Institute of Circular Economy (INCIEN)

The Role of the Circular Economy in Decarbonisation of Industry

Initiating a debate with Czech industry on additional pathways to carbon neutrality

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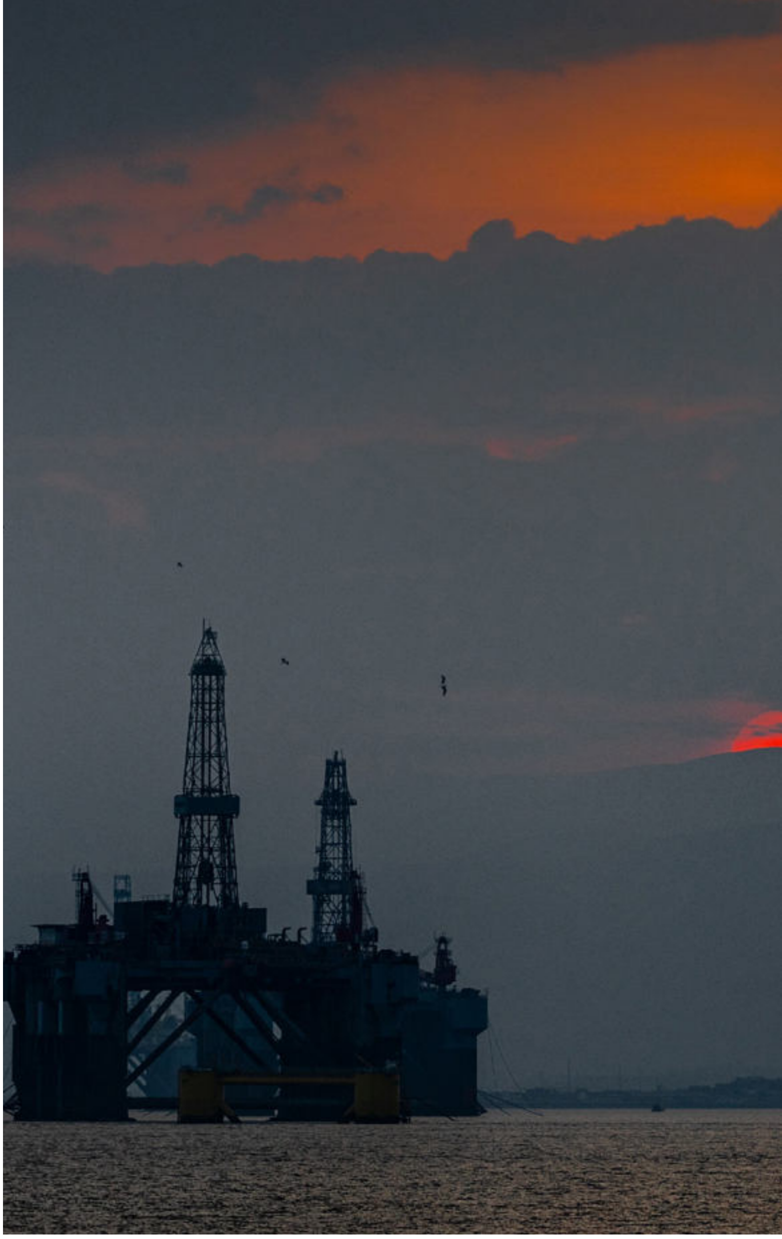
Executive Summary

The issue of climate change is to a large extent an energy problem. Much of the climate change debate still revolves around abatement of energy-related emissions, for example the combustion of fossil fuels in cars or the provision of electricity and heat to households or industries from coal-fired power plants.

Less discussed are the emissions that result from **material production**, which occupy as significant a share in global GHG emissions as agriculture, forestry and land use. Energy-intensive industries such as primary production of **steel, cement, chemicals and aluminium,** and major demand sectors that consume these materials, including **buildings** and **vehicles**, are major sources of such emissions.

The way materials are handled in the economy is the focus of the **Circular Economy (CE)**, a concept that aims at retaining the highest value of materials and products throughout their lifetime. While the focus of CE policy and practice has been largely waste management-oriented in the past, its critical role in industry decarbonisation (through materials recirculation and substitution, materials efficiency and circular business models) has been explored, quantified and increasingly recognised through a growing body of international research.

Under the **European Green Deal**, the EU's overall climate goal is to reduce GHG emissions by 2030 by 55% compared to 1990 and to achieve carbon neutrality by 2050. The EU's commitment to the CE and its potential to contribute to climate change mitigation is evident from the **New Circular Economy Action Plan** (CEAP 2.0) and the related legislative proposals currently being brought forward by the European Commission.



Despite the above, exploration of this topic in individual countries remains limited, especially in EU member states in Central and Eastern Europe (CEE). The **Czech Republic** is the third most carbon intensive EU economy per capita and the second most industrialised EU country as a share of gross value added, with a strong contribution from steel, metal fabrication, automotive, petrochemicals and construction sectors. It has a particularly high share of GHG emissions, relative to the EU average, from its carbon-intensive energy sector and from waste, due to a high level of landfilling. While industrial CO2 emissions including fuel combustion have fallen by 60% since 1990, those from

industrial processes and product use have only declined by 10%. **Iron and steel, non-metallic minerals (mainly cement) and chemicals account for 70% of industrial emissions, with those from iron & steel and petrochemicals especially significant as a share of the EU total.**

Decarbonisation therefore poses major challenges in terms of the cost and timing of the transition. Several decarbonisation studies and scenarios covering Czech industry have already been developed but they focus on energy-related and process technology-based pathways that are costly and rather difficult to scale in the short to medium term. They generally do not address the role of material efficiency and CE measures other than to highlight the importance of recycling, especially in steel. Similarly, current government policy documents and national strategies lack a detailed roadmap for industry decarbonisation and address the CE primarily in the context of resource efficiency and waste management, not climate change mitigation.

Addressing this gap is essential due to the potential cost-effectiveness of CE as a mitigation pathway. CEE countries will in general have less capital and resources to invest in the net-zero transition. Moreover, growing public debt due to the COVID-19 pandemic, spiralling energy prices from the conflict in Ukraine, rising costs of emissions permits and a generally more sceptical view of the climate agenda – all these factors make CE a highly relevant decarbonisation strategy to pursue systematically in the Czech Republic and the wider CEE region. Both supply- and demand-side circular strategies should be formally incorporated into future planning and roadmaps for the decarbonisation of Czech industry.

This study's primary objective, therefore, is to **stimulate the debate on CE and its potential to reduce GHG emissions in Czech heavy industry.** By doing so, our ambition is that this will lead to investment of additional resources in this under-explored and potentially cost-effective mitigation pathway. Our intent is not to comprehensively capture the full complexity of CE, let alone to attempt a modelling of emissions scenarios. As one of the first research papers in the Czech Republic to explore this specific topic across multiple sectors, its aim is rather to plant a seed for further investigation and ultimately for implementation of suitable CE measures. At the same time, it is also intended to be a current "state of play" summary of international research on this topic and, as such, a relevant contribution to the broader European debate on industry decarbonisation. In the context of the Czech EU Presidency, the authors hope it will amplify the growing awareness of this important industrial and climate policy opportunity not only "at home" but across the Union.

The long-term scenarios in the report may seem remote from more pressing current concerns. Yet the circular economy offers solutions, many of them available now, to shorten material supply chains, reduce energy consumption, conserve scarce natural resources and reverse biodiversity loss, all while at the same time advancing efforts to decarbonise heavy industry in a cost-effective way.

Research scope

The report looks at **four heavy-industry product value chains** (steel, cement and concrete, plastics, aluminium) and their **two largest demand sectors** (buildings construction and vehicles) representing leading sources of industrial GHG emissions. The CE decarbonisation opportunity for each value chain and sector and the associated "circularity decarbonisation levers" fall into two categories of impact:

- → **Supply-side measures** that reduce inputs of carbon-intensive primary materials through **materials recirculation** (recovery, recycling and reuse) or **substitution** by low-carbon or renewable materials or feedstocks.
- → **Demand-side measures** that reduce net demand for materials though **material efficiency** and **new business models** (such as product life extension, sharing and product service system models) in major value chains.

Overall findings

There are numerous potential pathways to achieving emissions reductions targets for heavy industry that apply different combinations of technologies and decarbonisation strategies in differing proportions. However, even the more conservative estimates in international studies reviewed for this report indicate that **the circular economy has a major and indispensable role to play in a net zero transition for these sectors by mid-century.**

Under global scenarios for net zero emissions, CE measures can eliminate 20–25% of total heavy industry CO2 emissions by 2050. In the EU, CE measures could save at least 40% and in one stretch scenario close to two thirds of annual GHG emissions in key heavy industry sectors by 2050. Importantly, circular pathways or solutions generally have much lower investment requirements than those based on new process technologies, electrification or carbon capture, use and storage (CCU/CCS), and the technologies for their implementation in most cases already exist. Given the large industrial base of the Czech economy, there is a clear opportunity to pursue such measures in the Czech context as a major and cost-effective route to decarbonisation.

While aspects of the circular economy are already being pursued in local industry, they are still on a limited scale and oriented mainly towards achieving higher levels of recovery and recycling of waste flows in the context of resource efficiency. There is a need for a systematic and quantifiable exploration of circular strategies, to fully capture their mitigation potential across a range of both supply- and demand-side measures. To unlock this potential, key challenges to address are a lack of awareness and policy support, limited allocation of investment resources relative to other pathways and the need for sustained joint action and collaboration, as well as fundamental changes in underlying business models, throughout the heavy industry value chain.

Steel

Iron & steel is a priority focus of efforts to decarbonise industry, as it accounts for around 5% of total GHG emissions in the EU, making it the largest single industrial product value chain in terms of carbon footprint. The most important CE levers to decarbonise steel are **increasing the share of scrap-based production** (Electric arc furnace route, EAF) and **optimising (reducing) long-term net steel consumption** in end-use applications, especially in buildings, transport and other infrastructure.

Globally, circular scenarios for steel indicate a potential to reduce steel demand by 20% to as much as 40% by 2050 relative to a business-as-usual scenario, while still providing the same economic benefits. In one circular scenario for the EU, steel demand by 2050 would be almost 30% lower than in a baseline scenario and scrap based EAF production would reach 70% of total production (up from 40% today), eliminating close to 60% of CO2 emissions from the EU steel industry.

Currently, emissions from Czech steelworks are significantly higher than the EU average due to a dominant (90%) share of primary production. The country is also historically a net exporter of steel scrap, with an annual export of over 2 million tonnes in recent years. This indicates a **major opportunity to decarbonise through a shift to scrap-based production**, while utilising domestic scrap reserves (close to 4 million tonnes in 2017). Both steelworks have initiated plans for EAF investment projects. However, it will be critical in the coming years both to **maintain an adequate local scrap supply** and to **scale affordable electricity generation from renewable sources** to ensure these projects are a viable long-term route to decarbonisation.

An updated and detailed material flow assessment of steel scrap within the Czech economy is needed to identify and implement measures for maximally efficient recovery, reuse and recycling of local scrap resources. Specific steps to increase the share of secondary steel production in the Czech Republic include ensuring coverage of the steel industry's future energy needs in long-term national energy plans and strategies as well as providing dedicated financial support for circular economy solutions for the modernisation and transition of the Czech steel sector and related infrastructure.

On the demand-side, key stakeholders in the domestic construction, automotive, metal fabrication and mechanical engineering industries should explore opportunities both to **switch to low-carbon steel products** and to **optimise their long-term steel consumption in end-use applications**, as part of strategies to reduce the scope 3 emissions in their value chain.

Cement

After steel, cement production is also a major focus for industry decarbonisation, as around two thirds of its emissions arise from the calcination process in the production of clinker, the primary component of Portland cement. While cement is on average only ~14% of concrete by mass, it accounts for 95% of its carbon footprint. The most significant CE levers to decarbonise cement are **reduction of the clinker-to-cement ratio**, the **recovery and use of concrete fines from construction and demolition waste (CDW) recycling** as a clinker substitute, **reduced cement-to-concrete ratios in concrete mixes** for specific applications and lower concrete use through **material efficiency in design and construction**. Due to the difficulty of abating cement process CO2 emissions, various low-carbon cement formulations are also being piloted that could deliver substantial CO2 savings in future. Overall, in one stretch scenario, circular measures could deliver as much as 60% of the savings required to reach net-zero emissions from EU cement production by 2050.

The emission factor of Czech clinker production is around the EU average and cement production accounts for around 2.5% of national CO2 emissions. According to the Czech Cement Producers Association, local cement plants have already achieved one of the most decarbonised energy mixes in the European cement industry. The clinker-to-cement ratio is slightly above the EU average.

With an expected decline in availability of traditional clinker substitutes, the **recovery of suitable tailings materials** from former mining sites in the Czech Republic, with an estimated potential volume of over 500 million tonnes, represents a promising source of future raw materials for cement production. There is also significant potential for **scaling up of concrete recycling**, both directly in concrete applications and for recovery of concrete fines as an additional clinker substitute, supported by a forthcoming EU standard. However, increased uptake will depend largely on changes in design and construction practices and improved incentives for adoption of recycled and low-clinker cement blends and concrete mixes in the downstream construction industry.

Pilot/demonstration projects, investment support on a par with other energy efficiency and process technology measures and updating of technical standards will enable wider adoption of these alternative clinker substitutes. The introduction of mechanisms for pricing cement products based on their carbon intensity could also support increased use of low-emission cement and concrete mixtures on construction sites.

Plastics

Circular opportunities to reduce CO2 emissions in the chemical industry apply mainly to plastics. Emissions per tonne of recycled plastics are on average already 80–85% lower than for virgin plastics, representing a huge potential for decarbonisation. However, **only 15% of waste plastics in the EU are currently recycled**, with recent studies suggesting that over a third of EU plastic waste flows goes unrecorded.

Reduction in plastics consumption and the development of a circular plastics system, based on **reuse models** and **maximum recovery and recycling** of waste plastics supplemented by **sustainable biomass feedstocks**, are therefore critical to decarbonisation of plastics. In one net-zero emissions scenario, the circular economy could deliver over 80% of the required emissions reduction in plastics by 2050, through a combination of demand reduction, mechanical recycling, scaled-up chemical recycling and bio-based plastics using sustainable biomass sources.

With recent changes in packaging legislation and official recycling definitions, there is now a more realistic view of the low level of actual recycling of plastic waste in the Czech Republic (in the case of packaging, less than one third of separately collected plastic waste in 2019 was ultimately recycled). This indicates a **major opportunity to move to a circular plastics system** that will not only address the problem of plastic waste and pollution, but also remove most of the CO2 emissions from plastics production and consumption in the economy.

While local rates of plastic waste collection are high (at around 75% for plastic packaging in 2020), major current barriers remain the low cost and high share of landfilling, weak recycling infrastructure and the lack of a Deposit Return Scheme for PET bottles. To remain competitive with linear plastic systems, circular business models need to be supported by government policies, creating effective incentives and mechanisms for the production and consumption of recycled plastics and reused products. Initial projects for chemical recycling and bioplastics produced from biowaste streams are promising developments that need to be scaled and supported, while ensuring they deliver significant reductions in CO_2 emissions from the plastics system on a lifecycle basis.

Aluminium

Aluminium has different dynamics to the other product value chains as its use as a **lightweight steel substitute to reduce operational energy emissions from vehicles** is a key demand driver, despite the high embodied emissions in primary aluminium. As a result, the scope for measures to reduce demand is less applicable, although increases in aluminium use per vehicle may be offset by design reductions in average vehicle size, more intensive vehicle use and vehicle lifetime extension.

Increasing the share of secondary aluminium in aluminium consumption (whether produced in the EU, or imported) is the key decarbonisation opportunity, as its emissions can be less than 5% of those from primary aluminium. Industry scenarios indicate that close to 50% of aluminium emissions in the EU would be eliminated by increasing the share of recycled aluminium in EU consumption to 50% by 2050.

There are almost no direct emissions from non-ferrous metals in the Czech Republic. However, there may be **significant embodied carbon in imported primary aluminium** used in the domestic automotive and metal fabrication industries that can be decarbonised through a switch to recycled grades. In automotive lightweighting applications, aluminium faces competition from high-strength steel supplied by domestic steelworks.

Although small in absolute scale, the Czech Republic significantly underperforms in **recycling of aluminium beverage cans**, with only a 22% recycling rate in 2019. Alongside planned improvements in the EKO-KOM collection network, the introduction of a Deposit Return Scheme is an internationally proven way to maximize collection and closed loop recycling.

Buildings construction

Circular actions have wide-ranging impacts both on **embodied emissions in materials** (principally cement and steel) as well as on **emissions from operational energy use** of buildings. At the same time, decarbonisation of the energy system will likely result in embodied carbon from materials use accounting for the dominant share of building lifecycle emissions within the next 10-15 years. There is a wide spread of scenarios on the contribution of circular actions to reduction of embodied carbon. Use of **wood structures** and **recycled materials** in place of primary steel and cement can dramatically reduce associated emissions. **Extending the lifespan of buildings** through modular design or renovation can avoid most of the materials demand (and associated embodied carbon) for an equivalent new build project. Beyond these measures, **more intensive use of buildings** (and a consolidation in the building stock) could potentially eliminate most of the remaining embodied CO_2 emissions. According to an analysis for G7 countries by the International Resource Panel, circular actions could also reduce lifecycle emissions from (residential) buildings by 35–40% by 2050, assuming a 20% reduction in residential space through shared housing.

Decarbonisation measures for buildings in the Czech Republic have to date focused mainly on operational emissions. There is nevertheless a **growing awareness of the need for sustainable consumption of building materials**, reflecting looming shortages in basic materials, increasing requirements for green public procurement and EU sustainability reporting requirements under which both property developers and construction firms will also need to measure and reduce their buildings' embodied carbon.

Recycling of building materials is growing but is still held back by quality and safety concerns as well as a lack of transparent data on CDW material flows. There is a perceived need for a **clear definition and classification of secondary building materials** that are approved for use in construction. Wood structures in multi-storey buildings continue to be restricted by fire protection norms. There is a large potential for building renovations that would prolong the lifespan of the building stock and reduce consumption of new building materials, but weak implementation of land protection and planning rules favours greenfield developments. The introduction of **minimum recycled content requirements** in public procurement for selected construction products and materials and **minimum thresholds for embodied carbon levels** in new buildings are potential ways to support the development of a more circular buildings materials sector.

In the construction and real estate sector in particular, the complexity of the challenges raised by sustainability and decarbonisation trends calls for sustained joint action and cross-disciplinary cooperation throughout the value chain.

Automotive industry

Circular measures and strategies can achieve deep reductions both in embodied carbon from materials used in automotive manufacturing (steel, plastics, aluminium) and in emissions from operational energy use. Circular actions with the greatest

impact are **more intensive use** (ridesharing or car-sharing), **lightweighting** (including downsizing of vehicles) and **vehicle lifetime extension**. However, evaluation of specific measures to reduce embodied carbon in vehicles raises complex questions about long-term manufacturing strategy and vehicle design innovation beyond the scope of this report.

As vehicle fleets shift to electric and other alternative fuels, the share of material production in vehicle lifecycle emissions will increase to 60% by 2040, according to estimates by McKinsey. 2050 scenarios indicate a potential for the CE to eliminate up to 70% of embodied carbon in vehicles in the EU and G7 and up to 40% of lifecycle GHG emissions in the G7.

In the Czech and CEE context, there is currently limited integration between CE and strategies to decarbonise vehicle production, but a growing pressure for original equipment manufacturers (automotive OEMs) to implement roadmaps for net-zero emissions, including Scope 3 emissions from industrial materials.

Closed loop recycling of materials from end-of-life vehicles (ELV) in the Czech Republic is limited by a fragmented ELV processing sector, shredding practices that result in downcycling, lack of data on material origin and unclear legal distinctions between waste and secondary raw materials. There is a **large untapped potential for increased reuse, remanufacturing and recycling** of used car parts and materials through online digital trading platforms.

OEMs currently lack economic incentives to prolong vehicle lifespans or shift their portfolio to smaller, lighter vehicles, but there is a potential to introduce economic incentives to increase consumer demand for smaller, more energy-efficient vehicles, such as those used in Denmark. The decarbonisation opportunity from car sharing models is at a nascent stage, and auto makers have concerns about negative impacts on their brand due to a perceived risk of faster vehicle wear and tear. Nevertheless, if scaled with OEM involvement, **car sharing could improve the utilisation rate of vehicle fleets, prolong OEM aftermarket revenue streams and create incentives for vehicle lifetime extension.**

Conclusions and recommendations

As this report argues, CE must be an integral part of plans to decarbonise hard-to-abate industrial materials and the sectors that consume them. While implicit in the European Green Deal, CE's role in climate policy, including decarbonisation of industry, needs to be further promoted, and its potential mitigation impact explicitly addressed, in EU, national and sectoral decarbonisation strategies.

At the EU level, there needs to be stronger alignment between the CEAP 2.0, the EU Industrial Strategy and the "Fit for 55" energy and climate package. The policy implications of an enhanced role for CE in industrial climate policy have been comprehensively explored by Agora Industry in its 2022 study "Mobilising the circular economy for energy intensive materials". Its recommendations for creating highly circular and resource-efficient markets for these materials in the EU are summarised below:

Market and demand creation policies	Enabling policies to maximise supply of high-quality recycled materials
1. Expand use of recycled content quotas to a wider set of plastic products (not just PET bottles); to steel, aluminium and plastics in vehicles; and to cement and concrete used in public construction projects. 2. Limit embedded life-cycle carbon emissions of construction materials in new buildings, in vehicles and in packaging. 3. Mobilise carbon pricing more effectively: Include waste incineration in the EU Emissions Trading Scheme (ETS), gradually shift from free allocation to full auctioning and introduce a Carbon Border Adjustment Mechanism (CBAM) to strengthen price incentives for recycled materials. 4. Reform product standards for materials to remove existing barriers to innovation for CO2 efficient or recycled materials (notably for concrete and plastics), at European and if necessary national levels. 5. Ban exports of EU waste to countries not adopting equivalently stringent recycling targets and practices.	6. Review recycling rates measurements, especially for end-of-life plastics, based on bottom-up analytical methods to take uncounted plastics waste misallocation into account and revise current recycling performance rates and targets. 7. Massively scale up support for breakthrough technologies to implement the circular economy and the new virgin material production routes for energy-intensive industry. 8. Require the adoption of best practice waste collection infrastructure and best available material sorting technologies at the recycling plant, including post-collection re-sorting of mixed waste to extract and send for recycling the up to 75% of the plastics than can be recycled in that mix. 9. Label, tax or ban inefficient material use and waste management practices, including overuse of packaging, sale of short-lived products, incineration of unsorted plastic waste, shredding of vehicles prior to copper content removal.

Source: Agora Industry (2022): Mobilising the circular economy for energy-intensive materials. How Europe can accelerate its transition to fossil-free, energy-efficient and independent industrial production, Chapter 3. Nine policy options for the European Green Deal

The EU legislative agenda to implement the CEAP 2.0 is now taking shape. The proposed Ecodesign for Sustainable Products Regulation (ESPR), presented in March 2022, represents a major step forward in "making sustainable products the norm", including reduced embodied emissions in final products, although the legislative and subsequent implementation process will be complex and contentious, with measures introduced over a six-year period (2024–2030). For construction materials and packaging, the proposed revision of the Construction Products Regulation (CPR) and forthcoming proposals for a revised Packaging and Packaging Waste Directive (PPWD) will also introduce enhanced measures to promote reuse, recycling and recycled content of products.

The EU's evolving framework for sustainable finance will also facilitate the integration of CE measures into decarbonisation plans and actions by industry and business. Phase II of the EU Taxonomy, with effect from January 2023, will define detailed criteria for sustainable investments for the four remaining Taxonomy objectives, including the transition to a circular economy. Under the forthcoming Corporate Sustainability Reporting Directive (CSRD), large companies (€40 million turnover and/or 250 or more employees) will be required (from 2025, for the 2024 financial year) to report their performance, targets and strategies in, among other areas, resource use and circular economy, as well as in all three "Scopes" of their GHG emissions. As a result, companies operating in major demand sectors for industrial materials will become increasingly aware of the embodied carbon in these materials and the need to reduce these emissions through a switch to low-carbon sources and/or demand reduction measures.

Although these initiatives are still at the proposal stage, the direction and contours of EU policy are clear and national government and industry stakeholders should start to prepare for them. This includes supporting and calling for expedited adoption of policies and measures that promote CE pathways to decarbonisation and actively participating in public consultations, working groups and EU research & innovation programmes such as Horizon Europe. Government and industry stakeholders should proactively evaluate regulations that limit the use of recovered and recycled materials and review national product standards to increase uptake of secondary raw materials. In both public and private sector procurement, specific processes, rules and criteria should be adopted and implemented to ensure that the circularity of products and solutions is prioritised as far as possible.

In the construction sector, planning and zoning rules need to be strengthened to promote brownfield projects and renovation of the current building stock, not only to improve energy efficiency but also to reduce the level of embodied carbon in construction. Fire codes should again be reviewed, revised and finally expanded to support large-scale wood construction in tall buildings, and timber should be included on the list of strategic/critical raw materials, considering its use as a low-carbon material in the construction and chemical industries, among others.

In Czech national policy, CE pathways to industry decarbonisation should be formally incorporated into key national strategies and actions plans. There is currently a window of opportunity to highlight and strengthen the role of CE in climate policy in the current development of the Czech Republic's Circular Economy

Action Plan 2022–2027, the review of the country's Secondary Raw Materials Policy and the potential formulation of an independent national Industrial Policy for 2030 with a view to 2050, among others. CE strategies should also be included in the update of the Czech National Energy and Climate Plan (NECP) to reflect the raised ambitions for emissions reduction by 2030 under the EU's "Fit for 55" package.

Given the synergies between CE, climate policy and the digitalisation agenda (including Industry 4.0/5.0), investment support for CE solutions should be placed on a more equal standing with technologies and processes to decarbonise primary industrial production. Although funding for CE measures is included in both the Physical Infrastructure and Green Transition pillar of the Czech Recovery and Resilience Plan and the OP TAK operational programme, it currently accounts for less than 5% of the total funding allocation in both cases. There is a clear case for stronger incentives and a higher emphasis on CE-related measures under EU and national subsidy programmes related to industry decarbonisation. Key areas of support should include breakthrough circular industrial technologies (with a roadmap currently under preparation by the European Commission), training and consultancy for SMEs, best-in-class waste collection and material sorting technologies, post-mining raw material recovery projects, CDW recycling, wood-based and modular construction and digital technologies contributing to increased circularity and material efficiency.

Finally, a successful transition to a carbon neutral circular economy in industry will require sustained joint action and collaboration throughout the value chain and between relevant sectoral organisations. In particular, there is a need for a dedicated stakeholder platform for strategic coordination of the many aspects of the circular transition in the Czech construction and real estate sector. These include the promotion of wood as a renewable construction material; circular design, modular construction and lightweighting of buildings; support for circular renovations and buildings lifetime extension; deployment and interoperability of digital tools (BIM, passporting, digital building logs, Level(s), virtual material banks), the use of selective demolition techniques, scale-up of CDW recycling and mainstreaming of secondary (recycled) building materials.

1

Introduction

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Background

Circular economy and industry decarbonisation – Global and European context

Climate change is ongoing as global mean temperatures have already increased by 1.1–1.3°C compared to pre-industrial levels. Global annual **greenhouse gas (GHG)** emissions are still rising due to increasing consumption of fossil fuels, land-use change and other anthropogenic sources of emissions, resulting in an ever-growing stock of GHGs in the atmosphere. On current trends, it is estimated the world will be 2.1–3.5 °C warmer by the end of this century compared to 1850. The last time global surface temperatures were sustained at or above 2.5°C higher than 1850–1900 was over 3 million years ago.[1]

The issue of climate change is to a large extent an energy problem. Much of the climate change debate still revolves around abatement of energy-related emissions, for example the combustion of fossil fuels in cars or the provision of electricity and heat to households or industries from coal-fired power plants**.** This energy-oriented debate stresses the need to substantially upscale renewable energy sources, accelerate coal-phase out in power plants, speed-up renovation and energy efficiency measures in buildings and industrial operations or support the uptake of electric vehicles, to name a few. This focus is understandable and highly relevant given that emissions directly related to energy are responsible for around 55% of global emissions.[2]

Less discussed are the emissions that result from **material production**, which occupy as significant a share in global GHG emissions as agriculture, forestry and land use. Globally, the share of GHG emissions from material production – solid materials including metals, wood, construction minerals and plastics – grew from 15% to 23% in the period from 1995 to 2015 (Hertwich, 2019). These material-related emissions are also often termed **"embodied carbon"**, as a large portion of fossil fuels had to be combusted to produce them and/or large volumes of CO2 were released into the atmosphere from the associated industrial processes (process emissions). Energy-intensive industries such as primary production of **steel, cement, chemical and aluminium**, and major demand sectors that consume these materials, including **buildings** and **vehicles**, are major sources of such emissions.

The way materials are handled in the economy is the focus of the **Circular Economy (CE)**, a concept that aims at retaining the highest value of materials and products throughout their lifetime. While the focus of CE policy and practice has been largely waste management-oriented in the past, its critical role in industry decarbonisation (through materials recirculation and substitution, materials efficiency and circular business models) has been explored, quantified and increasingly recognised through a growing body of international research.[3]

The European Union's commitment to the CE and its potential to contribute to climate change mitigation is evident from the **New Circular Economy Action Plan** (CEAP 2.0), as part of the **European Green Deal**. The EU's overall climate goal is to reduce GHG emissions by 2030 by 55% compared to 1990 and to achieve carbon neutrality by 2050. Following its **"Fit for 55"** policy package of July 2021, raising climate ambitions across the energy, buildings and transport sectors and the overall EU policy framework, the European Commission presented a first "circular economy package" (under CEAP 2.0) at the end of March 2022. This included a set of proposals to support sustainable production and the circularity of manufactured goods, including an expanded **Ecodesign Regulation** (covering energy-intensive industrial materials, among others) and a revised **Construction Products Regulation.**

Once fully implemented (by 2030), these proposals have the potential to substantially increase consumption of secondary (recycled) raw materials and promote material efficiency in product design, both in Europe and in export regions trading with the EU. The proposed revision of the **Industrial Emissions Directive (IED)** was also presented in early April. Although delayed, a second circular economy package is expected before the end of 2022, with proposals for a revised **Packaging and Packaging Waste Directive (PPWD)**, revised rules for chemicals under REACH, a harmonised EU methodology for life-cycle assessment (LCA) of products and other measures related to bioplastics, compostable plastics and microplastics.

CE and industry decarbonisation in Central and Eastern Europe – the case of the Czech Republic

Although there are ever more studies illustrating the link between CE and GHGs and while the EU's commitment to CE is evident, exploration of this potential in individual countries remains limited, especially in EU member states in Central and Eastern Europe (CEE).

For the **Czech Republic**, as the third most carbon intensive EU economy per capita[4] and the second most industrialised EU country,[5] decarbonisation poses major challenges in terms of the cost and timing of the transition. While the Czech Republic managed to reduce its emissions by 38% between 1990 and 2019,[6] its future ambitions have been relatively low. In the country's **National Energy and Climate Plan (NECP)**, a national strategy for GHG emissions reductions in accordance with the Paris Agreement and EU climate legislation, renewable energy sources were to reach only 22% of energy consumption by 2030 (versus an overall EU target of 32%), and no significant reductions were considered in industrial emissions until 2040. These targets will have to be substantially raised under the requirements of the "Fit for 55" package.

CE is already recognised as an integral part of the broader environmental policy agenda for industry, as reflected in the 2022 programme declaration of the **Czech Confederation of Industry** on priorities and requirements related to the environment.[7] Among others, the declaration calls for measures to: support the recycling sector (including chemical recycling and recycling of construction materials) and use of secondary raw materials and by-products, including via tax or direct incentivisation of recycled products and recyclates, green public procurement as a source of best practice, and subsidies in operational programmes. It also calls for the significance and role of industrial sectors that fulfil the principles of the circular economy to be identified and adequately reflected in relevant national policy and strategic planning documents. However, the role of CE as a pathway for industrial decarbonisation is not made explicit.

Several decarbonisation studies and scenarios covering Czech industry have already been developed but they focus on energy-related and process technology-based pathways that are costly and rather difficult to scale in the short to medium term.[8] They generally do not address the role of material efficiency and CE measures other than to highlight the importance of recycling, especially in steel. The insights available from international studies are often insufficiently granular or difficult to apply for individual member states as their geographical scope is mostly global or focused on the EU overall.

In other words, the role of CE levers that might provide substantial emissions cuts in CEE and Czech heavy industry remains poorly defined. Addressing this gap is essential due to the potential cost-effectiveness of CE as a mitigation pathway. CEE countries will in general have less capital and resources to invest in the net-zero transition. Moreover, growing public debt due to the COVID-19 pandemic, spiralling energy prices from the conflict in Ukraine, rising costs of emissions permits and a generally more sceptical view of the climate agenda – all these factors make CE a highly relevant decarbonisation strategy to pursue systematically in the Czech Republic and the wider CEE region.

This report was published in July 2022, as the Czech Republic was taking up its six-month Presidency of the EU Council. **Strategic resilience** of the EU economy is the one of the Presidency's five thematic priorities, reflecting Europe's current dependency on imported fossil fuels and the acute risks to competitiveness faced by its energy-intensive industries. This includes a commitment to supporting a "more efficient circular economy [that] will contribute to reducing the need for imports of primary materials".[9]

Although the report targets Czech industry, it is also intended to be a current "state of play" summary of international research on this topic and, as such, a relevant contribution to the broader European debate on industry decarbonisation. In the context of the Czech EU Presidency, the authors hope it will amplify the growing awareness of this important industrial and climate policy opportunity not only "at home" but across the Union.

The long-term scenarios in the report may seem remote from our current concerns. Yet the circular economy offers solutions, many of them available now, to shorten material supply chains, reduce energy consumption, conserve scarce natural resources and reverse biodiversity loss, all while at the same time advancing efforts to decarbonise heavy industry in a cost-effective way.

Research objective

This study's primary objective is to **stimulate the debate on CE and its potential to reduce GHG emissions in Czech heavy industry.** By doing so, our ambition is that this will lead to investment of additional resources in this under-explored and potentially cost-effective mitigation pathway. Our intent, therefore, is not to comprehensively capture the full complexity of CE, let alone to attempt a modelling of emissions scenarios. As one of the first research papers in the Czech Republic to explore this specific topic across multiple sectors, the aim is to rather plant a seed for further investigation and ultimately for implementation of suitable CE measures.

The project has been carried out in the following three phases:

Phase 1 – research & analysis: identify, review and synthesize the most up-to-date findings from international studies on the role CE can play in reducing GHG emissions. Identify key industries, CE levers and the mitigation potential of the most promising measures. Find consensus among studies and apply this knowledge in the context of Czech industry.

Phase 2 – activation & validation: engage with key industry stakeholders to validate findings from the first phase. Identify the drivers and obstacles to implementing the identified CE measures.

Phase 3 – dissemination & communication: communicate key findings to policy makers and/or broader (expert) audience. Identify and communicate key recommendations and define areas for further research.

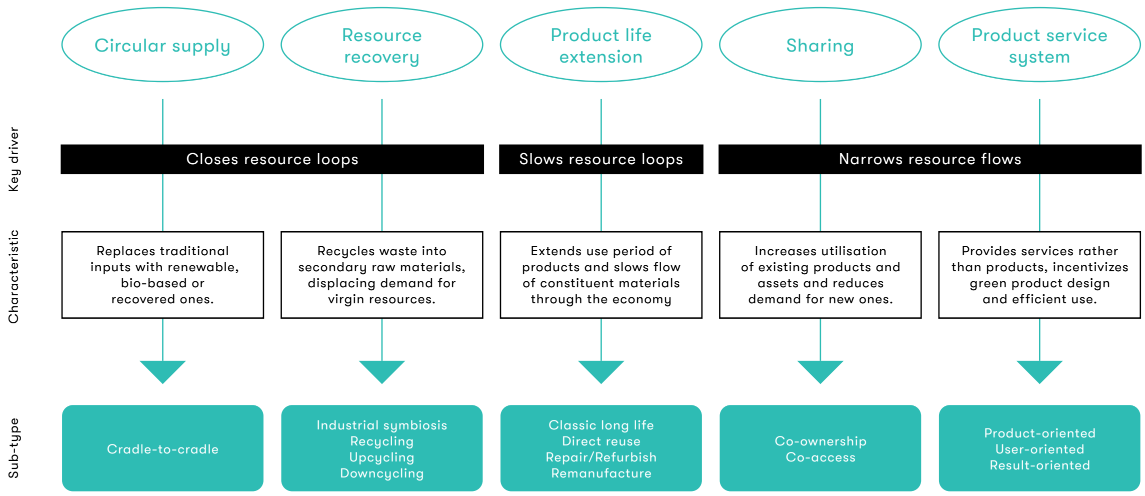
Scope and definitions

Circular Economy definition

The **Circular Economy (CE)** is a complex concept and there is still no widespread consensus on its exact scope and definition. In simple terms, we can distinguish between a narrower scope for CE that focuses on waste utilization and resource efficiency and a broader view that also includes service-based and sharing-oriented models. From the many available definitions of CE, in this study we have used as a reference framework the OECD's definition[10] that differentiates the following five key business models (i.e., the broader view):

1. **Circular supply models**, which replace traditional material inputs derived from virgin resources with bio-based, renewable, or recovered materials.
2. **Resource recovery models**, which recycle waste and scrap into secondary raw materials, diverting waste from final disposal while displacing demand for extraction and processing of virgin natural resources.
3. **Product life extension models**, such as repair and remanufacturing, which extend the use period of existing products, slow the flow of constituent materials through the economy, and reduce the rate of resource extraction and waste generation.
4. **Sharing models**, which facilitate the sharing of under-utilised products, and reduce demand for new products.
5. **Product service system models**, where services rather than products are marketed, improving incentives for green product design and more efficient product use.

A helpful simpler definition used by the consultancy Material Economics includes "under the umbrella of 'circular economy' any opportunity to provide the same economic service with less primary material."[11]



Some of the sources reviewed in this study refer to the circular economy models described above as “material efficiency”. The respective authors use this term as an overall category term for individual circular strategies. Considering this fact, we view the terms “material efficiency” and “circular economy” as different terms for the same or similar strategies. Each model then results in a CE action or mitigation lever that more specifically describes the potential action taking place (e.g., maximising secondary steel production via higher collection of scrap). These levers serve to pinpoint the potential of CE in abating GHG emissions in the respective industries.

Industry scope

Given the study’s focus on GHG emissions, the primary frame of reference for industry coverage is section 2 of the UNFCCC GHG inventory data classification for **“Industrial Processes and Product Use”**, which includes the following categories:

- → 2.A Mineral Industry
- → 2.B Chemical Industry
- → 2.C Metal Industry
- → 2.D Non-energy Products from Fuels and Solvent Use
- → 2.E Electronics Industry
- → 2.F Product Uses as Substitutes for ODS
- → 2.G Other Product Manufacture and Use
- → 2.H Other

As detailed in the next chapter, the highest GHG emissions in this category in the Czech Republic are from:

- → 2.C – Metal Industry (40%, mostly iron & steel production)
- → 2.F – Product Uses as Substitutes for ODS (24%, from refrigeration and air-conditioning)
- → 2.A – Mineral Industry (20%, mostly cement and lime production)
- → 2.B – Chemical Industry (13%, mainly petrochemicals and ammonia production)

Included also are section 1.A.2 emissions for **Fuel Combustion by Manufacturing Industries & Construction.** These are generated by similar sectors, albeit in differing proportions:

- → 1.A.2.f – Non-metallic minerals (28%)
- → 1.A.2.c – Chemicals (20%)
- → 1.A.2.a – Iron and Steel (15%)
- → All other manufacturing and construction (37%)

This picture largely coincides with the “heavy industry” sectors typically covered in international studies that have addressed this topic, i.e., “hard to abate” product value chains for iron & steel, cement and chemicals (including plastics). In addition, some studies include aluminium due to its high carbon intensity in primary forms. On the demand side, the largest downstream segments for these materials, internationally and in the Czech Republic, are buildings construction and the automotive industry. We have reviewed the same product value chains and demand sectors in this study.

Although a significant emissions category, "Product Uses as Substitutes for ODS" (ozone depleting substances) are not covered, as no significant data were found in international reports. Other sectors frequently included in international CE research in the context of GHG emissions are the agriculture and food value chain and the waste management industry. Although important, they are not included here as they are outside the focus of our current interest - heavy industry. For the same reason, we do not include the Land Use, Land-Use Change and Forestry (LULUCF) sector, which is also more complex in terms of calculating GHG emissions.

GHG emissions data

As referenced above, emissions data for the Czech Republic and comparisons with the EU are taken from the UN FCCC GHG inventory database, using the latest available annual data (2019).[12]

Research approach

Phase 1
Research & analysis

To identify key sectors, materials and relevant CE strategies and actions internationally and their potential application in Czech industry, we undertook the following steps:

1. Gather relevant background information, studies, and reports.

- → We created a list of potentially relevant studies, papers and reports from two main sources:
  - Think tanks, international organisations, consultancies (Agora Industry, Circle Economy, Ellen McArthur Foundation, Material Economics, McKinsey, IEA, OECD, Systemiq, WEF etc.) and industry associations.
  - Scientific databases (Google Scholar, Science Direct, Web of Science etc.).
- → We then developed a working list of studies based on three selection criteria:
  - The intersection of CE and decarbonisation.
  - Quantified data on the potential of CE to reduce GHG emissions.
  - Focus on industry and the heavy industry sectors of interest.
- → Over the course of the whole project, we screened over 100 studies, reports or papers, and selected approximately 40 for further review. **Of these 40, around half are new studies published after the initial research phase had been completed.**

2. Identify and review in-depth the most relevant international studies.

- → For the assessment of international trends, we selected **eight** studies or reports from **four** main sources (Agora Industry, IEA, IRP, Material Economics) covering multiple sectors and most closely aligned with our study objectives. In addition, numerous sector-specific studies were also reviewed for individual sectors. We then focused on the key scenarios and findings of these reports as a basis for identifying key materials, sectors, and circular strategies applicable to Czech industry.

3. Undertake a preliminary assessment of the target industry sectors in the Czech Republic.

- → Based on the identified potential and individual circular decarbonisation levers, we undertook a preliminary review of the target product value chains and key demand sectors in the national context, based on publicly available data at the time of writing, to summarize:

- The basic characteristics of each sector in the Czech Republic.
- The current focus of the domestic decarbonisation agenda.
- Status of key CE decarbonisation strategies in the Czech Republic.
- Key areas for further assessment.

Phase 2
Activation & validation

We then conducted four industry focus groups/discussions with over 25 key local stakeholders, focusing on two supply-side sectors (steel, cement) and two demand-side sectors **(automotive, construction)**, including:

→ **Steel:** Steel Union, representing steel makers in the Czech Republic.

→ **Cement:** Association of Cement Producers, ČEZ (largest CZ energy firm, focus on by-products from energy production), TVAR COM (engineering), Czech Business Council for Sustainable Development, Lafarge.

→ **Construction:** Skanska, Metrostav, KKCG, Czech Technical University, University Centre for Energy Efficiency in Buildings (UCEEB), Jakub Cígler Architects, Karel Goláň, ČKAIT (Czech Chamber of Authorized Engineers and Technicians in Construction), AZS 98 (Recycling association).

→ **Automotive:** ŠKODA AUTO (around 10 representatives, with a focus on sustainability functions).

Insights from these groups and subsequent feedback have been incorporated into the study.

Report structure

In Chapter 2, we provide an overview of the GHG emissions profile of target industry sectors in the Czech Republic, outline the current national policy frameworks for decarbonisation and the circular economy respectively and summarise some recent decarbonisation scenarios for industry published by private sector or non-governmental organizations. In Chapter 3, we present a high-level review of each industry sector, divided between supply-side product value chains and demand sectors, first highlighting the CE mitigation potential and associated levers from international studies, then reviewing the status of the decarbonisation debate and CE mitigation strategies in these sectors in the Czech Republic. In each section and in the executive summary, we draw preliminary conclusions from this initial review, including areas for more detailed evaluation in further research.

Current state of knowledge

A body of academic research has been developing over the past two decades on the mitigation potential of circular economy or "material efficiency" strategies that reduce demand for primary raw materials in industrial sectors. Drawing on this earlier research and using proprietary long-term scenario models, a series of larger-scale assessments published in the last several years by management consultancies, technical institutes and international organisations has sought to illustrate and quantify the potential contribution of CE to abatement of industrial emissions and demonstrate its importance to the net-zero transition.

Studies addressing the role of circular economy in industry decarbonisation

For this report we undertook a survey of the literature addressing this interface between CE and decarbonisation. It can be broadly categorised into four types of study, as described below.

Study type	Example	Characteristic
1 / Research papers and lifecycle assessments on specific products/processes	Academic research papers and articles covering individual materials, processes or specific industry sectors	Undertake a detailed assessment of a specific product segment or group of products.
2 / Meta-analyses of previous research studies	Quantifying thew benefits of circular economy actions on the decarbonisation of EU economy (Trinomics, December 2018). Saving resources and the climate? A systematic review of the circular economy and its mitigation potential (November 2020)	Conduct a review of prior studies and proprietary analyses undertaken by other organisations and evaluate comparability and useability of the study results.
3 / White papers or policy papers that draw on previous research studies	Completing the picture – How the Circular Economy Tackles Climate Change (EMF, Material Economics, September 2019). Think 2030 – A low-carbon and circular industry for Europe (EMF, IEEP, 2021)	Communicate major pathways and messages for policy makers on decarbonisation opportunities from circular actions with examples of mitigation potential from prior studies.
4 / Large multi-sector research reports with long-term decarbonisation scenarios	Build proprietary demand and lifecycle models from a wide range of previous research studies and data sources to develop long-term scenarios and estimates for decarbonisation potential from CE actions across multiple industrial sectors internationally (focus of this chapter).	

The industry sector analysis in Chapter 3 draws in particular from the following studies in the fourth category that use long-term scenario modelling and analysis to directly address the role of CE in decarbonisation across multiple sectors of interest. As these studies are referenced repeatedly in the report, source acronyms are used to cite them in the text, as indicated in the table below.

Title	Publisher	Month/year	Source acronym
Mobilising the circular economy for energy-intensive materials. How Europe can accelerate its transition to fossil- free, energy-efficient and independent industrial production	Agora Industry	03/2022	AGR
Energy Technology Perspectives 2020	International Energy Agency	09/2020	IEA:1
Iron & Steel Technology Roadmap		10/2020	IEA:2
Material Efficiency in Clean Energy Transitions		03/2019	IEA:3
Achieving Net Zero Heavy Industry Sectors in G7 Members		05/2022	IEA:4
Resource Efficiency and Climate Change – Material Efficiency Strategies for a Low-Carbon Future	International Resource Panel	11/2020	IRP
The Circular Economy – A Powerful Force for Climate Mitigation	Material Economics	06/2018	ME:1
Industrial Transformation 2050 – Pathways to Net-Zero Emissions from EU Heavy Industry		04/2019	ME:2

Industry scope and coverage of selected studies:

Study	Supply-side				Demand-side	
	Steel	Chemicals/ Plastics	Cement	Aluminium	Construction	Mobility
AGR	++	++	++	++	+	+
IEA:1	++	++	++	–	++	–
IEA:2	++	–	–	–	+	++
IEA:3	++	–	++	++	++	++
IEA:4	+	+	+	–	+	+
IRP	+	+	+	+	++	++
ME:1	++	++	++	++	++	++
ME:2	++	++	++	–	+	+

++ Detailed assessment + Summary assessment

In addition to the above multi-sector reports, a growing number of sector-specific analyses have been published over the past 1–2 years, with an increasing focus on roadmaps and scenarios to achieve net zero emissions by 2050. These are referenced individually in the report, as applicable. **A comprehensive list of reports relevant to this study (published up to the end of June 2022) is provided in Annex 1.**

Individual studies employ different scenario frameworks to illustrate the impact of circular actions. Some (IEA, ME:2) contrast a future (e.g., 2050) "baseline" emissions scenario, reflecting current policies or reference technologies, with a more ambitious "low-carbon" scenario that addresses the additional emissions reductions needed to limit global warming to 1.5 or 2°C. In some cases, the impact of circular strategies is included within this "low-carbon" scenario, in others it is shown as an incremental "circular" scenario to illustrate the additional impact of circular actions compared to a low-carbon scenario that considers primarily other decarbonisation pathways (such as low- or zero-carbon energy, CCUS or other new process technologies). In Chapter 3, we adopt the standardised terms "baseline", "low-carbon" and "circular" to differentiate these three types of scenarios. An overview of decarbonisation scenario frameworks used in each study is summarised below.

Overview of decarbonisation scenario frameworks used by author/publisher:

Publisher	Scenario framework
Agora Industry	Based on modelling provided by Material Economics, the study estimates additional CO_2 abatement potentials **in the EU** from enhanced circularity and material efficiency by material (steel, aluminium, cement/concrete, plastics) and downstream product sector (buildings, vehicles, plastic packaging) by **2030** and **2050**, relative to a "business-as-usual" (BAU) baseline.
International Energy Agency	Provides global scenarios for **major industrial material vale chains and demand sectors** over different timeframes **(2045, 2050, 2070)**, contrasting a baseline scenario with an overall low-carbon or net zero scenario that includes both circular actions **("material efficiency")** and other decarbonisation strategies. One study (IEA:3) includes a separate "material efficiency variant" that achieves the same emissions reductions as in a low-carbon scenario by reducing the scale of technology shifts and instead pushing circular strategies to their practical limits.
International Resource Panel	Focuses on **housing** and **cars** in **G7 countries** to **2050**. It has no baseline 2050 scenario for current trends, only three different low-carbon scenarios. The impact of circular actions (termed "material efficiency") is shown as an additional mitigation opportunity beyond the low-carbon scenarios. In contrast to other studies, IRP's analysis models the impact of circular actions on lifecycle emissions, not only "material-cycle" or "embodied" emissions.
Material Economics	Its first study (ME:1) on the topic provides **EU** scenarios for **major industrial material value chains and demand sectors** to **2050**. It has no baseline 2050 scenario for current trends, only a low-carbon scenario. The impact of circular actions is shown as an additional mitigation opportunity beyond the low-carbon scenario. A second study (ME:2) has a similar industry and geographic (EU) scope but, like the IEA, it contrasts a baseline 2050 emissions scenario with three net zero pathways (new processes, circular economy and carbon capture) that include both circular actions and other decarbonisation strategies in differing proportions.

Given the differences in their modelling techniques, data sources, assumptions, geographic scope and scenario time-frames, results of the selected studies are not directly comparable. Despite these differences and the resulting range of estimates, they provide a compelling illustration of the potential scale of the CE's contribution to mitigation of industrial CO2 emissions, supporting the primary objective of this study – **to stimulate the debate on CE and its potential to reduce GHG emissions in Czech heavy industry.**

Taken collectively, these studies focus on **four heavy-industry product value chains** (steel, chemicals and plastics, cement, aluminium) and their **two largest demand sectors** (buildings construction and cars or light-duty vehicles), representing the leading sources of industrial GHG emissions. The CE decarbonisation opportunity for each value chain and sector and the associated "circularity decarbonisation levers" fall into two categories of impact:

- → **Supply-side measures** that reduce inputs of carbon-intensive primary materials through **materials recirculation** (recovery, recycling and reuse) or **substitution** by low-carbon or renewable materials or feedstocks.
- → **Demand-side measures** that reduce net demand for materials though **material efficiency** and **new business models** (such as product life extension, sharing and product service system models) in major value chains.

It must be stressed that **there are numerous potential pathways to achieving emissions reductions targets for heavy industry** that apply different combinations of technologies and decarbonisation strategies in differing proportions. Nevertheless, based on the studies reviewed, **CE is an indispensable part of this overall mitigation portfolio.** In the discussion that follows, in view of the research objective, we focus on the contribution of CE within the scenarios presented and highlight a "circular pathway" in cases where multiple scenarios are defined.

Importantly, circular pathways or solutions generally have much lower investment requirements than those based on new process technologies, electrification or carbon capture, use and storage (CCU/CCS), and the technologies for their implementation in most cases already exist.[13]

To exploit the full potential of these circular pathways, the principal challenges to address are a lack of awareness and policy support and the need for sustained joint action and collaboration, as well as fundamental changes in underlying business models, throughout the heavy industry value chain.

1 | Climate Change 2021 – The Physical Science Basis (IPCC, October 2021)

2 | Completing the Picture, How the Circular Economy Tackles Climate Change (Ellen MacArthur Foundation, Material Economics, 2019), p. 13

3 | Material Economics (2018, 2019, 2022), EMF (2019), IEA (2020, 2022), International Resource Panel (2020), Eunomia (2021), SYSTEMIQ (2021, 2022), Agora Industry (2022), Circle Economy (2022) et al.

4 | Greenhouse gas emissions per capita (Eurostat, 2020)

5 | Industry as a share of gross value added (Eurostat, 2020)

6 | Total country GHG emissions without LULUCF (UNFCCC inventory)

7 | Programové prohlášení Svazu průmyslu a dopravy ČR – Životní prostředí 2022, October 2021

8 | See discussion in Chapter 2 of this report

9 | Czech Presidency of the Council of the European Union – Priorities (June 2022)

10 | Business Models for the Circular Economy – Opportunities and Challenges for Policy (April 2019)

11 | The Circular Economy – A Powerful Force for Climate Mitigation (Material Economics, 2018), p.24

12 | Greenhouse Gas Inventory Data – Detailed data by Party (UNFCCC). Further detail by sub-categories is provided in the "Annual European Union greenhouse gas inventory 1990–2019 and inventory report 2021" (EEA, May 2021).

13 | See Agora Industry (AGR, 2022, Chapter 1)

2

Czech Industry And The De-carbonisation Agenda

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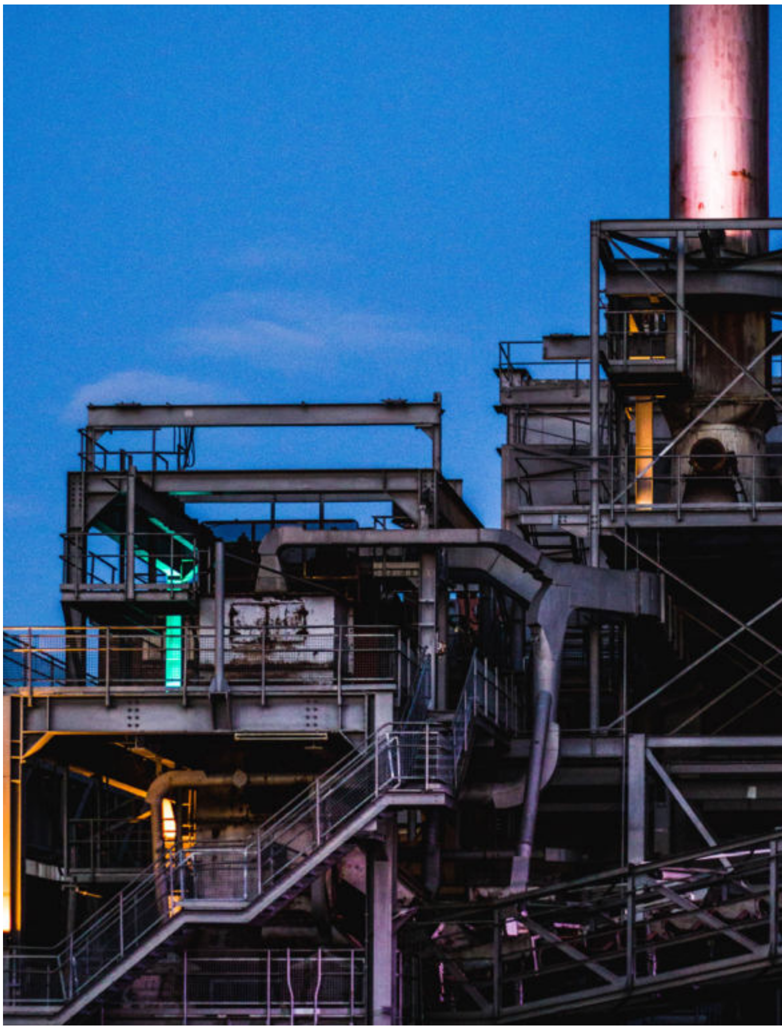
The Czech economy is the second most industrialised in the EU,[5] with a strong contribution from steel, metal fabrication, automotive, petrochemicals and construction sectors. It has a particularly high share of GHG emissions, relative to the EU average, from its carbon-intensive energy sector and from waste, due to a high level of landfilling. While industrial emissions have fallen by 60% overall since 1990, those from industrial processes and product use have only declined by 10%. Iron and steel, non-metallic minerals (mainly cement) and chemicals account for 70% of industrial emissions, with those from iron & steel and petrochemicals especially significant as a share of the EU total.

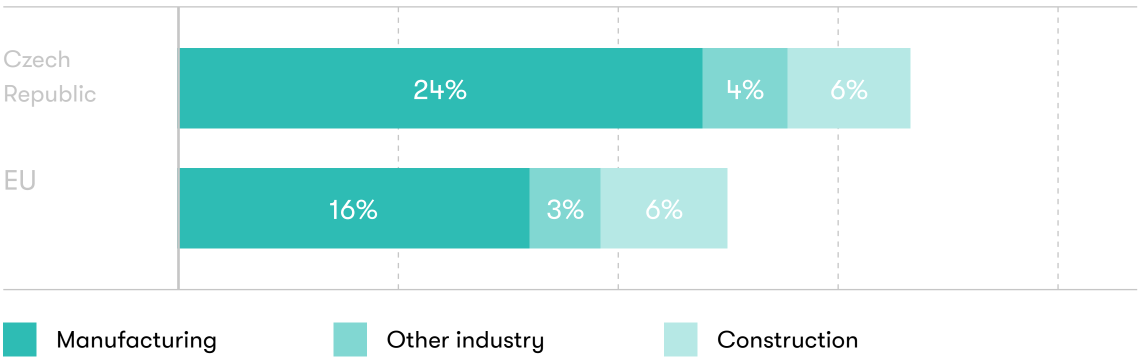
Current Czech government policy documents and national strategies currently lack a detailed roadmap for industry decarbonisation and address the CE primarily in the context of resource efficiency and waste management, not climate change mitigation. While private sector decarbonisation studies for Czech industry acknowledge a potential role for the CE, they consider (other than a shift to secondary steel production) only energy- and process technology-related pathways in their modelled scenarios. Both supply- and demand-side circular strategies should be formally incorporated into future planning and roadmaps for the decarbonisation of Czech industry.

Industry's contribution to the Czech economy

Historically, the Czech economy has relied heavily on industrial production, driven by a carbon-intensive energy system with a high share of coal-fired power generation. Even today, following restructuring and partial deindustrialisation of the economy since 1989, the Czech economy is the second most industrialized in the EU. The manufacturing and construction sectors combined accounted for 34% of total employment[14] and 30% of the economy's gross value added (GVA)[15] in 2020, well above the EU-27 average of 22%.[16] Construction contributed 6% of GVA and manufacturing 24%, with automotive assembly (5%), metal structures & products (3%) and machinery & equipment (2%) among the leading sub-sectors.[17]



Share of gross value added by industry sector (2020)



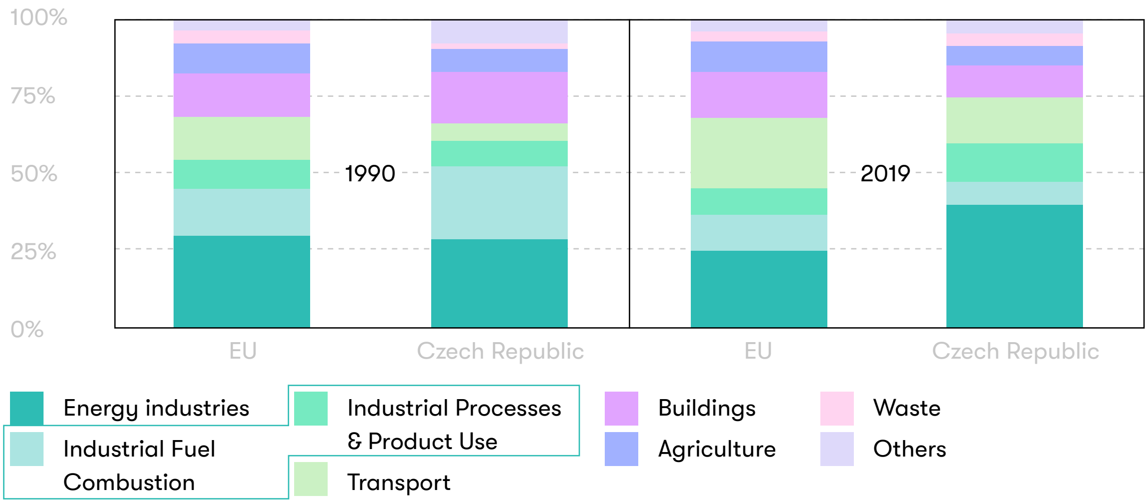
Source: Eurostat

Current GHG emissions profile of Czech industry

Total GHG emissions from the Czech economy in CO2 equivalent (CO2e), excluding Land Use, Land-Use Change and Forestry (LULUCF), have fallen by 38% since 1990, from 197 to 123 Mt CO2e in 2019. **Energy-related emissions**, which accounted for 76% of the 2019 total, decreased by 16% between 2009 and 2019, reflecting the reduced role of coal in the energy sector. However, the major difference in the emissions structure of the Czech economy relative to the EU remains its high share from energy industries; coal still accounted for half of domestic energy production in 2019.[18] Conversely, transport, buildings and agriculture sectors contribute a relatively larger share of EU emissions. The share of emissions from the Czech Republic's waste sector (4.3%), which includes the end-of-life phase of industrial materials, is also above the EU average (3.3%), reflecting the country's high proportion of landfilled municipal waste (48%, almost double the EU average rate).[19]

Industry (defined here as Industrial Fuel Combustion[20] plus Industrial Processes & Product Use, excluding Energy Industries) contributed just over 20% of total Czech Republic emissions in 2019, of which 7.6% from energy use (fuel combustion) and 12.6% from processes and product use, marginally lower than the EU overall share of 21%, due to the high share taken by the energy sector. The country's industrial GHG emissions have declined by over 60% in absolute terms since 1990. However, most of this reduction has come from fuel combustion (80% lower), while the reduction in "hard-to-abate" process and product use emissions has fallen by less than 10%.

Structure of total GHG emissions, EU versus Czech Republic

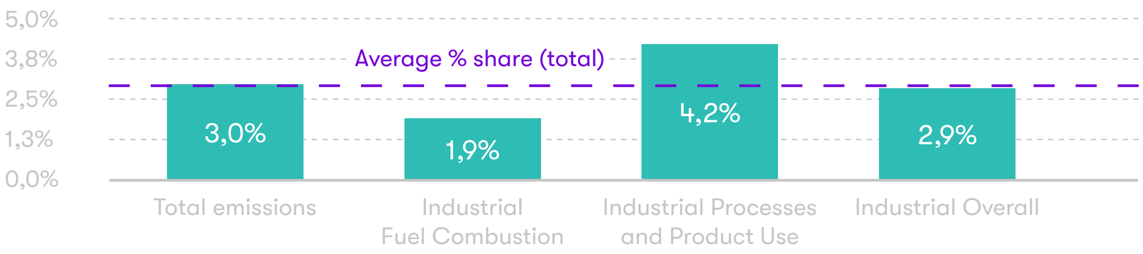


Source: Eurostat

Across all sectors combined, the Czech Republic contributes 3% of **total** GHG emissions in the EU. It has a similar share in the EU's overall **industry** emissions, a lower share of emissions from industrial fuel combustion but a significantly higher share of emissions from industrial processes and product use.

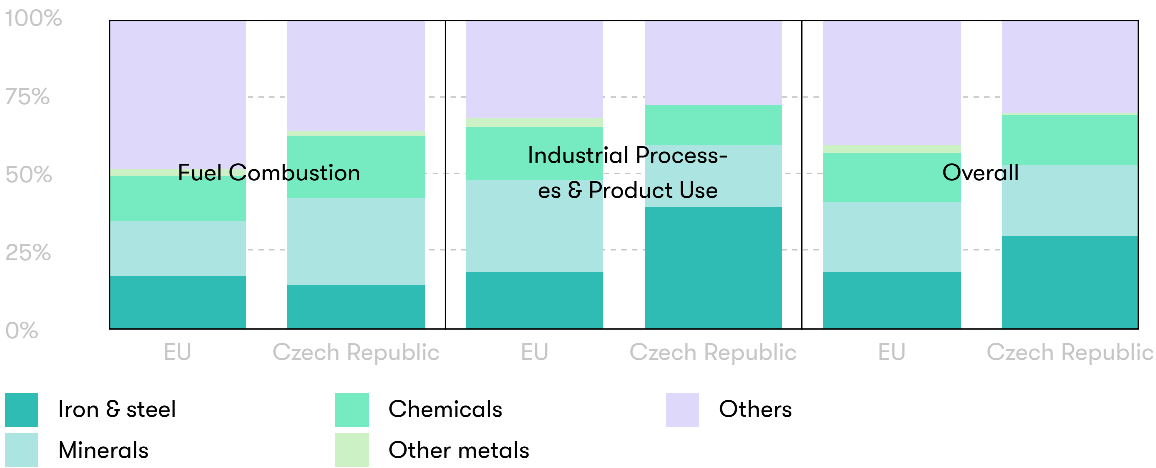
Consistent with international trends, three sub-sectors account for ~70% of overall **industrial** GHG emissions in the Czech Republic – **iron & steel, non-metallic minerals and chemicals**, a 10% higher share than for the same grouping in the EU. In the minerals sub-sector, over two thirds of emissions are from **cement production**, with the balance from lime production and other process use of carbonates. In the chemicals sub-sector, half of emissions are from **petrochemicals and carbon black production**, which provides inputs for virgin plastics and rubber production. There are almost no emissions reported for aluminium or other non-ferrous metals, as there is no primary aluminium production in the country. There are nevertheless significant embedded emissions in aluminium product imports consumed by the automotive and other metal-consuming industries. Among "other" industry sub-sectors, almost all emissions are generated by substitutes for ozone-depleting substances (ODS), principally hydrofluorocarbons (HFCs) used in refrigeration and air conditioning.

Czech Republic share of EU GHG emissions (2019)



Source: UNFCCC GHG inventory data, excluding LULUCF (2019)

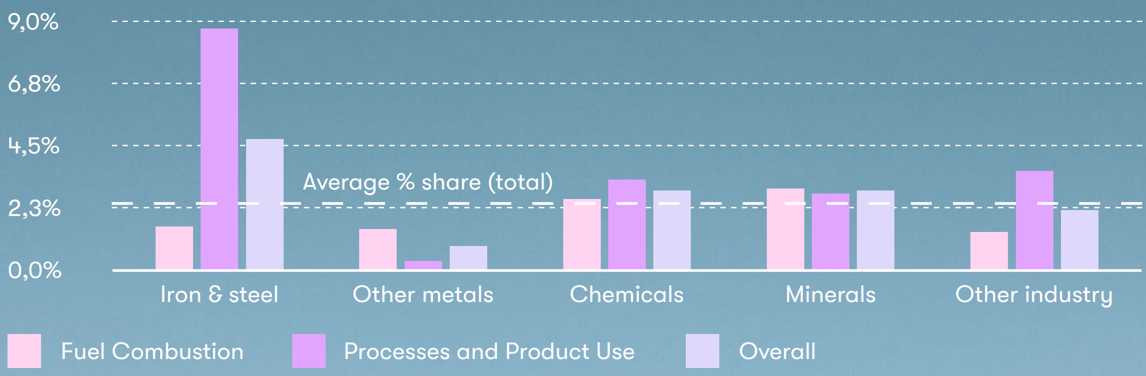
Structure of industrial GHG emissions, EU versus Czech Republic (2019)



Source: UNFCCC GHG inventory data, excluding LULUCF (2019)

As a share of the EU total GHG inventory, emissions from the Czech Republic's chemicals and minerals sub-sectors are in line with its overall share of EU industrial emissions (2.9%). Sub-sectors with shares significantly above the overall industry average are process & product use emissions from **iron & steel** and **petrochemicals & carbon black production** (~9% and ~7% of the EU totals respectively).

Czech Rep. share of EU industrial GHG emissions by sub-sector (2019)



Source: UNFCCC GHG inventory data, excluding LULUCF (2019)

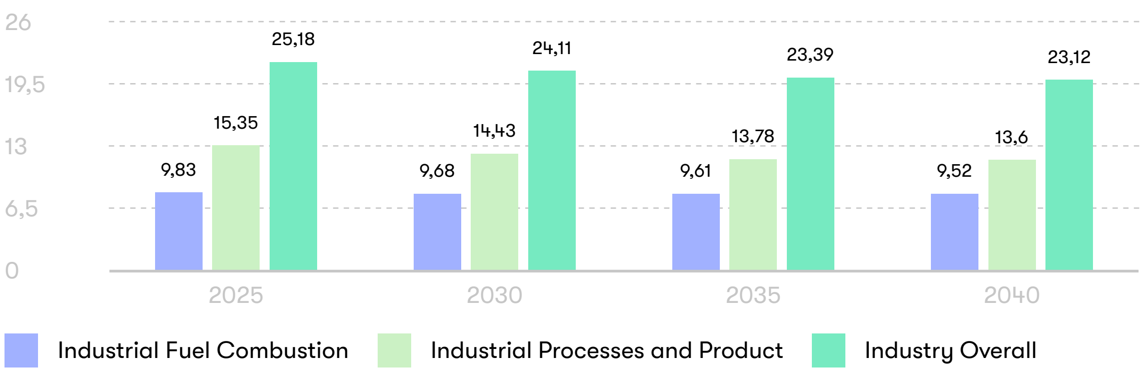
Status of the decarbonisation policy agenda for Czech industry

Several key policy documents guide the Czech Republic's strategy for climate change, including the **National Action Plan for Adaptation to Climate Change**, the **Climate Protection Policy** and the **State Environmental Policy.** As for other EU member states, a national strategy for GHG emissions reductions in accordance with the Paris Agreement and EU climate legislation was included in the Czech **National Energy and Climate Plan (NECP)**, published in November 2019. The NECP's projections for GHG emissions were based on commitments established in the EU's 2018 "Clean Energy for All" package. These have since been superseded by the EU's **2030 Climate Plan**, to be implemented under its **"Fit for 55" package.** The NECP did not consider significant reductions in industrial emissions either from energy or processes and product use, and only a "With Existing Measures" (WEM) scenario was used.

The NECP also did not further analyse industry emissions other than to state that: "The achievement of climate and energy goals in manufacturing industry, which includes, for example, the steel, chemical, ceramic, cement, glass, paper, brick and lime industries, is a separate and very complex issue. These industries have a particularly significant potential in this regard, and this fact should be considered in the framework of creating national strategies and policies. [...] The prerequisite is the rapid development of an independent industrial policy of the Czech Republic for 2021–2030 with a view to 2050, which will address the sector in a comprehensive way."

Subsequently, in September 2020, the Ministry of Industry and Trade (MIT) compiled a preliminary report for industry stakeholders as part of a **Study on Decarbonisation of the Economy in the Czech Republic**, focusing on the energy, metallurgy, nonmetallic mineral products, chemicals, and paper industries.[21] It provides an initial

Projection of industrial GHG emissions in the Czech NECP (Mt CO2e)



Source: Czech Republic National Energy and Climate Plan (November 2019) assessment of the potential impacts of the European Green Deal on Czech industry, looking at the current status and potential options for decarbonisation in the above industrial sectors covering ~65% of national GHG emissions. It explores emissions reduction scenarios based on different price levels of emissions permits (EUR 50, 80 and 100/tonne) as well as a zero-emissions scenario. The Industrial Transformation 2050 report by Material Economics is one of the sources cited for steel and cement. The contribution of the circular economy is briefly highlighted in the context of emissions reductions for these two materials, primarily in recycling and opportunities for these materials in green technologies and infrastructure, such as railways, turbines, EVs and green buildings, but is not explored in further detail. Otherwise, the study assumes that production volumes of major products will remain at close to current levels and with no significant change in the EU competitive environment.

During 2020, the Czech government also published an updated **Clean Mobility Action Plan** and a **Long-Term Buildings Renovation Strategy**, as required by EU energy and climate policy. The former defines policies, support mechanisms and targets for expansion of fleets and related infrastructure for electric vehicles and alternative fuels, to reduce operational GHG emissions from the transport sector, while the latter is a key component of the energy efficiency agenda and sets targets for reductions in operational energy use (and associated emissions) from buildings. Neither document defines specific emissions reduction targets nor addresses the embodied emissions in materials consumed by these sectors. Nevertheless, the Renovation Strategy indirectly supports buildings lifetime extension, one of the leading circular decarbonisation levers for buildings construction.

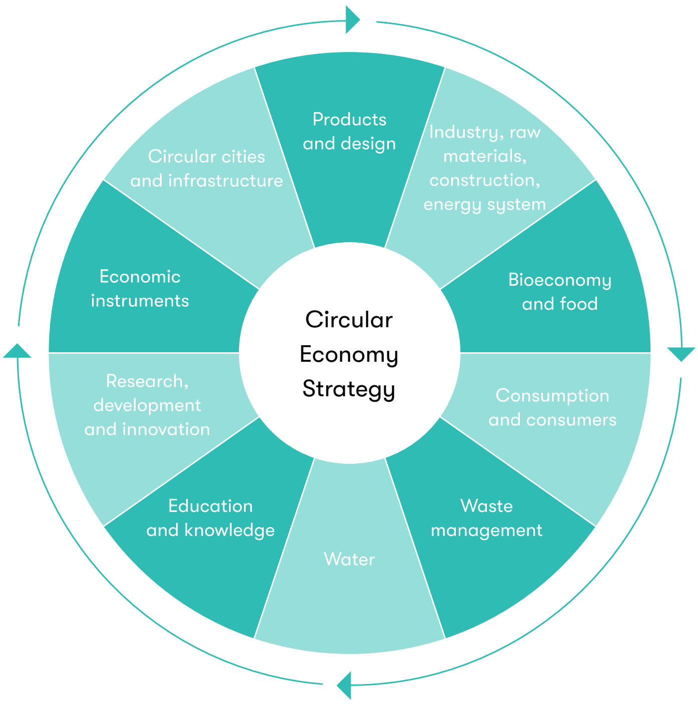
The revised **State Environmental Policy 2030** was adopted in January 2021, including an outlook to 2050. One of its strategic objectives is the **transition to carbon neutrality**, but the associated policy measures and targets, overall and for industry, focus entirely on clean and renewable energy, energy efficiency and the adoption of low-carbon process technologies. By contrast, the adjacent objective of a **transition to a circular economy** emphasises a resource efficiency and waste management agenda comprising the efficient management of raw materials, products and waste; reduction in the material intensity of the economy; maximising of waste prevention; and adherence to the waste management hierarchy.

In February 2022, the Ministry of Industry and Trade commissioned Deloitte Advisory to prepare a **financial and investment impact assessment of the "Fit for 55" package** on major sectors of the Czech economy, with a particular focus on energy-intensive industries. Preliminary results, as presented at a June meeting of the Government Council for Sustainable Development, indicated the need for a 10% increase on the investments already planned under the current NECP in order to meet the raised 2030 energy and GHG emissions targets (55% reduction in GHG emissions in 2030 compared to 1990 in industrial sectors, a 43% reduction in 2030 compared to 2005 in buildings and transport sectors and a 31% share of renewables in the energy mix).[22]

Government policy on the transition to a circular economy

Prior to the revised State Environmental Policy, two principal strategy documents supported aspects of the transition to a circular economy – the **Secondary Raw Materials Policy of the Czech Republic** (first published in 2014 and updated in 2019 for the period 2019-2022) and the **Waste Management Plan of the Czech Republic 2015–2024, with an outlook to 2035.** The latter was revised in January 2022 to reflect the requirements of the EU 2018 circular economy package, associated changes to the Czech Republic's waste legislation (in effect from January 2021), and an increased focus on the circular economy. While the potential for GHG emissions reduction from waste prevention and use of secondary raw materials is briefly mentioned, neither document explores this connection further in its current version.

The Czech Republic had until recently lacked a dedicated circular economy strategy or roadmap. **A Strategic Framework for the Circular Economy ("A Maximally Circular Czechia in 2040"),** in development since 2018 in cooperation with the OECD,[23] was published in November 2021. The document provides a comprehensive framework for national circular economy policy, comparing the EU and national situation and defining policy priorities and types of intervention for **ten priority areas** (see graphic). It also establishes linkages with the 2030 Czech Republic Strategic Framework, the State Environmental Policy, the National Recovery and Resilience Plan and other national policy and strategy documents. **Industry is part of one priority area, along with raw materials, construction and the energy sector.** The document makes numerous references to GHG emissions in relation to material consumption and use but does not establish a systematic connection between them. The Ministry of Environment (MoE) is currently developing a first **Action Plan** (covering the period 2022-2027) for implementation of the Framework, to be finalised in Q3/4 2022.



Source: Strategický rámec cirkulární ekonomiky České republiky 2040 (MOE, November 2021)

Recent decarbonisation scenarios for Czech industry

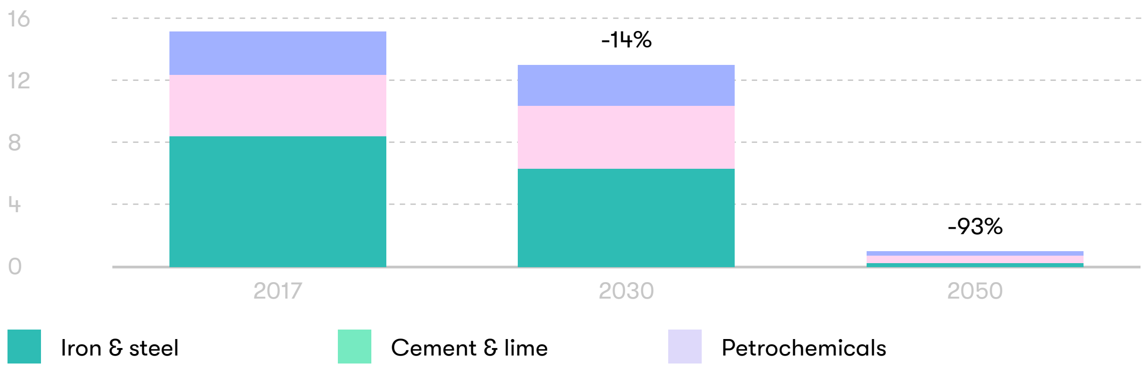
Since the adoption of the NECP, several independent decarbonisation scenarios for the Czech economy have been published by consultancies, think tanks or NGOs, in response to the raised ambitions committed under the EU's 2030 Climate Plan, specifically the commitment to reduce GHG emissions by 55% by 2030 and achieve carbon neutrality by 2050. An overview of four of these scenarios and their coverage of industry is summarised below.

Pathways to decarbonize the Czech Republic (McKinsey & Company, November 2020)

The report covers all sectors of the Czech economy, including a chapter on Industry. The authors acknowledge there are multiple possible pathways to reaching net-zero emissions but present what they consider to be a "cost-optimal pathway" to achieving this objective with minimum total costs to society. The scenario was developed using a proprietary toolkit (McKinsey's Decarbonization Pathways Optimizer) that draws on over 500 business cases covering every sector, with 2017 as the base year for emissions data. In a 2030 horizon, the main decarbonisation lever applied for three major industrial subsectors is electrification of processes, primarily in steel (EAF). The 2050 horizon assumes primarily technology shifts: for steel, to EAF and DRI-EAF using biogas, natural gas with CCS or green hydrogen; for cement and lime, biomass heating and CCS; and for ethylene, replacement of naphtha crackers by electric crackers by 2045.

Alongside these technology shifts, demand-side measures (such as construction recycling and lightweighting to reduce steel, use of cross-laminated timber to replace cement) are mentioned as an additional decarbonisation lever for industry, but they are not applied

McKinsey: Decarbonisation scenario for select industry sub-sectors (Mt CO2e)



Source: Eurostat data (2017), McKinsey analysis
Note: Only subsectors covered by this report are shown. McKinsey also includes Process Heat, Solid Fuels, Fugitive Emissions and Other sub-sectors in its "Industry" sector.

in the scenarios. The report states that "a similar or even greater contribution to the reduction of emissions may result from changes in consumer lifestyles and behaviours or the growth of a circular economy. Long-term climate strategies should also consider the potential for behavioural changes to impact the environment and energy consumption," providing examples from transportation, diet, food production and logistics, packaging and consumer durables and housing.

2050 Pathways Explorer for the Czech Republic (CLIMACT and AMO, October 2021)

A Czech Republic localised version of this open-source decarbonisation modelling tool from Belgian company **CLIMACT** has been developed in cooperation with the **Association of International Affairs (AMO).** It is currently available for around 30 countries. The tool provides a dynamic free-to-access model covering all energy sectors and GHG emissions, including the impact of materials use and production as well as societal, cultural and behavioural levers. The scenarios are not presented as forecasts and no specific likelihood is attached to them.

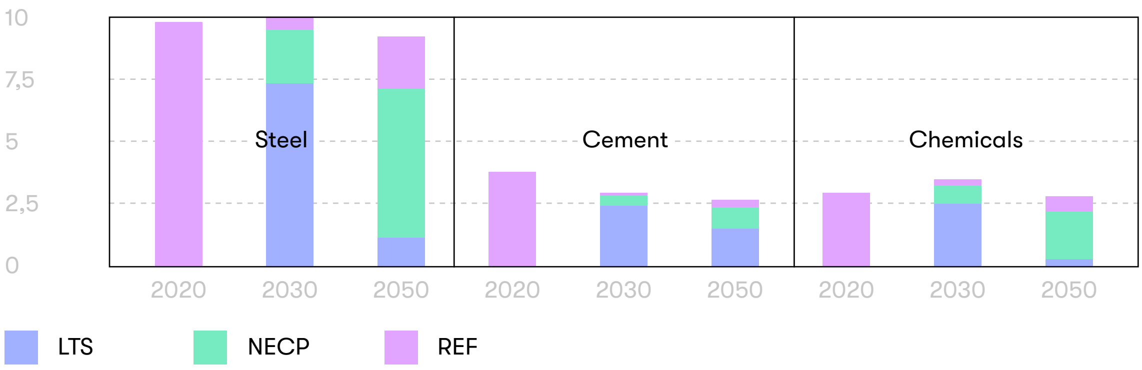
The model includes three pre-defined scenarios:

- **REF:** A baseline or reference scenario equivalent to "With Existing Measures" (WEM) in NECPs.
- **NECP:** A moderate ambition scenario similar to "With Additional Measures" (WAM) in the NECPs.
- **LTS:** A long-term scenario for 2050 carbon neutrality.

The following chart illustrates the difference in the three scenarios for sub-sectors of interest in this study based on the initial Czech release, with the LTS reflecting the lowest and the REF the highest emissions level.

Note: The presented scenario settings (for total Czech Republic GHG emissions, based on the initial version of the Explorer) assume a rapid shift from coal-based to renewable energy, 30% cumulative energy savings by 2050 and the transformation of industry by changing its fuel base and implementing CCUS technologies. Customised scenarios can be generated for a given sector or sub-sector by adjusting the level of ambition on individual parameters across nine categories of mitigation lever. For example, parameters under

CLIMACT/AMO: Decarbonisation scenario for select industry sub-sectors (Mt CO2e)



Source: CLIMACT 2050 Pathways Explorer (CZ), INCIEN analysis http://cz.pathwaysexplorer.climact.com/, extracted 11.11.2021

"Manufacturing" include linking material production to sector activity, technology optimisation (e.g., material efficiency, material switch), fuel mix and carbon capture.

The Energy Revolution: How to Secure Electricity, Heat and Transport without Fossils Fuels (Friends of the Earth Czech Republic and Greenpeace, October 2021)

This report by two leading environmental NGOs provides scenarios for decarbonisation of the Czech energy system to 2050, covering transport, industry and power generation sectors. The summary on industry references electrification and the use of hydrogen in the steel industry and assumes some reduction in crude oil demand from the phase out of single-use plastics and increased levels of plastics recycling.

The report does not otherwise provide a breakdown by industry sector and focuses on shifts in the energy mix, so has limited relevance for this assessment. Three scenarios from the **Institute of Sustainable Futures** are included in the report: a reference (baseline) scenario, a basic decarbonisation scenario and an advanced decarbonisation scenario. Emissions from industry fall by only ~22% by 2050 in the reference case, to zero by 2050 in the basic scenario and to zero by 2040 in the advanced scenario.

Six-sector specific recommendations for Czechia's Green Transition (Climate & Company, November 2021)

The overall focus of this joint study – by German sustainable finance thinktank Climate & Company in cooperation with Czech Technical University in Prague, Agora Energiewende and Eclareon Consulting – is the optimal use of EU budget funds for the green transition and associated investment priorities and policy reforms across six key economic sectors (buildings, district heating, energy, transport, grids, and industry). For industry, the study focuses on opportunities to **accelerate the shift towards green steel**, including a detailed analysis of the current policy environment, investment outlook and decarbonisation pathways for the domestic steel industry to 2030. Its key conclusions are summarised in the discussion on steel in Chapter 3.

14 | CSO – Labour market in the Czech Republic by sector 1993–2020

15 | CSO – Gross value added – by industry (current prices)

16 | Eurostat – Gross value added and income by industry

17 | CSO – Sector composition of the Czech economy (December 2020)

18 | Czech Republic 2021 – Energy Policy Review (IEA), p. 19

19 | Souhrnná data o odpadovém hospodářství ČR v letech 2009–2020 (MŽP)

20 | Section 1.A.2 of the UNFCCC GHG inventory classification: Fuel Combustion – Manufacturing Industries & Construction

21 | Studie dekarbonizace ekonomiky v ČR (část průmysl) (MIT, September 2020)

22 | První výstupy modelů dopadů Fit for 55 komentuje Rada vlády pro udržitelný rozvoj (Ministry of Environment, June 2022)

23 | OECD Environment Policy Paper No. 27 (June 2021)

3

Industry Sector Analysis

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A variety of scenarios exist for the overall impact of the circular economy on decarbonisation of heavy industry, both globally and for the EU. Even the more conservative estimates indicate that the circular economy has a major and indispensable role to play in a net zero transition for these sectors by mid-century. Under global scenarios for net zero emissions, CE measures can eliminate 20-25% of total heavy industry CO2 emissions by 2050. In the EU, CE measures could save at least 40% (AGR) and in a stretch scenario close to two thirds (ME:2) of annual GHG emissions in key heavy industry sectors by 2050.

Headline scenarios from multi-sector studies are summarised below. The decarbonisation potential and specific circular levers for individual sectors are discussed further in the following sections.

Global

Three heavy industries – **steel, chemicals (including plastics), and cement** – account for nearly 60% of **global** industrial energy use and about 70% of direct CO2 emissions from industry. In its flagship report, Energy Technology Perspectives 2020 (IEA:1), the **IEA** stated: "Technology performance improvements and material efficiency together contribute the most to emissions reductions in heavy industry in the near term [to 2040]. Adopting best available technologies yields gains in technology performance, while improving manufacturing yields, light-weighting and other material efficiency measures reduce growth in demand for materials.". In the IEA's more recent net zero scenario (IEA:4, 2022), material efficiency still contributes about 20% of total emissions reductions from global heavy industries even in an accelerated transition to 2050 (versus the 2070 timeframe used in the previous report).

Key circular (material efficiency) strategies included in the IEA's scenario include:

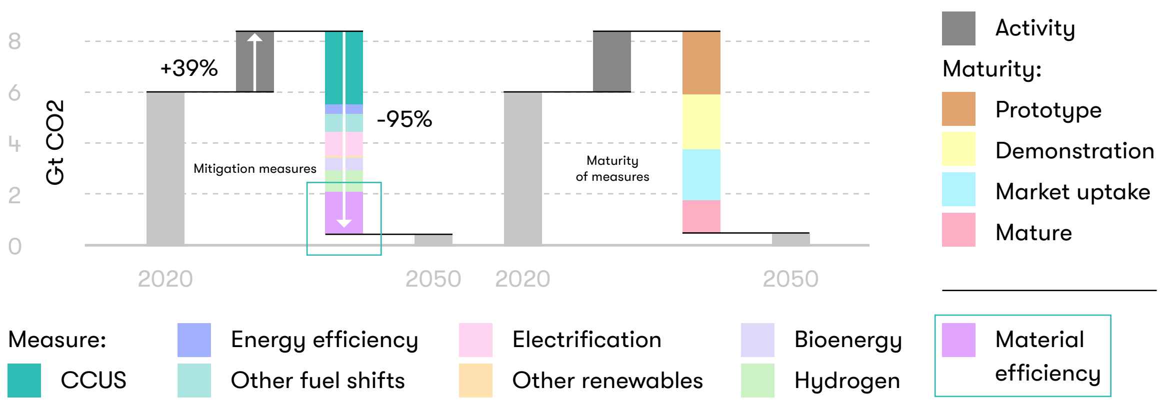
- → Changes to more efficient design and manufacturing methods.
- → Substitution of materials leading to lower lifecycle emissions.
- → Increased end-of-life reuse and recycling of materials.
- → Renovation (as opposed to reconstruction) of buildings to extend their lifetimes.
- → Modal shifts in transport to reduce the need for new vehicles and infrastructure.

European Union

Four industrial value chains account for more than 65% of EU industrial emissions: **steel, plastics, cement and aluminium. Material Economics** estimated (ME:1, 2018) that under a stretch circular scenario, emissions from EU heavy industry could fall by a further 55% compared to a 2050 low-carbon scenario, with 33% driven by materials recycling, 11% by material efficiency of products and 12% by new circular business models in mobility and buildings, notably sharing and life extension. In a follow-up study (ME:2, 2019), it further estimated that **circular measures could provide up to 64% of the total emissions reductions in the steel, chemical and cement industries** in a circular economy pathway to carbon neutrality by 2050, combining material efficiency and new business models with materials recirculation and substitution to displace primary materials.

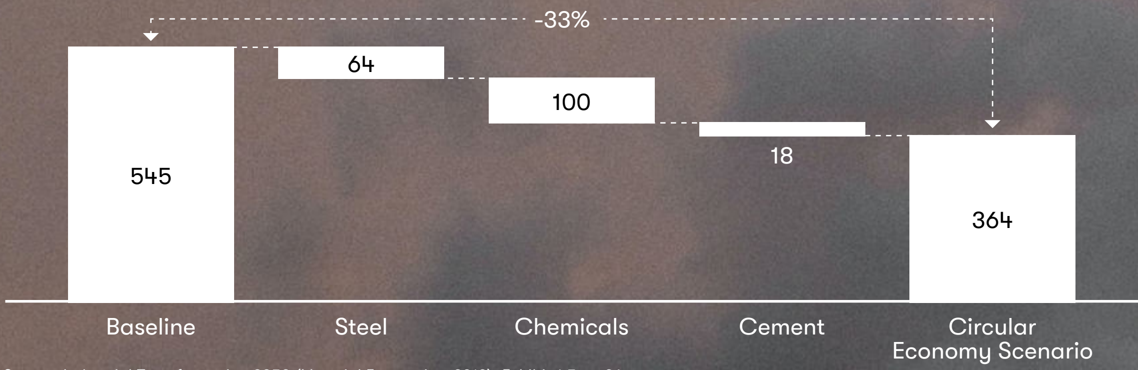
The most recent EU analysis on this topic, published by **Agora Industry** (AGR), using modelling tools from Material Economics, presents a more conservative scenario for the impact of CE measures, closer in overall mitigation potential to the alternative "new processes pathway" in the Material Economics report (ME:2). Including both materials production and downstream material efficiency in key sectors, the estimated total abatement potential for industrial CO2 emissions from CE measures is still around 240 Mt CO2e, representing **over 40% of current and 2050 projected baseline CO2 emissions from these sectors in the EU.**

IEA: Global direct CO2 emissions reductions in heavy industries by mitigation measure (Net Zero Emissions by 2050 Scenario), (Gt CO2e/year)



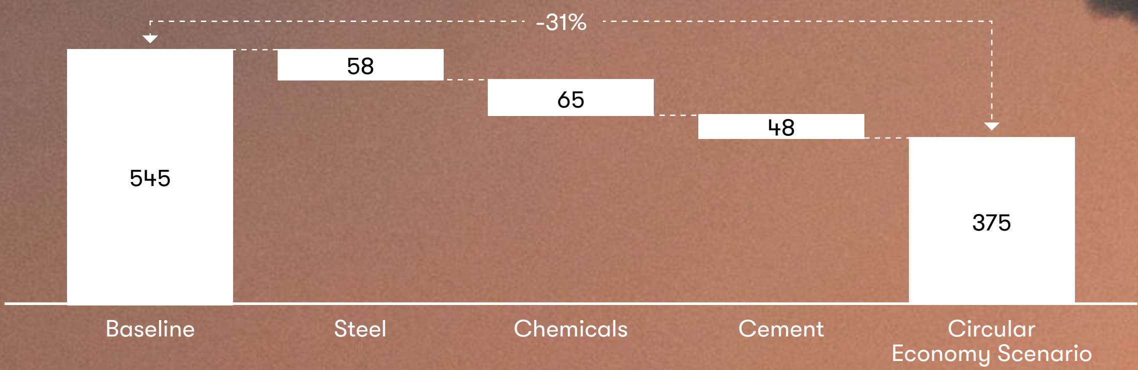
Source: Achieving Net Zero Heavy Industry Sectors in G7 Members (International Energy Agency, May 2022), p. 33

Material Economics: Circular economy scenario for net-zero EU emissions in steel, chemicals and cement Impact of material efficiency measures and new business models (Mt CO2e/year, 2050)



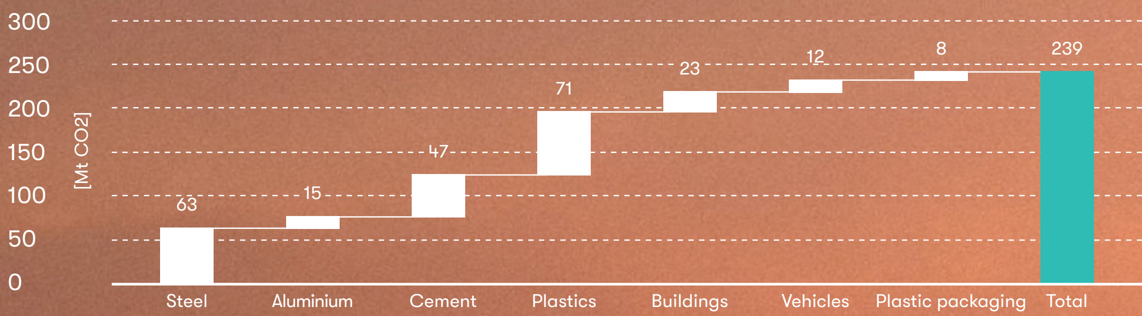
Source: Industrial Transformation 2050 (Material Economics, 2019), Exhibit 1.5, p. 26

Material Economics: Circular economy scenario for net-zero EU emissions in steel, chemicals and cement Impact of materials recirculation and substitution (Mt CO2e/year, 2050)



Source: Industrial Transformation 2050 (Material Economics, 2019), Exhibit 1.7, p. 31

Agora Industry: Estimated CO2 abatement potentials from enhanced circularity and material efficiency by material or product in 2050 (European Union)



Source: Mobilising the circular economy for energy-intensive materials (Agora Industry, March 2022), Figure 19, p. 49

Supply-side product value chains

Steel

Iron & steel is a priority focus of efforts to decarbonise industry, as it accounts for around 5% of total GHG emissions in the EU, making it the largest single industrial product value chain in terms of carbon footprint. The most important CE levers to decarbonise steel are increasing the share of scrap-based production (EAF route) and reducing long-term net steel consumption in end-use applications, especially in buildings, transport and other infrastructure. Globally, circular scenarios for steel indicate a potential to reduce steel demand by 20% to as much as 40% by 2050 relative to a business-as-usual scenario, while still providing the same economic benefits. In a fully circular scenario for the EU (ME:2), steel demand by 2050 would be almost 30% lower than in a baseline scenario and scrap-based EAF production would reach 70% of total production (up from 40% today), eliminating close to 60% of CO2 emissions from the EU steel industry.

Currently, emissions from Czech steelworks are significantly higher than the EU average due to a dominant (90%) share of primary production. The country is also historically a net exporter of steel scrap. This indicates a major opportunity to decarbonise through a shift to scrap-based production, while utilising domestic scrap reserves. Both steelworks have initiated plans for EAF investment projects. However, with domestic scrap generation slowing, it will be critical both to maintain an adequate local scrap supply and to scale affordable electricity generation from renewable sources to ensure these projects are a viable long-term route to decarbonisation.

International study insights

Circular economy levers for steel industry decarbonisation – SUPPLY SIDE

Maximising secondary steel production

→ Using electric arc furnaces (EAF) and steel scrap as the primary feedstock, steel production requires an estimated 10–15% of the production energy and produces only 20% of the greenhouse gas emissions compared to existing technologies (ME:2).

→ According to scenarios by Material Economics, secondary steel production could cover 70–85% of the EU's steel needs by 2050 (ME:1,2). Achieving this target would require an unprecedented expansion of end-of-life steel collection systems and more sophisticated scrap markets, requiring sorting by alloy (e.g., using laser-induced spectroscopy technologies). Copper contamination is also a barrier to steel recycling. This can be overcome by separating copper and steel in the recycling process, closed-loop recycling or designing products with end-of-life separation and dismantling in mind. More copper-resistant production processes may also be a solution.

Higher yield of semi-finished products

→ The term "semi-finished products" refers to crude steel products, such as steel plates, blocks or billets, that have undergone a first stage of processing (e.g., continuous casting) and are intended for further processing into fabricated steel products or products containing steel elements. Improving the yield of semi-finished products (ratio of material inputs to outputs) could contribute to a 7% cumulative reduction in global steel demand between 2020 and 2050 (and a **1.5% annual reduction in 2050**), mainly through improved production technologies and digitalisation. Examples of yield reductions in semi-finished production include scrap arising from imperfect shaping of steel semi-finished products or surface treatment technology (IEA:2).

Direct steel reuse

→ Increased rates of direct reuse (without remelting) can lead to a 15% cumulative reduction in global steel demand between 2020 and 2050 (and a **3% annual reduction in 2050**). This includes the reuse of steel from beams and building components, ship plates, pipes, etc. According to the IEA, key measures for steel reuse are, for example, the creation of 'material inventories' (to provide greater visibility of steel for reuse) or the introduction of government regulations that consider future steel reuse (IEA:2).

Circular economy levers for steel industry decarbonisation – DEMAND SIDE

Improved yield of semi-finished steel products

→ This measure applies to products that are made entirely from semi-finished steel or contain steel parts (for example, steel parts of cars or parts of buildings). Optimising the production yield of steel products (the ratio between inputs and outputs of materials) could contribute to a further 13% cumulative reduction in steel demand globally between 2020 and 2050 (and a **2.5% annual reduction in 2050**) (IEA:2), thanks to improved production techniques and digitalisation, including 3D printing and powder metallurgy (ME:1). The IEA projects that global production yields could improve by 10–20% by 2060.

Lower net steel consumption for products, buildings and services

→ A variety of demand-side measures, particularly in the construction and automotive industries, can significantly reduce the amount of new steel needed for a given product or service, including optimised building design and construction practices, extending the life of buildings, increased use of buildings, lightweighting of cars and trucks, and reduced vehicle sales due to changes in transport. The IEA estimates that such demand-side measures could together account for **12–13% of the reduction in global steel demand in 2050 and ~65% of the cumulative reduction in steel demand over the next thirty years** (IEA:2).

Use of high strength steel

→ A specific example of a measure to reduce steel consumption is the use of high-strength steel. In cars, for example, iron and steel parts account for up to two-thirds of the vehicle's weight. The use of high-strength steel can reduce the weight of some automotive parts by up to 40% compared with conventional steel. Reducing the weight of the vehicle also means reducing the greenhouse gas emissions from the operation phase of these cars, both for internal combustion vehicles and electric vehicles.[24]

Estimates of the decarbonisation potential of the circular economy

Global

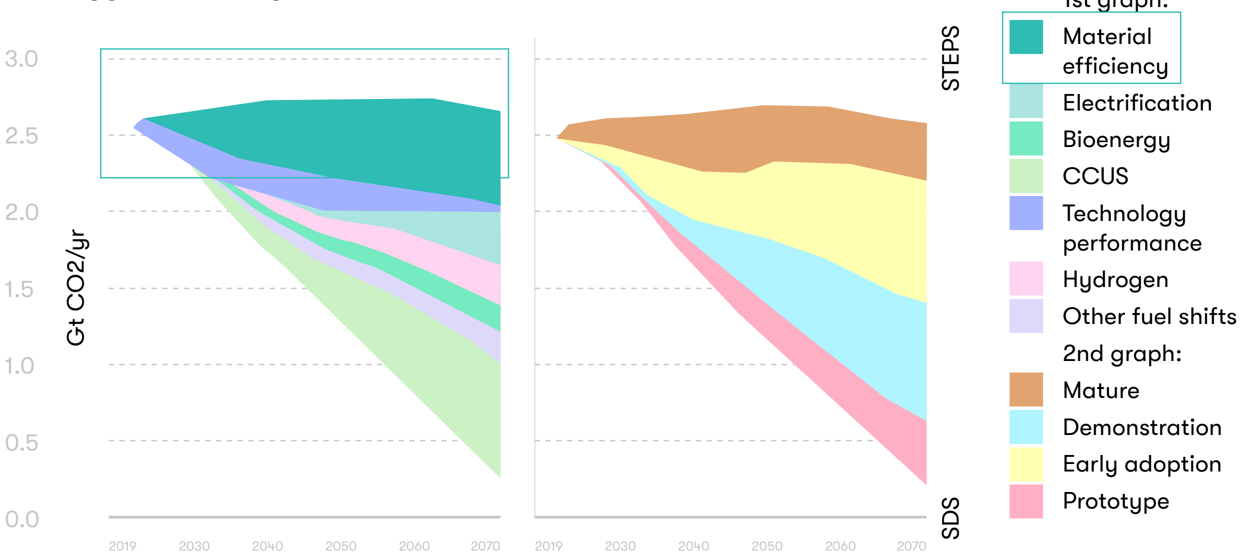
By reducing overall steel production, CE makes a major contribution to decarbonisation scenarios, contributing to an annual reduction in **global** emissions from steel production of over 40% by 2040 and 25% by 2070 – in the longer term, technological innovation will have a major impact, even as emissions reductions from circular measures continue to increase (IEA: 1,2, 2020). In the IEA's low-carbon-scenario, annual steel demand is almost 20% lower than in the baseline scenario by 2050 and almost 30% lower by 2070, due to the lightweighting of steel-containing products, less scrap production, the reuse of steel components in end-of-life products (e.g., steel beams in old buildings) and the extended lifetime of steel-based products and buildings.

In an updated Net Zero scenario (2021), the IEA assumes that 85% of emissions savings in global steel production up to 2030 will come from existing market technologies, including material and energy efficiency and a significant increase in scrap-based production, driven by increased scrap availability worldwide.[25]

For G7 countries, the IEA sets a conservative milestone of 60% scrap share in inputs to steel production by 2050, up from 53% in 2020 (IEA:4).

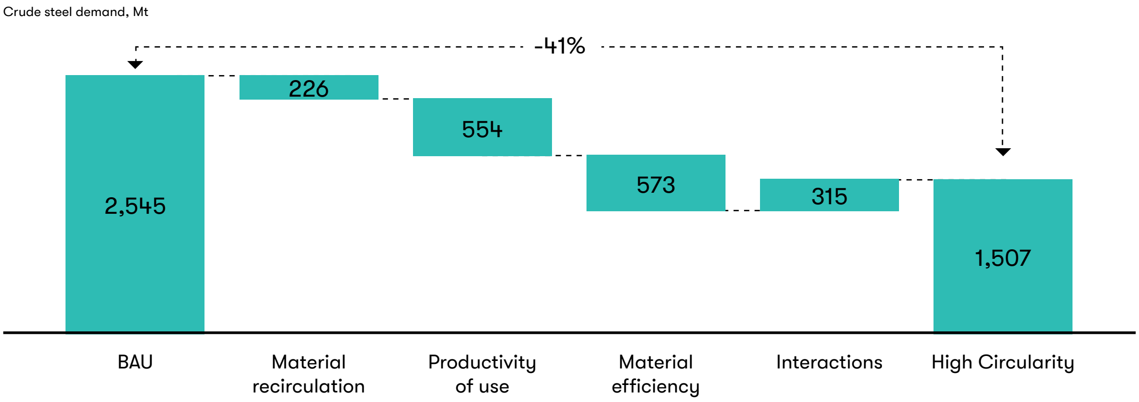
In its net zero sector transition strategy for steel, the Mission Possible Partnership presents a "high-circularity scenario" in which both supply-side and demand-side circular strategies would in a stretch case **save over 40% of crude steel demand in 2050 versus a baseline scenario.** Based on regional scrap availability modelling, this assumes that scrap share in total steel charge would reach 70% (versus 40% in a baseline), reducing iron ore consumption by 75% and saving 28 Gt of cumulative direct CO2 emissions (Scope 1 and 2) globally by 2050.[26]

IEA: Global CO2 emissions reductions in the iron and steel sector by strategy (Gt CO2e/year, 2019–2070) relative a baseline scenario



Source: Energy Technology Perspectives (IEA, October 2020), p. 205
Steps: Stated Policies Scenario. SDS = Sustainable Development Scenario.

MPP: Circular economy impacts on 2050 global crude steel demand in the High Circularity scenario (Mt)



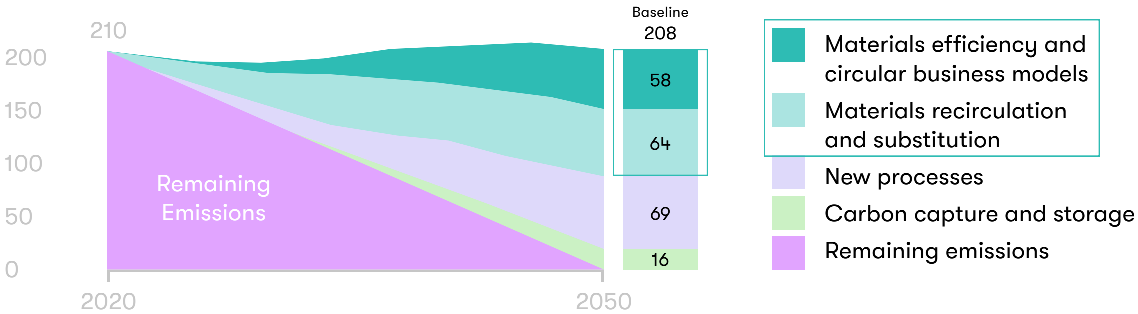
Source: Net-Zero Steel Sector Transition Strategy (Mission Possible Partnership, October 2021), Exhibit 5, p. 16

European Union

In the EU, ~60% of steel demand is currently met by primary steel (<2 tonnes CO2 per tonne) and 40% by secondary (scrap-based) steel production (~0.4 tonnes CO2 per tonne or less) (AGR). Material Economics (ME:1, 2018) estimated that in a 2050 low-carbon scenario without further circular measures, EU steel demand would remain at a similar level as today,[27] while the share of secondary steel would increase to 65%, reducing average CO2 emissions per tonne of production by more than 50%.[28] Under a stretch circular scenario, the share of secondary production could reach up to 85% of total EU steel production, with emissions reduced by a further 55% compared to the low carbon scenario. In a follow-up study (ME:2, 2019), Material Economics estimated that **circular measures could provide up to 59% of total steel sector emission reductions** under a circular net-zero pathway by 2050.

Excluding material efficiency measures in the downstream construction and automotive industries, Agora Industry's 2022 study (AGR) estimates that circular actions could achieve a 30% reduction in CO2 emissions from steel production by 2050 compared to a business-as-usual scenario, mainly through increased recycling capacity and cleaner scrap flows (lower copper contamination) to reduce downcycling and boost secondary steel applications.

Material Economics: Circular scenario for net-zero emissions in EU steel (Mt CO2e/year, 2050)



Emphasis on achieving more with steel already made and production based on recycled steel:

- Concentration on demand-side opportunities for materials efficiency and new circular business models for steel, such as car sharing, and material efficiency in construction.
- Increase in scrap-based production and recirculation of steel within EU. The share of steel produced through the electric arc furnace route increases to 70% by 2050.

Source: Industrial Transformation 2050 (Material Economics, 2019), p. 89

Czech Republic

Current focus of the domestic decarbonisation agenda

The Czech steel industry contributes 5% of the EU steel industry's total GHG emissions, both in terms of fuel combustion, processes and product use. More than 80% of its emissions are reported in the latter category (2.C.1.). Its relatively high emission factor reflects the dominant share of primary steel production – currently 90–95% of production in the Czech Republic (compared to 60% in the EU, 70% globally).[29, 30] The sector's capacity is close to 6 Mt of BF-BOF (Liberty Steel, Třinecké železárny) and 0.8 Mt of EAF. Crude steel production declined to 4.45 Mt in 2020,[31] recovering to 4.8 Mt in 2021 (in both cases 3.2% of total EU production). Total steel consumption (finished steel products) across the economy in 2021 was 8.2 Mt, the third highest per capita volume globally after South Korea and Taiwan.[32]

The main downstream sectors in the country (with an estimated share of total consumption) are construction (24%), metal products manufacturing (23%), automotive (19%) and mechanical machinery manufacturing (18%).[33]

According to the Czech Steel Union,[34] the local industry faces major challenges on many levels in the transition to carbon neutrality by 2050. Czech steelworks are expected to continue to need coking coal for the production process until at least 2030 but will increasingly rely on supplies from Poland or other international markets as coal mining in the Czech Republic is phased out. The declining number of emission allowances allocated under the EU Emissions Trading Scheme (EU ETS) and the sharp increase in the cost of additional allowances are imposing significant costs on the industry at a time when it is also having to invest heavily in low-carbon technologies and is facing increased operating costs. The EU steel industry is also under pressure from various forms of state support that benefit producers in other major manufacturing regions, notably China.

There are also concerns that under the EU Taxonomy for sustainable activities, steel companies may have less flexibility to secure financing for necessary transition projects due to greater caution and stricter criteria for eligible investments. In particular, the steel industry will be increasingly impacted by restrictions on coal financing, while alternatives to coking coal as a direct input for primary steel production are still lacking. As a result, the Union has stressed the urgent need to accelerate research, dissemination and deployment of innovative green technologies to meet 2050 carbon neutrality commitments.

The MIT's 2020 decarbonisation study[21] provides a detailed profile of the steel industry and highlights its strong links to other key sectors including automotive, construction and engineering, its strategic importance to efforts to achieve the EU's climate targets and its alignment with the circular economy, given the recyclability of steel. The sector plays an important role in decarbonisation not only by reducing its own direct emissions but also by supplying components and materials for green energy and transport infrastructure such as rail transport, wind turbines, electric vehicles and structural steel. The study considers two main pathways to decarbonisation, in line with the conclusions of the European Commission and Eurofer: electrification **(including increasing the share of EAF production using scrap)** or new process technologies (DRI using hydrogen or natural gas, process integration or CCU/CCS). **In addition to technology, the MIT study highlights the role of CE as one of the key factors in ensuring the transformation of the sector and calls for the avoidance of scrap exports outside the EU.**

The Steel Union likewise sees CE as key to the successful decarbonisation of the steel sector, but CE is yet not clearly reflected in official decarbonisation policies. It notes that DRI with natural gas will not be economically advantageous in the Czech Republic, especially in the event of an interruption of gas supplies from Russia. This technology option remains advantageous primarily for countries with a natural gas surplus, such as those in the Arab world. DRI processes using hydrogen would require a tenfold increase in electricity consumption, which would also have to be met from emission-free energy sources, in addition to huge demands on water consumption. It will therefore depend heavily on how technologies are implemented in practice and on the securing of sufficient volumes of 'green' hydrogen at globally competitive prices. The shift to both DRI and EAF technologies will also require the rebuilding of existing and new production infrastructure, as insufficient transmission/distribution capacity and lengthy permitting processes for reinforcing high voltage lines to steel works are currently barriers.

Status of selected circular decarbonisation measures

Maximising secondary steel production

An important recent contribution to the debate on decarbonisation of the Czech steel industry is a "flagship" analysis by Eclareon GmbH on pathways to **"Accelerate [the] shift towards to green steel"**, one of the "Six Sector Specific Ideas for Czechia's Green Transition", a joint study presented in November 2021 by Climate & Company, Czech Technical University in Prague, Agora Energiewende and Eclareon Consulting.[35] It sets as a key objective the maximisation of secondary steel production combined with electrification (EAF pathway) by 2030, leading to savings of 4.5 Mt of annual CO2 emissions. The study states that while only 10% of steel produced in the country in recent years is 100% scrap-based, the capacity to collect scrap steel is 5–5.5 Mt and more than 50% of collected scrap is exported. In this context, **more than 80% of the blast furnace capacity in the two main steel works needs to be reinvested by 2030, offering a major opportunity for a significant shift to secondary steel production.**

In the study's baseline scenario, 4.1 Mt of BF-BOF capacity would be replaced by scrap recycling and EAF, leading to a maximum additional investment cost of ~€ 540 mil. capex and ~€270 mil. per year opex. In addition to CO2 savings, 4 Mt of iron ore, 2 Mt of coal and 0.5 Mt of limestone would be saved per year. To cover the risk of scrap shortage in the coming years (after the conversion of the above capacity to EAF), an additional 0.5 Mt of (coal) BF-BOF capacity would be replaced by natural gas-based DRI-EAF primary steel as a complementary measure (but feasibility is currently in question in view of gas supply and price trends). The study highlights the importance of developing a low-carbon transition plan that leverages the country's scrap steel reserves and, in the long term, its hydrogen-ready natural gas network for the introduction of complementary pathways.

The MIT decarbonisation study recognises a shift to scrap production as the **most affordable route to decarbonise steel** but identifies several barriers to a widespread move in this direction. The following summary also incorporates input and feedback from INCIEN's discussions with the Steel Union during the study.

The first is availability of scrap on a global scale. Scrap is used in the steel industry in two basic types of production – **as an input to primary production in ore reduction** (blast furnaces), where scrap makes up to 30% of the input (125 kg scrap/1 tonne steel worldwide, 160 kg/1 tonne steel in the Czech Republic) and in **secondary steel production in electric arc furnaces (EAF)**, where scrap comprises up to 100% of input (710 kg scrap/1 tonne steel worldwide, 900 kg scrap/1 tonne steel in the Czech Republic).[36] The proportions depend, among other things, on the availability of scrap. Steel recycling also depends on the lifecycle time of steel applications, ranging from a few years to about 100 years depending on the type of structure (e.g., cars, building structural elements, water supply structures). In the Czech Republic, the period of intensive scrap recovery from machinery and equipment accumulated over the previous years is now coming to an end, with a lower volume of available scrap expected in the future. Worldwide, almost 2 billion tonnes of steel are currently produced, for which 2.4 billion tonnes of scrap would be needed. The actual global availability of scrap is around 500 Mt (400 Mt are processed directly in steelworks, and the remaining 100 Mt are traded).[30] From this perspective, scrap is currently scarce for total global steel production. Even if the entire global volume of scrap were traded, it would account for about one third of annual steel production needs, notwithstanding the fact that the scrap market operates in a very separate (autonomous) manner and cannot automatically ensure sufficient scrap for the needs of individual steelworks.

Another concern is the rising demand for steel due to urbanisation (and the construction and transport boom) in major emerging markets, which is driving up the price of steel scrap – in the first half of 2022 it was at the level of the 2019/2020 steel price and is expected to remain high in the foreseeable future.

The unsuitability of EAF technology for certain types of steel is also a factor, with scrap-base production making it difficult to achieve specific grades and grades of steel.

In 2018, Czech steel works consumed ~1.8 Mt of scrap for a total annual production of 5 Mt, representing ~30% of the average steel charge.[24] The Steel Union's analysis of steel scrap material flows showed that in 2017, total scrap generation was 4.3 Mt, consumption was 2.1 Mt and exports were 2.2 Mt. Of the total production, ~3 Mt of scrap was produced domestically outside the steel industry. The most recent data for 2021 shows that scrap imports into the Czech Republic are ~0.5 Mt, while exports are ~2.3 Mt, underlining the long-term trend of net exports[37] (indicative data only, exact actual data were not available at the time of this study). Scrap from the Czech Republic is exported to EU countries and limiting these exports is therefore very difficult given the rules of the EU Single Market. Even at the EU level, a long-term upward trend in non-EU steel scrap exports continues, with the value of net scrap exports doubling between 2015 – 2020.[38]

Liberty Steel in Ostrava is currently undertaking a modernisation project including plans to a shift to scrap-based EAF production. The MIT study assumed a 40% scrap share from a transition to hybrid furnaces, but a subsequent announcement by Liberty indicated an ambition for a gradual transition to a 100% scrap share. The current four existing tandem furnaces are to be replaced by two hybrid furnaces by 2025, including a 400 kV power line.[39] The investment is expected initially to reduce CO2 emissions by 50% through 70% scrap recovery.[40] As part of its Green Werk integrated transformation project, **Třinecké železárny** (Moravia Steel) is also preparing a partial switch to EAF based mainly on scrap, but implementation will depend on the direction of EU scrap exports policy and renewable electricity supply.[41] The shift to EAF production is currently threatened by rising electricity prices. Electricity consumption in EAF or hybrid furnaces with 100% scrap-based production is 3-4 times higher than for traditional technologies (e.g., blast furnaces). Overall, there is concern in the domestic steel industry that the Czech Republic does not have sufficient energy supply planned for future needs.

Higher yield of semi-finished products

The scope for optimising domestic production is considered minimal. Semi-finished products (billets, gates, etc.) are produced in all steel companies in the Czech Republic on modern continuous casting plants (CCP) and then further rolled on rolling lines, mostly controlled by computers. Production losses on both types of equipment are negligible and are fully recovered in the form of steel waste to the steelmaking process of the company.

Direct steel reuse

From the industry's perspective, the main obstacle to reuse is the difficulty of guaranteeing the quality of reused steel products. Ex-works steel products have precise dimensions and meet the material requirements of the technical standards for their specific application (construction, engineering). They are supplied by a steel maker that guarantees these properties, the product requirements are quantified in the relevant technical standards and the supplied steel must meet the safety requirements throughout the lifetime of the product. By contrast, steel obtained for direct reuse has no guarantor of its properties. In addition, steels from different producers may be used in buildings and structures (the market for steels and steel products is fully liberalised worldwide) and the individual types of steel used cannot be easily identified at the end of the life of the building/structure. Even if this were resolved, including in practical use, each piece of reused steel will need to be tested (for minimum mechanical tests) to ensure that it is suitable for the intended reuse. As such, the industry prioritises the current practice of collecting and recycling scrap and end-of-life steel products in smelters, where the steel can be given specific properties during production and processing into products, while meeting the characteristics required by the end user.

Lower steel consumption in products, buildings and services, including use of high strength steel

The Czech steel industry has been developing **high-strength steel for lightweighting** cars and trucks as an alternative to high-emission primary aluminium production. These types of steel make it possible to reduce the weight of steel automotive parts or structures by up to 40%, which contributes to reducing steel consumption in vehicle production as well as reducing emissions during operation due to the lower weight of vehicles. This is now common practice in the industry. In future, designers of machinery and equipment produced in downstream industries may also take advantage of the properties of high-strength steels. For the upgrading and repair of existing products, use of high-strength steel is conditional upon the functionality of the upgraded product being maintained and the existing prescribed product requirements being met.

24 | Oběhové hospodářství oceli sedí (Steel Union, October 2019)

25 | Net Zero by 2050 – A Roadmap for the Global Energy Sector (International Energy Agency, May 2021), pp. 126–127

26 | Net-Zero Steel Sector Transition Strategy (Mission Possible Partnership, October 2021)

27 | Note: Eurofer projects a long-term increase in steel consumption.

28 | Including reducing CO2 emissions per tonne of primary and secondary steel by 2050.

29 | World steel in figures (Wordsteel, 2022)

30 | Steel Union internal data (2022)

31 | European Steel in Figures 2021 (Eurofer)

32 | Apparent steel use 2021 (Worldsteel, 2022)

33 | Steel Union – Percentages include total steel consumption, which consists of both domestically produced steel and imported steel.

34 | EU cannot decarbonise without a level playing field on the global market (Konstrukce.cz, March 2021)

35 | Six Sector Specific Ideas for Czechia's Green Transition (Climate & Company, November 2021)

36 | Steel Union Analysis (2022)

37 | Internal analysis of the Steel Union, CZSO data

38 | European steel in figures (Eurofer, 2021)

39 | Low-CO2 emissions projects (Eurofer)

40 | LIBERTY Steel launches major carbon neutral project in Czech Republic (Liberty Steel, November 2020)

41 | Steelworks transformation will begin with the construction of new technology (Třinecké železárny, June 2022)

Cement and concrete

After steel, cement production is also a major focus for industry decarbonisation, as around two thirds of its emissions arise from the calcination process in the production of clinker, the primary component of Portland cement. While cement is on average only ~14% of concrete by mass, it accounts for 95% of its carbon footprint. The most significant CE levers to decarbonise cement are reduction of the clinker-to-cement ratio, the recovery and use of concrete fines from CDW recycling as a clinker substitute, reduced cement-to-concrete ratios in concrete mixes for specific applications and lower concrete use through material efficiency in design and construction. Due to the difficulty in abating cement process CO2 emissions, various low-carbon cement formulations are also being piloted that could deliver substantial CO2 savings in future. Overall, in one stretch scenario (ME:2), circular measures could deliver as much as 60% of the savings required to reach net-zero emissions from EU cement production by 2050.

The emission factor of Czech clinker production is around the EU average (EEA, 2019) and cement production accounts for around 2.5% of national CO2 emissions. Local cement plants have already achieved one of the most decarbonised energy mixes in the European cement industry. The clinker-to-cement ratio is slightly above the EU average. With an expected decline in availability of traditional clinker substitutes, the recovery of tailings materials from former mining sites is a promising source of future raw materials. There is also significant potential for scaling up of concrete recycling, both directly in concrete applications and for recovery of concrete fines as an additional clinker substitute, supported by a forthcoming EU standard. However, increased uptake will depend largely on changes in design and construction practices and improved incentives for adoption of recycled and low-clinker cement blends and concrete mixes in the downstream construction industry.

International study insights

Circular economy levers for cement industry decarbonisation – SUPPLY-SIDE

Reduced clinker-to-cement ratio

- **Average clinker content in cement in the EU is 77%.**[42]
- **Reducing the clinker content of cement is one of the primary ways to reduce emissions from cement production, by substituting clinker with less emission-intensive supplementary cementitious materials (SCMs)**, such as ground limestone, ground blast furnace slag (GBFS) and fly ash. As the potential to increase use of these current main SCMs is limited or declining, significant new sources are required, principally natural or calcined pozzolans (e.g., calcined clays) of which deposits are unevenly distributed across the EU (ME:2). So-called "LC3" cements use a combination of limestone and calcined clay and may help to replace fly ash and GBFS as these resources will be reduced or modified by the phase out of coal and coal-based steel production (AGR).
- **Substitute SCMs could replace up to 40% of clinker in cement in the EU by 2050 in a stretch case (ME:2). The European Cement Association, Cembureau, has adopted an EU target of 26% clinker replacement by 2030 and 35% by 2050.**
- Ecocem (France) has a technology it claims can replace as much as 80% of clinker using a combination of techniques in parallel: GBFS, optimised particle sizes and substitution of other engineered geopolymers (in case of its scarcity, GBFS could potentially be replaced by these geopolymers). Such technologies, if scalable, could produce even more significant clinker-to-cement ratio reductions in the future (AGR).
- In addition to substitution during industrial cement production, there may also be opportunities to add clinker substitutes along with cement into concrete on constructions sites (IEA:3).

Alternative binders and novel cements

- **Many alternative binders and cements are under development** (including belite clinker, calcium sulpho-aluminate clinker, calcium sulfo-aluminate cement, alkali-activated binders, magnesium silicate clinkers) **and some will likely play a role in a net-zero transition.** However, those with the greatest emissions savings potential tend also to be the least available, and there are various technical barriers to adoption (ME:2).

- → Globally, the Global Cement and Concrete Association (GCCA)[43] estimates that alternatives to Portland clinker cements will be only 1% and 5% of cement globally in 2030 and 2050 respectively, contributing less than 1% reduction in overall concrete emissions in 2050.
- → CEMBUREAU indicates a potential for 20-30% CO2 emissions savings in cements based on these alternative clinkers due to lower energy requirements, but their use is limited to specific applications. For the EU it targets a 2% reduction in process emissions by 2030, increasing to 5% by 2050.

Concrete recycling

- → **There is ongoing innovation on ways to recycle concrete fines** (small particles from crushing of used concrete), by re-grinding and medium-temperature heating of used concrete. These can be used as a less-carbon intensive substitute for clinker, as a source of calcium carbonate in cement. To achieve this, concrete must be effectively separated from other building materials such as plaster and bricks (IEA:1, ME:2).
- → By 2050, CO2 emissions per tonne of cement in the EU would be 0.6 tonnes for primary cement compared with only 0.1 tonnes for recycled cement (over 80% lower emissions intensity). With the adoption of cement recycling as a common practice, average emissions from EU cement production (before CCU/CCS) could fall by a quarter to 0.48 tonnes by 2050, compared to today's 0.62 tonnes of CO2 per tonne of cement (ME:1).
- → **Recycled concrete** can also replace natural aggregates used in concrete and reduce emissions from transport of these aggregates due to the shorter supply chains of local construction and demolition waste.

Recovery of unreacted cement

- → **Technologies are being developed to enable recovery of the 30-40% of end-of-life cement that is unreacted as a raw material for new concrete production** (ME:2).
- → Pilots by SmartCrusher (Netherlands) have demonstrated the potential to recover this unreacted cement, which can replace up to 80% of new cement in construction, saving almost half of the CO2. This technology is also able to retrieve aggregates from end-of-life concrete with improved properties relative to new aggregates, resulting in 15% lower demand for cement in the concrete mix than with virgin aggregates (ME:1).

Circular economy levers for cement industry decarbonisation – DEMAND-SIDE

Reduced cement content in concrete

- → **Cement constitutes on average 14% of concrete by mass but 95% of its CO2 footprint.**

→ **The required strength, reliability and durability of concrete could be maintained using as little as half the current amount of cement.** This can be achieved by reducing over-specification of cement and modifying production to achieve the same strength, while substituting half or more of the binder (cement) with advanced filler materials (ME:2).

→ Improved concrete packing also optimises the size of aggregates when mixing concrete, to reduce the amount of cement needed to fill spaces for a concrete of the same strength. Admixtures (e.g., plasticisers or dispersants) can improve workability and reduce cement requirements for a given strength of concrete. Fillers such as ground limestone, dolomite, basalt and quartz can also be added to concrete to reduce cement content (IEA:3).

→ CEMBUREAU estimates that digitalisation (to optimise delivery, monitoring during transport, pouring and use of admixtures, measure the carbon footprint of concrete, and improve aggregates grading) can reduce the ratio of cement in concrete by 5% and 15% in the EU by 2030 and 2050 respectively.

→ **These types of measures require major changes to current industry practices, including longer hardening times and coordinated action across the value chain.**

Lower concrete use per structure and service

→ **As described in the later section on buildings, various demand-side strategies in construction can significantly reduce the amount of new concrete required for a given structure or service, including:**

- innovative design and space optimisation.
- use of lightweight materials and structural optimisation.
- composite framing.
- precasting and prefabrication.
- use of wood as a substitute building material.
- construction waste reduction and yield improvement.
- more intensive use of buildings and building lifetime extensions, especially through renovation.

→ GCCA[43] estimates that greater efficiency of concrete use in design and construction (choice of concrete floor slab geometry and system, choice of concrete column spacing and optimisation of concrete strength/element size/reinforcement percentage) could achieve 7% and 22% CO_2 emissions reductions in concrete globally by 2030 and 2050 respectively. CEMBUREAU's roadmap has similar estimates for Europe but anticipates these savings may be offset by increased concrete demand from flood protection, transport and renewable energy infrastructure.

Recarbonisation of cement in processing of end-of-life concrete

→ **Cement has a natural tendency to recarbonate (through reabsorption of CO2 by calcium-rich hydrated fines).** Finely crushed end-of-life concrete can be exposed to air to maximise its rate of CO2 absorption. Alternatively, concrete fines can be heated in a CO2-rich environment to accelerate their recarbonation rate, for example using the exhaust gases from a cement kiln. Fastcarb (France) is an example of a project developing more effective techniques for reseparating end-of-life concrete into its constituent components, recarbonating them in this way and remaking clinker, with the co-benefit of reducing use of other scarce resources, such as sand and limestone (AGR).

Estimates for the decarbonisation potential of the circular economy

Global

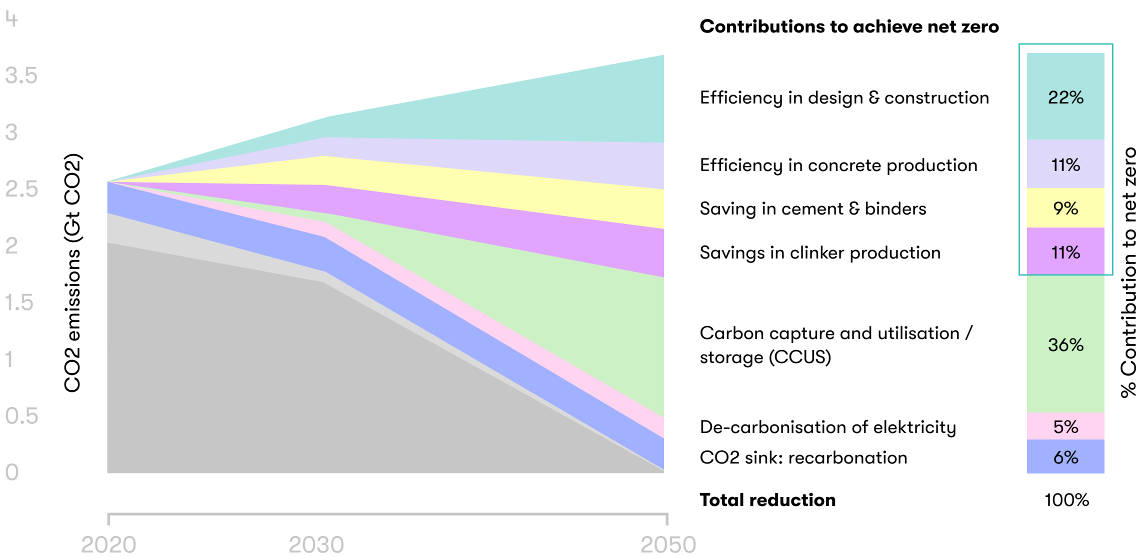
In GCCA's recent 2050 net-zero concrete roadmap,[43] **53% of the total contribution to net-zero emissions for concrete is expected to come from actions related to CE**, either through cement and clinker savings in concrete or greater material efficiency in global use of concrete.

European Union

In the EU, cement is the largest contributor to CO2 emissions from building materials, accounting for 30% of embodied carbon in buildings. For each tonne of cement produced, around 0.7 tonne of CO2 is emitted. Even with process improvements, EU 2050 emissions from cement would be close to current levels, so material efficiency measures to reduce cement consumption are critical to decarbonisation (ME:1). In its 2019 analysis, Material Economics considered multiple pathways to achieving net-zero emissions in EU cement by 2050. In a circular economy pathway with lifecycle optimisation of cement use, it estimated **the same economic benefits in terms of built area and infrastructure availability could potentially be achieved with 65% less cementitious material than required under current practices**, accounting for over 60% of total emissions savings (ME:2).

Relative to a 2017 baseline, the 2050 decarbonisation roadmap from Cembureau targets a more conservative 38% of emissions savings from circular economy measures, including decarbonated or low carbon clinker (6%), reduction in the clinker-to-cement ratio (11%), improvements in concrete mix (8%) and efficiency in concrete use (13%). The roadmap depends substantially on the deployment of CCU/CCS for 42% of total emissions reductions.

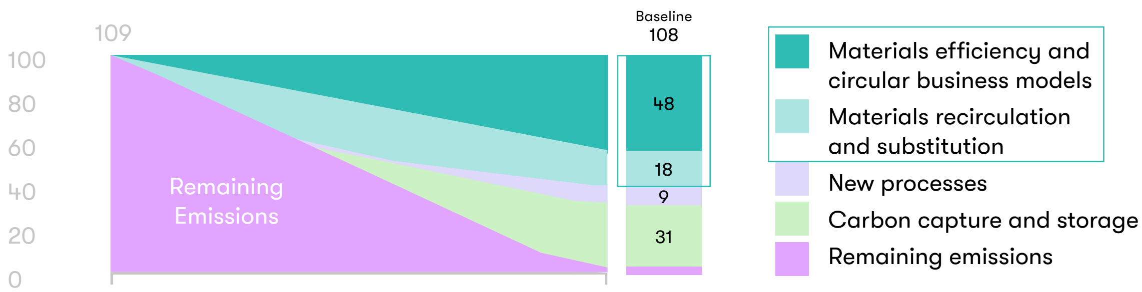
GCCA: Global net-zero pathway for cement & concrete by mitigation strategy (Gt CO2e/year, 2020–2050)



Source: GCCA 2050 Cement and Concrete Industry Roadmap for Net Zero Concrete (October 2021), p. 24

In its 2022 study (AGR), Agora Industry highlights the very challenging infrastructure requirements of such a reliance on CCU/CCS and various barriers in connecting such as large share of EU clinker and cement production to the associated infrastructure. Excluding material efficiency measures in the construction industry, the study estimates that **circular actions could achieve a 15% reduction in CO2 emissions from cement production by 2030** (10% from new binder formulations, 5% from cement recycling) and **45% by 2050** (30% from new binder formulations, 15% from cement recycling), compared to a business-as-usual scenario. The savings from cement recycling assume that about 15% of the annual volume of EU concrete demolition waste is recovered for cement recycling and at least 60% of the cement fines in this waste are fully recovered and re-used to displace virgin cement clinker.

Material Economics: Circular economy pathway for net-zero emissions in EU cement (Mt CO2e/year, 2050)



Emphasis on materials efficiency, new business models, and substitution:

- The pathway sees concerted effort by actors throughout the value chain including cement producers, concrete manufacturers, architects, construction companies, demolition companies to jointly capture two-thirds of the materials efficiency and substitution potential
- Key enablers include revision of standards to enable new practices, behavior change and diffusion of new practices across the value chain, and digitisation and introduction of new construction processes

Source: Industrial Transformation 2050 (Material Economics, 2019), p. 181

Czech Republic

Current focus of the domestic decarbonisation agenda

Annual cement production in the Czech Republic is around 4.5. million tonnes, representing ~2% of European production. Production of clinker emitted ~3 million tonnes of CO2[44] in 2020 (2 million from the calcination process, 1 million from fuel combustion). This represents 2.5% of total EU cement emissions (from calcination) and 2.4% of total emissions in the Czech Republic.[45] Emissions from fuel combustion are expected to be reduced in the future through incremental increases in the use of alternative energy sources such as hydrogen or biomass. A technological barrier remains that electricity cannot be used at present due to the high temperatures (~1,450°C) required for kiln firing. However, with an average 85% use of alternative fuels from waste co-processing, including 30% biomass, **Czech cement plants already have one of the most decarbonised energy mixes in the European cement industry.**[46]

According to the MIT's 2020 industry decarbonisation study,[47] the primary way to reduce process emissions is through carbon capture and utilization or storage (CCU/CCS). However, the study notes that these are very energy-intensive technologies, which involve the development of the necessary infrastructure at a European level. In 2021, the Czech Republic allocated CZK 7.4 billion under the Modernisation Fund to reduce CO2 emissions in industry, one of the objectives being the decarbonisation of cement production, mainly through a reduction in energy intensity.[48]

At least one cement plant in the Czech Republic is currently preparing for CCU/CCS in the form of a pilot project, supported by the both the Innovation and Modernisation Funds, expected to be established within 7–10 years.

Consistent with CEMBUREAU's 2050 roadmap, Czech cement industry representatives emphasize that cement decarbonisation can only take place in the context of the construction industry and the whole cement and concrete life cycle, i.e., the "5Cs" of clinker – cement – concrete – construction – re-carbonation, as complete decarbonisation of cement alone is not possible. A new decarbonisation roadmap of the Czech Cement Manufacturers Association (SVC ČR), published in June 2022, broadly follows the CEMBUREAU 5C framework.[46]

Status of selected circular decarbonisation strategies

Clinker-to-cement ratio

According to the SVC ČR, the average clinker content of cements in the Czech Republic was 79% in 2020. SVC ČR estimates that the industry could substitute up to 5% of clinker with decarbonised SCMs or recycled concrete fines in the foreseeable future. The availability of major SCMs in the Czech Republic is limited and a shortage is expected in the future: within 10–12 years for high quality blast furnace slag, and within 25 years for fly ash. This shortage may be caused, for example, by the reduction of steel industry activities or high prices of high-quality slag. According to ČEZ representatives, a uniform agreement should also be reached among EU member states on the treatment of limestone, which should be considered a rare raw material and used only where it is urgently needed.

In this respect, **the Czech Republic has a considerable untapped potential in the form of old tailings ponds and tailings dumps from former mining sites**, which contain more than 500 million tonnes of tailings material with a granulometry of 0–200 μ (micrometres), 200–1000 μ and 1000–4000 μ. These waste materials could become the raw material base of the Czech Republic with applications in the construction industry, but at present the use of these materials is complicated by the issue of their classification – whether they are 'abrasives' or 'fillers'. In the future, there is the possibility of using these post-mining waste materials in cooperation with the state enterprise DIAMO, which specialises in remediation of the consequences of mining activities after uranium, ore and part of coal mining.

Both the MIT decarbonisation study and the SVC ČR's decarbonisation roadmap see one of the most promising areas for cement emission reductions to be the **selection of appropriate cement blends for different concrete applications**, allowing for greater use of cement with a lower clinker-to-cement ratio. Some CEM II blends have a clinker content as low as 65%. CEM III blends (using blast furnace slag) can go as low as 5% clinker, but currently account for less than 5% of production.

A related strategy is the **differentiation of cement prices according to clinker content**, but this also faces various obstacles, with the MIT study stating that such a practice is not currently feasible in view of changing investment opportunities, the cyclical nature of construction activity and other uncertainties arising from the constantly evolving EU legislation. There are cases of concrete mixes with lower cement content being used, for example for foundations, but the general practice on site is to use as few different concrete mixes as possible, resulting in an overuse of cement in the concrete.[49]

Alternative binders and novel cements

Although various alternative clinkers are currently being developed at European level, the availability of these blends in practice in the Czech Republic is not expected until 2040 and beyond. According to the SVC ČR, the situation is complicated by concrete standards and Euro codes, which favour current silicate clinkers. The consensus in the Czech cement industry is that the development of new concrete and cement blends is currently technologically possible, but is hampered by the current legislation, which does not go hand in hand with the Green Deal.

Concrete recycling and cement content in concrete

There are promising projects in the Czech Republic that use construction waste instead of natural gravel in concrete, reducing the cement content by 45 kg per m^3 of concrete.[50] This is a critical trend as it is anticipated that **more than half of the operating stone and sand quarries in the country are likely to close within the next 10 years**, and expansion or opening of new quarries is typically a complex and long-drawn-out process.[46]

An average of 3.5% of secondary raw materials (recycled concrete fines) were used for clinker firing and 19.1% of secondary raw materials (recycled aggregates) were used in production of final concrete in 2018.[51] Greater recycling of concrete and other construction waste is encouraged by the trend towards preferential financing from banks and investors for projects that meet sustainability and proposed EU Taxonomy criteria, including greater recycling of construction and demolition waste. Different properties of recycled concrete, such its water absorption or sharpness, are a barrier in practice, and the frost resistance of recycled concrete also seems to be problematic.

A 2021 construction project in Warsaw, Poland, in cooperation with Skanska, focused on the issue of frost resistance and curing time of concrete with recycled Vertua (low-emission concrete) and produced the following findings: the addition of so-called winter additives, which increase the price of concrete by EUR 1.1 per 1 m3, was necessary for concrete at low temperatures (-10C). The curing time of this type of concrete for vertical building elements varies between 24–36 hours depending on the weather and the type of concrete elements, with a drying time of around 12 hours for thinner elements such as walls or columns.

From a regulatory point of view, an opportunity for greater recovery of recycled concrete for cement production is the **forthcoming non-harmonised European standard for cement with a component containing fine particles from recycled concrete.** Discussion and approval of this standard is expected in 2023.

42 | Cementing the Green Deal – Reaching Climate Neutrality Along the Cement and Concrete Value Chain by 2050 (Cembureau, May 2020)

43 | CONCRETE FUTURE – The 2050 Cement and Concrete Industry Roadmap for Net Zero Concrete (GCCA, October 2021)

44 | Svaz výrobců cementu ČR – DATA 2020 (2021)

45 | EEA – Annual European Union Greenhouse Gas Inventory 2021 (May 2021)

46 | SVCČR – RoadMap dekarbonizace českého cementářského průmyslu (June 2022)

47 | MPO – Studie dekarbonizace českého průmyslu, Ch.8 – Nekovové minerální výrobky (September 2020)

48 | MŽP – Modernizační fond otevírá další 3 výzvy. 7,4 miliardy korun radikálně sníží emise CO2 v průmyslu (July 2021)

49 | Sustainable materials with both eyes open (UIT Cambridge, 2012)

50 | For example, Cementum

51 | Czech Statistical Office (CSO) and SVC ČR

Plastics

Circular opportunities to reduce CO2 emissions in the chemical industry apply mainly to plastics. Emissions per tonne of recycled plastics are on average already 80–85% lower than for virgin plastics, representing a huge potential for decarbonisation. However, only 15% of waste plastics in the EU are currently recycled, with recent studies suggesting that over a third of plastic waste flows goes unrecorded. Reduction in plastics consumption and the development of a circular plastics system, based on reuse models and maximum recovery and recycling of waste plastics supplemented by sustainable biomass feedstocks, are therefore critical to decarbonisation of plastics. In one net-zero emissions scenario (ME:2), the circular economy could deliver over 80% of the required emissions reduction in plastics by 2050, through a combination of demand reduction, mechanical recycling, scaled-up chemical recycling and bio-based plastics using sustainable biomass sources.

With recent changes in packaging legislation and official recycling definitions, there is now a more realistic view of the low level of actual recycling of plastic waste in the Czech Republic. This indicates a major opportunity to move to a circular plastics system that will not only address the problem of plastic waste and pollution, but also remove most of CO2 emissions from plastics production and consumption in the economy. While local rates of plastic waste collection are high, major current barriers remain the low cost and high share of landfilling, weak recycling infrastructure and the lack of a Deposit Return Scheme for PET bottles. Initial projects for chemical recycling and bioplastics produced from biowaste streams are promising developments that need to be scaled and supported, while ensuring they deliver significant reductions in CO2 emissions from the plastics system on a lifecycle basis.

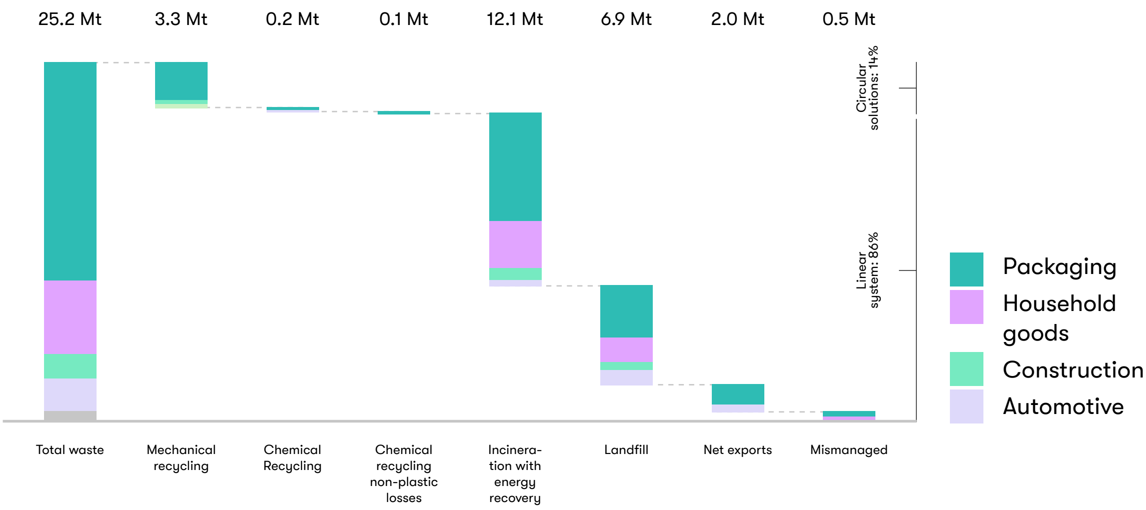
International study insights

According to a recent study by Systemiq,[52] EU plastics consumption in four sectors accounting for 75% of total plastics demand – packaging, household goods, construction, and automotive – is expected to increase by 30% between 2020 and 2050.

Currently, only about 15% of collected waste plastics from these sectors in the EU is ultimately recycled, with the remainder either incinerated with energy recovery, landfilled, exported or littered. This landfill and incineration volume corresponds to almost 30 MtCO2e of net emissions per year and a material value loss €35–55 billion. Moreover, there is a 45% reporting gap between EU plastic demand (51.4 Mt, 2019) and officially reported plastic waste (29.1 Mt, 2019), much too large to be accounted for by additions to plastic stock-in-use. This indicates that a large volume of plastics waste, not included in the Systemiq analysis, is currently "missing" in the EU waste management system.

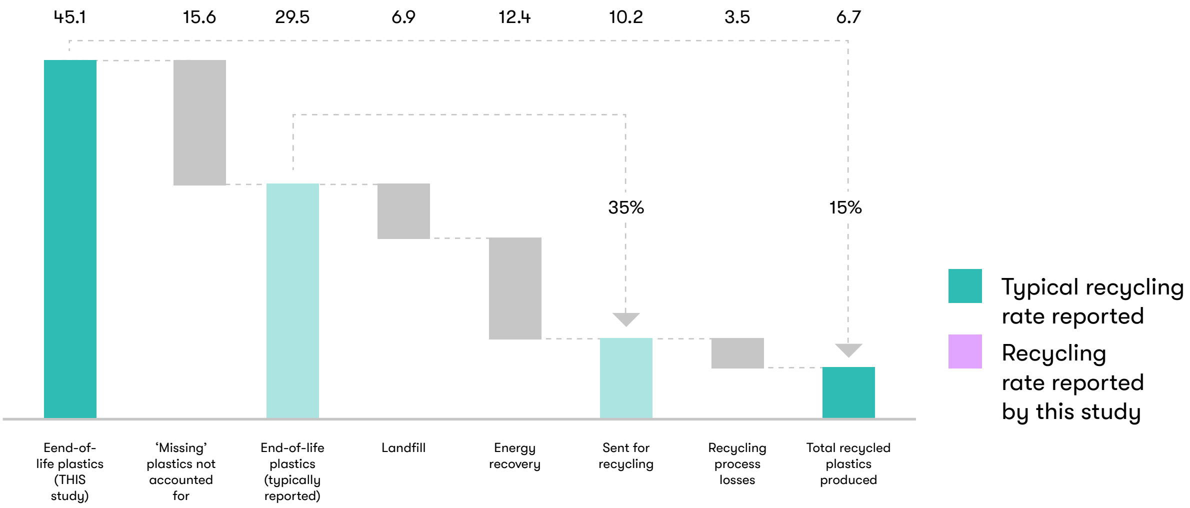
In a 2022 analysis of this "missing plastics",[53] Material Economics estimates the true volume of EU waste plastics (across all sectors) at around 45 Mt in 2020, after allowing for annual additions to in-use stock. This is over 50% higher than the ~30 Mt/year reported in official statistics as "separately collected" waste plastics. Of separately collected plastics, 41% were incinerated, 24% were landfilled, and 35% sent for recycling. Of the 10 Mt sent for recycling, only 60% was finally recycled, with the remainder exported or lost in the recycling process. **A final recycling rate of 15% also applies, therefore, to the total volume of EU waste plastics across all sectors.**

Systemiq: 86% of plastic waste in the European system is currently disposed of, exported or mismanaged in 2020
2020 Physical fate of plastic waste in Europe across four sub-systems



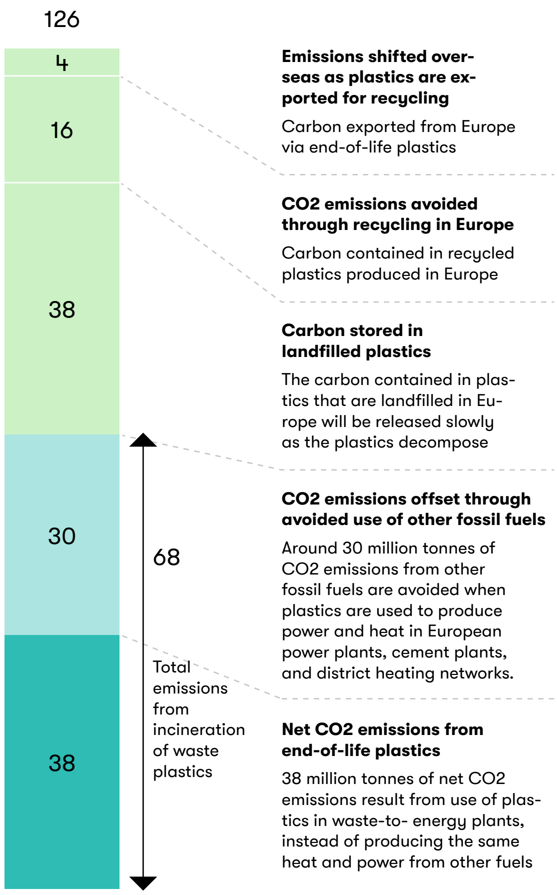
Source: ReShaping Plastics: Pathways to a Circular, Climate Neutral Plastics System in Europe (Systemiq, April 2022), p.25

Material Economics: Treatment of end-of-life plastics in Europe, 2020
Million tonnes of plastics, EU28 + NO/CH



Source: Europe's Missing Plastics (Material Economics, March 2022), pp. 17 and 21

Material Economics: Treatment of European end-of-life plastics, 2020
Million tonnes CO2 equivalents



Source: Europe's Missing Plastics (Material Economics, March 2022), pp. 17 and 21

Circular economy levers for decarbonisation of plastics – SUPPLY-SIDE

Increased mechanical recycling

- Even today, emissions from mechanical recycling are ~80% lower than those from virgin plastics and the even greater emissions from end-of-life incineration of virgin plastics are avoided. In a "circular economy pathway" by Material Economics (ME:2, 2019), up to ~35% of waste plastics would be reused or mechanically recycled by 2050 (over treble the current EU rate) and **mechanically recycled plastics would meet ~25% of plastics demand, contributing close to 20% of the reduction from 2050 baseline emissions to net zero,** with chemical recycling meeting almost half of demand.
- Agora Industry estimates that increased mechanical recycling would contribute a 27% reduction in EU CO2 emissions from plastics by 2050 versus a baseline scenario. Mechanical recycling is the most energy-, material- and cost-efficient recycling technology but it requires relatively pure waste streams to avoid downcycling. Wider use of tools such as Deposit Refund Schemes (beyond bottles) and eco-design rules to eliminate contaminants and favour polymer types suitable for mechanical recycling will be critical to reducing the volume of plastic that ends up in mixed municipal waste (AGR, 2022).

Scale-up of chemical recycling

- As chemical recycling can achieve like-virgin quality, it is an attractive option for plastics unsuited to mechanical recycling. Emerging technologies include depolymerisation, feedstock recycling by pyrolysis or gasification and solvolysis. In a net-zero system, almost all carbon in the inputs must be transformed into outputs to maintain a high carbon mass balance. **In an optimal case, CO2 emissions per tonne can be reduced by over 90% relative to virgin plastics.** In a "circular economy" pathway, assuming optimal contributions from mechanical recycling and demand-reduction measures**, chemical recycling covers almost 50% of plastics demand and contributes close to 30% of emissions reductions** (ME:2, 2019).
- Agora Industry estimates that scaled chemical recycling could contribute a 44% reduction in EU CO2 emissions from plastics versus a baseline scenario. Among others, chemical recycling can be used to maximise the recovery of waste plastics from mixed waste streams, which are typically too contaminated for quality mechanical recycling. Up to 75% of plastics from these streams can be recovered and still be viable for chemical recycling (AGR, 2022).
- Chemical recycling should be used to tackle the hardest-to-address waste streams, in particular enabling circularity for food packaging with stringent safety and hygiene requirements. Chemical recycling infrastructure must be implemented correctly, with adequate policy support, to

avoid building out plastic-to-fuel routes or increasing the system's GHG emissions.[52]

Use of sustainable biomass feedstock (bioplastics)

- In a stretch case (ME:2, 2019), recycled plastics (mechanical and chemical) can only cover 60–70% of EU plastics demand by 2050, leaving a gap to be filled in achieving a zero-carbon plastics system. Even with a 70% recycling rate, around two thirds of the embodied carbon would be released as CO2 within 15 years. Various biomass feedstocks can be processed into bioethanol, bio-methanol, biogas or bio-naphtha (e.g., via anaerobic digestion or gasification) for production of conventional plastics. Biogenic carbon emitted upon end-of-life incineration of the plastic is offset by carbon sequestered during growth of the biomass, with no net emissions. However, given the scarcity of sustainable biomass resources, bio-based plastics should be used strategically within a broader circular plastics system through flexible processes that can use biomass streams with the lowest opportunity costs. **In different pathways, bio-based plastics would contribute 27–33% of the reduction from 2050 baseline emissions to net zero.**
- While EU climate policy supports sustainable biomass utilization, the proposed revision of the second Renewable Energy Directive (RED II) mandates that member states to set up support schemes in accordance with the biomass hierarchy and prohibits the use of biomass from "primary and highly biodiverse forests". This may result in supply shortages from 2030 once industry demand for biomass feedstock increases.[55]

Circular economy levers for decarbonisation of plastics – DEMAND-SIDE

Plastics re-use and extending product lifetimes

- Agora, citing Material Economics, estimates that suitable support schemes for reduction and reuse approaches in plastic packaging could reduce emissions in the plastics value chain overall by around 11% in 2050, compared to a baseline scenario (AGR).
- In Systemiq's modelling for plastic packaging specifically, reuse models could in an optimised scenario lead to 30% less plastic packaging and associated waste by 2050, while cutting GHG emissions by 26% compared to baseline packaging demand.[52]

More intensive use of plastic-containing products

- **Continuous innovation could further reduce current use of plastics in packaging for consumer goods by at least 20% while providing the same functionality.** Circular design principles can help reduce the volume of plastic used or reduce mass through use of higher-strength plastics (ME:2).

- → In another example, structural materials, such as reinforced composites (e.g., for wind turbine blades), can be designed to a tighter specification to **reduce the amount of material required relative to thicker or over-designed components.**[56]

Material or product substitution

- → In general, replacing plastics with lower-carbon substitutes or significant behavioural and/or lifestyle changes can significantly reduce net demand for plastic.[57]
- → Up to 25% of current plastics used in packaging used could be substituted by fibre-based alternatives offering similar barrier properties, formability, transparency, etc. (ME:2).
- → Prioritising reuse systems, Systemiq's modelling assumes that a more limited 8% of plastics use in packaging would be substituted by paper, coated paper or compostables by 2050, in cases where reuse models are not applicable and assuming these alternatives have a reduced climate impact.[52]

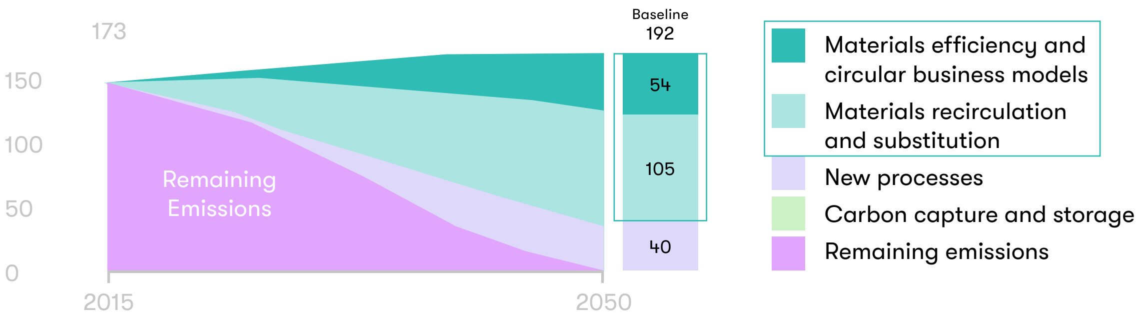
Estimates for the decarbonisation potential of the circular economy

European Union

In its 2019 study (ME:2), Material Economics modelled a circular pathway in which **circular actions could provide over 80% of the total emissions reductions for plastics to net zero by 2050**, by more ambitious scaling up of chemical recycling while harnessing biomass feedstocks to replace the remaining virgin fossil-based inputs. Plastics production would be 30% lower than in a baseline scenario, with over 60% mechanically or chemically recycled and the balance produced from biomass feedstock.

In its 2022 "missing plastics" analysis,[57] Material Economics stresses **the criticality of increasing the circularity of the plastics system.** Without an increase in

Material Economics: Circular economy pathway for net-zero emissions in EU plastics (Mt CO2e/year, 2050)



Emphasis on demand-side measures to achieve a materials efficient and circular plastics sector:

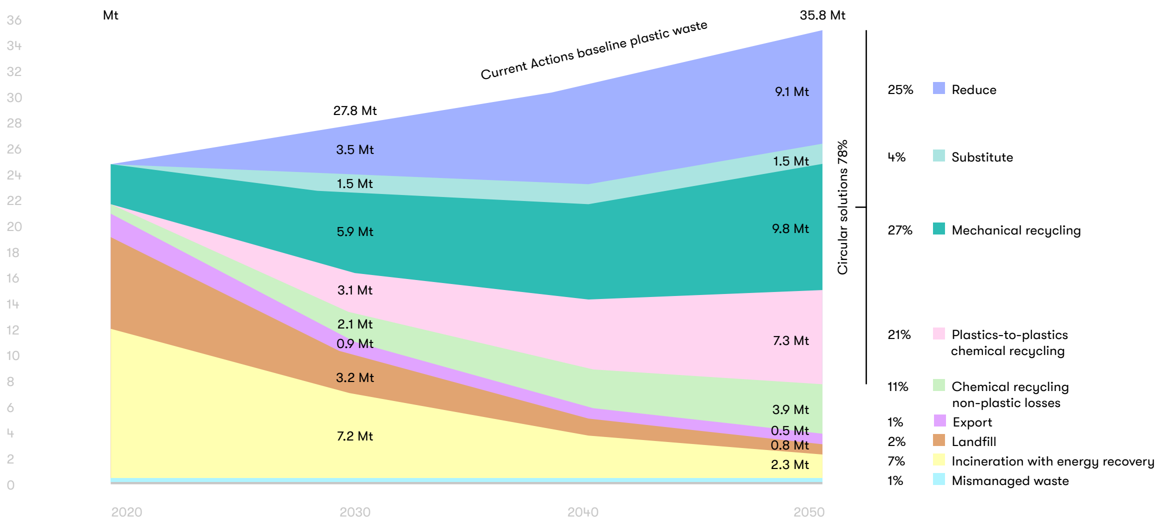
- Emphasis on demand-side opportunities for materials efficiency, materials substitution and new circular business models for plastics, resulting in the decreased production volume to 52 Mt by 2050
- Highly circular scenario with 62 percent produced through mechanical and chemical recycling, and remaining 38 percent from biomass feedstock

Source: Industrial Transformation 2050 (Material Economics, 2019), p. 131

recycling, it illustrates that net EU emissions from incineration of end-of-life plastics could balloon by 2050 to 126 Mt CO2e, due to a 30% growth in plastics volumes, additional incineration due to landfill phase-out and a reduction in the "offset benefit" from displacing fossil fuels combustion in a low-carbon energy system. Agora Industry (AGR) also highlights this risk, noting that, in the absence of effective recycling incentives, the EU's landfill phaseout by 2030 and restrictions on waste exports under the Commission's proposed revision of the Waste Shipment Regulation will serve to drive up the amount of incineration.

The Circularity Scenario developed by Systemiq[52] would achieve **78% circularity in the European plastics system by 2050, reducing by 80% end-of-life plastic disposal by 2050 compared to today and effectively reducing CO2 emissions by 65% through complementary system interventions in the plastics value chain.** This would require an estimated €160–180 billion of investments between 2020 and 2050, but circularity levers are assessed to be the fastest, most affordable, most effective, and most reliable method of reducing GHG emissions and plastics waste, with most of the associated benefits achievable before 2040.

Systemiq: Physical fate of plastic from packaging, households goods, automotive and construction 2020–2050 (Mt)



Source: ReShaping Plastics: Pathways to a Circular, Climate Neutral Plastics System in Europe (Systemiq, April 2022), p.12

Czech Republic

Current focus of the domestic decarbonisation agenda

A key of focus of the decarbonisation agenda in the Czech chemical industry has been the potential impacts of the European Green Deal and related business opportunities, especially in the plastics and rubber sub-sectors, which account for almost 70% of the industry's total employment. A sectoral feasibility and impact study was published in August 2020 by CETA on behalf of the Association of the Chemical Industry of the Czech Republic (SCHP ČR) to assess the impact of decarbonisation on the domestic industry, with a focus on economic and social (employment) impacts rather than technical pathways.[58]

A High-level Working Group for the Chemical Industry also operates under the auspices of the Czech MIT and SCHP ČR. At its April 2021 meeting, the group discussed the MIT's Study on Decarbonisation of the Czech Economy, the national Hydrogen Strategy, development of renewable energy sources and the impact of the EU Taxonomy on financing of energy projects.[59] At its January 2022 meeting, the Working Group further discussed the impact of the EU "Fit for 55" package, including the availability of competitively priced renewable and low-carbon energy, support for the deployment of breakthrough technologies, the availability of public and private finance and robust carbon leakage protection, including the Carbon Border Adjustment Mechanism (CBAM).[60]

For the chemical industry, the MIT's 2020 decarbonisation study focused on NACE 20 (production of chemicals substances and preparations) as the primary source of GHG emissions from the sector. Among its conclusions are that technologies used by the domestic industry already reflect Best Available Techniques (BAT) under the IPPC regime and there are no known alternatives in the medium term that could achieve substantial further double-digit reductions in emissions from either fuel combustion or process use. Partial solutions include the ongoing switch from coal to gas and recovery of waste heat and gas. Longer-term, green hydrogen, power-to-gas or electrification, which require decarbonisation of electricity at affordable price levels, and CCUS are potential pathways but costs and timing for mass-scale adoption remain highly uncertain. **The viability of recycling technologies is noted as a variable, while biomass is listed as a possible zero-emissions energy source.**

In May 2022, CETA published an impact study[61] for the SCHP ČR on the long-term competitiveness of the chemical industry in the context of current energy price developments and decarbonisation. The study focuses on the need to secure state support for the chemical industry in the short term and address greater energy efficiency and alternative energy sources over the longer term. It does not discuss issues related to plastics recycling.

Status of selected circular decarbonisation strategies

Major polymers produced by the Czech chemical industry include PVC, polypropylene (PP), polyethylene (PE), polystyrene (PS) as well as butadiene for synthetic rubber production. However, the domestic plastics industry is mainly concentrated in the downstream plastics converting (and rubber products) sectors, which are not a significant source of direct emissions in GHG inventory data. The Czech Republic is the 9th largest plastics consumer in the EU in terms of converter demand, at around 1.3 million tonnes per year, but its demand structure differs significantly from the EU average. While the largest segments in the EU are packaging (40%) and construction (20%), followed by automotive (10%) and electronics (6%), the leading segments in the Czech Republic are automotive (~45%) and electronics (~25%), reflecting the role of component industries for Czech, German and other auto makers.[62]

Mechanical recycling

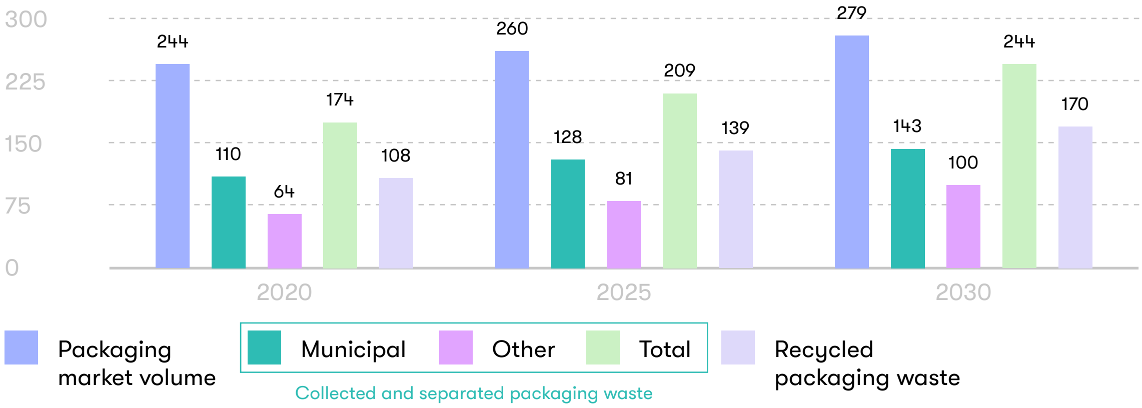
Plastics recycling has long been the most "visible" agenda associated with the circular economy internationally and domestically. However, policy discussions and media coverage of this topic are still focused on waste management, pollution prevention, reduction in landfilling and securing compliance with EU municipal waste recycling targets, while the contribution of recycling to emissions reductions is little discussed and not clearly understood.

Packaging historically accounts for over 60% of annual plastic waste produced in the country. The Czech Republic has also until recently led EU rankings for plastic packaging "recycling", with a recycling rate of over 50% versus the EU average of 42%.[63] However, this was a function of differing statistical definitions, with Czech Republic data classifying waste collected and sorted for further use as "recycled plastics". Under the country's amended Packaging Law, implementing the EU revised Packaging & Packaging Waste Directive (2018), the definition of recycling from 2021 is now the point of actual conversion of waste plastic into final products.

A major obstacle to development of secondary plastics supply in the Czech Republic has been the **continuing high rate of landfill at 1.6 times the EU average**, with the new Waste Law postponing its phase-out from 2024 to 2030, and with low, albeit progressively increasing, fees for landfilling of municipal waste. A second major obstacle to plastics recycling has been **weak demand for waste plastics**, with recycling mostly limited to recovery of industrial process waste or "cleaner" waste flows (e.g. PET bottles and hygiene products packaging) that can be more effectively sorted on the Czech Republic's predominantly manual waste sorting lines.[64]

Under the new waste legislation, EKO-KOM, the authorised packaging company for the EPR packaging waste collection and recovery system in the Czech Republic, introduced in 2021 a first phase of **eco-modulation** fees (categorised into flexible and rigid/hollow plastics and, for PET, into transparent, clear colored and opaque) to motivate producers towards use of more recyclable packaging types.[65] The potential introduction of a **Deposit Return Scheme (DRS)** for PET bottles and beverage cans, like that introduced in Slovakia from January 2022, has been under discussion in the Czech Republic for several years. Under the Iniciativa pro zálohováni, five leading

Plastic packaging targets in the EKO-KOM system (Kt/year)



Source: Waste strategy 21+ (EKO-KOM, September 2020)

beverage companies in the country have formed an alliance to renew the public debate on the introduction of a universal deposit system for these package types.[66]

In the implementation study for its "Strategy 21+", EKO-KOM projected a collection and sorting rate for plastic packaging of 67% by 2025 and 70% by 2030 and an effective recycling rate, based on the new definition, of 53% by 2025 and 61% by 2030, exceeding EU mandated levels of 50% and 55% over the same period. In its 2021 results, the collection and sorting rate was already 75% but, within this, 35% was incinerated for energy use and 43% actually recycled.[67]

Consumption of **expanded polystyrene (EPS)** in the Czech Republic was 62,200 tonnes in 2021, of which 85% in the construction industry and the remainder mostly in packaging, including protective packaging for appliances. The volume of waste EPS was 7,500 tonnes, of which 80% from packaging and the balance mainly offcuts from construction work, and 40% of this volume was recycled.[68] The Czech EPS Association has made a voluntary commitment as a member of the European association EUMEPS to raise the collection and recycling rate of waste EPS to 50% by 2025. Among the main barriers to greater recycling identified at an April 2022 workshop were a continuing lack of information about material flows, weak policy support for recycling, low costs of landfill and lack of separate collection infrastructure in housing estates and other residential areas. Through EUMEPS, The EPS Association is part of the international PolyStyreneLoop project, which opened a 3,300 tonne/year demonstration plant in the Netherlands in June 2021 for closed loop chemical recycling of EPS building insulation waste.[69]

Chemical recycling

The SCHP ČR is actively pursuing opportunities in chemical recycling at the EU level and domestically with government and industry stakeholders. The WastEN Cluster, a technical expert group, conservatively estimates that **chemical recycling can reduce CO2 emissions per tonne by up to 60% compared to virgin sources,**[70] while Material Economics (ME:2) indicated **even a 90% reduction may be possible in a long-term optimal technology scenario.** Chemical recycling (primarily pyrolysis and plasma gasification) is now officially catalogued as a method for both energy recovery and material recycling in Annex 5 of the new Czech Waste Law and is eligible for EU or national subsidies under multiple programmes. In 2021, Orlen Unipetrol commissioned a pilot pyrolysis unit at its Litvínov refinery for chemical recycling of plastic waste and rubber tyres, with plans to scale up to recycling of plastic waste streams nationwide. Outputs will provide feedstock for basic petrochemicals (ethylene, propylene, butadiene, benzene), and be used to increase production of transport fuels.[71]

Bioplastics

The critical challenge is to develop bioplastics based on sustainable biomass sources (such as wood, straw, waste from water treatment and biogas plants, waste cooking oil and other waste streams), and avoid problematic bioplastics in terms of biodegradability, microplastics, incompatibility with other waste streams in collection systems or competition with agricultural land use. The carbon footprint and overall environmental impact of bioplastics should also be evaluated against alternatives based on rigorous lifecycle analysis (LCA).

Due to lack of scale and difficulty of effective recycling, much bioplastic waste is currently best suited to incineration.[72] ORLEN Unipetrol also has an ongoing project to recycle waste hydrogenated vegetable oil (HVO) as a feedstock for its ethylene unit in Litvínov. It received international certification for the process in November 2021, produced its first batch of bio-based PP and can also produce PE, ethylene and benzene using the same feedstock. In early 2022, the facility had a processing capacity of 5,000 tonnes of HVO, with plans to increase this initially to 10,000 tonnes/year and eventually 100,000 tonnes/year.[73]

52 | ReShaping Plastics: Pathways to a Circular, Climate Neutral Plastics System in Europe. (Systemiq, April 2022).

53 | Europe's Missing Plastics (Material Economics, 2022)

54 | ReShaping Plastics: Pathways to a Circular, Climate Neutral Plastics System in Europe (Systemiq, April 2022)

55 | Towards a Net-Zero Chemical Industry: A Global Policy Landscape for Low-Carbon Emitting Technologies (WEF, May 2022)

56 | The Future of Petrochemicals (International Energy Agency, October 2018)

57 | Europe's Missing Plastics (Material Economics, 2022), pp. 22–23

58 | Feasibility and Impact Study of the European Green Deal and of Industry Decarbonisation on the Chemical Sector of the Czech Republic with Focus on Employment (CETA, August 2020)

59 | Pracovní skupina na vysoké úrovni pro chemický průmysl – „Dekarbonizace chemického sektoru v ČR“ (April 2021)

60 | Pracovní skupina na vysoké úrovni pro chemický průmysl – balíček „Fit for 55“ (January 2022)

61 | Dopadová studie: Dlouhodobá konkurenceschopnost chemického průmyslu v kontextu vývoje cen energií a dekarbonizace (CETA, May 2022)

62 | Update of the Secondary Raw Materials Policy 2019–2022 – Material Flow Analysis (December 2018), Ch. 3

63 | Plastics – The Facts 2020 (Plastics Europe)

64 | Recyklace plastů: proces a jeho problémy (Zajímej.se, December 2020)

65 | Ekomodulace poplatků se blíží (EKO-KOM, April 2021)

66 | Výrobci nápojů sdružení v Iniciativě pro zálohování chtějí plošný zálohový systém na PET lahve a plechovky (November 2021)

67 | Výroční shrnutí 2021 (EKO-KOM, May 2022)

68 | Press release – Sdružení EPS je o krok blíž cirkulární ekonomice (June 2022)

69 | Press release – PolyStyreneLoop (June 2021)

70 | Recyklace komunálních odpadů a plastových směsí (Klastr WastEN, August 2021)

71 | ORLEN Unipetrol testuje chemickou recyklaci odpadních plastů (SCHP ČR, May 2021)

72 | Fakta a mýty o bioplastech (INCIEN, December 2020)

73 | ORLEN Unipetrol pokračuje ve strategii udržitelnosti. Vyrobil certifikovaný obnovitelný polypropylen z odpadního rostlinného oleje (March 2022)

Aluminium

Aluminium has different dynamics to the other product value chains as its use as a lightweight steel substitute to reduce operational energy emissions from vehicles is a key demand driver, despite the high embodied emissions in primary aluminium. As a result, the scope for measures to reduce demand is less applicable, although increases in aluminium use per vehicle may be offset by design reductions in average vehicle size, more intensive vehicle use and vehicle lifetime extension. Increasing the share of secondary aluminium in aluminium consumption (whether produced in the EU, or imported) is the key decarbonisation opportunity, as its emissions can be less than 5% of those from primary aluminium. Industry scenarios indicate that close to 50% of aluminium emissions in the EU would be eliminated by increasing the share of recycled aluminium in EU consumption to 50% by 2050.

There are almost no direct emissions from non-ferrous metals in the Czech Republic. However, there may be significant embodied carbon in imported primary aluminium used in the domestic automotive and metal fabrication industries that can be decarbonised through a switch to recycled grades. In automotive lightweighting applications, aluminium faces competition from high-strength steel supplied by domestic steelworks. Although small in absolute scale, the Czech Republic significantly underperforms in recycling of aluminium beverage cans, with only a 22% recycling rate in 2019. Alongside planned improvements in the EKO-KOM collection network, the introduction of a Deposit Return Scheme is an internationally proven way to maximize collection and closed loop recycling.

International study insights

Replacement of primary aluminium by secondary (recycled) aluminium can reduce emissions per tonne of production by over 95%. Recycled aluminium accounts for about one third of global aluminium production, a proportion that has remained stable over the past two decades. Around 80% of scrap aluminium globally is currently collected and recycled. Closing the loop on the remaining scrap volume (comprising about 5% of "new" scrap and 30% of "old" scrap from stock-in-use applications) will be a major challenge.[74] Nevertheless, as the EU currently imports close to 30% of required primary aluminium, increasing the rate of scrap recovery and recycling within the EU is one of the principal levers for decarbonising regional aluminium supply.[75]

Circular economy levers for aluminium decarbonisation – SUPPLY-SIDE

Improved product design

→ More end-of-life aluminium could be recovered if initial product design facilitated the separation of components upon dismantling. The EU's framework for extended producer responsibility could help achieve cleaner scrap flows (ME:1).

Functional specification of metal performance

→ A shift away from the current practice of specifying the precise composition of alloys, to specifying and buying aluminium based on function instead would support higher levels of recycling and reduce downcycling (ME:1).

Reducing losses and preventing downcycling

→ Key enablers are increased collection and lower scrap by preventing mixing of different aluminium types, improved sorting by alloy, reduced number of alloy specifications, changed product design for recycling and additional closed loops. Significant losses that occur in municipal waste systems at end-of-life stage of consumer products could be reduced by additional deposit systems (like those used for beverage cans) and separation of metals ahead of other treatment.

More effective dismantling processes

→ Creating effective automated disassembly systems or extending current technologies to separate auto parts before shredding would help prevent alloy mixing and enable cleaner used metal flows (ME:1).

Efficient scrap markets

→ A more efficient market for scrap can be supported by real-time information on scrap flows available in an area, tracked through distributed ledgers or other IT platforms (ME:1).

Production process development

→ Methods could be introduced to improve the commercial viability of removing impurities from aluminium, including improvement of current aluminium refining methods such as electrolysis, electroslag refining, fractional solidification and fluxing refining (ME:1).

Reuse of aluminium

→ Considering technical potential identified in earlier studies, current reuse rates by application could increase in a 2060 circular scenario from negligible levels currently to nearly 20% in building and construction applications and 30% or higher in transportation, electrical and consumer durable applications (IEA:3).

Circular economy levers for aluminium decarbonisation – DEMAND-SIDE

Improved semi-fabrication and product manufacturing yields

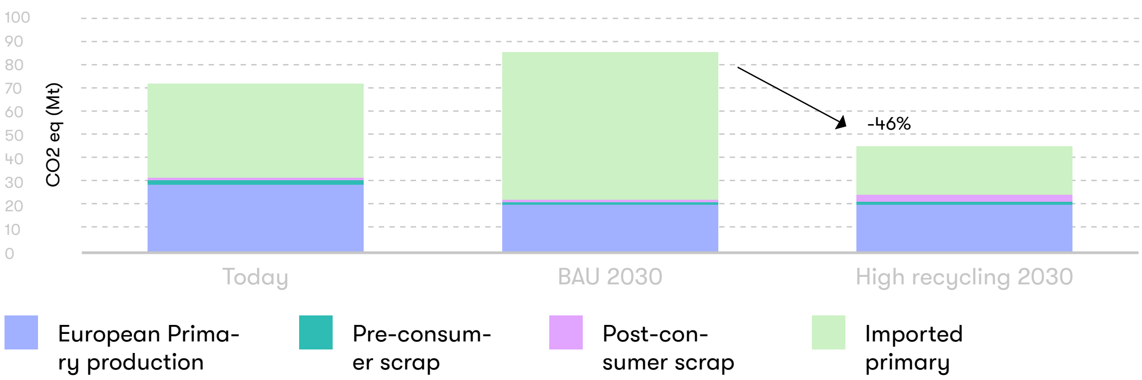
→ Globally, aluminium manufacturing yields (the ratio of material outputs to inputs) are lower than for steel at 50–75% for semi-fabricated products and 90% for most end-use product applications. In a circular scenario, manufacturing yields are 10–20% higher than current or 2060 baseline levels (IEA:3).

→ Some car manufacturers still generate over 40% scrap, although best practice is close to 25%. New production techniques, such as additive manufacturing, could also lower scrap volumes (ME:1).

Lower aluminium use per structure and service

→ As described in the later section on passenger cars, demand-side strategies in mobility can reduce

European Aluminium: CO2 emissions avoided by replacing import of primary aluminium with recycled aluminium in Europe (Mt CO2e/year, 2019 versus 2050)



Source: Circular Aluminium Action Plan (European Aluminium, April 2020), Figure 7, p. 1

the absolute amount of aluminium required despite an increase in relative demand from vehicle lightweighting, in particular, reduction in average vehicle sizes, more intensive vehicle use (ridesharing, car-sharing) and vehicle lifetime extension.

Estimates for the decarbonisation potential of the circular economy

According to Material Economics (ME:1), the potential for aluminium recycling is increasing in tandem with demand growth for aluminium as a lightweighting material. End-of-life aluminium could meet over 40% of demand globally by 2050, sharply reducing CO_2 emissions as remelting existing aluminium can use less than 5% of the energy required for primary production.

Key levers for maximising this potential are **reduced aluminium losses in each use-cycle** (currently 25–30% of material inputs), **improved end-of-life treatment, collection and sorting to reduce down-cycling, and designing products for disassembly and recovery of aluminium.**

The Circular Aluminium Action Plan of European Aluminium, anticipates that 50% of the EU's overall aluminium demand could be satisfied by recycled aluminium by 2050, reducing CO_2 emissions in aluminium consumed from all sources (domestic and imported, primary and secondary) by 37% to 2030 and 46% to 2050.

Czech Republic

Current focus of the domestic decarbonisation agenda

There are 13 operating primary aluminium smelters in the EU (in France, Germany, Greece, Netherlands, Spain, Romania, Slovakia, Slovenia and Sweden), 10 in EFTA countries (Norway and Iceland) and one in the UK.[76] There is no energy-intensive primary production of non-ferrous metals from ores in the Czech Republic. Main domestic facilities for aluminium metal supply and semi-fabricated products include two extrusion plants, one rolling mill and seven recycling plants.[77] In addition, there are 37 foundries for non-ferrous metal castings, with annual production of 95 kt in 2020.[78] These facilities consume aluminium and its alloys in the form of imported primary or semi-fabricated products (e.g., flat rolled, extrusions) or scrap.[79] Consequently, domestic aluminium production has minimal direct emissions other than from fuel combustion; all non-ferrous metals combined account for only 0.1% of total country GHG emissions. There is no visible decarbonisation agenda for aluminium; the Association of Czech Foundries[80] is the only non-ferrous metals sector organisation. **Nonetheless, there are significant embodied emissions in imported primary aluminium and semi-fabricated products.** Aluminium is included in the EU's proposed Carbon Border Adjustment Mechanism (CBAM), which will impose a carbon tax on, and raise prices of, non-EU aluminium imports.

Status of selected circular decarbonisation strategies

Due to its high emissions intensity, increasing aluminium recycling (material recirculation) is the principal circular decarbonisation lever for aluminium in all markets. Production of aluminium scrap (waste) in the Czech Republic was 86 kt in 2019,[81] with imports of ~127 kt and exports of 71 kt,[82] indicating an apparent scrap demand of ~140 kt.

In the **automotive industry**, use of aluminium as a **lightweighting** material is a long-established international trend to achieve fuel economies and emissions savings. A tool from European Aluminium and the International Aluminium Institute compares the impact of different lightweighting solutions on their net GHG emissions over the full vehicle lifecycle.[83] Škoda Auto has saved up to 150 kg in vehicle weight in some models through use primarily of aluminium castings in components including engine block housings, cylinder heads, covers, clutch and transmission housings, etc.[84] However, considering impact on vehicle design, much lower cost of steel and easier recyclability, Škoda and others have increasingly focused on use of high-strength steel.[85]

Demand for **aluminium beverage cans**, while relatively low in the country, has been growing rapidly from a small base. 18 kt of aluminium packaging was added to the market in 2019, but only 22% was recycled, one of the lowest rates in the EU.[86] Almost all collected packaging waste is recycled but collection rates have been impacted by the limited number of metal packaging collection containers in the EKO-KOM network, with many consumers instead disposing of cans in municipal mixed waste. The number of containers has risen at least tenfold since 2019, including an initiative to allow collection of metal in plastic containers. Despite this, EKO-KOM projects only a 39% recycling rate for aluminium packaging by 2025, missing the EU's target of 50%, due to infrastructure limitations related to low aluminium packaging demand, technical limitations of waste management facilities and associated sorting capabilities. The 2030 target of 60% is considered achievable.[87] As of 2021, due to low domestic collection rates, up to 80% of aluminium cans for recycling are imported.[88] Aluminium cans are included in the recent call by the Iniciativa pro zálohováni for a renewed public debate on the introduction of a universal deposit return system.[66]

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74 | Aluminium for Climate: Exploring pathways to decarbonise the aluminium industry (World Economic Forum, November 2020)

75 | Circular Aluminium Action Plan (European Aluminium, April 2020), p. 12

76 | European Aluminium Association – Market Overview 2019 (2020)

77 | Overview of European aluminium industry by plant (European Aluminium)

78 | European Foundry Association (CAEF) statistics 2020

79 | MPO – Politika druhotných surovin ČR, (2018), p.54

80 | https://www.svazslevaren.cz/

81 | ČSÚ – Produkce, využití a odstranění odpadů – 2019, p.29

82 | UN COMTRADE database

83 | European Aluminium Association – Automotive life-cycle assessment model

84 | Škoda – Škoda pod lupou: zaostřeno na detail (June 2017)

85 | Patří ještě budoucnost aluminiu? Výrobci aut dávají přednost vysokopevnostní oceli (April 2020)

86 | Souhrnné údaje o obalech a obalových odpadech, jejich recyklaci a využití v ČR (MŽP)

87 | Waste Strategy 21+ (EKO-KOM), pp. 9, 42, 73–77

88 | Časopis Odpady – Hliníkové plechovky jsou pro recyklaci trochu problém (February 2021)

Demand-side sectors

International studies also focus on two demand-side sectors with the largest contribution to CO_2 emissions on a global and EU basis: **construction** (specifically **buildings**) and **mobility** (specifically **passenger cars**). Construction and manufactured goods each account for ~40% of emissions from global materials production in terms of material use with a climate impact. Residential is the most important segment in construction and passenger cars are the most important category of manufactured goods, with materials contributing ~55% to cradle-to-gate emissions of the final products in both sectors (IRP, 2020).

Buildings construction

Circular actions have wide-ranging impacts both on embodied emissions in materials (principally cement and steel) as well as on emissions from operational energy use of buildings. At the same time, decarbonisation of the energy system will significantly increase the share of building lifecycle emissions from materials use in the coming decades. There is a wide spread of scenarios on the contribution of circular actions to reduction of embodied carbon. Use of wood structures and recycled materials in place of primary steel and cement can dramatically reduce associated emissions. Extending the lifespan of buildings through modular design or renovation can avoid most of the materials demand (and associated embodied carbon) for an equivalent new build project. More intensive use of buildings (and a reduction in the building stock) could potentially eliminate most of the remaining embodied CO2 emissions. According to IRP's analysis for G7 countries, circular actions could also reduce lifecycle emissions from (residential) buildings by 35-40% by 2050, assuming a 20% reduction in residential space through shared housing. The construction sector is where most of themes explored in this report come together. In practice, measures to reduce embodied carbon will need be pursued in the wider context of sustainable construction practices that integrate the technical, economic and social as well as climate and environmental aspects of buildings. Decarbonisation measures for buildings in the Czech Republic have to date focused mainly on operational emissions. There is nevertheless a growing awareness of the need for sustainable consumption of building materials, reflecting looming shortages in basic materials, increasing requirements for green public procurement and EU sustainability reporting requirements under which both property developers and construction firms will also need to measure and reduce their buildings' embodied carbon. Recycling of building materials is growing but is still held back by quality and safety concerns as well as a lack of transparent data on CDW material flows. There is a perceived need for a clear "recycling mix" of secondary building materials that can be used in construction. Wood structures in multi-storey buildings remain restricted by fire protection norms. There is a large potential for building renovations that would prolong the lifespan of the building stock and reduce consumption of new building materials, but loose land protection and planning rules continue to favour greenfield developments. In the construction and real estate sector in particular, the complexity of the challenges raised by sustainability and decarbonisation trends calls for sustained joint action and cross-disciplinary cooperation through the value chain.

International study insights

The construction and use of buildings affects almost every sector of the economy. To date, decarbonisation policies and actions have focused on reducing emissions in the operational phase of buildings (operational carbon from energy use). However, in the context of the 2050 net-zero transition and evolving requirements for sustainability or "ESG" reporting, the topic of **embodied carbon** and by extension, **"whole life carbon"** of buildings is becoming an unavoidable part of the decarbonisation agenda, both for policy makers and for investors, developers and affected businesses, particularly as the latter look at ways to reduce their "Scope 3" CO2 emissions.

The built environment is responsible for 37% of annual global CO2 emissions.[89] **Within this, 10% (or 27% of building sector emissions) is embodied carbon from lifecycle carbon emissions of building materials.** Average embodied carbon in new buildings in Europe are **600 kg CO2e/m2**, of which 70% is emitted upfront, in the materials manufacturing and construction phases of the building lifecycle.[90] Cement and steel represent the majority of this embodied carbon in all key sectors of construction. As the energy sector decarbonizes, it is inevitable that embodied carbon will occupy the dominant share in total building sector CO2 emissions in the coming decades.

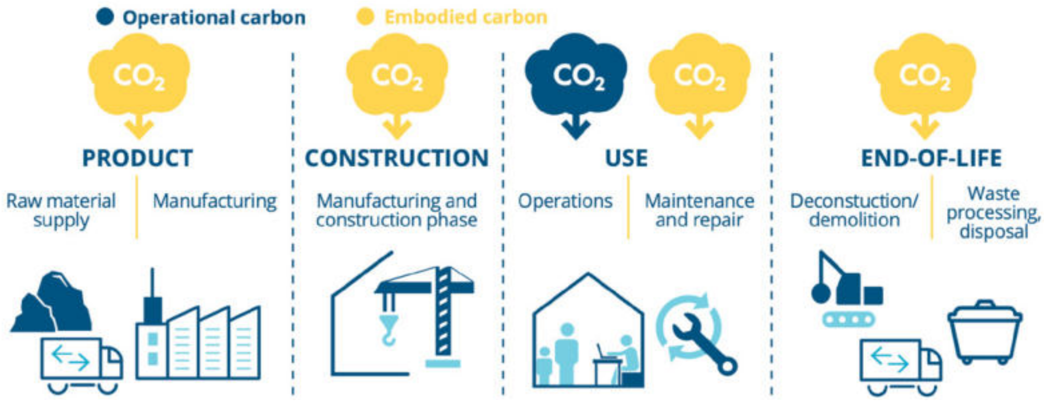
Circular economy levers for the decarbonisation of construction – SUPPLY-SIDE

Wood as a substitute building material

→ **Wood is an effective alternative to reinforced concrete and masonry due to its carbon sequestration capacity,** with potential G7 embodied carbon savings of up to 8%, assuming the use of sustainably sourced wood products (IRP).

→ According to studies in the UK, new off-site, modular timber frame systems can save up to 50% of embodied carbon and 35% of embodied energy compared with traditional residential building methods and materials. Cross-laminated timber (CLT) is a promising substitute for concrete, particularly in multi-storey buildings (ME:1). In another estimate, the **embodied carbon from (sustainably sourced) wooden beams required for 1 m2 of floor space are 85% lower than for an equivalent concrete floor slab** (4 kg versus 27 kg) (ME:2).

→ The EU building stock currently comprises 48% single-family homes and 27% multi-family homes, with a high potential for wood construction but low current market penetration (8–10% and 1–5% in these two segments respectively). In a very con-



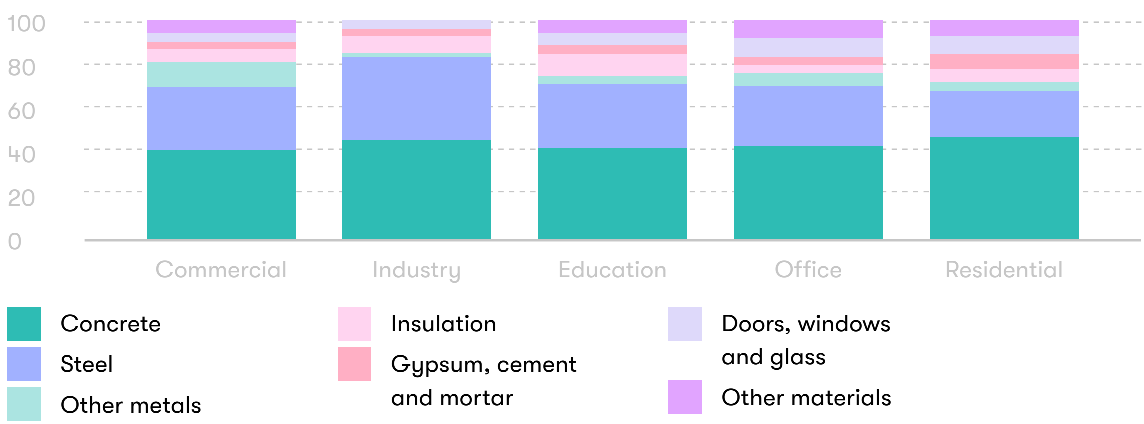
Source: Whole-life carbon: challenges and solutions for highly efficient and climate-neutral buildings (Building Performance Institute Europe, May 2021), p. 6

servative estimate, up to 5% of concrete used in buildings could be substituted by wood, with updating to building codes as a key enabler (ME:2).

Re-use of materials and components

- → Steel-based elements, including structural elements and cold-formed steel framing, can be reused without harming material properties, safety and overall sustainability (IEA:1).
- → As discussed in the chapter on cement, unhydrated cement can also potentially be recovered and reused from end-of-life concrete, although technologies are not yet commercialised (IEA:1).
- → Reuse of precast concrete elements may be possible if taken into consideration at the design phase, especially for a new building that is nearby, to avoid long-distance transport of heavy blocks (IEA:3).
- → Material Economics (ME:1) has estimated that 15% of structural building components in the EU could be reused by 2050 through the adoption of more modular building design. IRP's modelling for the G7 goes even further, with close to 30% of steel and concrete components reused in residential construction by 2050 (IRP).

WBCSD: Embodied carbon breakdown by material for key building types (Europe)



Source: Decarbonizing construction – Guidance for investors and developers to reduce embodied carbon (WBCSD, July 2021), p. 46

End-of-life recovery and recycling of building materials

- **Embodied carbon savings between primary and secondary (recycled) steel and cement production in the EU are substantial: ~ 80% for steel (currently) and ~85% for cement** (by 2050, excluding CCS/CCU) (ME:1,2).
- In 2016, recycling of building materials already saved 15-20% of embodied carbon from avoided primary production of materials for residential buildings in the G7. Improved recycling could save an additional 14–18% by 2050 (IRP).
- Up to 40% of clinker in cement can remain unused (or unhydrated) and potentially be used again to replace new cement. Cement recycling in the EU should become widespread by 2050, resulting in an almost ~25% decline in emissions intensity of cement production (ME:1).

Circular economy levers for decarbonisation of construction – DEMAND-SIDE

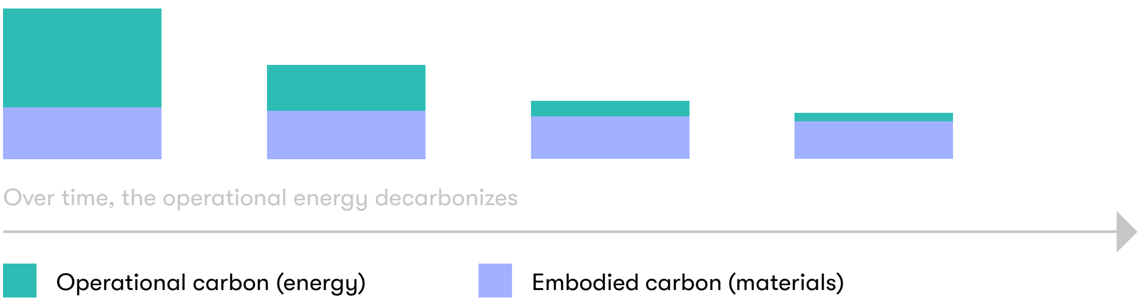
Innovative design and space optimisation

- Building layouts can be designed to reduce material use (e.g., terraced housing vs. single-detached homes, apartment block layouts with shorter perimeter walls, 3for2 design for tall buildings with façade- and floor-integrated mechanical and electrical elements for enhanced ventilation and thermal gains, while saving over 15% of material mass and cost), enabled by holistic approaches, digital design and digital manufacturing (IEA:3).

Use of lightweight materials and structural optimisation

- **Lighter buildings designed closer to technical specifications consume less material and can reduce G7 embodied carbon by 8–10% by 2050** (IRP). An example of lightweighting is the use of cold-formed steel framing in structural applications in mid-rise and multi-housing

WBCSD: Increase in share of embodied carbon from materials over time



Source: Decarbonizing construction – Guidance for investors and developers to reduce embodied carbon (WBCSD, July 2021), p. 9

buildings, alongside advances such as panellised systems (IEA:1).

- → Structural optimisation customises components to their specific function by improving the design of structural elements through modelling tools and industrialising parts of the value chain through off-site quality control or material flow management tools. This includes material-efficient innovative modular building design, increased use of higher-strength steel and pre-tensioned and precast reinforced concrete (IEA:2,3).
- → Relative to a baseline (or "stated policies") scenario, the IEA has modelled that these practices would reduce cumulative cement and steel demand in buildings construction globally by ~ 15% and ~25% respectively over the period 2019–2070, mainly through improved modelling and planning (IEA:1). Over the period to 2050, they would contribute 13% of a cumulative reduction in total steel demand globally (and a 2.5% reduction in 2050 demand) (IEA:2).

Respecting specifications

- → Designers generally specify concrete elements with the tightest requirements related to strength, composition and aggregates, etc. **Enhancing building design could theoretically lead to over 30% savings in steel use and over 15% in cement use** (IEA:3).
- → High-strength steel has potential to reduce materials use by 30–40% in a range of applications, including buildings. By one estimate, up to 50% of steel used in buildings can be beyond what is required for structural purposes (ME:1).

Composite framing

- → This practice enables use of various materials with complementary physical properties in the core building structure. More advanced practices such as prestressing steel cables in reinforced concrete beams or slabs facilitate optimisation of buildings components. Pretensioned concrete elements increase resistance to buildings loads, while saving materials through thinner slabs, longer beams or reduced need for load-bearing columns, especially in high-rise buildings (IEA:3).

Precasting and prefabrication

- → These processes optimize the size, shape and manufacturing of buildings components and accelerate construction. Concrete precast allows lower cement-to-water ratios, enhancing durability. Digital processes such as 3D printing provide a way to design more complex and larger components at once, without assembling various pieces together, although viability on mass scale has yet to be demonstrated. Concrete precasting may also enable commercialisation of alternative binding materials for low-carbon cements by standardisation of processes that capture and store CO2 during the controlled curing process (IEA:1,3).

Construction waste reduction and yield improvement

- At the design stage, accurate specification of buildings components reduces the risk of wasting materials. On-site, improved material flow management may reduce damage and inefficient use of materials. Digitalisation also provides opportunities to facilitate monitoring of waste reduction objectives (IEA:3).
- Measures such as these could reduce waste during construction in the EU to 5% through best practice (from around 15% currently) (ME:1).

More intensive use of buildings

- **During business hours, even before the COVID-19 pandemic, average utilisation of EU office space was only ~40% of capacity.** In a circular scenario where building space per person in EU is reduced by 5%, embodied carbon would fall by a similar percentage (ME:1). This was an assumption made before the pandemic, and the potential for office space rationalisation is likely to be significantly greater in its aftermath.
- According to IRP's modelling, a 20% reduction in G7 floor space demand (through more intensive use of floor space) could reduce embodied carbon in residential construction by almost 75% by 2050, through peer-to-peer lodging, increased household size/cohabitation and shift from single- to multi-family houses. This would also save over 20% in operational CO_2 emissions from lower energy use for heating and cooling, an absolute reduction as large as that associated with reduced use of construction materials (IRP).

Building lifetime extensions, especially through renovation

- Average lifetime of residential buildings can exceed 80 years in Western Europe. In non-residential

sectors, lifespans globally rarely exceed 50 years, as commercial activities change frequently. Lifetimes could be extended to more than 100 years for residential buildings and 70 years or more for other sectors (IEA:3).

→ Lifetimes can be extended through use of more durable materials, better construction techniques, more flexible and modular spaces for later repurposing, and renovating of old buildings. **Renovations typically involve 40–80 times less material mass than reconstruction from scratch and even less for steel and cement.** Newly refurbished commercial or industrial buildings can have up to the same lifetime as a new one, and renovations typically prolong residential building lifetimes by 30–60% (IEA:1).

→ In steel, for example, the IEA has modelled that **building lifetime extension would be the single greatest contributor to global demand reduction for steel**, accounting for 32% of the cumulative reduction to 2050 (and a 6% reduction in annual 2050 demand), relative to a baseline (or "stated policies") scenario (IEA:2).

→ Although building renovations are promoted under the EU's "renovation wave" strategy, it is important that several key objectives are addressed in parallel when designing and carrying out renovations, including flexibility in use, adaptability, modularity and climate change resilience, in addition to retrofits for greater energy efficiency (AGR).

Estimates for the decarbonisation potential of the circular economy

Global

The construction sector (including buildings and infrastructure) currently accounts for all global cement demand and ~50% of steel demand. Buildings construction accounts for ~50% of cement and ~30% of steel demand. In IEA's low-carbon scenario (IEA:1), circular actions would contribute around one third of a 95% overall reduction in global emissions from cement and steel consumption in buildings construction by 2070.

G7 countries

The International Resource Panel's 2020 study (IRP) explores how circular strategies can reduce emissions across **the full lifecycle** – including design, construction, operation and demolition - of buildings, i.e., on a "whole life carbon" basis. This is achieved through a combination of:

→ reduction in the volume or carbon intensity of construction materials used.

→ decreased energy use during operation, through more intense building utilisation.

→ extension of building lifetimes.

→ reuse or recycling of building materials and components.

Using this lifecycle approach (including both embodied and operational carbon), the implementation of circular (material efficiency) strategies results in an additional 35–40% reduction in lifecycle CO2e emissions by 2050 in SSP (2°C global warming) scenarios and a 10%

reduction in a 1.5°C warming scenario that relies more extensively on energy efficiency and decarbonised energy.

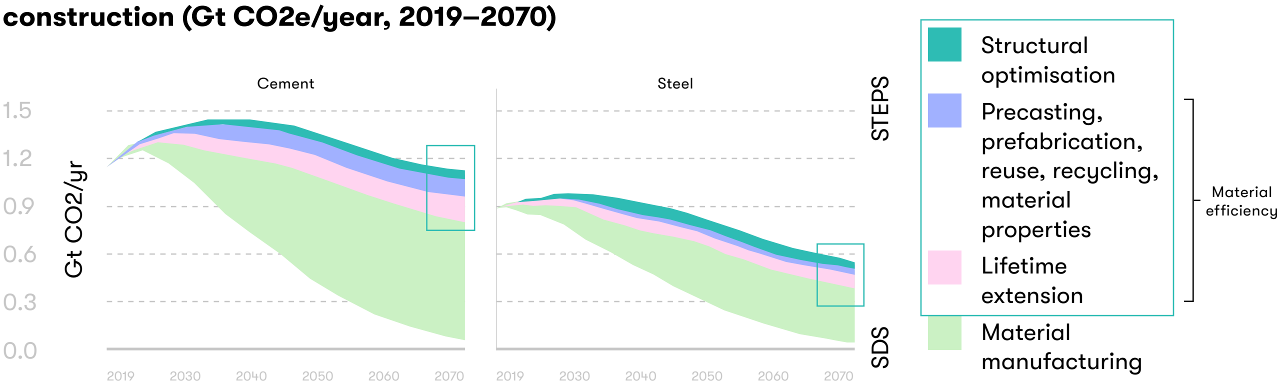
European Union

Material Economics (ME:1) has estimated that EU embodied carbon in buildings in a 2050 low-carbon scenario without additional circular actions would grow by 11% over current levels. **Circular actions could reduce this by ~35% through a combination of cement recycling (6%), waste reduction (4%), reuse of building components (9%), material efficiency (10%) and sharing (6%).** Beyond 2050, a further 19% reduction could be achieved through longer building lifetimes.

In a 2020 analysis for the European Environment Agency (EEA),[91] **modelling of the combined impact of eight types of circular economy action on cement and steel manufacturing and use in the EU construction sector resulted in a 61% overall reduction in emissions from these materials** in a "high-ambition" scenario (assuming 100% implementation of circular actions in the sector).

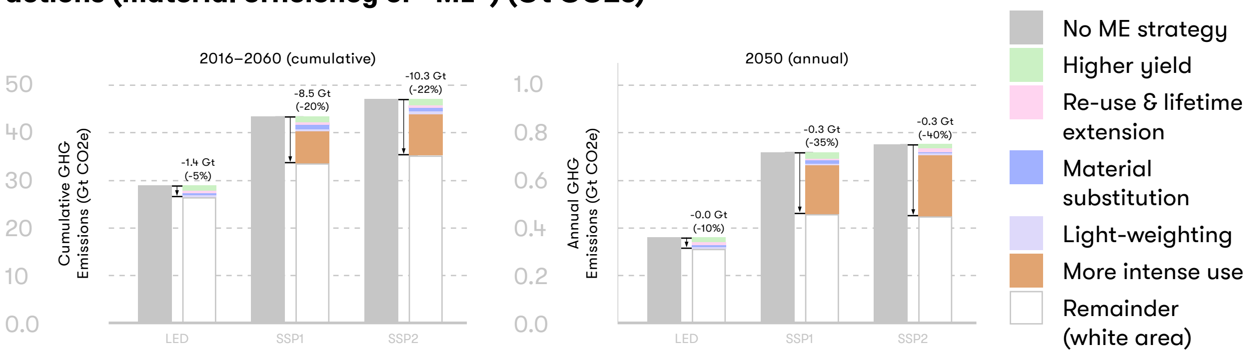
This reflects the long-term (2050) potential of circular actions versus a static 2015 baseline of construction activity in the EU. The actions with the greatest decarbonisation impact were use of innovative pre-cast concrete, use of timber as a replacement for concrete, space optimisation in office buildings, reducing overspecification of structural steel and cement, and reuse of structural steel and structural concrete elements.

IEA: Global embodied carbon in buildings construction (Gt CO2e/year, 2019–2070)



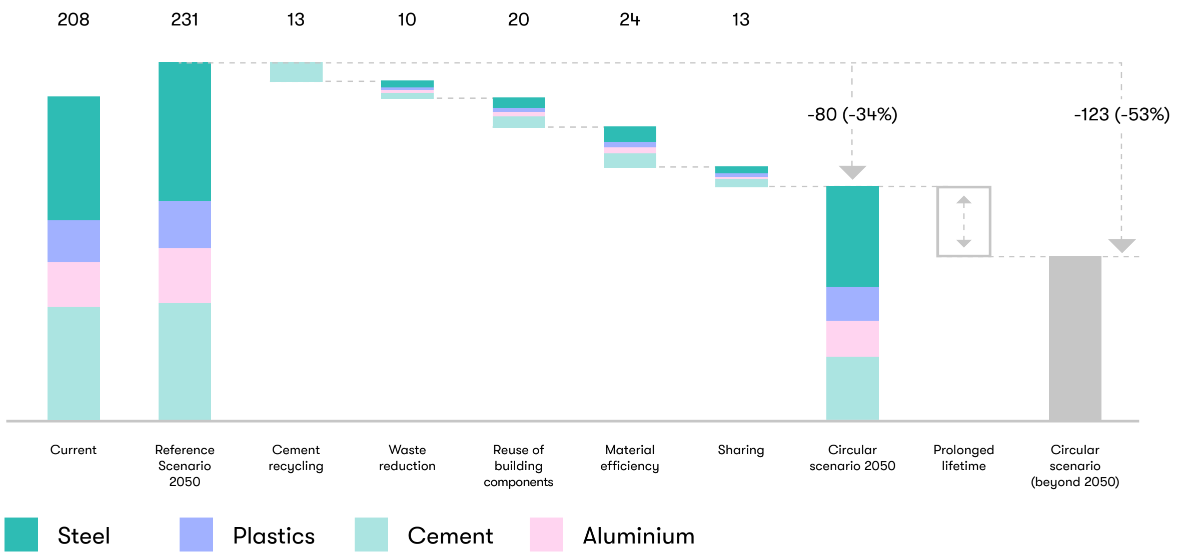
Source: Energy Technology Perspectives (IEA, October 2020), p. 234
Steps: Stated Policies Scenario. SDS = Sustainable Development Scenario.

IRP: 2016–2060 cumulative and 2050 annual reductions in lifecycle GHG emissions in residential buildings in the G7 due to circular actions (material efficiency or "ME") (Gt CO2e)

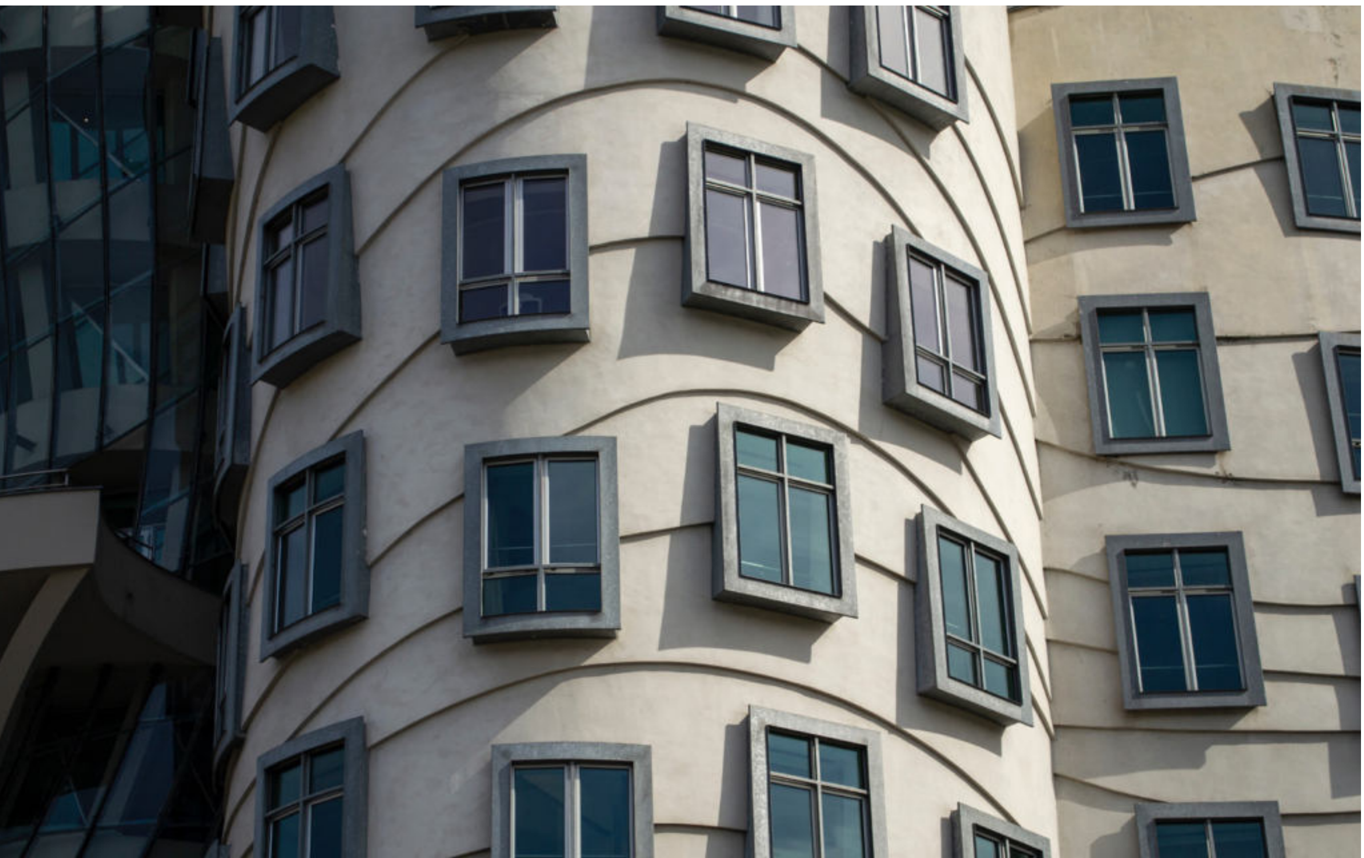


Source: Resource Efficiency and Climate Change – Material Efficiency Strategies for a Low-Carbon Future (IRP, November 2020), p. 42;
Scenarios: LED – Low Energy Demand; SSP – Shared Economic Pathways (1 and 2)

Material Economics: CO2 emissions from materials used in buildings (Mt CO2 per year)



Source: The Circular Economy – A Powerful Force for Climate Mitigation (Material Economics, June 2018), p. 156



Czech Republic

Current focus of the domestic decarbonisation agenda

Dedicated decarbonisation efforts to date in the Czech construction and real estate sectors have focused on the operational phase of buildings and on renovations leading to energy efficiency. Energy consumption in buildings in the residential sector contributes approximately 30% of total national GHG emissions, or 30 Mt of CO2e.[92] According to the 2020 McKinsey decarbonization study for the Czech Republic, the energy efficiency of ~70% of existing Czech buildings can be improved significantly, and the most efficient way to decrease GHG emissions from buildings is to reduce operational energy demand by improving insulation, installing intelligent heat control systems, and changing owners' behaviour, etc.[93] The association Chance for Buildings prepared a study in 2020 which indicated a potential 87% reduction in operational CO2 emissions from all buildings in the Czech Republic through renovation and energy efficient retrofits.[94]

Initiatives to reduce embodied carbon in newbuild and renovation projects through material efficiency remain relatively underdeveloped, and less attention has been paid to the design, construction and demolition phases of buildings, including the potential to reduce the whole life carbon of buildings through renovation and lifetime extension.[95] A notable exception is efforts to introduce environmentally responsible procurement into mainstream practice, which requires construction companies to reduce consumption of raw materials, reuse materials and recycle or segregate waste during construction, along with an amendment to the public procurement law, effective from January 2021.[96] However, green procurement practices are so far rarely applied in practice as contracting authorities (both public sector organisations and private investors) are still unwilling or unable to adopt them for various reasons, not least due to price considerations.

Status of selected circular decarbonisation strategies

Wood as a substitute building material

As an example, Skanska and the architectural studio JCA are currently working on residential and office building projects that maximise the use of wood. Unfortunately, these are still stand-alone buildings, and greater use of wood in multi-storey buildings has so far been hampered by legislative barriers, particularly regarding fire protection standards for buildings. This issue has a subject of debate for at least 20 years, but it has not yet been possible to adopt standards for multi-storey wooden buildings, such as those in place in countries like Austria or Norway. The fragmented and traditional structure of the domestic wood processing industry is also cited as a barrier.

Re-use of materials and components

Initiatives to promote the reuse of materials and building components are still in their infancy in the Czech Republic. An example in this area is AZS Recyklace odpadu, which is preparing to open a construction REUSE centre in Pilsen as part of the operation of an already operating recycling centre for construction and demolition waste (CDW).

End-of-life recovery and recycling of building materials

Currently, the most developed circular measure in the Czech construction industry is the recycling of building materials at the end of their useful life, which is driven in part by a perceived shortage of strategic materials. According to the Czech Ministry of Environment, some local construction materials are expected to be in short supply in future due to the anticipated closure of some stone and sand quarries, and the country could face shortages of some basic building materials in the future.[97] The largest volumes of materials mined domestically are construction raw materials (64 million tonnes in 2019), with the most important commodities being building stone and gravel. In view of this risk, both the Ministry of Industry and Trade and the Ministry of Environment foresee in their strategic documents an increase in investment in the treatment and further use of CDW.[98]

Although both the government and sector experts are aware of the threat of raw material shortages, Czech society generally does not perceive primary raw materials as a scarce resource, which only supports the perception of materials with a recycled component as being of inferior quality and restricts their wider use in practice. For many investors and end-users, the use of recycled materials is still unacceptable and for construction companies, the production and use of recycled materials is often uneconomic as a result. For many applications of recycled building products, a lack of standardisation of recyclates (with some exceptions) is a barrier, as they can vary in technical properties and quality and are not therefore suitable for widespread use. There is also a lack of balance in the debate about use of non-conventional building materials, such as recycled concrete, that would weigh the increased cost and technological complexity in scaling up supply against the benefits of its use in terms of resource conservation and lower embodied carbon.

Proper separation of CDW on construction sites in the Czech Republic is only carried out for large-scale projects or by companies that can justify it financially, for example due to the additional costs of transporting CDW to recycling centres. This problem is also found at a pan-European level, as shown for example by the Horizon Europe RECONMATIC project. A key issue is the complexity of construction processes and the frequent lack of time and space for on-site sorting, for example in the case of city centre construction sites. For smaller projects this practice is generally not followed and according to experts this is expected to remain the case for the foreseeable future. Another reason for the poor functioning of the CDW management system is the lack of reliable data collection and reporting on the quantity and composition of CDW from construction projects.

The European Commission is currently working on a list of materials that should be considered as secondary raw materials and diverted from landfill (i.e., not classified as waste). This initiative is part of the current revision of the Construction Product Regulation (CPR). The CPR is currently under review in the Czech Republic, with an estimated review timeframe of 5 years, to be followed by approval by the relevant European bodies and national parliaments. It will be important to transfer the results of this initiative to the Czech construction industry, but there remains a lack of capacity and an insufficient number of relevant technical experts. **Related to this initiative is a call from construction industry actors for a "recycling mix" that would provide guidance on what materials can be effectively recycled and an analysis of the current recycling capacity in the Czech Republic, which in some cases is not fully utilised.** This is the case, among others, for plasterboard recycling, which is technologically possible in the Czech Republic (at a recycling facility in Počerady), but where there is lack of demand for recycled plasterboard.

There is also an opportunity to **introduce environmentally responsible procurement into mainstream practice**, requiring construction companies to reduce the consumption of raw materials, reuse materials and recycle or separate waste during construction. For example, the Directorate of Roads and Motorways is currently developing rules and conditions for mainstreaming responsible procurement into road construction. While a requirement for environmentally responsible procurement has been included in the amended Public Procurement Act, a coherent and binding approach for implementing this requirement and establishing clear criteria is lacking. In practice, responsible procurement is often still not applied, mainly due to a preference for lowest price as the primary criterion for awarding public contracts in the construction sector.

Respecting specifications

The Czech construction industry follows Eurocodes for the design of building structures, which are regularly revised and updated. According to experts from ČKAIT, EURO-codes (introduced after 2004) are materially inefficient and, following their introduction, consumption of materials for load-bearing structures of buildings in the Czech Republic increased by 20-30%. Material overspecification is standard practice in construction plans to ensure safety and the longest possible service life of buildings, based on modelling and predictions. There remains a concern that reduction in specifications could impact building safety, with associated liability implications, as architects, designers and structural engineers, etc. do not wish to be held responsible for potential structural failures and reduced safety of buildings. In the Czech environment, structural engineers and designers have a lifelong responsibility for all calculations, subsequent durability and quality of buildings, so it is understandable that they strictly follow standards and best practices to comply with all safety rules. The first step towards less oversizing of buildings is to change building standards and specifications. To adapt (change) the specifications, a discussion on European harmonised standards needs to be held within the European Committee for Standardisation (CEN), where the agreement of all 33 member countries is required to adapt uniform rules.

Precasting and prefabrication

There is historical resistance by the Czech public to prefabrication in the construction industry due to its association with the mass construction of "panel housing estates" in the second half of the 20th century. Despite this, prefabrication is a common practice today. This is a natural consequence of the shortage of skilled labour in the construction industry, for which prefabricated and modular buildings are an effective solution. There are housing projects in the Czech Republic, for example in Vlkýš, that can be completely dismantled at the end of their useful life and later reassembled, generating a maximum of 5% construction waste. A technical barrier may be a reduced hardening rate. A key aspect of prefabrication is the ability to handle the precast relatively quickly after unloading, usually 12 hours after pouring. Many alternatives in cement work well in terms of gradual strength build-up, but often have difficulty achieving the rapid minimum initial strengths required for handling the concrete product. This can be a problem when time and space on construction sites are limited.

Building lifetime extensions, especially through renovation

As mentioned above, there is a vast potential for reconstruction and renovation of buildings in the country to achieve higher energy efficiency or to extend building lifetimes over the long term. This needs to be set against specific characteristics of the building stock and the so-called moral lifespan of buildings, beyond which further renovation or modernisation will fail to meet functional needs or be economically feasible.

In the Czech Republic, 0.6 – 0.8% of buildings are currently renovated annually (the EU average is about 1%). According to the Chance for Buildings, this percentage needs to be increased at least threefold to realise the potential for reducing emissions and energy consumption,[99] but there is a lack of economic, legal or social motivation. A key factor is a continuing focus on the lowest possible price of the building materials used, which prevents the adoption of higher quality materials with better properties and longer service life.

Due to weak protection of land, there is continuing development of the open countryside with new housing, which is linked to a long-term high demand for single-family houses. This has led to a preference for new build developments, with renovation and refurbishment of existing houses remaining a secondary concern. In addition to extending the life of the structure, extending the life of the equipment and technology inside the buildings also plays a role. Although technologies evolve and change with time, guarantees of durability and longevity remain the same or are non-existent, and there is still a lack of demand in the country for manufacturers to guarantee longer product and technology life. This is something that should be addressed in the coming years by the EU's proposed Ecodesign for Sustainable Products Regulation (ESPR) and the revised CPR.

89 | Although the focus of this section is on buildings, infrastructure is also a major source of GHG emissions, both from the production of materials for road construction, bridges, viaducts, etc. and from transport of raw materials.

90 | Towards embodied carbon benchmarks for buildings in Europe (Ramboll, Aalborg University Build, KU Leuven, March 2022)

91 | The decarbonisation benefits of sectoral circular economy actions (Ramboll, Fraunhofer ISI and Ecologic Institute for the European Environment Agency, February 2020)

92 | Národní plán obnovy – Renovace budov a ochrana ovzduší (2021), p.2

93 | McKinsey – Pathways to decarbonize the Czech Republic (December 2020), p.53

94 | ECEEB – Potenciál pro snížení provozních emisí CO2 z českého fondu budov (June 2020), p.1

95 | Principy a řešení udržitelné architektury (Rethink Architecture, 2020), p. 31

96 | Ministerstvo práce a sociálních věcí – Odpovědné veřejné zadávání

97 | Strategický rámec cirkulární ekonomiky České republiky 2040 (2021)

98 | Ministerstvo životního prostředí – Státní politika životního prostředí České republiky 2030 s výhledem do 2050 (January 2021), p.69

99 | Dlouhodobá strategie renovace budov v České republice (Update, Šance pro budovy, May 2020)

Automotive industry

Circular measures and strategies can achieve deep reductions both in embodied carbon from materials used in automotive manufacturing (steel, plastics, aluminium) and in emissions from operational energy use. As vehicle fleets shift to electric and other alternative fuels, there will be increasing focus on decarbonisation of the materials cycle of cars. 2050 scenarios indicate potential reductions from circular actions of up to 70% for embodied carbon in vehicles in the EU and G7 and up to 40% for lifecycle GHG emissions in the G7. Circular actions with the greatest impact are more intensive use (ridesharing or car-sharing), lightweighting (including downsizing of vehicles) and vehicle lifetime extension. Evaluation of specific measures to reduce embodied carbon in vehicles raises complex questions about long-term manufacturing strategy and vehicle design innovation beyond the scope of this report.

In the Czech and CEE context, there is limited integration between CE and strategies to decarbonise vehicle production, but growing pressure for OEMs to implement roadmaps for net-zero emissions, including Scope 3 emissions from industrial materials. Closed loop recycling of materials from end-of-life vehicles (ELV) is limited by a fragmented ELV processing sector, shredding practices that result in downcycling, lack of data on material origin and unclear legal distinctions between waste and secondary raw materials. There is a large untapped potential for increased reuse, remanufacturing and recycling of used car parts and materials through online digital trading platforms. OEMs currently lack economic incentives to prolong vehicle lifespans or shift their portfolio to smaller, lighter vehicles.

The mitigation opportunity from car sharing models is at a nascent stage, and auto makers have concerns about negative impacts on their brand. If scaled with OEM involvement, car sharing could improve utilization rate of vehicle fleets, prolong OEM aftermarket revenue streams and create incentives for vehicle lifetime extension.

International study insights

Fuel-related emissions currently comprise 80–85% of lifecycle emissions for ICE cars and trucks, while 15-20% arise from the supply chain of materials used in vehicle production. Light-duty vehicles account for around 7% of global demand for steel and 12% for aluminium and LCVs and heavy-duty vehicles a further 4% of steel and 10% of aluminium (IEA:3).

Under current EU legislation, the share of renewable and alternative fuels in transport (including electromobility, advanced biofuels and hydrogen) must reach at least 14% by 2030. However, under the Commission's "Fit for 55" package of legislative proposals from July 2021, average emissions from new vehicles are to fall by 55% by 2030 compared to current (2021) levels and to zero by 2035. In the shift to electric cars and other alternative fuels, industrial materials will make up an increasingly larger proportion of vehicle lifecycle emissions. According to estimates by McKinsey & Company and Accenture within the Circular Car Initiative,[100] **global emissions from material production could reach 60% of automotive life-cycle emissions by 2040.**

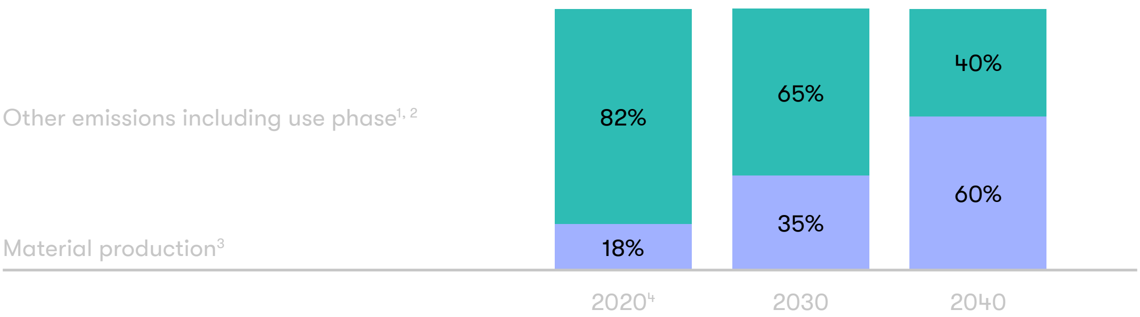
At a European level, while CO2 emissions, energy consumption and waste generation per car during the production phase have already fallen by 33%, 7% and 7% respectively since 2005, energy efficiency and shift to renewable energy have been the main source of emissions reductions to date.[101] There is therefore increasing attention being paid to the overall lifecycle emissions from vehicles, including embodied carbon in materials, as part of long-term industry roadmaps to achieve carbon neutrality across the value chain by 2050.

Circular economy levers for automotive industry decarbonisation – SUPPLY-SIDE

Reuse and remanufacturing

- → **Reuse and remanufacturing** (achieving the same functionality as new parts) of individual car components, especially engines and tyres, **can reduce embodied carbon in cars by 70–90% compared to the production of new parts (IRP).**
- → Remanufactured equipment reduces energy consumption for material production by approximately 98% and energy consumption for assembly by approximately 40%.[102]
- → Material Economics has projected that the share of remanufactured parts in cars will increase from the current 5% (baseline scenario) to 11% (circular scenario) by 2050 (ME:1).

WEF: Emissions from material production will have higher share than other life-cycle emissions in percentage share (based on required sales volumes)



1. Assumed constant range of 15,000km/vehicle per year and 10-year lifetime as baseline – End-of-life emissions not considered here
2. 2018 average ~120g CO2/km, target today 95g CO2/km; future assumptions: 2030 75g CO2/km; 2040 50g CO2/km; 0.10-0.16kWh/km for xEV
3. Average material emissions: ICE 3,000, EV 7,400, PHEV 5,000, HEV 4,000kg CO2 per vehicle as of model (hold constant as decarbonization in focus)
4. Current BEV, PHEV, HEV penetration in relevant regions at 4–8%; 2030: BEV 33%, PHEV 12%, HEV 7%; 2040: BEV 60%, PHEV 27%, HEV 13%

Source: Forging Ahead – A materials roadmap for the zero-carbon car (World Economic Forum, December 2020), p. 8

Enhanced end-of-life recovery and recycling of materials

- → **Use of recycled materials can offset up to 50 % of embodied carbon in vehicle production.** Global recycling rates for metals are relatively high (~70% for steel, 67% for copper and 87% for aluminium) and are expected to increase only slightly in the future, while **recycling rates in plastics are expected to increase up to 70% in 2050 compared to 18% in 2015** (IRP:1).
- → Typically, however, recycled materials from cars are downcycled and do not achieve sufficient quality to be reused in automotive applications, necessitating further improvements in recycling infrastructure.[103, 104]

Circular economy levers for automotive industry decarbonisation – DEMAND-SIDE

Fabrication yield improvements

- → Current average material yields in vehicle production are only 70–80% for steel and 80–85% for aluminium. These percentages could increase through improvements in the operational efficiency of production processes, the development of new processes with higher yields, and changes in component design. These and other measures such as reuse of production scrap and recovery of end-of-life products can **reduce annual material cycle GHG emissions by 38% by 2050** compared to 2015 (IRP).

Vehicle lifetime extension

- → Vehicle lifetime extension reduces the pressure to use energy-intensive materials and thus potentially reduces the production of greenhouse gases. Longer lifetimes can be supported by material choice, predictive maintenance, modular design and remanufacturing, higher component reuse rates and longer internal lifetimes of electric drivetrains. In one circular scenario, the **average lifetime of cars in the EU could increase by 60% from 280,000 km (baseline) to 450,000 km (circular system) by 2050** (ME:1).
- → This should focus on vehicles with low operational emissions. Lifetime

extension for electric vehicles and increased reuse of parts leads to additional lifecycle GHG emissions savings of 5–13% in the G7, assuming a 20% lifetime extension by 2060 for PHEVs, BEVs and FCVs but no extension for ICEVg, ICEVd and HEVs (IRP).

Vehicle lightweighting (material substitution)

→ By lightweighting cars, a net reduction of 1 Gt of CO2eq emissions from materials production can be achieved globally by 2070, in addition to a further 2 Gt reduction in CO2eq emissions from vehicle use. Lightweighting can also increase a vehicle's driving range, which would facilitate a faster uptake of battery electric vehicles and potentially smaller batteries (IEA:1).

→ According to the IRP study, **lifecycle GHG emissions from cars in G7 countries could fall by 9% by 2050 due to lightweighting, and embodied carbon by 14–19%** (IRP).

→ Steel comprises 50–65% of a vehicle's weight and is responsible for 30–40% of an average vehicle's embodied carbon emissions. Lightweighting in cars and trucks would contribute an 11% cumulative reduction in global steel demand by 2050 (and a 2% reduction in 2050 demand) through better adaptation of parts to their function, increased use of high-strength steel and substitution by lighter materials (e.g. aluminium, magnesium alloys, plastics and carbon fibre reinforced polymers) (IEA:2).

→ In a material efficiency scenario, **passenger cars in 2060 could be on average 40% lighter than in 2015,** both for internal combustion engine (ICE) and electric vehicles (BEV) (IEA:3).

Downsizing (reduction in vehicle size across fleets)

→ Downsizing of vehicles in practice means moving customers to a smaller vehicle segment, i.e., from light truck to van/SUV; from van/SUV to passenger car; or from passenger car to micro car. Depending on vehicle segment and powertrain, downsizing can reduce **vehicle weight by 16–44% and fuel use by 9–37%.**[102]

More intensive vehicle use (ridesharing, car-sharing)

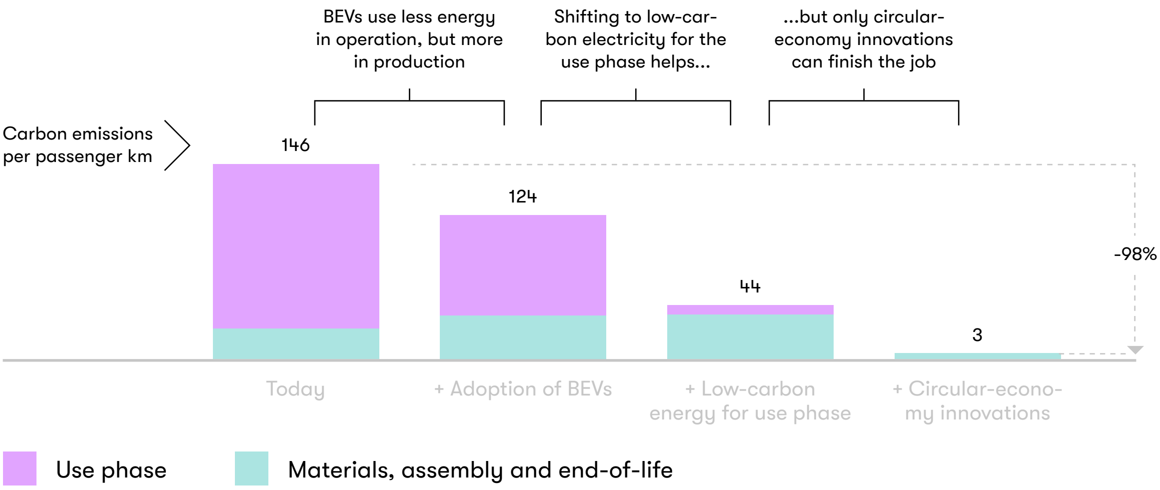
→ Ridesharing and car-sharing change the way vehicles are used, which can lead to a reduction in the total number of vehicles and the resulting demand for vehicle materials. **If 25% of journeys in the G7 were made by ridesharing, it would reduce GHG emissions across the system by 13–20%. If 15–25% of cars were shared in 2050, this would reduce CO2eq emissions by 6–10%** (IRP:1).

→ In a circular scenario for the EU automotive sector, Material Economics assumed ~65% sharing of the total passenger car fleet in 2050, with the number of shared cars per million passenger kilometres being on average 77% lower than for privately owned cars (0.6 million cars vs. 2.6 million) and average occupancy 17% higher (1.91 passengers vs. 1.63 in the baseline scenario) (ME:1).

- → In steel specifically, broader changes in transport activity could contribute **10% of cumulative reduction in steel demand to 2050 (and a 2% reduction in 2050 demand)**, through shift to public transport, cycling and shared mobility, more efficient freight transport and reduction in travel due to urban densification, teleworking and reduced discretionary travel (IEA:2).

Estimates for the decarbonisation potential of the circular economy

Established by the World Economic Forum (WEF) and the World Business Council for Sustainable Development (WBCSD), the **Circular Cars Initiative** (CCI) has published several analyses on materials roadmaps, business models and policy actions to accelerate the shift towards a zero-emissions automotive sector on a full life-cycle basis. As illustrated below, circular innovations account for almost 30% of CCI's overall roadmap to decarbonising an illustrative hatchback car and almost all of emissions reductions following a shift to BEVs using low-carbon energy.



Source: Forging Ahead – A materials roadmap for the zero-carbon car (World Economic Forum, December 2020), p. 5

G7 countries

In modelling of emissions reductions in light-duty vehicles, the International Resource Panel (IRP) has assessed the impact of circular actions on material and energy use in vehicle production, energy use in vehicle operations, and availability of recycled materials. By 2050, IRP estimates that these strategies could **reduce annual embodied GHG emissions in vehicle production and end-of-life disposal by 57–70% in the G7.** Several of these actions also reduce energy use in manufacturing and operation of vehicles. The associated emissions reductions from operational energy savings would be several times larger than those from embodied emissions, including in scenarios with a gradual shift towards electric and fuel cell vehicles.

Across all circular actions, **GHG lifecycle emissions for manufacturing, operation and end-of-life management of cars in the G7 could fall by 28% to 40% in 2050**, with ridesharing, car-sharing and a shift towards smaller vehicle sizes having the greatest potential impact.

European Union

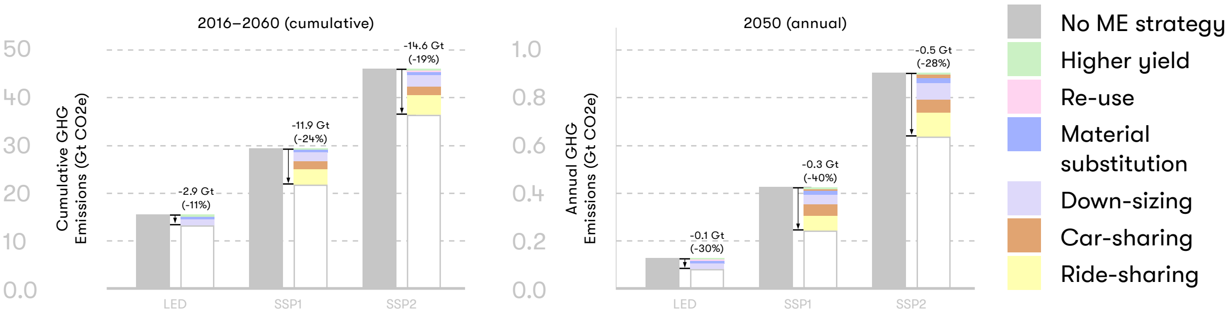
In earlier modelling by Material Economics (ME:1), EU embodied GHG emissions in passenger cars in a 2050 low-carbon scenario would still increase by 22% compared to 2018 due to higher volume.

Circular actions could reduce this by 70% through a combination of reuse and remanufacturing (6%), lightweighting (15%), longer lifetime (34%) and sharing (15%).

In addition, a circular scenario could reduce total costs of ownership per passenger km and externalities and public costs of car transportation by three quarters relative to today.

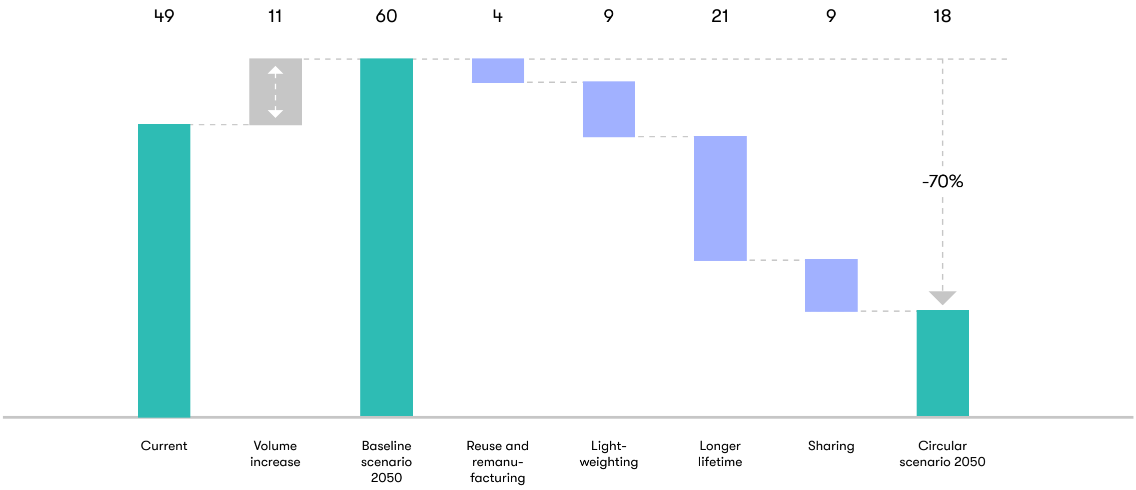
In a detailed assessment of decarbonisation benefits from product-as-a-service approaches, Systemiq has more recently analysed two **Car-as-a-Service (CaaS)** models: **car subscriptions** and **free-float carsharing**. It estimates that these models could decarbonise 25% and 45% of BEV **lifecycle emissions** per passenger km respectively.

IRP: 2016–2060 cumulative and 2050 annual reductions in lifecycle GHG emissions in passenger cars in the G7 due to circular actions (material efficiency) (Gt CO2e)



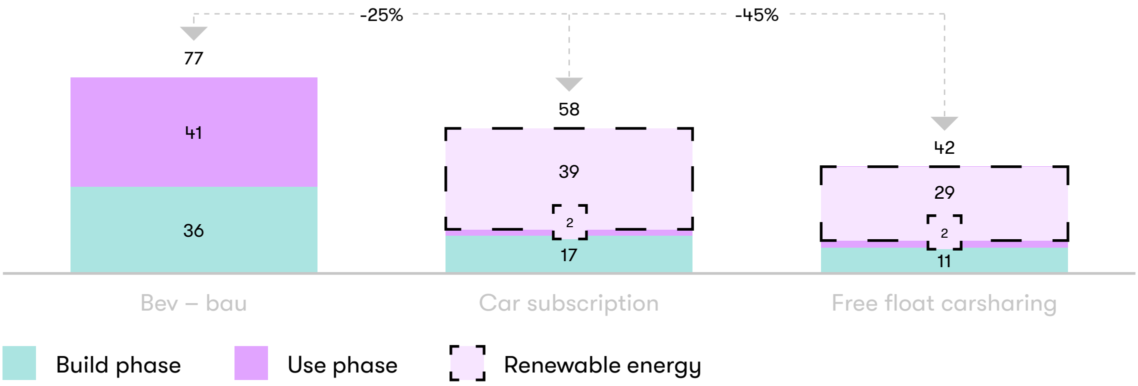
Source: Resource Efficiency and Climate Change – Material Efficiency Strategies for a Low-Carbon Future (IRP, November 2020), p. 54.
Scenarios: LED – Low Energy Demand; SSP – Shared Economic Pathways (1 and 2)

Material Economics: CO_2 emissions from materials used in EU passenger cars, 2050 (Mt CO_2 per year)



Source: The Circular Economy – A Powerful Force for Climate Mitigation (Material Economics, June 2018), p. 133

Systemiq: Emissions / decarbonization in g CO_2 / pkm



Source: Everything as a Service (XAAS) (Systemiq, 2021), Exhibit 17, p. 67

Czech Republic

Current focus of the domestic decarbonisation agenda

The automotive industry is the Czech Republic's largest single industrial sector, accounting for a quarter of industrial output and exports and 9% of GDP.[105] It employs over 180,000 people directly in manufacturing (14% of total manufacturing employment, one of the highest shares in the EU[106]) and approximately half a million in the automotive supply chain overall. The Czech Republic is the 3rd largest manufacturer of passenger cars in the EU, with a ~10% share of EU production in 2020, and the 11th largest worldwide.

The primary focus of current decarbonisation efforts both internationally and in the Czech Republic remains the emissions from fuel/energy consumption of vehicles in the use phase. National GHG emissions from car road transport were 11.7 Mt CO2e in 2019, or 10% of total country emissions, over two and half times higher than the 1990 level. The number of registered passenger cars in the Czech Republic doubled between 1990 and 2014 and increased by a further ~20% by 2020.[107] At the same time, the average age of the passenger car fleet (14.9 years) remains among the highest in the EU.[106]

As a leading consumer of steel, aluminium, plastics and other carbon-intensive industrial materials, the Czech automotive industry has a important role to play in further reduction of lifecycle GHG emissions from materials in the production, maintenance/repair and end-of-life phases of vehicles, especially in view of the sector's very high external trade focus – around 90% of vehicles produced and over 75% of output from the automotive supply chain are exported to EU and global markets.[105]

Škoda Auto is the largest automotive OEM in the Czech Republic, accounting for ~65% of domestic production of passenger cars in 2019 and 2020.[105] In its Environmental Mission Statement, the group has announced plans to reduce its lifecycle GHG emissions from passenger cars and light commercial vehicles by 30% by 2025 relative to 2015 and production-related environmental externalities (CO2, energy, water, waste, volatile organic compounds) by 45% per vehicle relative to 2010. The group is also actively pursuing the application of circular economy principles. Projects to date have included a takeback system for tyres, reuse of car batteries for stationary energy storage applications and the use of recycled steel, aluminium and plastic recyclates in vehicle production, making up 19%, 11% and 1% respectively of the vehicle weight of a Škoda Octavia.[108] However, the circular economy (CE) and decarbonisation are currently not closely linked in Škoda or in the VW Group's internal strategies, as there is still a limited awareness in the industry that CE can significantly help in meeting decarbonisation targets. This is partly due to the complexity of measuring CE's contribution to decarbonisation using the current set of key performance indicators (mainly focused on CO2 emissions in the context of green energy strategies). Volkswagen Group is currently working on creation of specific set of measurements concerning the circular economy.[109]

Decarbonisation of vehicle production was a leading topic at the 4th annual **CEE Automotive Supply Chain 2021** conference held in Olomouc in October 2021. In the view of the President of the Automotive Industry Association of the Slovak Republic (ZAPSR), the share of zero-emissions vehicles in new car sales is likely to reach 60–70% by 2030, as auto OEMs compete to outperform mandated emissions norms and targets, while "zero-emissions" will over time increasingly encompass not only the use phase but vehicle manufacturing and even Scope 3 emissions in the automotive supply chain.[110]

Status of selected circular decarbonisation strategies

Key levers for automotive OEMs and suppliers are **fabrication yield improvement** to minimise scrap and material waste, **vehicle lightweighting** through material substitution in individual components and reduction in average vehicle size, and vehicle life extension through modular design and the use of higher durability materials. These are highly complex issues of long-term manufacturing strategy and vehicle design innovation well beyond the scope of this review. The following summary includes feedback from a stakeholder workshop with Škoda Auto representatives held in April 2022, with insights from other public domain sources as indicated.

Reuse and remanufacturing

Reusable components comprise only ~2% of vehicle weight as most ELVs are obsolete models with little demand for aftermarket parts, although car OEMs are legally obliged to keep spare parts for about 10 years. Certain parts have been remanufactured for many years within the VW Group including Škoda Auto. The problem of remanufacturing lies in compatibility over time, as a result of which new parts are often incompatible with older ones due to product development. Another difficulty that car manufacturers may face is the quality evaluation of vehicles, as each type of car is given a certification based on specific parts. Once the vehicle contains remanufactured parts (of different properties or materials used compared to brand new parts), it may not meet the quality evaluation criteria, and the re-evaluation is expensive and problematic process.

Enhanced end-of-life recovery and recycling of materials

The ecological disposal of **end-of-life vehicles (ELVs)** in the Czech Republic is governed by Law no. 542/2020 Coll. on end-of-life products, applying the provisions of EU Directive 2000/53/ES and later amendments.[111] Vehicle and equipment manufacturers are required to factor in the dismantling, reuse and recovery of vehicles as part of their design and manufacturing so that 85% of the vehicle by weight is reusable and/or recyclable and 95% is reusable and/or recoverable. The same levels of reuse, recovery and recycling are required of waste treatment facilities for the processing of ELVs, in line with the principles of the waste management hierarchy. Since 2013 (with the exception of 2020, due to COVID-related business disruptions), the annual number of ELVs has steadily increased, reaching over 175,000 in 2019, as the car fleet was renewed during a period of economic recovery.[112] The average weight of ELVs in 2018 was 1 tonne, of which ~78% steel (mostly recycled by steel works for production of construction steel), ~3% non-ferrous metals and ~2% plastics.

The simplest, and most common, processing techniques used by Czech ELV processors are shredding or partial dismantlement followed by shredding, which has the disadvantage of devaluing various recovered material components compared to disassembly, leading to downcycling. A further inefficiency of the sector is the highly fragmented network and low productivity of processing facilities, which results in an inefficient control system for recycled materials.[113] There are currently up to 500 dismantlers in the Czech Republic and automotive OEMs only cooperate with some of them, due to the poor quality of service offered by many of them (and absence of an inspection body). Therefore, while materials are returned to the automotive industry through recycling (e.g., as scrap metal), automotive OEMs do not have accurate data on their origin. The illegal export of cars outside the EU and the transfer of ownership and apparent 'loss' of vehicles in national registers are other reasons for the ineffective tracking of material flows in the Czech automotive industry. Another key barrier to recycling is a lack of clarity in national legislation on the difference between waste and secondary raw materials. As a result, materials that are legally defined as waste cannot be used as secondary raw materials. This situation has led automotive OEMs, including Škoda Auto, to call for the creation of a voluntary take-back system for materials that would extend the already existing mandatory take-back system (discarded batteries, vehicles, etc.).

Overall, there is a large untapped potential for enhanced recovery of materials into the vehicle manufacturing and aftermarket value chain from the Czech ELV processing sector, for example in the form of online platforms offering spare parts for reuse and remanufacturing (cooperation with IT sector).

Another way of recycling that Škoda Auto, among others, is following is the use of recycled substitute materials in car interiors. These substitutes can be bio-based materials (corn, coconut fibres) or recycled waste materials (PET bottles, fishing nets), which replace emission-intensive materials such as plastics, leather or metals and thus help car manufacturers meet decarbonisation targets.[114, 115]

Fabrication yield improvement

Industry 4.0 (and 5.0) concepts can support yield improvements by optimising and integrating production processes across the value chain. Fully automated production facilities can produce even small production batches to meet the needs of specific customers and production runs while maintaining the efficiency of mass production. The automotive sector globally and in the Czech Republic has long been at the forefront of automation, just-in-time and "lean" manufacturing trends, so this remains part of an ongoing optimisation agenda to minimise waste and align material planning across all tiers of the supply chain. The Czech automotive components and systems industries must be as well prepared as possible to take advantage of emerging raw-material, technological, production and process innovations and evaluate them strategically in the context of material efficiency.[116]

Vehicle lifetime extension

The average age of ELVs received for destruction over the past decade by Czech processors is ~20 years. Considering high average age of the passenger car fleet in the Czech Republic, circular measures in the form of lifetime extension of cars are questionable, as the older vehicles are relatively emissions intensive. In the case of newer and more efficient cars, auto makers (Škoda Auto) are often not sufficiently motivated to extend vehicle lifetime due to their limited profit from vehicle's use phase (service), caused by the fact that customers stop visiting authorised service centres once the warranty period expires. New business models need to be explored. Automotive OEMs also need to meet new regulations and standards, which is leading to the constant upgrading of production of new cars rather than to lifetime extension of the existing ones.

Vehicle lightweighting (material substitution)

Lightweighting may involve trade-offs between higher material-cycle emissions for reductions in use-phase emissions, especially if steel is substituted by primary aluminium to reduce vehicle weight and improve fuel economy or the range of electric cars. Another example of such a trade-off is the use of composite materials or a combination of different materials to lighten cars, which can ultimately lead to more difficult recycling. However, there are promising projects in the Czech Republic, such as the activities of Lavaris,[117] which is developing technologies to enable the recycling of composite materials, such as the recycling of old tyres.

Downsizing (reduction in vehicle size across fleets)

The current global trend is towards buying larger cars (family trips, social status, etc.), with SUVs currently being very popular.[118] To meet this demand, automotive OEMs have been producing more larger cars and are less motivated to produce smaller vehicles due to lower margins. In the Czech Republic, customers are also not motivated to buy smaller cars as there is no system of benefits for users with smaller, less emission-intensive cars (as opposed to good practice examples from other European countries such as Denmark). The role of the state is crucial here, with measures such as reduced tax for owners of smaller cars etc.

More intensive vehicle use (ridesharing, car-sharing)

Car-sharing is an embryonic but rapidly growing market in the Czech Republic. According to the Czech Car-Sharing Association, the size of the professional car-sharing fleet in the country rose from 30 in 2014 to over 1,500 by April 2022 (from members of the association).[119] Car-sharing services are for now popular mainly with the younger generation (20-30 age group), due to flexibility of use (per-minute billing), drop-off location and choice of vehicle for different purposes, etc. Car-sharing vehicle fleets, like those for rental or operational leasing, also comprise new vehicles meeting the latest emission standards and already some electric cars (e.g., GreenGo). The user base is mainly in Prague, but gradually expanding to other regional cities.[120] In addition, the peer-to-peer carsharing platform HoppyGo (for privately owned cars) reported 2,500 registered cars in its system as of June 2022.[121]

Nevertheless, the shared car fleet is still a tiny fraction of the 6.1 million total passenger car fleet in the country.[105] Any future increase in car sharing may also be affected by concerns from vehicle manufacturers that faster wearing of shared cars may lead to negative customer perceptions of the brand.

100 | Forging Ahead – A materials roadmap for the zero-carbon car – Circular Car Initiative Papers (WEF, December 2020)

101 | European Automobile Manufacturers' Association (ACEA), indicators on resource-efficient production

102 | Material efficiency and climate change mitigation of passenger vehicles (Paul Wolfram, Qingshi Tu, Niko Heeren, Stefan Pauliuk, Edgar G. Hertwich) (September 2020)

103 | Driving Ambitions: The Business Case for Circular Economy in the Car Industry (WEF, May 2022)

104 | Why the Automotive Future is Electric (McKinsey & Company, September 2021)

105 | AutoSAP – Czech Automotive Industry Association statistics

106 | ACEA, Automotive Industry Pocket Guide 2021/2022

107 | Transport Yearbook Czech Republic 2020 (Ministry of Transport)

108 | Škoda Sustainability Report 2019–2020, pp. 55-57

109 | Insights from working group discussion with Škoda representatives (April 2022)

110 | AutoSAP – News release on CEE Automotive Supply Chain 2021 conference (October 2021)

111 | Zákon o výrobcích s ukončenou životností (December 2020)

112 | Vybrané ukazatele z Informačního systému odpadového hospodářství Modul autovraky (MŽP)

113 | Update of the Secondary Raw Materials Policy 2019–2022 – Material Flow Analysis (December 2018), Ch. 7

114 | Budoucnost patří recyklaci (Česká automobilová asociace)

115 | Sustainability report (Škoda Auto)

116 | Strategic Framework for the Circular Economy – Circular Czechia 2040 (November 2021), pp. 57

117 | https://cs.lavaris.eu

118 | Automotive Trends Report 2021 (US Environmental Protection Agency)

119 | https://ceskycarsharing.cz/

120 | Česky carsharing hlásí boom. Pandemie ale některé firmy potrápila (Lupa.cz, June 2021)

121 | https://hoppygo.com/en/

4

Annexes

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Annex 1. List of international studies by industry sector — 126

Annex 2. Acronyms and abbreviations — 130

Annex 1. List of international studies by industry sector

The following list provides links to selected reports and analyses published by organisations active in the topic of decarbonisation of industry that address or recognise at least to some degree the role or the circular economy or material efficiency in reducing GHG emissions. The list includes items published until the end of June 2022. Studies are listed in reverse chronological order.

Industry (multiple sectors)

Achieving Net Zero Heavy Industry Sectors in G7 Members (International Energy Agency, May 2022)

Scaling Up Europe – Bringing Low-CO2 Materials from Demonstration to Industrial Scale (Material Economics, April 2022)

Mobilising the circular economy for energy-intensive materials (Agora Industry, March 2022)

Circularity Gap Report 2022 (Circle Economy, February 2022)

Everything as a Service (XAAS), How Businesses Can Thrive in the Age of Climate Change and Digitalisation (Systemiq, September 2021)

A comprehensive set of global scenarios of housing, mobility, and material efficiency for material cycles and energy systems modelling (Journal of Industrial Ecology, March 2021)

Resource Efficiency and Climate Change, Material Efficiency Strategies for a Low-Carbon Future (International Resource Panel, November 2020)

Global scenarios of resource and emission savings from material efficiency in residential buildings and cars (Nature Communications, October 2020, published August 2021)

Energy Technology Perspectives 2020 (International Energy Agency, September 2020)

Making Mission Possible, Delivering a Net-Zero Economy (Energy Transitions Commission, September 2020)

Saving resources and the climate? A systematic review of the circular economy and its mitigation potential (Environmental Research Letters, August 2020, published November 2020)

Boosting Circularity: Materials Efficiency and Circularity in the Manufacturing Sector (Energy Transitions Commission, October 2019)

Completing the Picture, How the Circular Economy Tackles Climate Change (Ellen MacArthur Foundation, Material Economics, September 2019)

Industrial Transformation 2050, Pathways to Net-Zero Emissions from EU Heavy Industry (Material Economics, May 2019)

Industrial Transformation 2050, Towards an industrial strategy for a climate-neutral Europe (Institute for European Studies, April 2019)

Material efficiency in clean energy transitions (International Energy Agency, March 2019)

Quantifying the benefits of circular economy actions on the decarbonisation of the EU economy (Trinomics, December 2018)

Mission Possible: Reaching net-zero carbon emissions from harder-to-abate sectors (Energy Transitions Commission, November 2018)

The Circular Economy, A Powerful Force for Climate Mitigation (Material Economics, June 2018)

Circular economy potential for climate change mitigation (Deloitte Sustainability, November 2016)

Steel

Technologies to decarbonise the EU steel industry (EU Joint Research Centre, June 2022)

Moving towards Zero-Emission Steel – Technologies Available, Prospects, Timeline and Costs (Trinomics, for European Parliament, ITRE Committee, December 2021)

Six-sector specific recommendations for Czechia's Green Transition (Climate & Company, November 2021)

Net-Zero Steel Sector Transition Strategy (Mission Possible Partnership, October 2021)

Steeling Demand: Mobilising buyers to bring net-zero steel to market before 2030 (Energy Transitions Commission, Material Economics, July 2021)

Emission reduction strategies in the EU steel industry, Implications for business model innovation (Journal of Industrial Ecology, April 2021)

Iron and Steel Technology Roadmap (International Energy Agency, October 2020)

Low Carbon Roadmap Pathways to a CO2-Neutral European Steel Industry (EUROFER, November 2019)

Mission Possible: Reaching net-zero carbon emissions from harder-to-abate sectors -Sectoral Focus Steel (Energy Transitions Commission, January 2019)

Cement

Decarbonisation Roadmap for the Czech Cement Industry (Czech Cement Manufacturers Association, June 2022, in Czech)

Concrete Future – The GCCA 2050 Cement and Concrete Industry Roadmap for Net Zero Concrete (Global Cement and Concrete Association, October 2021)

Decarbonizing the cementitious materials cycle – A whole-systems review of measures to decarbonize the cement supply chain in the UK and European contexts (Journal of Industrial Ecology, February 2021)

Decarbonisation pathways for the EU cement sector – Technology routes and potential ways forward (New Climate Institute, November 2020)

Cementing the European Green Deal – Reaching Climate Neutrality Along the Cement and Concrete Value Chain By 2050 (Cembureau, May 2020)

Mission Possible: Reaching net-zero carbon emissions from harder-to-abate sectors -Sectoral Focus Cement (Energy Transitions Commission, January 2019)

Technology Roadmap – Low-Carbon Transition in the Cement Industry (International Energy Agency, April 2018)

Chemicals and plastics

Towards a Net-Zero Chemical Industry: A Global Policy Landscape for Low-Carbon Emitting Technologies (World Economic Forum, May 2022)

ReShaping Plastics – Pathways to a Circular, Climate Neutral Plastics System in Europe (Systemiq, April 2022)

Europe's Missing Plastics (Material Economics, March 2022)

Implementing Low-Carbon Emitting Technologies in the Chemical Industry: A Way Forward (WEF, November 2021)

Chemicals – Tracking Report (International Energy Agency, November 2021)

Waste in the Net-Zero Century, Greenhouse Gas Impacts of Mixed Waste Sorting (Eunomia, August 2021)

Waste in the Net-Zero Century, How Better Waste Management Practices Can Contribute to Reducing Global Carbon Emissions (Eunomia, May 2021)

Mission Possible: Reaching net-zero carbon emissions from harder-to-abate sectors – Sectoral Focus Plastics (Energy Transitions Commission, January 2019)

The Future of Petrochemicals – Towards a more sustainable chemical industry (International Energy Agency, October 2018)

Aluminium

Closing the Gap for Aluminium Emissions: Technologies to Accelerate Deep Decarbonization of Direct Emissions (Mission Possible Partnership, December 2021)

Aluminium for Climate: Exploring pathways to decarbonize the aluminium industry (World Economic Forum, November 2020)

Circular Aluminium Action Plan – A Strategy for Achieving Aluminium's Full Potential for Circular Economy by 2030 (European Aluminium, April 2020)

Vision 2050, European Aluminium's Contribution to the EU's Mid-Century Low-Carbon Roadmap (European Aluminium, April 2019)

Buildings construction

Building renovation: where circular economy and climate meet (European Environment Agency, July 2022)

Modelling the Renovation of Buildings in Europe from a Circular Economy and Climate Perspective (Metabolic, July 2022)

Circular Buildings: constructing a sustainable future (Holland Circular Hotspot, May 2022)

Towards embodied carbon benchmarks for buildings in Europe (Ramboll, Aalborg University Build, KU Leuven, March 2022)

The business case for circular buildings: Exploring the economic, environmental and social value (WBCSD, October 2021)

Green Building Principles: The Action Plan for Net-Zero Carbon Buildings (World Economic Forum, October 2021)

Embodied Carbon – A Hidden Heavyweight for the Climate: How financing and policy can reduce the carbon footprint of building materials and construction (Programme for Energy Efficiency in Buildings (PEEB), October 2021)

Decarbonizing construction – Guidance for investors and developers to reduce embodied carbon (WBCSD, July 2021)

Net-zero buildings: Where do we stand? (WBCSD, July 2021)

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0
10
20
30
40
50
60
70
80
mph
90
100
110
120
130
140
150
160

Annex 2.
Acronyms and abbreviations

Acronym	Designation
AMO	Association of International Affairs
SCHP ČR	Association of the Chemical Industry of the Czech Republic
BAU	Business as Usual
BEV	Battery Electric Vehicle
B2B	Business To Business
CBAM	Carbon Border Adjustment Mechanism
CCU/CCS	Carbon Capture Use /Carbon Capture Storage
CEE	Central and Eastern European
CETA	Centre for Economic and Trade Analysis.
CE	Circular Economy
CLT	Cross-Laminated Timber
CZK	Czech Crown
MIT	Czech Ministry of Industry and Trade
MŽP	Czech Minitry of Environment
NECP	Czech National Energy and Climate Plan
ČSÚ	Czech Statistical Office
DRS	Deposit Return Scheme
DRI	Direct Reduced Iron
EAF	Electric Arc Furnace
EV	Electric Vehicle
EMF	Ellen MacArthur Foundation
ELV	End-of-life Vehicle
EEA	European Environmental Agency
EFTA	European Free Trade Association
EGD	European Green Deal
EUMEPS	European Manufacturers Association of Expanded Polystyrene
EU	European Union
EU ETS	European Union Emissions Trading Scheme
EPS	Expanded Polystyrene
EPR	Extended Producer Responsibility
FCV	Fuel Cell Vehicle

Acronym	Designation
GHG	Green House Gas
GDP	Gross Domestic Product
GVA	Gross Value Added
IEEP	Institute for European Environmental Policy
INCIEN	Institute of Circular Economy
IPPC	Integrated Pollution Prevention and Control
ICEV	Internal Combustion Engine Vehicle
IEA	International Energy Agency
IRP	International Resource Panel
LULUCF	Land Use, Land-Use Change and Forestry
LCA	Lifecycle Analysis
LCV	Light Commercial Vehicle
LTS	Long-Term Scenario
LED	Low Energy Demand
ME	Material Economics
MEF	Material Efficiency Variant
Mt	Million tonnes
CEAP	Circular Economy Action Plan
NGO	Non-Governmental Organization
OECD	Organisation for Economic Co-operation and Development
ODS	Ozone Depleting Substances
PHEV	Plug-in Hybrid Electric Vehicle
PET	Polyethylene Terephthalate
PVC	Polyvinyl Chloride
SSP	Shared Socioeconomic Pathways
SPS	Stated Policies Scenario
SCM	Supplementary Cementitious Material
SDS	Sustainable Development Scenario
SVC ČR	Czech Association of Cement Producers
TAČR	Technology Agency of the Czech Republic
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
WEM	With Existing Measures

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Study
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