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The zero-carbon car: Abating material emissions is next on the agenda

The automotive industry could abate 66 percent of emissions from their material production at no extra cost by 2030—if industry participants work together and start now.

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The automotive sector is critical to achieving net-zero global emissions by 2050, the foundation of the road map toward limiting global warming to 1.5 degrees Celsius above preindustrial levels. Many original-equipment manufacturers (OEMs) are accordingly setting aggressive decarbonization targets to meet this challenge.[1]

Since 65 to 80 percent of emissions an automobile generates are from tailpipe emissions,[2] and corresponding indirect emissions come from fuel supply, the industry has understandably focused on electrifying powertrains. However, to reach the full potential of automotive decarbonization—and achieve the zero-carbon car—industry players now must turn their attention to material emissions as well (Exhibit 1).

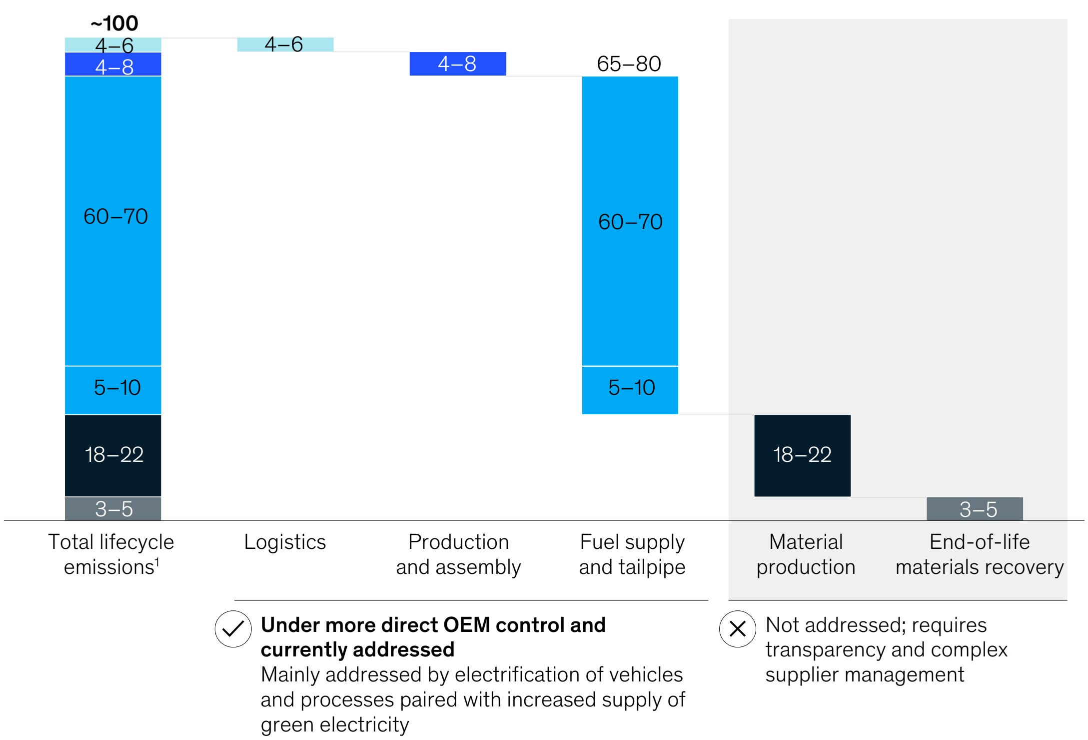
As tailpipe emissions decrease, emissions from vehicles' materials will increase both absolutely and relatively and soon become a larger share of life-cycle emissions. We estimate that the growing market share of battery electric vehicles that have higher baseline material emissions—and the changing energy mix required to power them—will boost material emissions from 18 percent of vehicles' life-cycle emissions today to more than 60 percent by 2040 (Exhibit 2). This jump presents both a

[1] For the purposes of our discussion, we will focus on internal combustion engine vehicles.
[2] Based on industry analysis and interviews with subject-matter experts.

Exhibit 1

The automotive industry has largely focused on the reduction of tailpipe emissions, but reducing material production emissions is also a priority.

% of total current life-cycle emissions of internal combustion engine vehicles

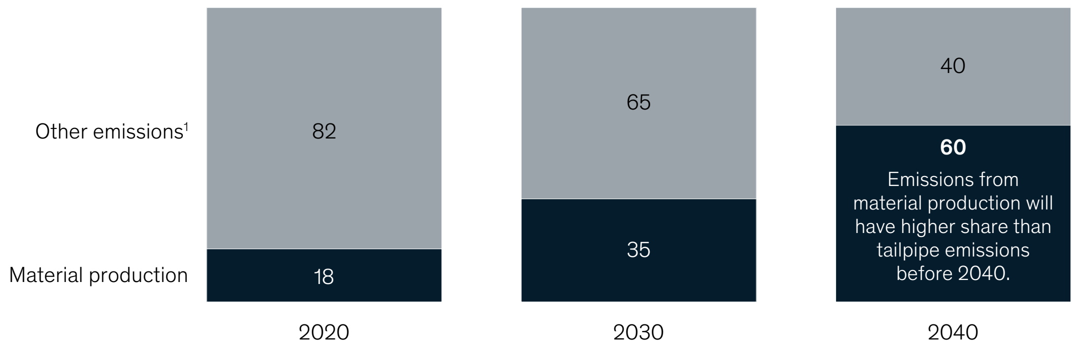


[1]For C-segment vehicle.
Source: Natural and bio Gas Vehicle Association; expert interviews; McKinsey analysis

Exhibit 2

Emissions from material production may reach 60 percent of life-cycle emissions by 2040.

% of life-cycle emissions, (based on required sales data)



[1]Assumed constant range of 150,000 km/vehicle as baseline – End-of-life emissions not considered here.
[2]2018 average ~120gCO2/km, target today 95 gCO2/km. Future assumptions: 2030 75 gCO2/km; 2040 50 gCO2/km.
Source: High level estimation of Circular Cars Initiative (2020) for ambitious EV adoption scenario

challenge and an opportunity on the path to the zero-carbon car.

Developing strategies to address these material emissions today is key because achieving large-scale decarbonization will be a long-term endeavor. This effort requires industry participants to adopt and scale the use of new technologies and their associated processes while managing changing flows of materials. What's more, availability for some low-carbon technologies, such as electric arc furnaces, may be limited in the short term, so early adopters stand to gain outsize benefits. Industry participants should begin to outline the transition now.

To lay the foundation for this transition, we have investigated both the carbon abatement potential as well as the cost implications of a comprehensive set of technical levers for a near-to-full range of automotive materials. This analysis helps to detail the automotive manufacturing ecosystem's path toward the zero-carbon car.

Our analysis shows that for an internal combustion engine vehicle (ICEV), 29 percent of material emissions could be abated in a cost-positive way by 2030. The industry—indeed, automotive manufacturing ecosystems—should prioritize the methods that can help achieve such savings. Most of these savings involve electrifying existing processes, using low-carbon energy sources, adopting and scaling new technologies that reduce process emissions, and both allowing for increased use of recycled materials and actually recycling a greater share of materials.

About 60 percent of these cost-positive decarbonization approaches involve aluminum and plastics. More expansive use of recycled aluminum, new smelting technologies, and green electricity can reduce emissions from aluminum production by about 73 percent from their current levels while also reducing production costs. Similarly, recycled materials such as polypropylene or polyethylene, especially for plastics in parts of vehicles that are not generally visible, can produce savings and cut emissions from plastic production by 34 percent. Scaling nylon recycling technologies could further decrease total plastics emissions by up to 92 percent (Exhibit 3).[3]

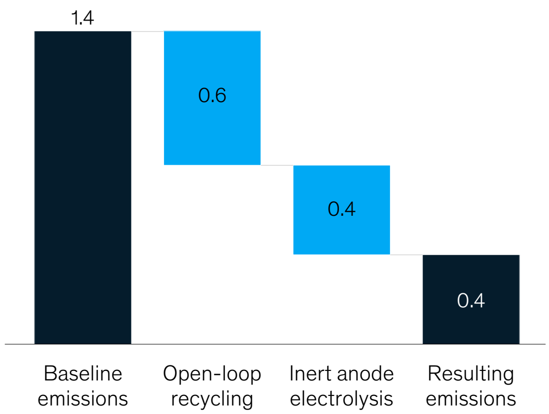
[3] The 92 percent decrease in emissions includes carbon credits earned from averted oil extraction.

Exhibit 3

The automotive industry can decrease aluminum and plastics' material emissions significantly while decreasing production costs.

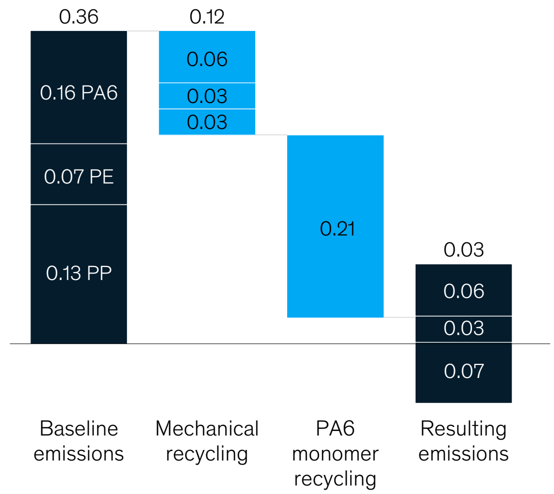
Aluminum, tCO_2 per vehicle[1]
Inert anode technology shift with green electricity and open-loop recycling

73% reduction from baseline



Plastics, tCO_2 per vehicle[1]
Mechanical recycling considering limitations by required material quality

34% reduction from baseline without and 92% reduction from baseline with monomer recycling



Note: Figures may not sum, because of rounding.
[1] Tons of CO_2; in this analysis we are considering a premium SUV model with 1.95 tons vehicle weight: 1.04 tons steel; 0.29 tons aluminum, 0.10 tons rubber, 0.07 tons PP, 0.03 tons PE, 0.05 tons glass, 92 kilowatt-hour battery.
Source: McKinsey Abatement Model Analysis

Further emissions abatement would add costs, but the associated technologies—such as electric arc furnaces and direct reduced iron for steel production—could scale in the long term. Hydrogen-based steelmaking in particular is already technically feasible. However, widespread adoption is dependent on costs, the necessary supply chain, and the regulatory changes that support this transition.[4]

Automobile manufacturing could further reduce its current emissions if manufacturers increase production of relatively carbon-intensive components such as battery cells in regions with low-carbon power grids; indeed, such activity is already occurring in some areas. If the industry were to implement the measures that have potential for cost savings, those savings could then be applied to an additional 37 percent of abatement measures to offset the measures' costs. The net result would abate 66 percent of emissions while keeping vehicle costs the same.

Despite the environmental and economic promise of decarbonizing materials in the automotive value chain, the specific path forward is challenging because a coordination problem lies at its heart. The carbon-abatement methods we describe require the work of multiple parts of the value chain. In fact, most of the material emissions we've identified are outside OEMs' direct control. For example, our analysis indicates that 79 percent

[4] For more on decarbonizing steelmaking, see Christian Hoffmann, Michel Van Hoey, and Benedikt Zeumer, "Decarbonization challenge for steel," June 3, 2020, McKinsey.com.

of emissions from aluminum production occurs during the smelting process. What's more, many of the technologies required are not yet available at scale and would require significant up-front investments, and the flow of materials is complex and difficult to track. This opacity makes it challenging to prioritize decarbonization efforts based on the size of different materials' and processes' carbon footprints.

And while there are multiple viable ways to fully decarbonize the majority of automotive materials, many of these paths are mutually exclusive. Different players along the automotive supply chain might pursue divergent approaches and set disparate standards, which can create inefficiencies and lead to higher material costs and delay and limit emissions abatement. Indeed, none of the decarbonization approaches we describe can be implemented by a single organization—or an isolated segment of the value chain. An OEM-led, coordinated, collaborative approach across the automotive value chain is critical to optimize impact and costs.

As a first step, OEMs have to understand the decarbonization potential and the cost implications of the materials they use. They can use this information and their own aspirations to evaluate their progress toward their individual decarbonization goals, identify technologies they'll need to adopt, and work with other participants in the value chain to realize their vision (Exhibit 4).

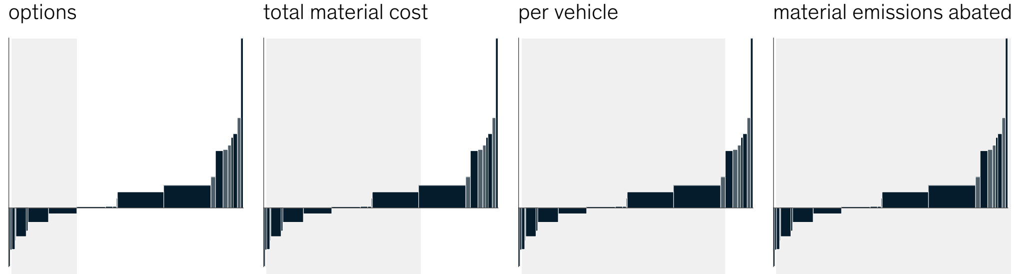
As they explore and articulate their role, OEMs should identify the areas in which they most want to exert influence and where they can create the most competitive advantage.

Exhibit 4

OEMs' approach to decarbonizing materials depends on their ambitions and their customers' willingness to pay.

Illustrative pathways Pathway

	Cost-positive Limit actions to cost-positive decarbonization options	**Net-zero cost** Limit actions to achieve a net-zero impact on total material cost	**"Sustainability premium"** Allow for €200+[1] additional material cost per vehicle	**Zero-emission** Full zero-carbon vehicle pathway with >95% material emissions abated



Example actions	• Mechanical recycling • Open-loop recycling	• Steel: increased scrap and share in electric arc furnace (EAF) route • Plastics: pyrolysis	• Biogas-based direct reduced iron (DRI) for EAF • Increased natural rubber share	• Plastics: power-to-chemicals (PE)

Ambition

Low → High

[1]Example additional material cost, reasonable range to be determined.

To make emissions abatement cost effective, OEMs must also collaborate with other ecosystem players. This effort requires an intensive assessment of their suppliers and occasionally a willingness to work with other OEMs to capture the abatement potential at reasonable costs. For example, a coalition of OEMs could harvest high-grade aluminum from end-of-life vehicles.

OEMs should also stay updated on practices and technologies in other industries that could contribute to their decarbonization efforts once these other industries' efforts reach maturity. For instance, many industries chemically recycle plastics, a technology that OEMs could also adopt if it proves to be both carbon saving and cost positive.

After electrifying powertrains, reducing material emissions is the next big opportunity for the automotive industry to define its role in global decarbonization efforts. There are a number of cost-effective ways forward and long-term strategies to act on—but automotive OEMs must take the first step toward replacing the vehicles on today's streets with the zero-carbon car of tomorrow. As leaders of the value chain, they can rally the industry and surrounding players and maintain their place in the driver's seat throughout this transition.

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