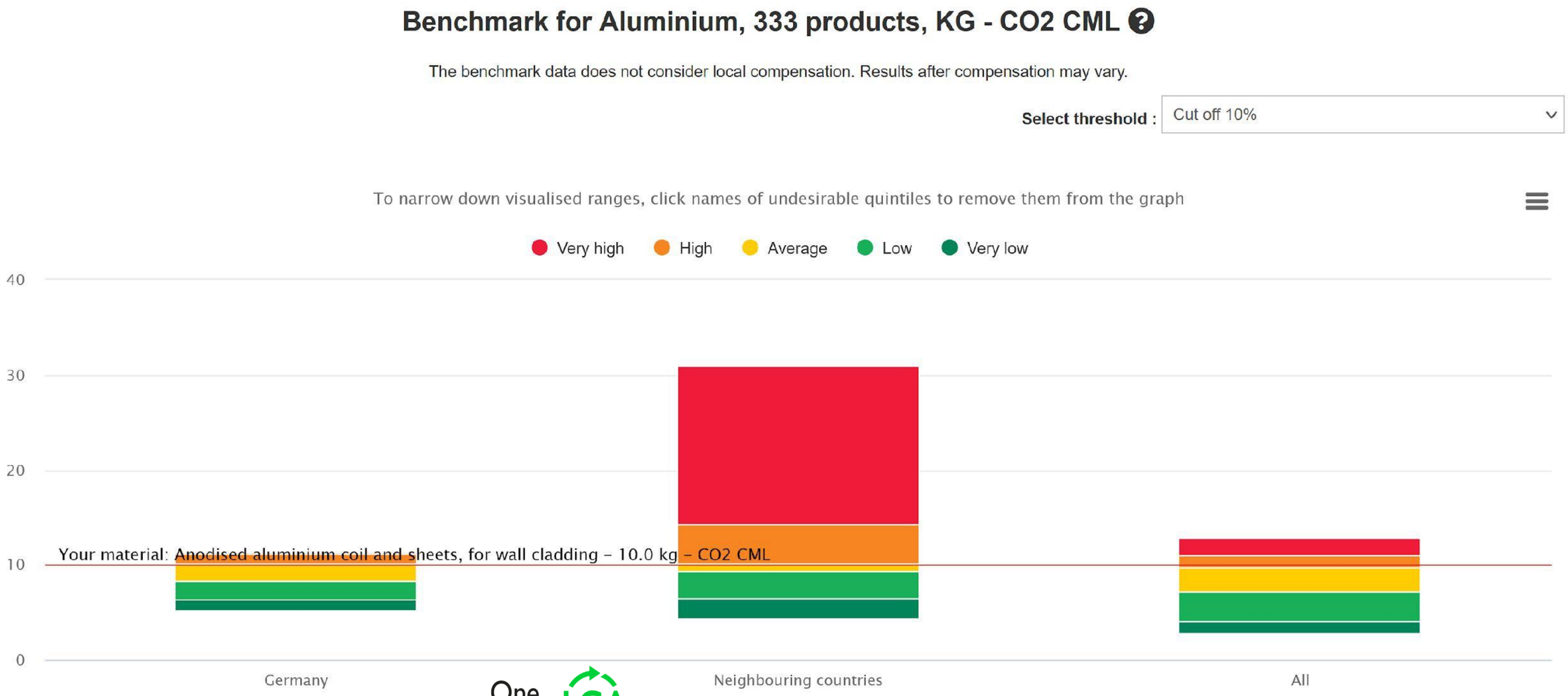
Range of aluminium impacts is vast, when recycling rates are considered



Steel and aluminium

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Metals are extremely recyclable, but focus should still to be on reuse as product and favouring low-carbon primary production

STEEL SCRAP COVERS 25 % OF GLOBAL DEMAND

ALUMINIUM SCRAP COVERS 30 % OF GLOBAL DEMAND

Wood and Wood-based products

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DO’s

- Consider material efficiency
- Consider end of life utilisability
- Consider impact of chemicals and additional protective layers timber structures would require
- Consider mass reduction timber allows to achieve for structures and foundations

DON’Ts

- Use illegally logged timber or timber from unsustainable forestry
- Let timber get landfilled at end of life (this causes huge methane emissions)
- Use unnecessary treatment or painting if not functionally required
- Don’t think carbon storage is permanent unless you secure reuse

Wood- typical impacts

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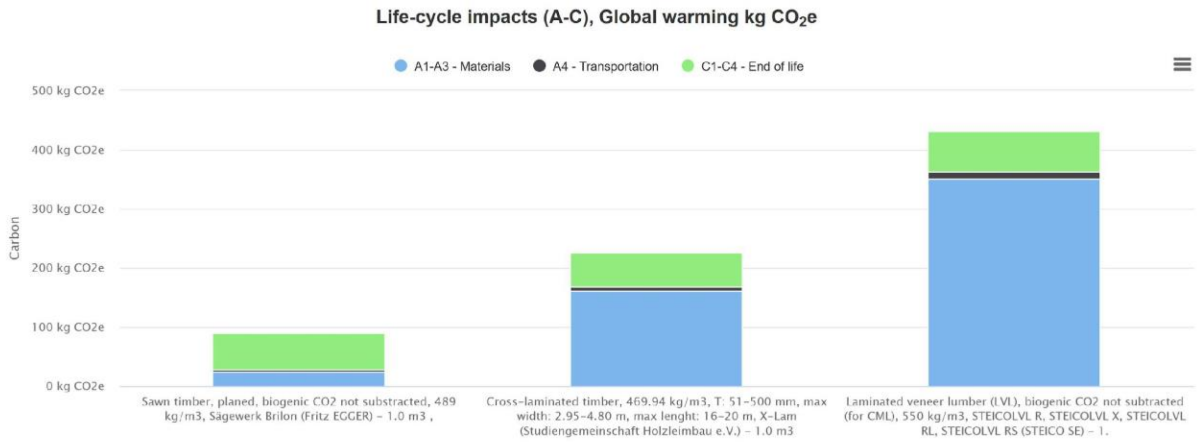
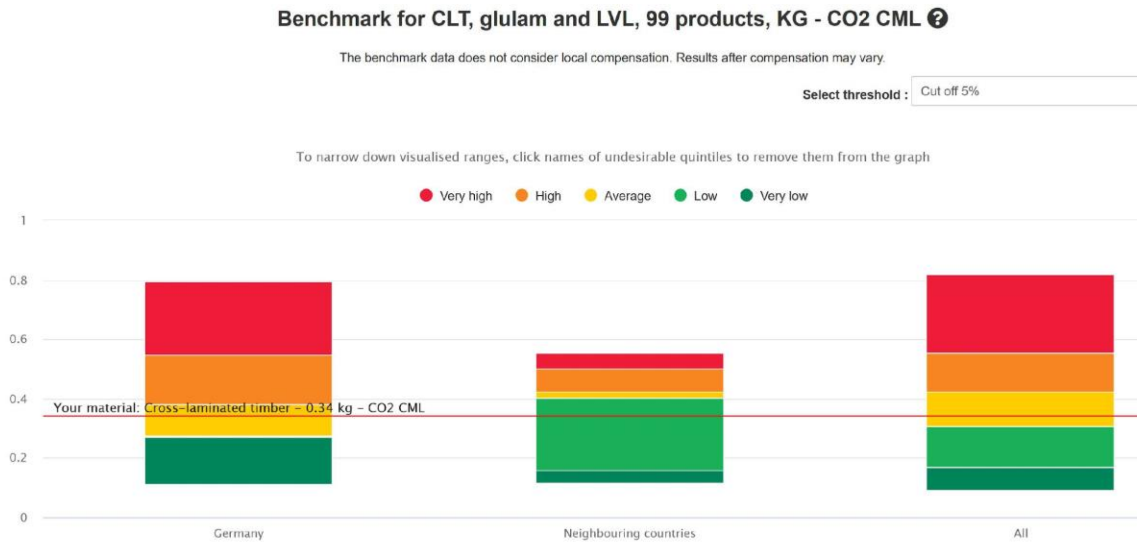
TYPICAL IMPACT

Sawn timber has naturally lower impacts than clt, glulam or lvl



LOWER CARBON CLT

Manufacturers also have some differences between products, but be wary of their accounting methods



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Insulation

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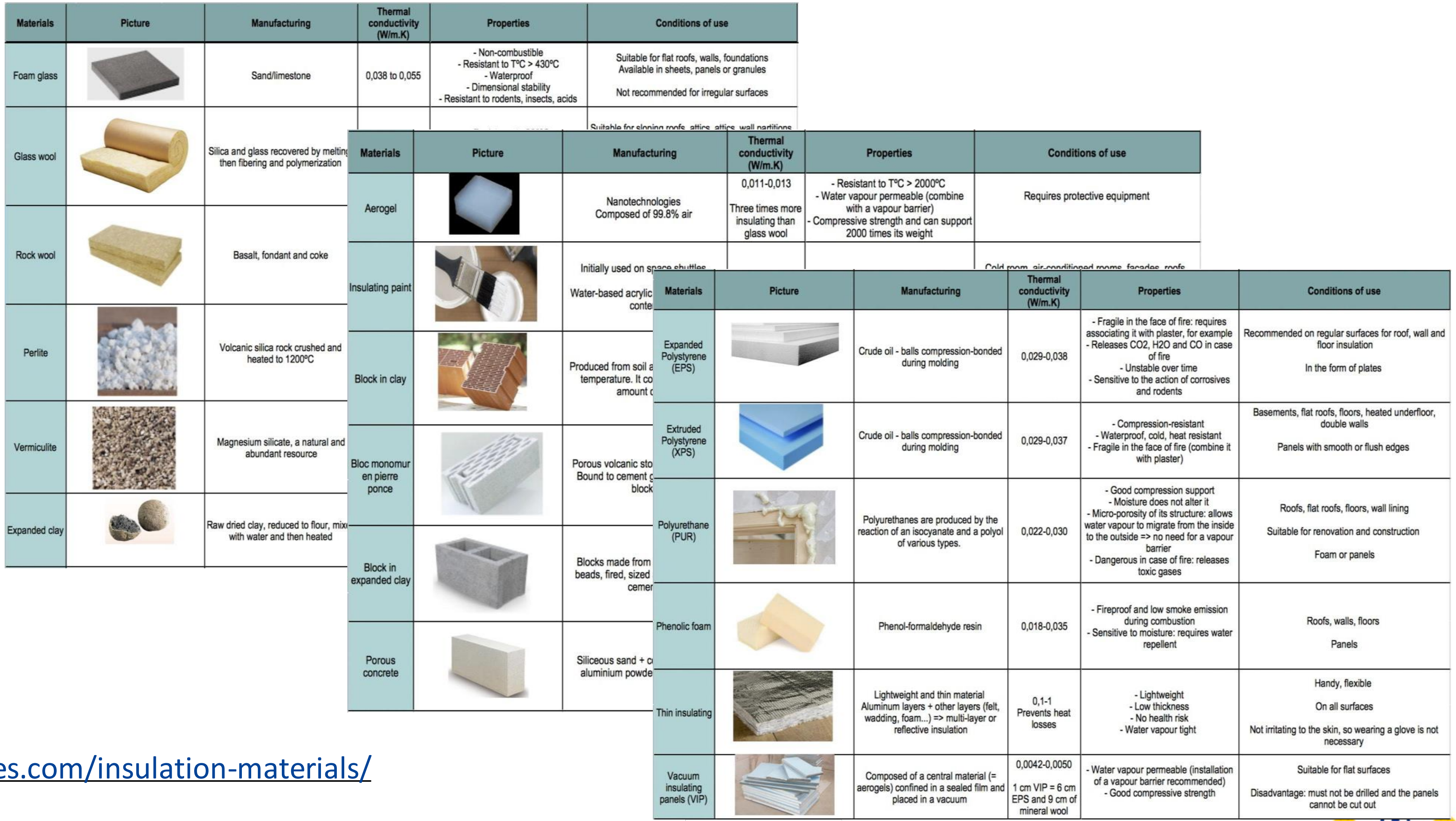
There's a vast range of types of insulation



Materials	Picture	Manufacturing	Thermal conductivity (W/m.K)	Properties	Conditions of use
Foam glass		Sand/limestone	0,038 to 0,055	- Non-combustible - Resistant to T°C > 430°C - Waterproof - Dimensional stability - Resistant to rodents, insects, acids	Suitable for flat roofs, walls, foundations Available in sheets, panels or granules Not recommended for irregular surfaces
Glass wool		Silica and glass recovered by melting then fibering and polymerization			Suitable for sloping roofs, attics, attics, wall partitions
Rock wool		Basalt, fondant and coke			
Perlite		Volcanic silica rock crushed and heated to 1200°C			
Vermiculite		Magnesium silicate, a natural and abundant resource			
Expanded clay		Raw dried clay, reduced to flour, mix with water and then heated			

Materials	Picture	Manufacturing	Thermal conductivity (W/m.K)	Properties	Conditions of use
Aerogel		Nanotechnologies Composed of 99.8% air	0,011-0,013 Three times more insulating than glass wool	- Resistant to T°C > 2000°C - Water vapour permeable (combine with a vapour barrier) - Compressive strength and can support 2000 times its weight	Requires protective equipment
Insulating paint		Initially used on space shuttles Water-based acrylic conte			Cold room, air-conditioned rooms, facades, roofs
Block in clay		Produced from soil a temperature. It co amount			
Bloc monomur en pierre ponce		Porous volcanic sto Bound to cement g block			
Block in expanded clay		Blocks made from beads, fired, sized cemen			
Porous concrete		Siliceous sand + c aluminium powde			

Materials	Picture	Manufacturing	Thermal conductivity (W/m.K)	Properties	Conditions of use
Expanded Polystyrene (EPS)		Crude oil - balls compression-bonded during molding	0,029-0,038	- Fragile in the face of fire: requires associating it with plaster, for example - Releases CO2, H2O and CO in case of fire - Unstable over time - Sensitive to the action of corrosives and rodents	Recommended on regular surfaces for roof, wall and floor insulation In the form of plates
Extruded Polystyrene (XPS)		Crude oil - balls compression-bonded during molding	0,029-0,037	- Compression-resistant - Waterproof, cold, heat resistant - Fragile in the face of fire (combine it with plaster)	Basements, flat roofs, floors, heated underfloor, double walls Panels with smooth or flush edges
Polyurethane (PUR)		Polyurethanes are produced by the reaction of an isocyanate and a polyol of various types.	0,022-0,030	- Good compression support - Moisture does not alter it - Micro-porosity of its structure: allows water vapour to migrate from the inside to the outside => no need for a vapour barrier - Dangerous in case of fire: releases toxic gases	Roofs, flat roofs, floors, wall lining Suitable for renovation and construction Foam or panels
Phenolic foam		Phenol-formaldehyde resin	0,018-0,035	- Fireproof and low smoke emission during combustion - Sensitive to moisture: requires water repellent	Roofs, walls, floors Panels
Thin insulating		Lightweight and thin material Aluminum layers + other layers (felt, wadding, foam...) => multi-layer or reflective insulation	0,1-1 Prevents heat losses	- Lightweight - Low thickness - No health risk - Water vapour tight	Handy, flexible On all surfaces Not irritating to the skin, so wearing a glove is not necessary
Vacuum insulating panels (VIP)		Composed of a central material (= aerogels) confined in a sealed film and placed in a vacuum	0,0042-0,0050 1 cm VIP = 6 cm EPS and 9 cm of mineral wool	- Water vapour permeable (installation of a vapour barrier recommended) - Good compressive strength	Suitable for flat surfaces Disadvantage: must not be drilled and the panels cannot be cut out

https://www.ecopassivehouses.com/insulation-materials/

Insulation

Co-funded by the Erasmus+ Programme of the European Union

DO's	DON'Ts
• Avoid spray foam and foam insulation with unspecified blowing agents (esp. Outside eu/eea) • Prefer recoverable insulation (avoid chemical bonds with moisture barrier) • Consider low-carbon or carbon-storing insulation materials • Consider impact of insulation layer thickness on total structural materials demand (if walls become 100mm thicker, what does it mean)	• Allow for use of spray foam and use of unspecific foam insulation materials • Reduce insulation to grow energy use without considering life-cycle impact • Forget to recycle clean insulation waste for built on site projects

Gypsum

Co-funded by the Erasmus+ Programme of the European Union

Gypsum is recovered both from nature and from the flue gas of coal-fired power plants and used in several types of construction products

GYPSUM BOARDS

Installed with steel or wood studs, do ensure adaptable installation

FINISHING PLASTER

For levelling non load bearing surfaces

FLOORING SCREED

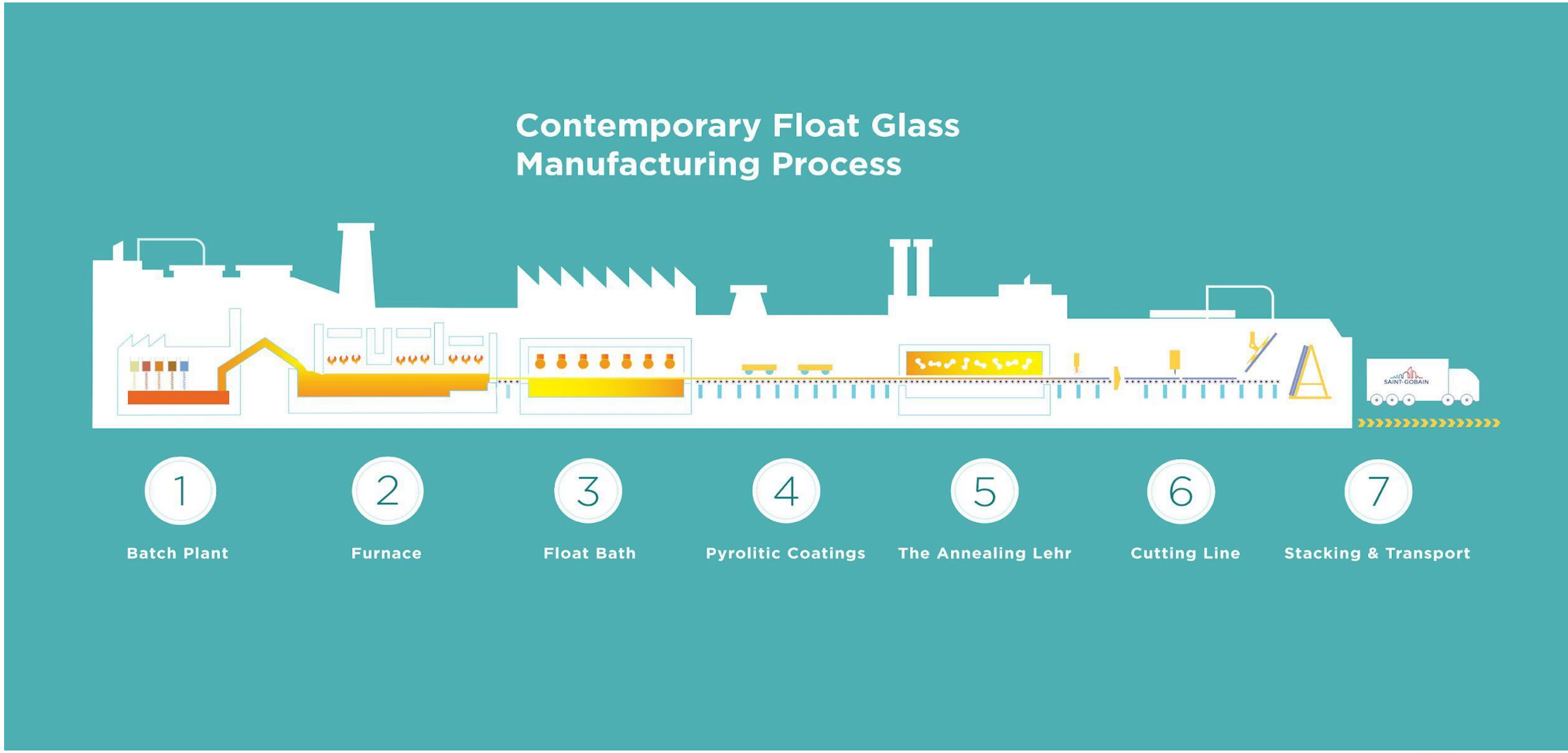
Alternative to cement flooring screeds

Glass

Co-funded by the Erasmus+ Programme of the European Union

https://in.saint-gobain-glass.com/glass-manufacturing-process

Float glass is made from silica sand in an integrated process in temperature of up to 1600°C. Once made, it lasts for a very long time.



Bricks

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Bricks have a climate impact themselves, and they are laid using a cement-based mortar

FIRED BRICKS

Fired clay. Impact mostly from the fuel.

AIR-DRIED BRICKS

Not load bearing (unless cementious)

RECLAIMED BRICKS

Separated from the mortar already

WALL SECTIONS

Sections from walls come with mortar

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QUIZ!

TUS
Technological University of the Shannon: Midlands Midwest
Ollscoil Teicneolaíochta na Sionainne: Lár Tíre Iarthar Láir

CONSTRUCTION BLUEPRINT

CONSTRUCTION BLUEPRINT

Thank You

Insert Organiser Logo Here
For illustrative purposes only delete this shape from final presentation

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TUS Technological University of the Shannon: Midlands Midwest

FUNDACIÓN LABORAL DE LA CONSTRUCCIÓN

BAU INDUSTRIE Nordrhein-Westfalen

Gospodarska zbornica Slovenije – Zbornica gradbeništva in industrije gradbenega materiala

DAS DEUTSCHE BAUGEWERBE

BZB Bildungszentren des Baugewerbes e.V.

AKMH

CCCA-BTP Le réseau de l'apprentissage BTP

Cenfic Centro de Formação Profissional da Indústria da Construção Civil e Obras Públicas do Sul

CENTRE IFAPME Liège-Huy-Verviers

European Federation of Building and Woodworkers EFBWW

ŠOLSKI CENTER KRANJ

CNC Confederación Nacional de la Construcción

EBC Construction SMEs Europe

FFB Fédération Française du Bâtiment

FIEC European Construction Industry Federation

Lietuvos Statybininkų Asociacija

Związek Zawodowy Budowlani

SATAEDU

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