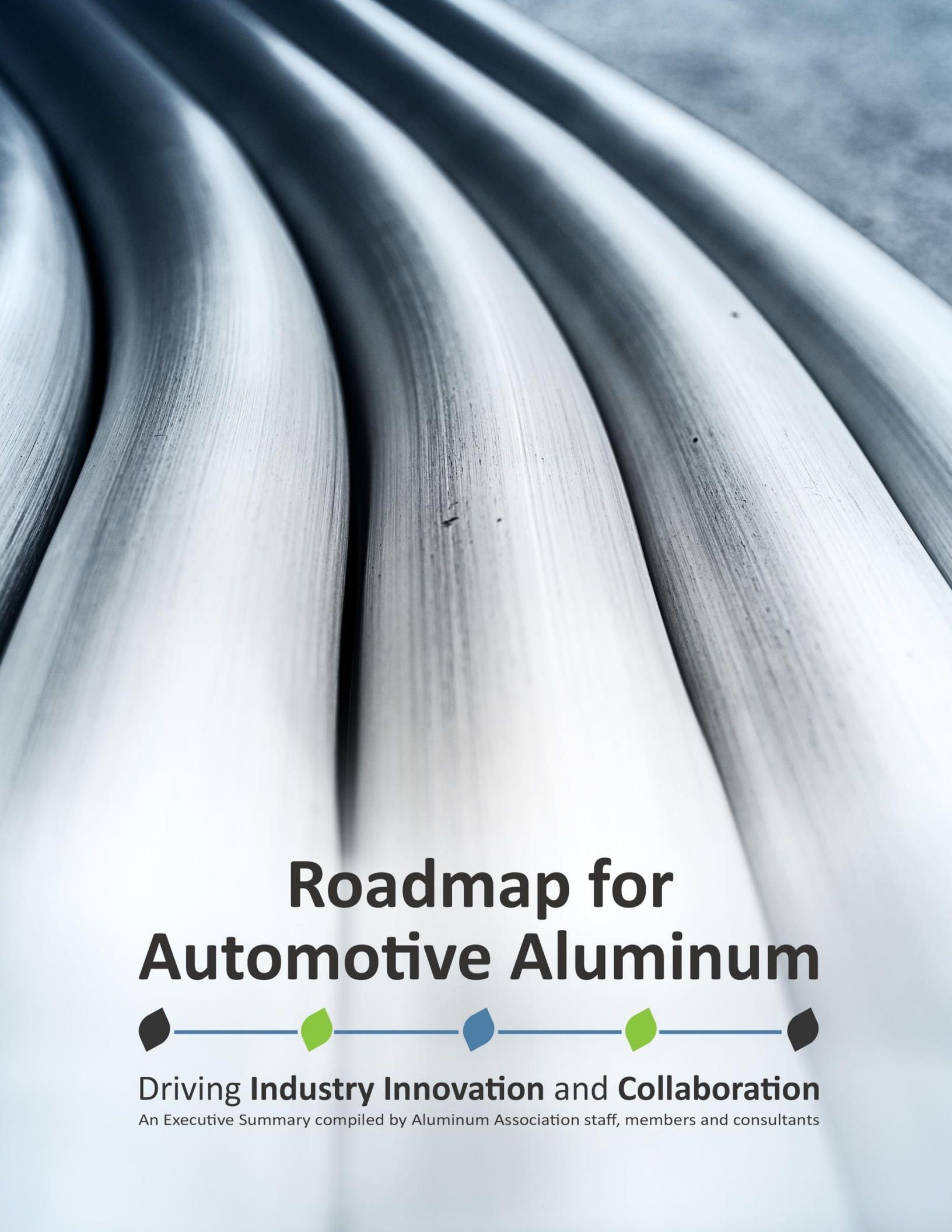

Roadmap for Automotive Aluminum

Driving **Industry Innovation** and **Collaboration**

An Executive Summary compiled by Aluminum Association staff, members and consultants

Aluminum is a foundational element in the architecture of past, present and future vehicles. From Audi's dominance in the early 1990s with the A2 and A8, to the 1997 all-aluminum Chrysler Prowler, and to more recent innovations such as 2015 aluminum-bodied F-150 and Jaguar's first all-electric car, the I-PACE, automotive aluminum design spans decades. As the fastest growing automotive material, preferred by engineers for both internal combustion engine (ICE) vehicles and electric vehicles (EV), aluminum will drive the design of next-generation mobility solutions.

Automakers and suppliers alike are innovating at rapid pace to set trends and respond to an ever-changing landscape of consumer demands and global priorities to protect the planet. To address these trends and remain in lockstep with environmental priorities, the aluminum industry heard a call from automakers for greater collaboration and co-engineering to understanding key technologies aluminum producers are working on near-and long-term. The 2022 Roadmap for Automotive Aluminum, a blueprint developed collaboratively among aluminum producers, answers that call by identifying research and development (R&D) goals to advance aluminum production for the next decade.

The purpose of the Roadmap is to detail, at every step of the value chain, solutions for the next decade of automotive products. The aluminum industry identifies several sustainable pathways forward– collaboration to optimize vehicle systems, technologies to predict alloy properties, processes to consolidate parts for efficiency in design of future vehicles, and the expansion of recycling and sorting processes for a more environmentally-sound manufacturing ecosystem. Aluminum companies collectively identified five key themes that contribute to the overall goal to improve vehicle performance and increase aluminum's value to automakers.

Design Engineering

Design is an iterative decision-making process typically supported by fundamental sciences, process design tools, computational models, and a wide spectrum of physical and chemical properties data. Design Engineering, the first theme of the Roadmap, outlines three key goals that center around collaboration among automakers and suppliers: raise awareness of the advantages of aluminum to build a better vehicle, resolve key design challenges, and create future products that boast superior performance.

Aluminum industry experts will continue working with automotive design engineers to pinpoint imperatives across automotive programs, and to implement aluminum in strategic areas of the vehicle for optimal results in both production and performance. Over the next five to 10 years, the aluminum industry aims to establish open access resources for design data harmonization across the entire value chain, optimize material joining processes for efficiency, and improve aluminum component manufacturability for strong and durable future vehicles. Ultimately, this collaboration will result in improvements in structural design for increased vehicle weight savings. Aluminum manufacturers are also aiming to create common specifications to communicate with OEMs efficiently, with greater flexibility. The industry will also facilitate more research to develop detailed, relevant and updated material data for forming and manufacturing simulations. These goals will usher in new opportunities for designing products with greater safety, recyclability, and performance for longevity and end-user satisfaction.

New Alloys and Products

Aluminum has long derived its strength from defense and aerospace applications. It is imperative for engineers to use learnings from these applications to innovate the next generation of 6xxx and 7xxx alloys for use in the automotive market.

The Roadmap presents several goals to improve aluminum alloy performance characteristics, expand research of form-specific grades, and increase recycling capabilities. Through these goals, the aluminum industry sees opportunities in cast and extruded aluminum forms, rolled aluminum (namely to enhance strength and formability) and recyclable alloys. The industry is committed to working with automakers to redesign alloys and develop suitable new alloys for different processes.

There are three concrete data-driven action plans to respond to new alloy and product challenges. First, the industry must tailor alloys for high performance in OEM-specific applications to meet automotive requirements. Next is the importance of harnessing data analytics and predictive modeling of alloy properties. Technology will improve design and production of new alloys. Finally, there is a need to create standardized methods for testing, validating performance, and qualifying new materials and components.

Future Vehicles

The onslaught of widespread aluminum-intensive EVs is just around the bend as new vehicles enter the market. Aluminum already offers low-weight, high-strength solutions for future vehicles, based on its inherent corrosion-resistance, efficiency and crash-performance benefits. As electrification grows, a 2020 DuckerFrontier North American Light Vehicle Aluminum Content Outlook confirms demand for aluminum extrusions and high-pressure aluminum diecast parts will grow due to increased use in applications like battery housings, motor housings and body structural components.

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Future vehicles goals defined in the Roadmap address the components and markets that offer the greatest potential for aluminum, including the capture of a significant share of BEV markets and preparedness for vehicles designed in 2025, with a focus on weight-range balance. While there is a major focus on passenger vehicles, aluminum is also poised for expanding its reach into commercial and heavy-duty vehicles, military vehicles, last-mile delivery vehicles, and more. As with all other Roadmap themes, the Future Vehicles goals cannot be met without major research priorities, including the exploration of high-formability alloys, alloy development for battery components, and production methods to increase value and efficiency for BEVs.

Next-Generation Fabrication Technologies

Joining is a critically important fabrication technology in automobile manufacturing. Independent of material, joining processes are critical in all automotive applications as they influence vehicle durability, noise vibration harshness (NVH) performance, handling and collision energy management. In addition to traditional manufacturing processes such as casting and extrusion, aluminum can be used in a powder form for additive manufacturing (AM) opportunities in automotive parts.

The Roadmap's goals for next-generation fabrication focus on improving manufacturing methods to enhance the value of aluminum compared to competing materials in existing and future vehicles. Generally, next-generation processing offers opportunities to lower material costs, improve production quality, and enhance sustainability on the manufacturing plant floor. The industry has already experienced castings innovations like Tesla's giga-castings strategy to produce the Model Y with a single rear body piece that replaced 70 different parts in the vehicle. Other automakers are adopting this process for parts efficiencies, too. The aluminum industry identified three action plans to keep up the pace of evolution in the development of next-generation fabrication processes: alloy and mill process development to improve formability, real-time process data collection at all steps in the manufacturing process, and smart manufacturing practices to continue innovating for industry 4.0.

The aluminum industry is a key contributor to the U.S. manufacturing sector, invested more than $4 billion in over the last decade to support growing demand for the metal.

Recycling and Sustainability

While the aluminum used in automotive applications already contains a great amount of recycled content, there is a strong opportunity for even more. In a 2020 paper published in Resources, Conservation & Recycling Journal (RCR), experts from the University of Michigan, Ford and Light Metal Consultants LLC used a dynamic flow analysis to estimate aluminum automotive body sheet (ABS) scrap generated from today's highest selling vehicles in America. They found that if production continues at current volumes, "aluminum ABS scrap from these vehicles will increase to approximately 125,000 tons per year in 2035 and 246,000 tons per year in 2050. The majority of this scrap will be available for U.S. processing with [approximately] 10 percent of deregistered vehicles exported or achieving vintage status."

Developing the next generation of high-speed, alloy-selective, low-cost sorting technologies for shredded aluminum scrap is a priority as the aluminum industry looks ahead to prepare for this wave of ABS scrap. Goals for aluminum recycling and sustainability range from an improved, more efficient infrastructure for aluminum scrap recovery to increased utilization of scrap and the wide promotion of automotive aluminum as a sustainable solution across all manufacturing phases. The industry sees opportunity to work with automakers to improve vehicle end of life (EOL) recycling, decrease carbon emissions from wrought aluminum production, and align with competing materials on a common baseline for comparing carbon levels for material processing. The goals in this theme are inherently important, and will work with other themes within the Roadmap such as incorporating design elements that ensure parts can be disassembled and recycled efficiently to help establish the circular economy that is so critically needed in transportation.

Blueprint for Industry Innovation

This tremendous undertaking could not be possible without the strategic input of aluminum producers and stakeholders across the value chain. As automakers, suppliers and federal regulators alike face unique obstacles in a world riddled with supply chain disruptions, worker shortages, technology barriers and an ever-growing call to combat climate change, the aluminum industry is here to support with smart solutions. The Aluminum Association's Aluminum Transportation Group (ATG) is proud to represent aluminum member companies who are committed to ongoing collaboration using the Roadmap as a blueprint for industry innovation.

This Roadmap is only the beginning. Year over year, the ATG and its members will re-evaluate pathways and themes identified within the document to reflect fluctuations in the market, shifts in the environment, and any unforeseen industry evolution. All future ATG work will center around the advancement of design engineering; new alloys, grades, and products; future vehicles; next-generation aluminum fabrication technologies; and recycling and sustainability themes.

Today, aluminum offers the fastest, safest, most environmentally-friendly and value-added way to increase vehicle performance, boost fuel efficiency, extend battery range and reduce emissions. The aluminum industry is a key contributor to the U.S. manufacturing sector, invested more than $4 billion in over the last decade to support growing demand for the metal. Aluminum producers are united in their common goal to move the needle forward for the future of sustainable transportation. The Roadmap facilitates that unity and progress, as a dynamic and living document to be reviewed, revisited and revised over the next decade.