Net-Zero Roadmap

for Autoclaved Aerated Concrete

Executive summary

This roadmap sets out a pathway for Autoclaved Aerated Concrete (AAC) products to reach net-zero emissions by 2050 with the potential to become carbon negative, thereby absorbing more carbon dioxide from the atmosphere than they produce.

The roadmap aligns the European Autoclaved Aerated Concrete Association (EAACA) and its members with the objectives of the Paris Agreement to limit global warming to 1.5°C and supports policies to decarbonise Europe's buildings and construction sectors.

AAC is a lightweight, yet strong and durable building material that offers ultra-efficient thermal insulation, optimum fire protection, and a high load-bearing capacity. With its net-zero roadmap and the potential to become carbon negative, AAC has a role to play as a building material in helping to reduce the life-cycle emissions of Europe's buildings.

The roadmap sets out the main levers that must be applied to achieve this. We have drawn these from known technologies and have based our net-zero target on a life-cycle analysis provided by an independently verified Environmental Product Declaration. As the majority of CO_2e emissions come not from the manufacture of AAC itself, but from the manufacture of two key raw materials – cement and lime – the roadmap draws on the decarbonisation pathways published by global and European cement and lime industry associations.

The building and construction sectors account for a significant share of Europe's greenhouse gas emissions that contribute to climate change. Through this roadmap, the EAACA and its members are committed to achieving net-zero emissions in AAC products by 2050 and supporting the development of a climate-neutral Europe.

The AAC roadmap uses known technologies and is based on a life-cycle analysis from an independently verified Environmental Product Declaration.

About the EAACA

The European Autoclaved Aerated Concrete Association (EAACA) represents the interests of producers of autoclaved aerated concrete (AAC) and their national associations across Europe. Founded in 1988, EAACA has members from 19 countries operating more than 100 production sites and producing 17.5 million m^3 of AAC per year, enough to build about 400,000 homes.

EAACA in numbers

19 member countries

101 production sites

17.5 million m^3 of AAC per year

Equivalent to **400,000** homes

What is AAC?

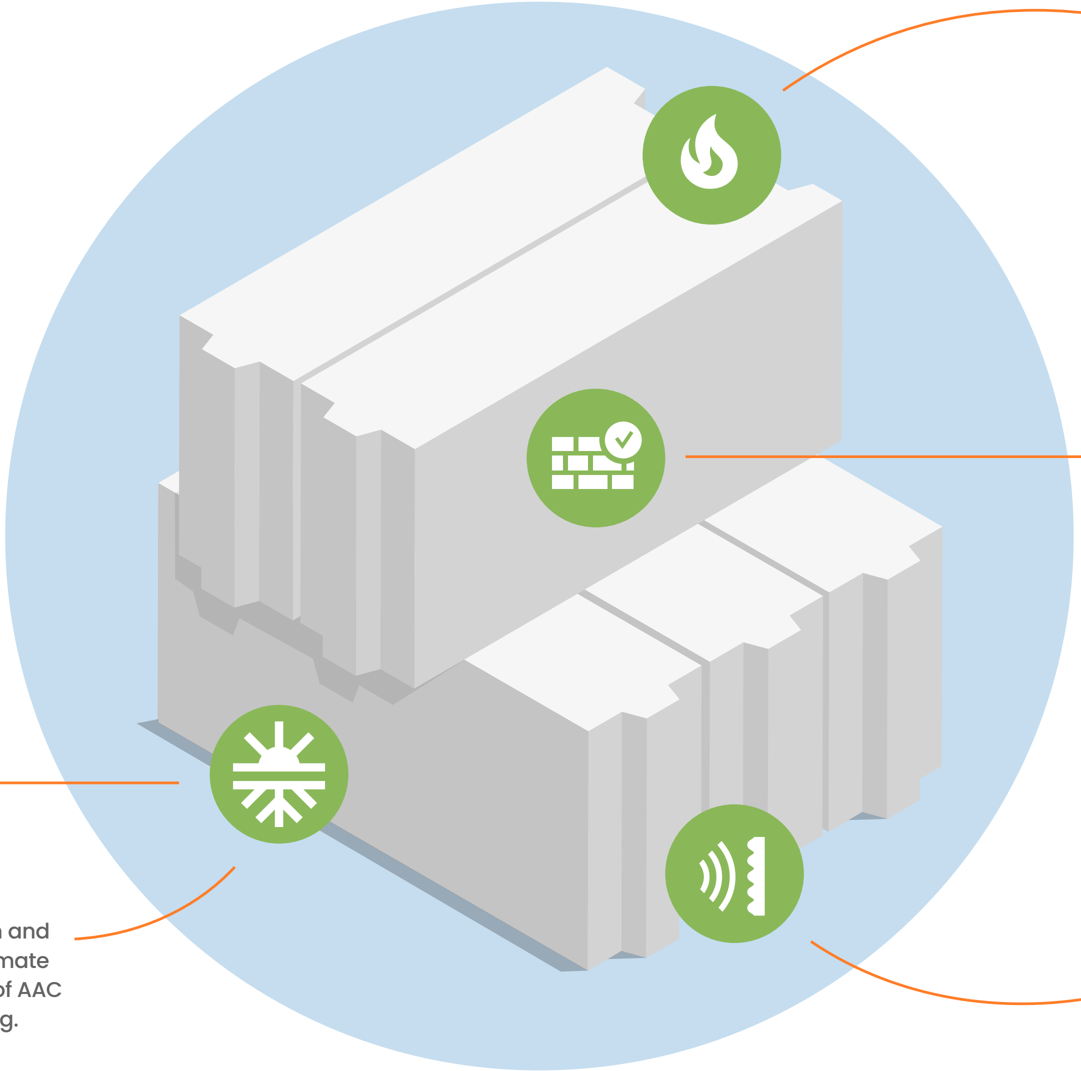
Autoclaved Aerated Concrete (AAC) is a lightweight, yet strong and durable building material that offers ultra-efficient thermal insulation, optimum fire protection, and a high load-bearing capacity.

The first AAC production started in 1929 in Europe and it is now produced in a wide range of formats, from blocks to large wall, floor and roof panels. Due to its light weight (20% of the weight of conventional concrete), AAC products are easy to handle, cut and shape with standard tools. Construction times are typically 2-5 times faster with AAC than conventional methods. AAC is also durable and long-lasting with a reference service life of 150 years.

AAC has become one of the most widely used building products around the world for residential, commercial and industrial construction. In Europe, AAC volumes are expected to remain steady at around 17.5 million m^3 per year for the forseeable future.

AAC's unique characteristics

AAC's unique characteristics mean low energy, passive, zero carbon, zero energy and even plus energy houses can be realised with monolithic, single leaf and cavity wall masonry constructions.



Thermal insulation performance

Thanks to the air pores in the material, AAC has excellent thermal efficiency which allows for significant savings on heating and cooling costs. The benefits can be highly significant since AAC constructions offer excellent solutions to provide low energy buildings. AAC constructions in the building fabric and envelop provide low levels of heat loss, with low levels of thermal transmittance (U values), low levels of linear thermal bridging and excellent airtightness.

Thermodynamic performance

AAC's combination of density, thermal transmission and heat storage capacity provides optimum indoor climate and living comfort. The thermodynamic behaviour of AAC helps to save energy for heating and air conditioning.

Fire resistance

AAC provides the highest security against fire and meets the most stringent fire safety requirements. Due to its purely mineral composition, AAC is classified as a non-combustible building material. It is both resistant to fire up to 1200°C and does not allow the spread of flame. AAC is also free of pollutants, which means that in the case of fire, no toxic substances are generated or released.

Structural performance

AAC is extremely strong and durable despite its light weight. This high load bearing capacity at a comparably low mass results in comparably low raw material expenditure. AAC's solidity comes from a solid matrix of calcium silicate hydrates that encloses its millions of air pores and from the process of curing in a pressurised steam chamber, an autoclave. Its excellent mechanical properties make it an appropriate construction material for earthquake zones.

Sound insulation

AAC has excellent sound insulation properties compared to other building materials with the same weight.

How is AAC made?

AAC is made from cement, lime, fine sand, other siliceous materials, gypsum, water and a small amount of aluminium powder (manufactured from a by-product of aluminium). When AAC is mixed and cast in forms, several chemical reactions take place that give AAC its light weight and thermal properties:

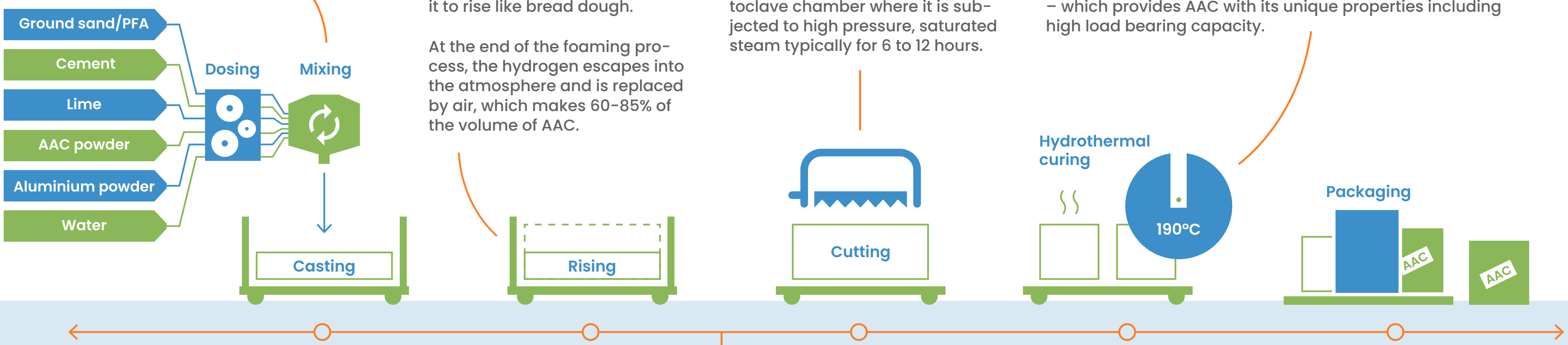
In the alkaline raw materials mixture, aluminium particles react to form millions of microscopic hydrogen bubbles.

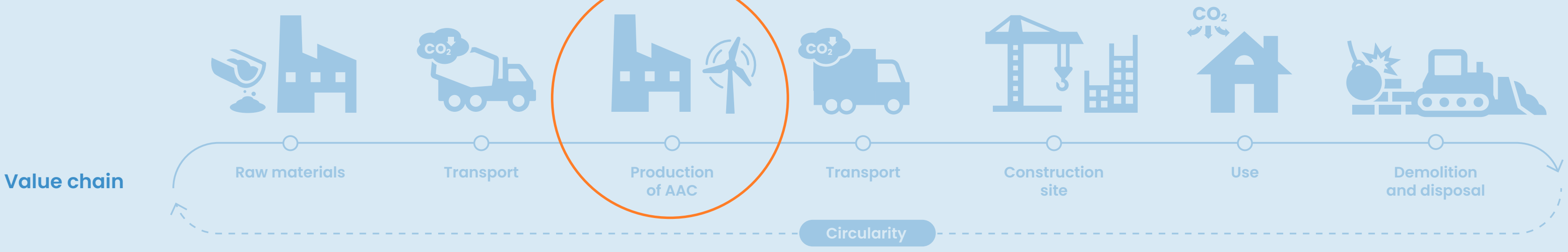
The hydrogen gas foams and increases the volume of the raw mix creating bubbles up to 3 millimetres in diameter, causing it to rise like bread dough.

At the end of the foaming process, the hydrogen escapes into the atmosphere and is replaced by air, which makes 60-85% of the volume of AAC.

When the AAC cake is removed from the mould, it is solid but still soft. It is then cut into either blocks or elements and placed in an autoclave chamber where it is subjected to high pressure, saturated steam typically for 6 to 12 hours.

During this steam pressure hardening process, when the temperature reaches 190 °C and the pressure reaches 800 to 1,200 kPa, quartz sand reacts with calcium hydroxide to form calcium silicate hydrates – in particular tobermorite – which provides AAC with its unique properties including high load bearing capacity.





AAC carbon emissions

Based on a life-cycle analysis, the majority of emissions – around 74% – come from the manufacture of cement and lime. Around 13% of emissions come from the manufacture of AAC itself.

Based on a life-cycle analysis (LCA), the majority of CO_2e emissions come not from the manufacture of AAC itself, but from the manufacture of two key raw materials – cement and lime. Together, cement and lime account for approximately 74% of the life-cycle emissions of a typical AAC product.

These emissions lie upstream with the cement and lime producers and are an unavoidable result of the chemical reaction that occurs when carbon is removed from limestone to produce clinker, the main ingredient in cement. The CO_2 released in this reaction makes the decarbonisation of cement and lime challenging, though not unsolvable.

Emissions from the production of AAC in factories account for approximately 13% of life-cycle emissions, which are significantly lower than those associated with cement and lime. The main source of these production emissions are fossil fuels such as coal and natural gas that are used to power the boilers that provide steam to the autoclaves. Emissions from electricity generated to power ball mills, offices, warehouses and other facilities amount to approximately 3%.

The remaining emissions lie with other companies in the value chain for activities that include transportation of raw materials and distribution of the AAC product to the construction site (around 3%), emissions that occur on the construction site (2%) and the end-of-life disposal of AAC to the landfill (5%).

The LCA is based on an Environmental Product Declaration (EPD) independently verified by the Institut Bauen und Umwelt (IBU) using data sourced from a representative AAC factory in 2020. The LCA covers the full cradle-to-grave emissions, from the production of the raw materials and manufacture of the AAC product, to transport, building site construction and the use stage of the completed building, through to end-of-life demolition, waste processing and disposal.

The LCA shows that the cradle-to-grave GWP (Global Warming Potential) impact of $1m^3$ of AAC manufactured in the reference plant with a bulk density of 388 kg/m^3 is 104 kg CO_2e. This includes recarbonation, a process in which all cement and lime-based products naturally absorb CO_2 from the atmosphere during their lifespan, acting as permanent carbon sinks during the use phase of a building and when it is pulled down and recycled. Recarbonation of concrete is a well-established science and recognised by the IPCC in its Sixth Assessment Report as an important carbon emissions sink.

As indicated in the EPD, AAC products can absorb 77 kg of CO_2 per m^3, with 80% of recarbonation achieved after 50 years and 95% within 80 years[1].

The diagram on the right provides an overview of the main sources of emissions for AAC. As recarbonation removes emissions, it is not included in the graph and the GWP impact has been adjusted to include the gross emissions impact without it.

Emissions sources for AAC

2%

Construction Site

Process emissions from the assembly of AAC units at the construction site

3%

Electricity

Production of electricity used to power ball mills, offices, warehouses and other facilities

3%

Transportation

Combustion of fuels in vehicles transporting raw materials to factories and finished products to customers

5%

Disposal to landfill

Process emissions from the demolition and disposal of buildings at end-of-life

13%

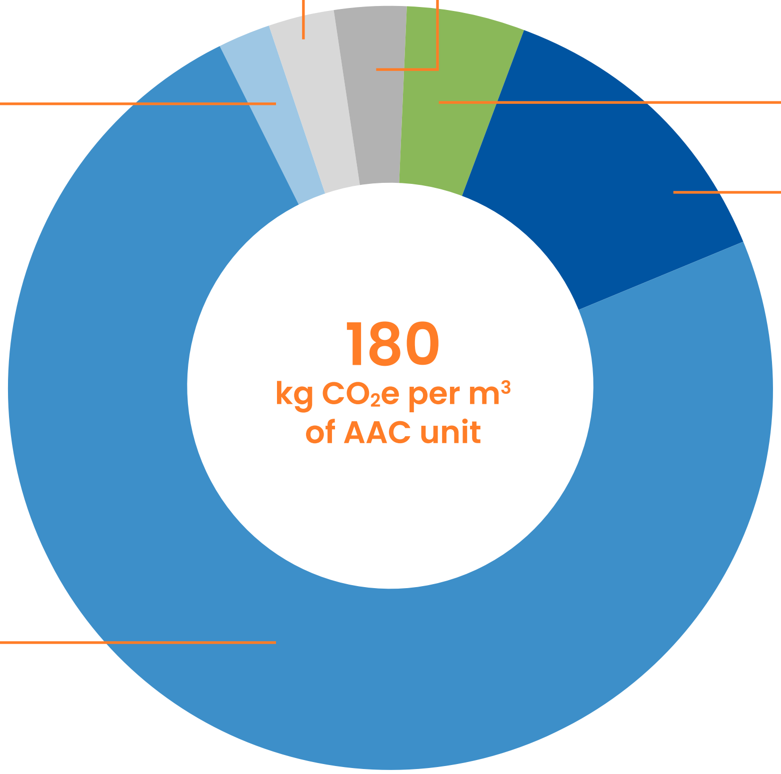
Manufacturing

Combustion of fuels to power autoclaves, dryers, shrink-wrapping units and forklifts used in the manufacture of AAC

74%

Raw materials (cement & lime)

Process emissions from the manufacture of cement and lime (primarily carbonation)



1. Walther, H. B., 'CO2 absorption during the use phase of autoclaved aerated concrete by recarbonation', AAC Worldwide, Issue 1, 2022, https://www.aac-worldwide.com/category/science-innovation/2031 (accessed on 28 January 2022)

Roadmap to net-zero emissions

The net-zero roadmap sets out a pathway for AAC products to reach net-zero emissions by 2050 and the potential to make AAC products carbon negative through recarbonation, thereby absorbing more carbon dioxide from the atmosphere than they produce.

The roadmap aligns the EAACA and its members with the objectives of the Paris Agreement to limit global warming to 1.5°C and with policies to decarbonise Europe's building stock and construction sectors.

These sectors are key contributors to Europe's greenhouse gas (GHG) emissions:

- The use of buildings accounts for 40% of Europe's energy consumption and 36% of CO_2 emissions.
- GHG emissions from material extraction, manufacturing of construction products, as well as construction and renovation of buildings are estimated at 5-12% of total GHG emissions.

With its excellent thermal performance and the potential to achieve net negative CO_2 emissions, AAC has a role to play as a building material in helping to reduce the life-cycle emissions of Europe's buildings.

The roadmap is based on a review of opportunities to decarbonise AAC production in Europe.
Importantly, it draws on the decarbonisation roadmaps published by the Global Cement and Concrete Association[2], the European Cement Association (CEMBUREAU)[3] and MPA UK Concrete[4] which put European cement manufacturing on a credible pathway to achieve net-zero emissions by 2050. The roadmap from the European Lime Association (EuLa)[5] is expected to follow a similar decarbonisation pathway.

2. Global Cement and Concrete Association, 'Concrete Future', Global Cement and Concrete Association, 2021, https://gccassociation.org/concretefuture/wp-content/uploads/2021/10/GCCA-Concrete-Future-Roadmap-Document-AW.pdf (accessed on 28 January 2022).
3. The European Cement Association, 'Cementing the European Green Deal', The European Cement Association, https://lowcarboneconomy.cembureau.eu/wp-content/uploads/2020/05/CEMBUREAU-2050_ROADMAP_FINAL.pdf (accessed on 28 January 2022).
4. MPA UK Concrete, 'UK Concrete and Cement Industry Roadmap to Net Zero', MPA UK Concrete, 2020, https://thisisukconcrete.co.uk/TIC/media/root/Perspectives/MPA-UKC-Roadmap-to-Beyond-Net-Zero_October-2020.pdf (accessed on 28 January 2022).
5. Ecofys, 'A Competitive and Efficient Lime Industry', European Lime Association, 2014, https://www.eula.eu/wp-content/uploads/2019/02/A-Competitive-and-Efficient-Lime-Industry-Technical-report-by-Ecofys_0.pdf (accessed on 28 January 2022).

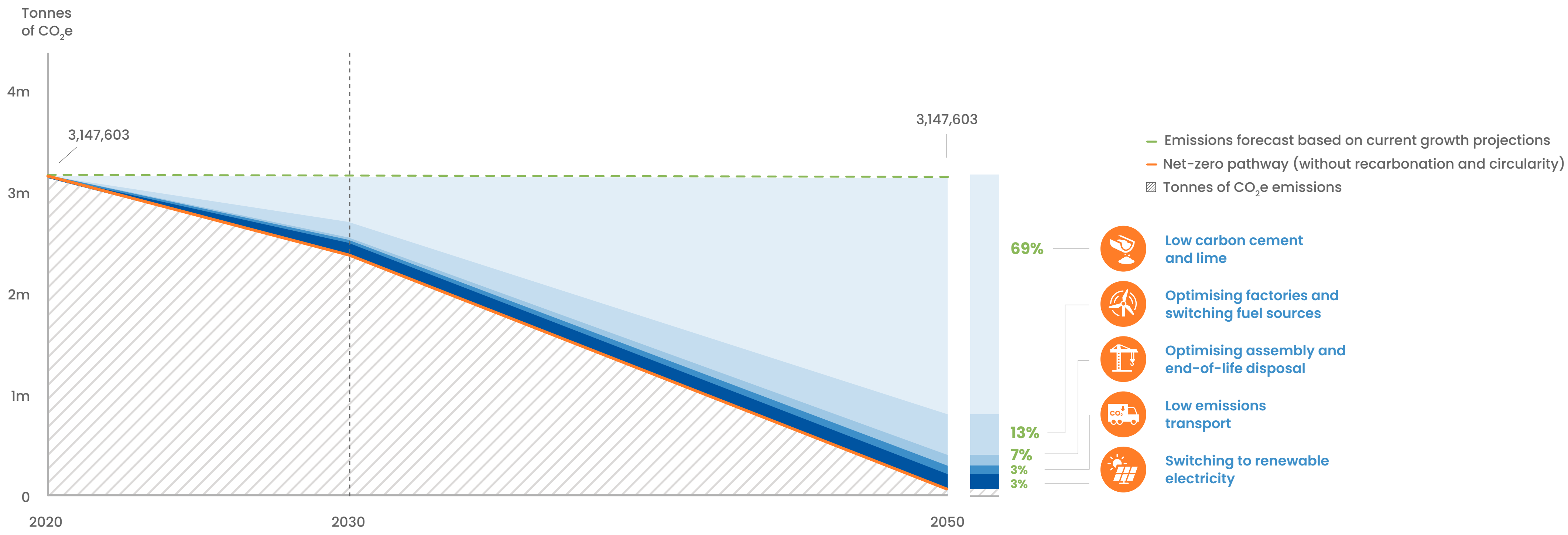
Net-zero roadmap

AAC emissions in Europe

CO_2e emissions for AAC in Europe were 3.1 million tonnes in 2021, based on annual production of 17.5 million m^3 of AAC. Around 2.3 million tonnes of this were upstream emissions from the cement and lime producers, and 0.4 million tonnes were from emissions derived directly from the manufacture of AAC in factories.

Annual AAC production is expected to remain steady for the forseeable future.

The net-zero roadmap for AAC products is outlined in the chart below which includes 4% of unavoidable emissions that cannot be removed though the cement and lime roadmaps. Circularity and recarbonation have the potential to address these and achieve negative emissions but are not shown in the chart. These levers are discussed in the following section.



Key levers to reduce emissions

The roadmap sets out the main levers based on known technologies that AAC manufacturers will have access to across Europe, though the pathway and speed of travel will vary between companies.

Low carbon materials

Low emission transport

Switching to renewable energy

Optimising factories

Low emission transport

Decarbonising industry processes

Recarbonation

Decarbonising industry processes

Raw materials

Switching to low-carbon cement and lime binders that are used as raw materials in the manufacture of AAC.

Transport

Working with transport suppliers that provide low or no emissions services to transport raw materials to AAC factories.

Production of AAC

Switching to renewable energy sources together with efficiency improvements within factories that manufacture AAC.

Transport

Working with transport suppliers that provide low or no emissions services to transport AAC products to the construction site.

Construction site

Decarbonising the construction site assembly of AAC products.

Use

Through recarbonation, cement-based products such as AAC absorb CO_2 during during their lifespan.

Demolition and disposal

Decarbonising the demolition and disposal of AAC products.

Circularity

Recycling and re-use of AAC.

Key levers to reduce emissions

The two main levers to get to net zero are using low-carbon cement and lime raw materials, and switching to renewable energy sources together with efficiency improvements within factories that manufacture AAC. Two additional levers – circularity and recarbonation – have the potential to make AAC products carbon negative.

Low carbon cement and lime

The use of low-carbon cement and lime binders in the production of AAC would reduce the overall carbon footprint for AAC by 69%. According to industry decarbonisation roadmaps, net-zero cement and lime will be achieved through the use of:

- Carbon capture storage and utilisation (CCS & CCU)
- Low carbon clinker through switching from fossil fuels to renewable energy to heat kilns
- Alternative binders
- Clinker substitution
- Carbon neutral transport
- Recarbonation[6]

6. To avoid double counting, the EAACA does not count the recarbonation recognised in the cement and lime roadmaps.

Switching fuel sources and optimising factories

Emissions associated with the production of AAC are significantly lower than those from cement and lime. Efficiency improvements together with switching to renewable energy sources to power autoclaves, dryers, shrink-wrapping units and forklifts within factories would reduce emissions by 13% through the following steps:

1. Improvements in process control and modernisation of plant equipment
2. Replacing fuels such as lignite, coal, heating oil and diesel with fuels with lower CO_2 emissions, such as natural gas and biodiesel
3. Switching from natural gas to renewable electricity or to hydrogen when available

Decarbonising construction site assembly, and demolition and disposal

These industry processes lie with companies downstream in the value chain from AAC manufacturers. As they decarbonise in line with Europe's climate goals, it is expected that 7% of AAC life-cycle emissions will be removed.

Low emissions transport

Working with transport suppliers that provide low or no emissions transport services for transport of raw materials to the factory, and for transport from the factory to the construction site would reduce emissions by 3%.

Switching to renewable energy

Switching to 100% renewable electricity for ball mills, offices, warehouses and other facilities would reduce emissions by 3%.

Circularity

Adopting circular processes for the recycling and re-use of AAC has the potential to reduce emissions by up to 15% initially, then declining to 1% by 2050 as the cement and lime raw materials are decarbonised.

For AAC production, up to 20% of the cement and lime raw materials can be replaced through the use of:

- AAC scrap, cracks and leftovers occurring from production
- Leftover AAC cuttings from construction sites
- AAC recovered from building demolition rubble

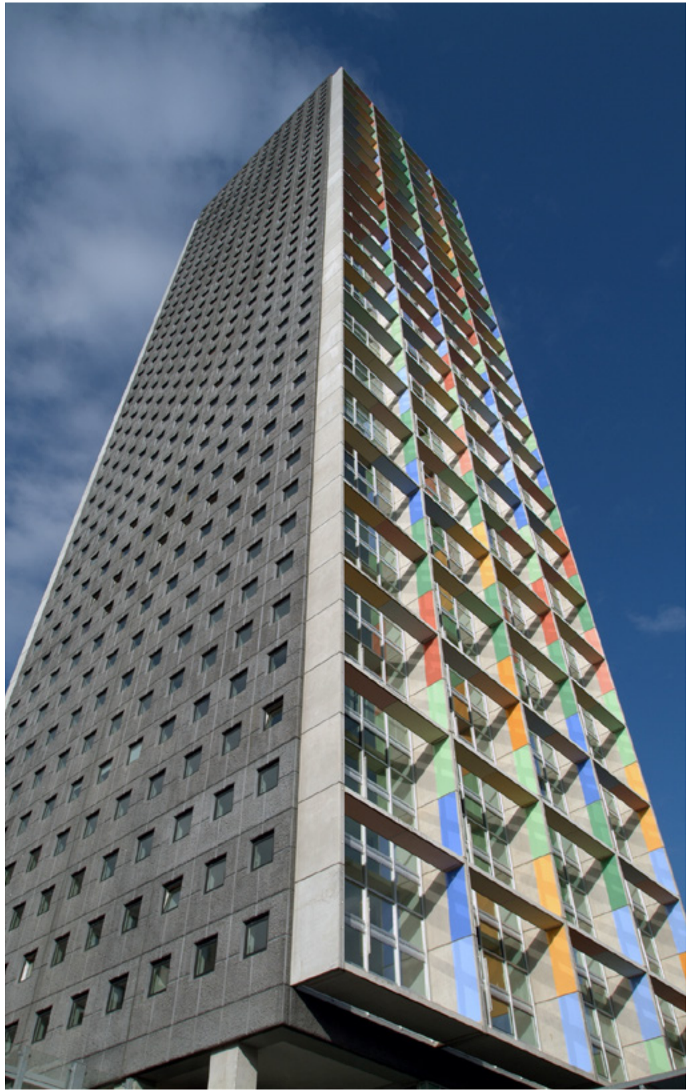
With annual waste-volumes of AAC expected to exceed production volumes in Europe from 2040 onwards, there is significant potential to establish an industry-wide circular economy process for AAC.

Recarbonation

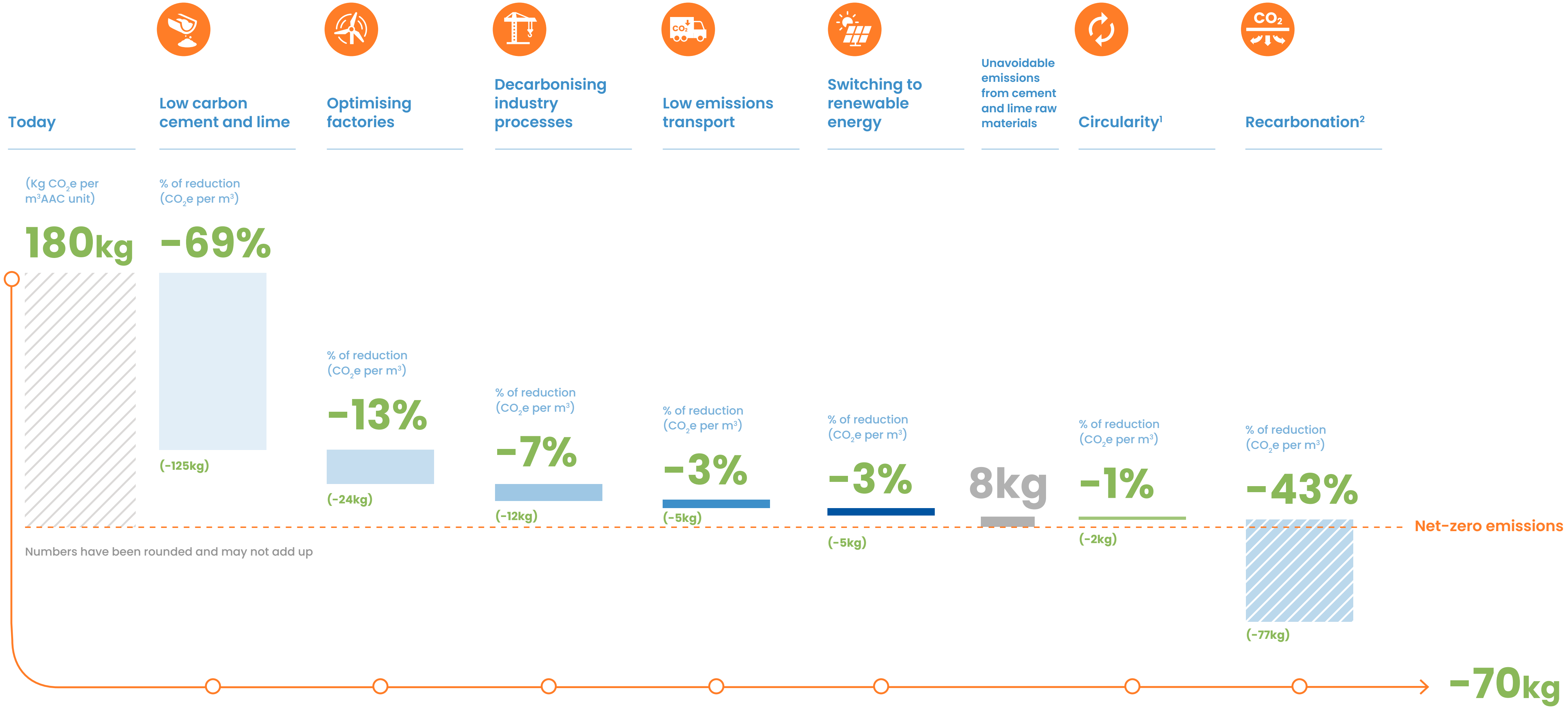
Cement-based products absorb CO_2 during their lifespan, acting as permanent carbon sinks during the use phase of a building and when it is pulled down and recycled. This process of recarbonation would reduce overall emissions by 43% and has the potential to make AAC products carbon negative. As indicated in the EPD, AAC products can absorb 77 kg CO_2 per m^3 if complete recarbonation is achieved. Recarbonation reaches around 80% after 50 years and 95% by 80 years. This roadmap assumes a 95% recarbonation rate.

Beyond net zero

Fully implemented, these levers deliver a decarbonisation roadmap for AAC products that reduces emissions from 180 kg to -70 kg of CO_2e per m^3 by 2050, thereby removing more carbon from the atmosphere than is produced.



The AAC roadmap: From 180 kg to -70 kg of CO_2e per m^3 by 2050



1. Replacement of 20% cement and lime raw materials; 2. Derived from a representative AAC factory (normalized to an average dry density of 388 kg/m3, year under review 2020)

Monitoring progress

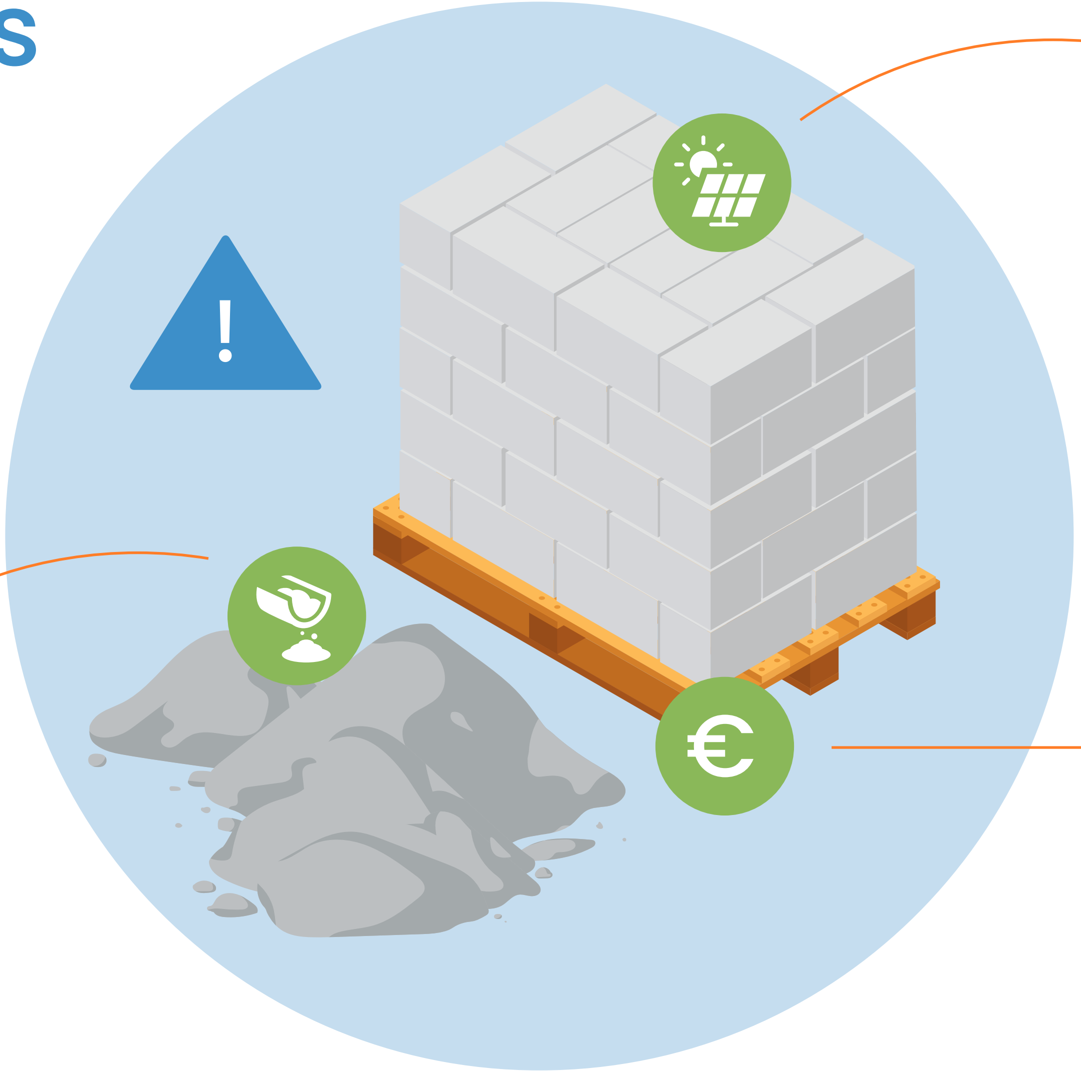
The EAACA and its member companies commit to implementing the roadmap to achieve net-zero emissions by 2050 and to monitor and communicate progress frequently. To support this, the EAACA will phase in GHG reporting requirements for members that align with upcoming corporate sustainability reporting requirements in the EU and the UK. The EAACA will also work to facilitate knowledge sharing and best practice among members to assist them in implementing the roadmap.

Partnerships for Net Zero

With open innovation concepts and partnership networks we will aim at integrating a broader spectrum of ideas, experiences and also materials in our own innovation processes. A special emphasis will be put on new, less carbon-intensive raw materials, in particular alternative binders as a substitute for cement and lime in AAC production.

Challenges and risks

The roadmap provides a viable pathway to net zero for AAC manufacturers but does face three principal risks:



1. Success of the cement and lime roadmaps

The roadmap relies on the success of the cement and lime industry roadmaps to decarbonise by 2050. These roadmaps depend on widespread adoption of CCU and CCUS technology which has an uncertain economic model, and on innovation to develop alternative binders which have not yet been proven as viable raw materials for AAC production.

2. Access to renewable energy sources

To remove factory emissions in the production of AAC, EAACA members will require access to renewable electricity and to hydrogen as fuel sources. Currently, EU and UK hydrogen policy and infrastructure plans are at an early stage and it is unlikely that hydrogen infrastructure will be rolled out at a uniform pace across member countries.

3. Investment costs

Implementing the roadmap will require long-term action and investment by AAC manufacturers.

The main cost for EAACA members is the investment required to upgrade the boilers that provide steam to the autoclaves to run on lower carbon fuel sources. The speed at which this investment occurs will vary between members.

Policy recommendations

The EAACA and its member companies are committed to achieving net-zero emissions by 2050 and ensuring that AAC plays its role in decarbonising Europe's buildings. These goals can be achieved with policy action that helps to:

1. **Support the success of the European cement and lime decarbonisation roadmaps by ensuring:**
   - A level playing field on carbon pricing for European manufacturers against importers of cement and lime
   - The widespread deployment of CCU and CCUS infrastructure

2. **Energy policy that supports the availability of renewable electricity and hydrogen for Europe's industrial sector.**

3. **Policies that capture the full life-cycle emissions for buildings and construction products to:**
   - Allow for recarbonation to be accounted for CO_2 abatement
   - Take into account the benefits of properties such as thermal mass in avoiding emissions for heating and cooling buildings
   - Support the development of industry-wide approaches to circularity
   - Acknowledge that CO_2 emissions from the manufacturing phase account for only a minor share of the total GHG emissions in the life cycle of a building. The largest contribution to CO_2 emissions comes from the use phase.

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- Denmark – H+H International A/S
- Estonia – Bauroc AS
- France – Xella Thermopierre SA
- Germany – Bundesverband Porenbetonindustrie e.V.
- Germany – Verband Bauen in Weiß e.V.
- Germany – Wehrhahn GmbH
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- Netherlands – Aircrete Europe
- Poland – Stowarzyszenie Producentów Betonów Concrete Producers Association
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