



Dow Automotive Systems

Breakthrough to a World Challenge BETAMATE™ Structural Adhesives



I. Overview

BETAMATE™ Structural Adhesives were first introduced by Dow Automotive Systems for use in lightweight vehicle manufacturing in 1999. Since then, various formulations of BETAMATE Adhesives have helped improve vehicle safety and durability, while saving weight and increasing design flexibility. Ultimately, hundreds of millions of lives have benefitted from stringent safety regulations and continual improvements in automotive and commercial transportation.

Now, with a global focus on fuel efficiency and vehicle emission reduction, BETAMATE Adhesives are again leading the industry as a key enabler – this time for mass reduction. As populations grow and economies around the globe develop and improve their transportation infrastructure, the number of vehicles in the world will continue to grow above GDP, offering increased, safer mobility to more people.

II. Executive Summary

Automakers today face the challenging task of designing and producing vehicles that meet consumer expectations and government standards for safety, comfort, performance and sustainability. Increasingly, environmental impacts are a central consideration in vehicle development, both in terms of fuel efficiency and CO₂ emissions throughout the vehicle's lifecycle.

The impact of greenhouse gas (GHG) emissions on climate change is now commonly recognized and, since the Kyoto Protocol, more countries and industries have committed to reducing their GHG footprint. Fossil fuels have come under pressure as a main cause of CO₂ production and for strategic sourcing reasons. Gasoline prices at the pump are peaking at record levels and remain very high in many areas of the globe, impacting consumer buying habits and business profitability. For example, fuel cost accounts for 30% of the total operational cost for road freight operators. The transportation sector has been and still remains the single largest consumer of oil, with 43% of consumption from road transportation alone, and one of the primary producers of CO₂, representing 22% of the total.²

Despite significant improvements, vehicle safety is another major challenge – with 1.24 million fatalities in 2010, adding to a much larger number of severe injuries with human and

BETAMATE Structural Adhesives represent a breakthrough solution addressing energy and climate change, as well as safety and health, two of the pressing world challenges that Dow has committed to improve as part of our 2015 Sustainability Goals. Since inception, BETAMATE Adhesives have already contributed to an estimated 23.3 billion kg carbon dioxide (CO₂) avoidance and 2.65 billion gallons of gasoline savings, while delivering a tangible return to Dow and its shareholders, increasing our overall industry visibility as well.

Acknowledging the technical and commercial success of the franchise and the game-changing vehicles the technology has enabled, the time has come to formally recognize BETAMATE Adhesives as one of Dow's "Breakthroughs to World Challenges."

Following is a complete explanation of the global situation, our customers' needs and our solution for improving safety and health as well as sustainability.

social costs – particularly in the developed regions of the world. With the strong vehicle build growth projected in the coming years – a 5% compound annual growth rate until 2020 – and a constant shift of vehicle ownership and road congestion toward emerging markets, these impacts will be further amplified and drive the industry to change at an unprecedented pace.

One of the challenges to lightweight material implementation in vehicles has been the selection of effective joining technologies, especially for dissimilar lightweight substrates such as high strength steel, aluminum, magnesium and composites. BETAMATE™ Structural Adhesives are an enabling technology for dissimilar material assembly, where traditional joining techniques such as welding and riveting are limited in their applicability.

Other benefits of structural adhesives include increased load bearing capability and increased static and dynamic stiffness, leading to improved safety and crash behavior, reduced vibrations and noise, optimized ride and handling characteristics, and extended vehicle life span and long-term value via higher durability. The value of lightweighting is even more pronounced in electric vehicles as a way to offset the additional battery load (up to 900 lbs) and to extend the vehicle driving range.

III. How the World Benefits from BETAMATE™ Structural Adhesives

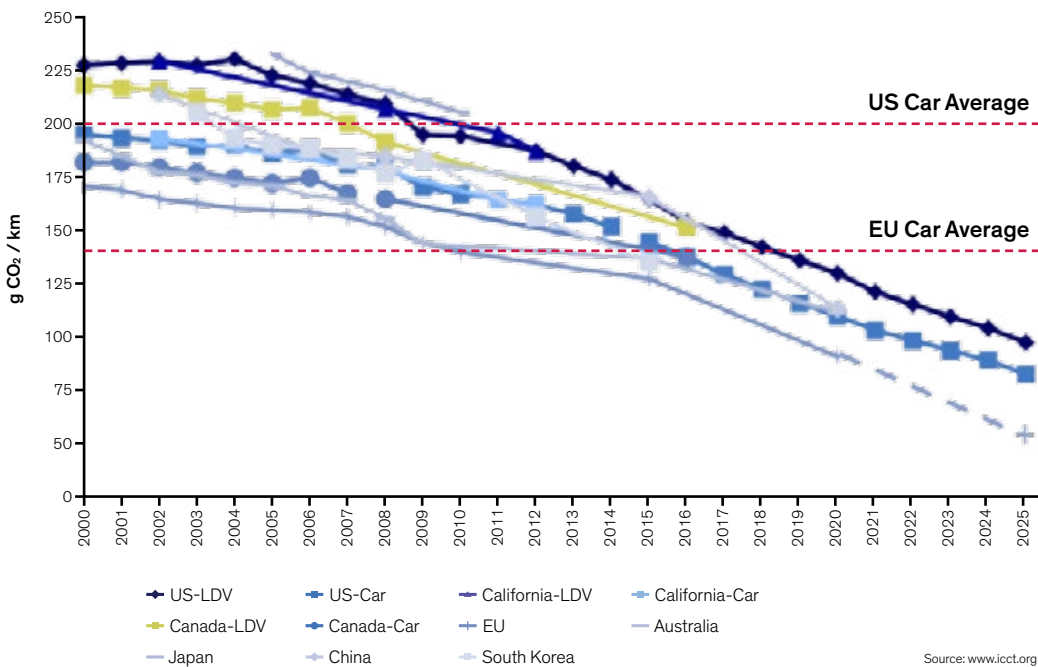
In recent years, sustainability has increasingly come to the forefront as a key consideration in vehicle design and manufacturing. In the US and the European Union, in particular, aggressive new fuel efficiency and GHG emission standards are already being implemented, with more aggressive targets expected for 2020–2025. Major emerging markets – including China, Brazil, India and Russia – are also pressed by air quality challenges in megacities and the fastest motorization growth rate in history.

Consumer behavior also is changing the marketplace. As energy prices continue to represent a substantial portion of budgets, customers are purchasing more fuel-efficient vehicles. In parallel, vehicle original equipment manufacturers (OEMs) are working hard to address a growing and valuable segment of customers that prefers large vehicles (full-size pickups and SUVs) by drastically reducing fuel consumption. Further,

consumers are rewarding companies that they feel align with their own values, which means increasing scrutiny on the efficacy of corporate sustainability goals.

These facts point to a need – on the part of transportation vehicle manufacturers – for substantially increased fuel economy and a decreased manufacturing footprint in a very short period of time, while still delivering improvements in safety and performance that customers have come to expect. These increases are less likely to come from radical vehicle redesigns, unknown technologies or expensive new vehicle programs. Instead, enabling technologies like BETAMATE™ Structural Adhesives represent an important tool for automakers to facilitate lightweight vehicle assembly using existing manufacturing processes to achieve the desired benefits.

Global Passenger Car and Light Vehicle Emission Legislation 2005–2025



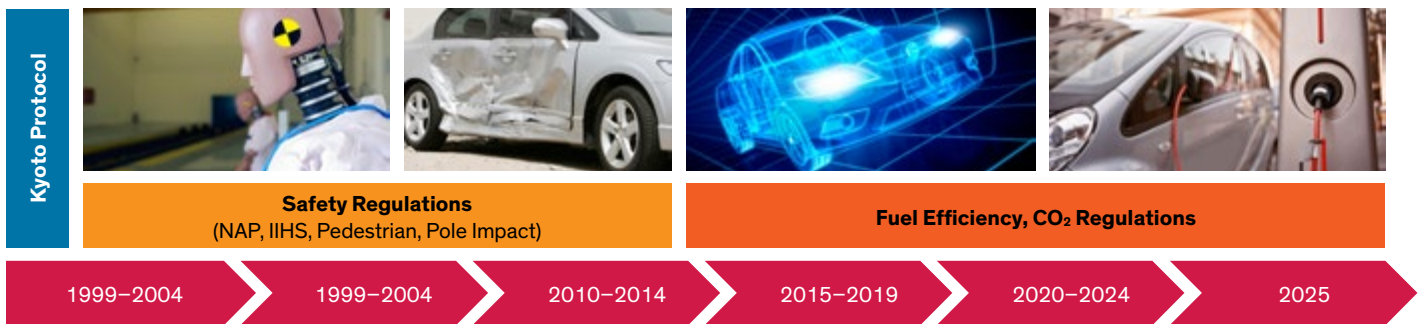
Source: www.icct.org

IV. Introduction of BETAMATE™ Structural Adhesives as a Breakthrough Technology

Although industry experts assume that steel will remain the primary material for mass market vehicle structures, metals with lower density such as aluminum and magnesium, as well as carbon fiber-reinforced composites (CFRC), are increasingly finding their way into vehicle structures. Reliable assembly of dissimilar materials is beyond the capabilities of conventional joining technologies such as welding and mechanical fastening, and adhesives have emerged as the most attractive solution. In recent years, structural adhesives have shown accelerated adoption, far exceeding car build rates. Dow Automotive Systems pioneered the introduction of structural adhesives in body-in-white applications at the end of the 1990s and continues to lead the market, successfully leveraging different material science technologies to address evolving customer needs.

BETAMATE™ Adhesives – Development vs. Industry Drivers

Industry Drivers



Dow Developments

- BETAMATE™ Crash Durable Adhesive first to market
- BETAMATE™ Gen 2
 - Process improvement
 - Aluminum assembly
 - Global expansion
- BETAMATE™ Gen 3
 - Shelflife improvement
 - Composite assembly
 - Optimized corrosion
 - 1st C-OEM business
- BETAMATE™ NEXT: Enabling ultimate mass reduction for multi-material and dissimilar substrate joining

V. Breakthrough Criteria Alignment

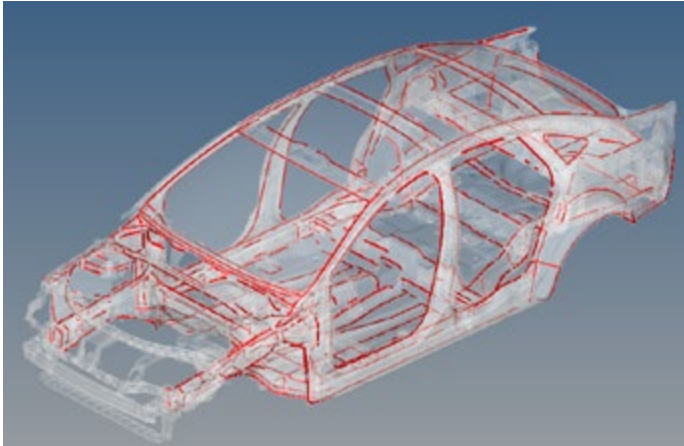
BETAMATE™ Structural Adhesives align perfectly with the breakthrough criteria of Energy and Climate Change and improved Health and Safety. For the Energy and Climate change criteria, the use of structural adhesives facilitates reduced vehicle weight, which improves fuel efficiency and reduces GHG/CO₂ emissions throughout the vehicle’s life, which can be up to 15 years for passenger vehicles.

Structural adhesives facilitate mass reduction of the body structure via metal down-gauging, lightweight material integration and parts consolidation. This primary mass reduction then enables the rightsizing of the vehicle engine, drivetrain, suspensions and fuel tank, yielding an additional 0.7 kg of secondary mass saving for every 1 kg primary mass reduction.⁴

In applications of structural adhesives where designers are optimizing for weight reduction, evidence suggests that 0.6 to 1.1 kg of mass can be reduced for every meter of structural adhesive applied.

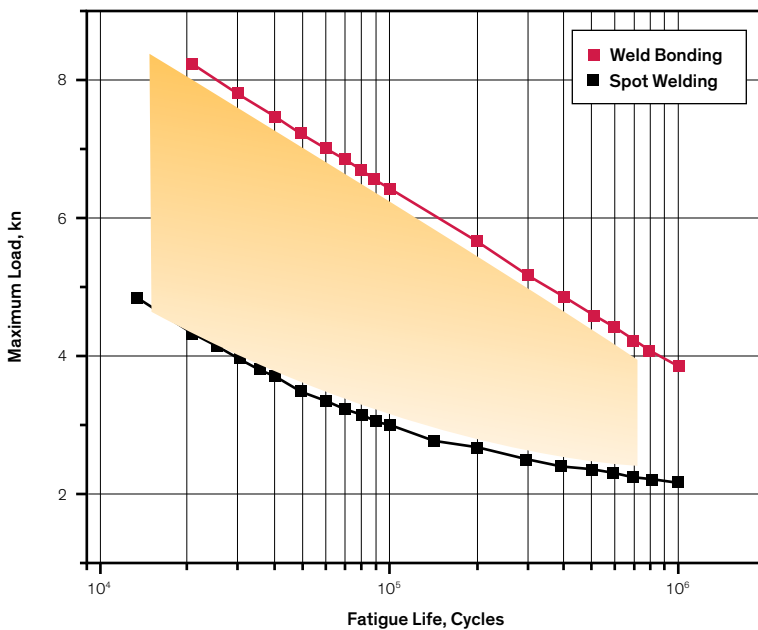
Over a 15-year life span, a vehicle is expected to consume 5,000 to 10,000 gallons of fuel and emit up to 90 metric tons of carbon dioxide.⁵ A detailed assessment of the benefits enabled by BETAMATE Adhesives since its inception (assuming a 5-year vehicle life) for a mid-size vehicle program estimates a total CO₂ avoidance of 23.3 billion kg and 2.65 billion gallons of gasoline saved – representing slightly more than 1% of total CO₂ emitted and gasoline used by new vehicles introduced during the timeframe considered.

The use of structural bonding also enables clear improvements in vehicle safety, due to maximum load transfer and yielding of the substrate materials as well as improved joint durability.

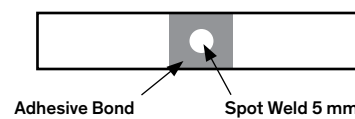


Why are Structural Adhesives Effective?

- Reduce stresses in bonded joints, which improves vehicle durability
- Enables down gauging of steel, which reduces weight
- Higher loads can be sustained, which improves crash and safety performance



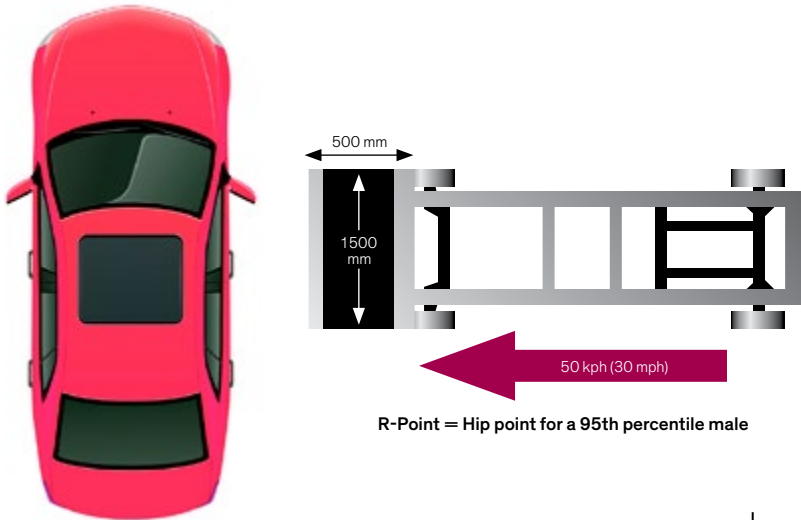
- **Spot Welding:** Standard joining technique
- **Weld Bonding:** Adhesive bonding with welding secondary attachment



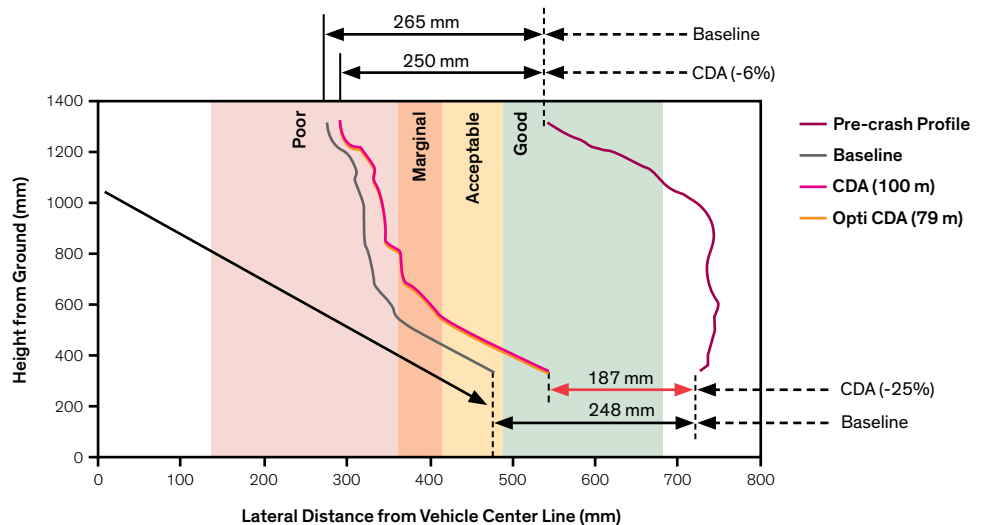
- Increased load-carrying capability allows down-gauged substrate for weight reduction

Regulated test procedures have confirmed the positive impact of structural adhesives as demonstrated by computer-aided engineering and real vehicle tests. These improvements result in lower intrusion and reduced deceleration of the vehicle occupants, and ultimately contribute to a reduction in fatalities and injury severity when passive safety systems, e.g., safety belts, are correctly utilized.

Improved Performance in Crash Impact with Structural Adhesives



Structural adhesives reduce the intrusion distance into vehicles by 25% with side impact collisions protecting occupants



VI. Life Cycle View

Dow Automotive Systems purchases renewable energy – produced at a biomass facility – to produce BETAMATE™ Structural Adhesives for use in North America. The energy is produced by Midland Cogeneration Venture Limited Partnership (MCV), with Dow purchasing and retiring the associated renewable energy certificates for the years 2014–2017. This transaction was registered with the Michigan Renewable Energy Certification System (MIRECS), the state agency responsible for validating Renewable Energy Certificate transfers, and specifically attributed the certificates to Dow Automotive Systems and BETAMATE Structural Adhesives.

Overall, BETAMATE Adhesives do not contain hazardous air pollutants or heavy metals. BETAMATE Adhesives do, however include bisphenol A. While this is considered a substance of concern, it is not banned in industrial use. Safeguards include listing this information on MSDS and using proper personal protective equipment in manufacturing. Due to the nature of the product, spills are not anticipated, and Dow communicates ways to help customers prevent this material from entering the aquatic environment.

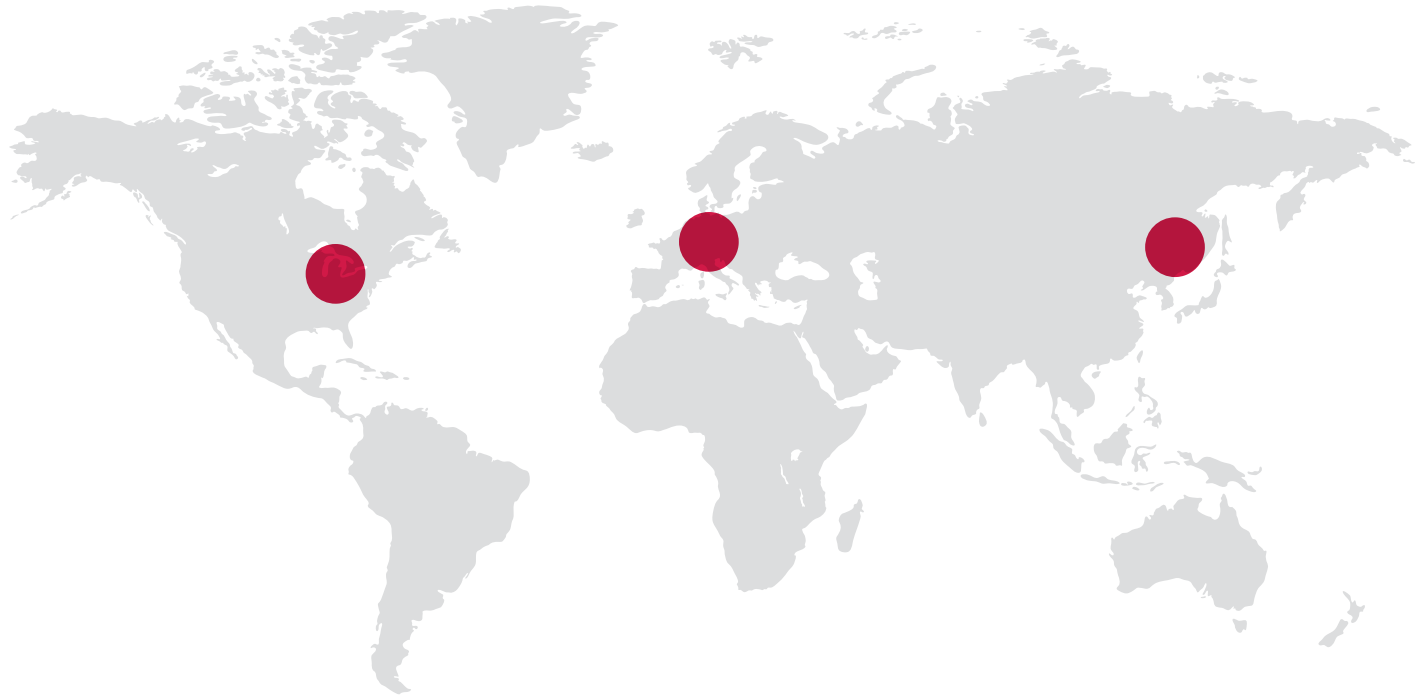
VII. Financial Impact to Dow

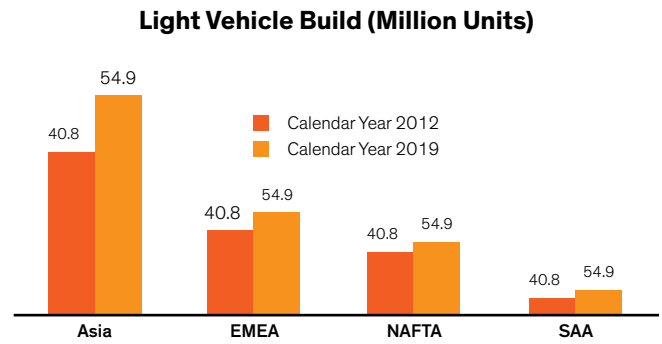
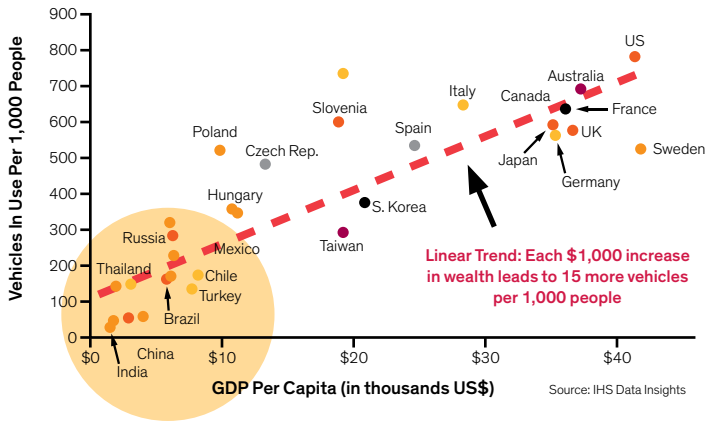
Structural adhesives hold approximately 15% share of the \$1.5 billion/year vehicle assembly market, still dominated by welding and mechanical assembly, yet they exhibit a growth rate four times that of GDP, and Dow is the undisputed market leader. As a differentiated technology platform, BETAMATE™ Structural Adhesives offer high value to customers and have been a major contributor to Dow Automotive Systems' growth, with further advancement expected over the next decade.

VIII. Industry and Geographic Profile

Early adopters of BETAMATE™ Adhesives have included leading German OEMs, such as BMW, Daimler, Audi and VW. These companies have carried the technology into emerging markets where they have a growing footprint, including China, Brazil, Mexico, Russia and India. Subsequent proliferation has occurred at other OEMs – including GM, Ford, FIAT-Chrysler and Hyundai-Kia – and Chinese OEMs have been extremely fast followers as well.

Adjacent market proliferation is occurring from passenger cars to heavy-duty trucks – with PACCAR as a notable example – as well as other commercial transportation vehicles, such as buses, rail and trailers. Having expanded alongside our customers, Dow Automotive Systems benefits from a unique manufacturing footprint in all key regions and can deliver an unparalleled portfolio with a streamlined supply chain.





Considering demographic, disposable incomes and individual as well as freight mobility needs, the center of gravity for the global transportation industry will constantly shift towards emerging countries. Due to incumbency and further proliferation in those regions and vehicles, during this decade, BETAMATE™ Structural Adhesives will make a significant impact on the lives of hundreds of millions more consumers, as they continue to contribute to the development of safer and more sustainable mobility in mature economies.

References:

- ¹ Roland Berger "Are we running out of oil?"
- ² <http://www.iea.org/publications/freepublications/publication/CO2emissionfromfuelcombustionHIGHLIGHTS.pdf>
- ³ http://gamapserver.who.int/gho/interactive_charts/road_safety/road_traffic_deaths/atlas.html
- ⁴ Feasible Amount of Mass Reduction for Light Duty Vehicles for Model Years 2017-2025 Under Contract DTNH22-11-C-00193; NRC: Workshop on Exploring Options for Lighter-Weight Vehicles February 12-13, 2013 – H. Singh (harry.singh@edag-us.com)
- ⁵ <http://www.fueleconomy.gov>

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