

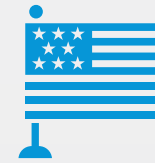
# Automotive Lightweighting Everything Counts

Unlocking the opportunities with simulation



# Executive summary

Lightweighting is a hot topic throughout the automotive industry, as OEMs accelerate efforts to comply with the fast approaching fuel economy and emission standards deadlines. Additionally, consumers are purchasing—or are planning to purchase—vehicles with increased fuel economy, adding to the pressure on OEMs to deliver more fuel-efficient vehicles. With different options available to achieve fuel economy targets, lightweighting is emerging as a clear favorite. In an effort to keep pace with OEMs, suppliers are rapidly developing new manufacturing methods, materials, and designs. As leaders in the space emerge, others must also shift focus to remain competitive. This report explores the driving forces behind the lightweighting movement, the utilization of plastic and composite materials, and the simulation requirements necessary to validate and implement lighter alternatives.



## US Drivers

Corporate Average  
Fuel Economy fleet  
average by 2025

54.5mpg



## EU Drivers

CO2 Emission  
Standards fleet  
average by 2021

95g/km



## China Drivers

Corporate Average  
Fuel Consumption  
Standard by 2020

47mpg

## Industry Response



Vehicle  
Lightweighting



Powertrain  
Efficiency



Alternative  
Energy

## Results

10% ↓ = 6-7% ↑

Vehicle Weight  
Reduction

Fuel Economy  
Increase Estimate



# *The Road to Lightweighting*

Reducing weight to increase the fuel economy of a vehicle is not a new concept. However, the topic of lightweighting has intensified as government regulation deadlines inch closer each day. Examining the regulations and the different options available for OEMs to achieve compliance, it's easy to see why lightweighting is gaining in popularity.

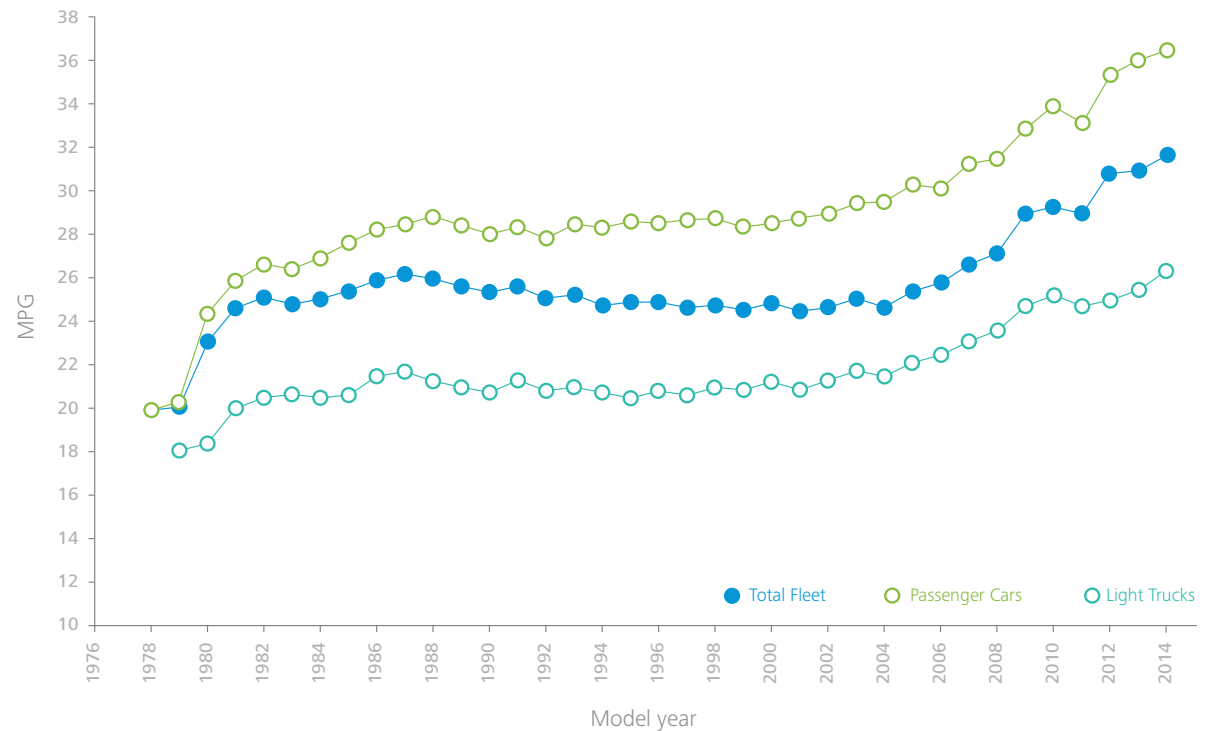


## A new standard in efficiency

Corporate Average Fuel Economy (CAFE) was enacted in 1975 with the purpose of reducing energy consumption by increasing the fuel economy of cars and light trucks. The National Highway Traffic Safety Administration (NHTSA) has recently set standards that will increase CAFE levels rapidly over the next several years, to improve the nation's energy security and save consumers money at the pump.

The next major milestone in CAFE requires that automakers must deliver an *average* fuel economy across their passenger vehicle fleet of 54.5 miles per gallon by 2025. As an average, this requirement won't mean that every car rolling off the assembly line must get 54.5 miles per gallon. CAFE is measured more generously than the numbers on the window sticker, but increasing the CAFE standards does have a significant impact on the fuel economy of vehicles (as can be seen in figure 1).

## The impact of CAFE on auto manufacturers



**Figure 1:** CAFE standards were aggressively increased from 1978 to 1984. As a result, fuel economy also increased. However, between 1985 and 2007 CAFE standards were not meaningfully raised—and MPG flatlined.

# Many paths to explore

There are many different approaches to meeting the upcoming fuel efficiency standards, including vehicle lightweighting, powertrain efficiency, and electrification. OEMs typically use a combination of these three approaches (and a few others) to boost the fuel efficiency of their vehicles.



## ***Vehicle Lightweighting***

Lighter Metals  
Plastics  
Composites

Vehicle lightweighting utilizes different lightweight materials—including aluminum, magnesium, high-strength steel, plastics, and carbon fiber—to replace components on a vehicle to reduce the total weight. A 10% weight reduction in a vehicle typically leads to a 6% to 7% increase in fuel economy.<sup>1</sup>



## ***Powertrain Efficiency***

Turbocharging  
Smaller Engines  
Advanced Controls

New powertrain technologies can also lead to increases in fuel economy. OEMs are turbocharging smaller engines, adding friction-reduction measures throughout the engine, and implementing advanced controls, such as stop-start and regenerative braking systems.



## ***Alternative Energy***

Hybrids  
Electric Vehicles  
Fuel Cells

Electrification of vehicles already exists in many forms and will continue to grow. They include conventional engines with supplemental electric motors, conventional hybrids, plug-in hybrids, and fully electric vehicles.

## The pragmatic choice

With all the different approaches available, OEMs are currently favoring lightweighting because of how relatively straightforward it can be. In its simplest form, lightweighting is basically just replacing existing parts on the vehicle with lighter versions of the parts that perform the same function. In contrast, powertrain technologies and electrification require large engineering investments, advanced vehicle controls, and significant changes in the manufacturing process.

## *A new environmental philosophy*

Producing more fuel-efficient vehicles conserves billions of barrels of oil, cuts carbon pollution, protects consumer choice, and enables long-term planning for automakers. Over the lifetimes of the vehicles sold to the standards of model years 2017 to 2025, the CAFE program is projected to save approximately 4 billion barrels of oil and reduce greenhouse gas (GHG) emissions by 2 billion metric tons, with net benefits to society in the range of \$326 billion to \$451 billion.<sup>2</sup> In addition, the use of recycled plastic and composite materials by the automotive industry has reduced waste. All of these efforts combined will have a significant impact on the environmental footprint of new vehicles.



*Waste*



*Energy*



*Emissions*



*CAFE*



# *Why Plastics & Composites*

Although vehicle lightweighting is not a new concept, the materials and manufacturing processes involved in lightweighting applications are evolving. Cost reductions and advancements in materials are increasing the lightweighting opportunities within vehicles. Improved manufacturing techniques allow OEMs to push the limits and develop parts that were traditionally unfeasible.



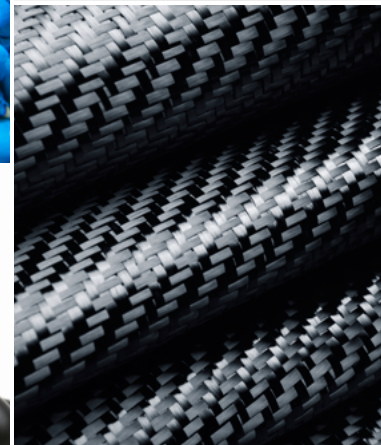
# Plastics and composites

Although different materials can be used to achieve lightweighting goals, this report focuses primarily on plastic and composite materials.

Plastics are already used in abundance within vehicles; they represent upwards of 50% of a typical vehicle's volume, but as little as 10% of the vehicle's weight.<sup>3</sup> While plastics are abundant, many opportunities still exist for lightweighting utilizing plastic and composite materials, due to the development of new materials and manufacturing processes.

There are more than 100 different types and grades of plastic used in the average vehicle. These are categorized by performance requirements: appearance, resistance, rigidity, weight, and cost. Three types make up some 66% of the total plastics used in a car: polypropylene (32%), polyurethane (17%), and PVC (16%).

[Click to view a table of common polymers utilized in vehicles](#)



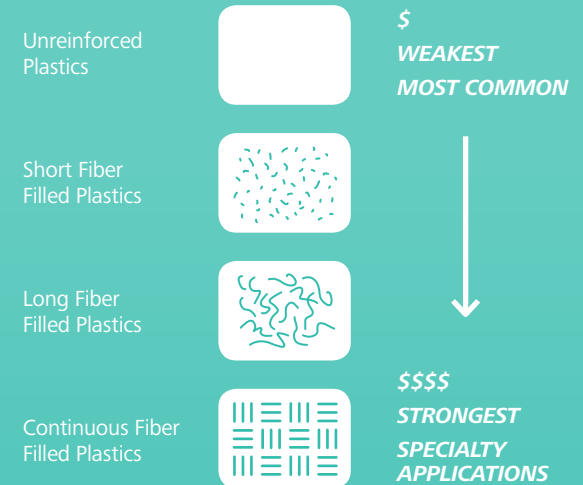


# Increasing strength and stiffness

Plastics can also be reinforced with fiber materials for added strength and stiffness. This is commonly referred to as fiber-reinforced polymer or fiber-reinforced plastic (FRP). Fiber reinforcement generally comes in three basic forms: short fiber reinforcement, long fiber reinforcement, and continuous fiber reinforcement.

Specifying the orientation of reinforcing fibers can increase the strength and resistance to deformation of the polymer. Reinforced polymers are strongest and most resistant to deforming forces when the polymer's fibers are parallel to the force being exerted, and are weakest when the fibers are perpendicular. Compared to conventional steel, glass FRP composite systems can reduce mass by 25–30%, while carbon composite systems can reduce mass by 60–70%.<sup>4</sup>

## Plastic reinforcement



### Short Fiber

Most of these fibers are smaller than the diameter of a human hair, so they tend to look more like powder. They are the easiest to use in the manufacturing process, but contribute the least amount of strength.

### Long Fiber

Typically referred to as "pellets," these fibers can be up to ½" (13mm) in length. They can inhibit flow and make it harder to fill a mold, but they offer better strengthening properties than short fibers.

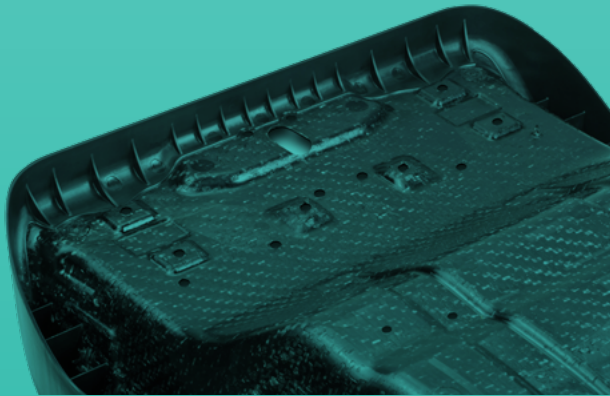
### Continuous Fiber

These fibers tend to be 0.063 inches to several feet wide and up to several thousand feet long. The fibers are unidirectional and run longitudinally (long direction). They can also be made into woven mats. This type of fiber is the most expensive, but contributes the most amount of strength.



# Overmolding

Continuous fiber reinforcement offers the greatest strength and stiffness properties, but doesn't lend itself to intricate shapes, ribs, bosses, bolt locations, etc. To address these shortcomings, fields like multi-material injection molding or overmolding technologies (where one material is molded into another one) are rapidly expanding. In addition, overmolding is an excellent method to produce lightweight, technical parts and can help reduce production and assembly costs. Wider application of overmolding plastics components are helping to meet the demands of the automotive industry and leading to many new, more modern design features.



**Figure 2:** As you can see, the intricate details of the part are constructed with plastic polymers and the areas which require extra strength and stiffness are reinforced with continuous fiber.

# Design advantages

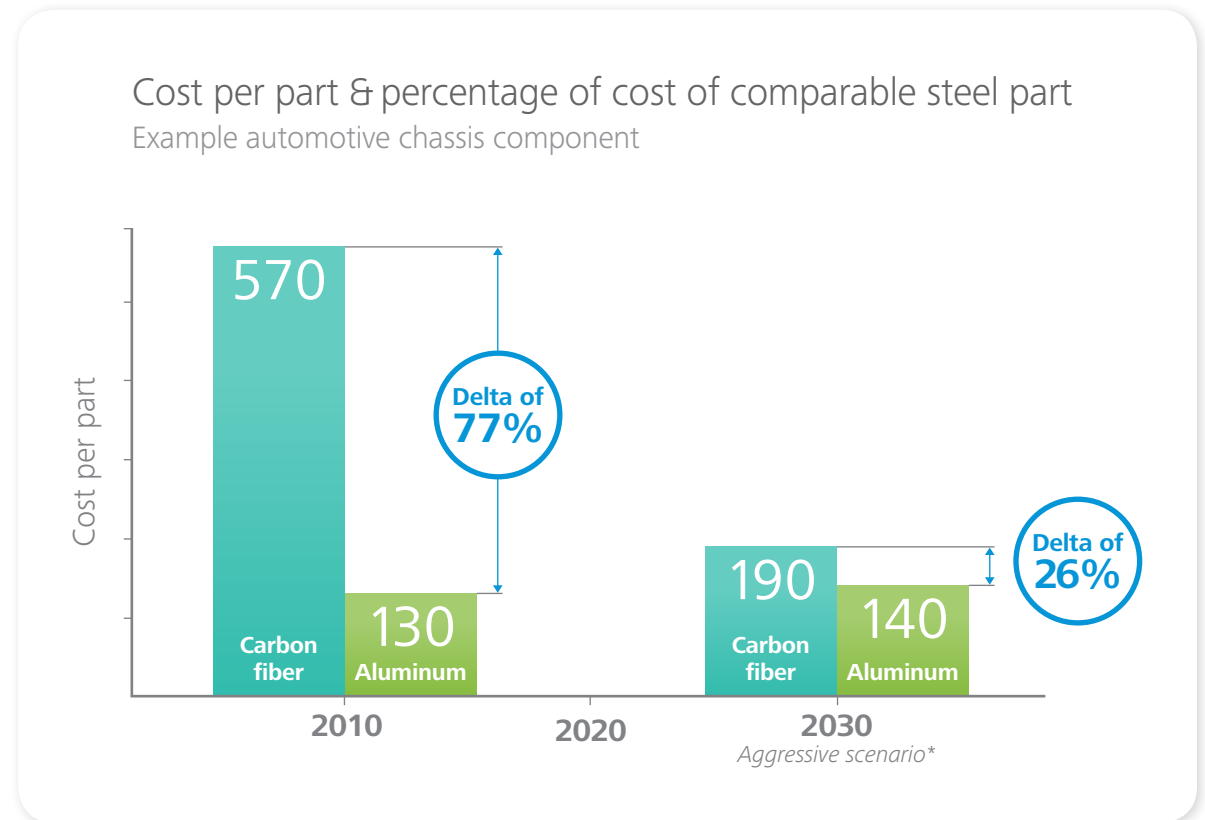
Utilizing plastic and composite materials for designs offers more advantages than just the weight reduction of parts. Plastics and composites can also be shaped and formed into very complex shapes and designs that would otherwise be impossible. In addition, opportunities exist to reduce the actual number of components in a design down to a single plastic part. Such components minimize part failure within assemblies, reduce tooling and assembly costs, provide watertight seals if required, and can increase sound absorption and safety properties.

A wide variety of plastic materials exist which exhibit a vast range of desirable properties. They can be made with different levels of transparency, flexibility (soft, flexible, or hard), and in almost any shape, size, or color. They can even be heat-, chemical-, and corrosion-resistant. They are excellent thermal and electrical insulators but can alternately be electrically and thermally conductive. It is this versatility that makes plastic materials extremely cost-effective in so many different applications.

Plastics can be formed using a variety of manufacturing processes such as injection molding, compression molding, microcellular injection molding, etc. This flexibility in the manufacturing process allows plastics to satisfy a wide range of requirements.

# The cost gap between aluminum and carbon fiber will shrink over time

As weight is reduced using plastics or carbon fiber, the total cost of production is generally higher. However, because there are only a finite number of ways for OEMs to reach CAFE standards by 2025, significant investments in new manufacturing methods are being pioneered to reduce costs.



**Figure 3:** Shrinking Delta – the cost gap between aluminum and carbon fiber is anticipated to shrink from 77% to 26%.

\*Assuming increase in energy cost for both carbon fiber and aluminum

Source: McKinsey





# *The Power of Simulation*

Traditionally, automotive designers have strong experience in designing metal parts, but they tend to lack experience in designing for advanced materials. Additionally, there is a new push to further lightweighting efforts into structural components. Simulation allows designers to fully explore different lightweighting opportunities and gain confidence in their designs before making costly tooling and manufacturing investments.

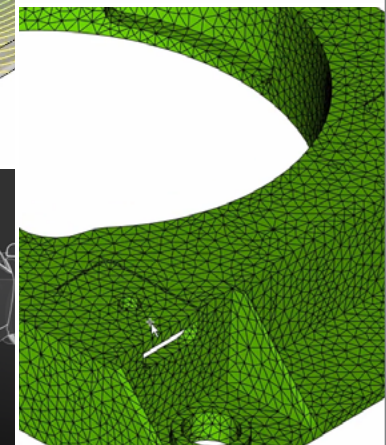
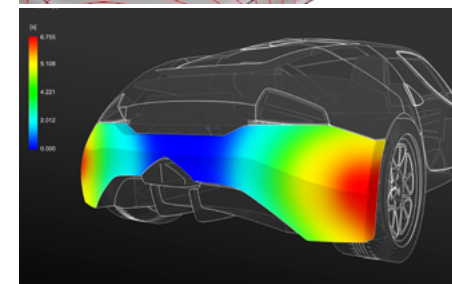
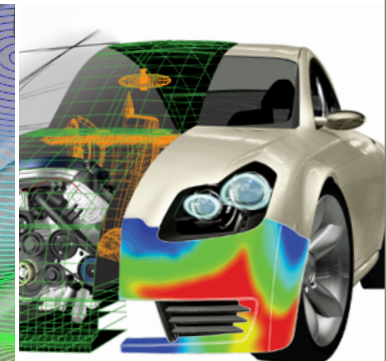
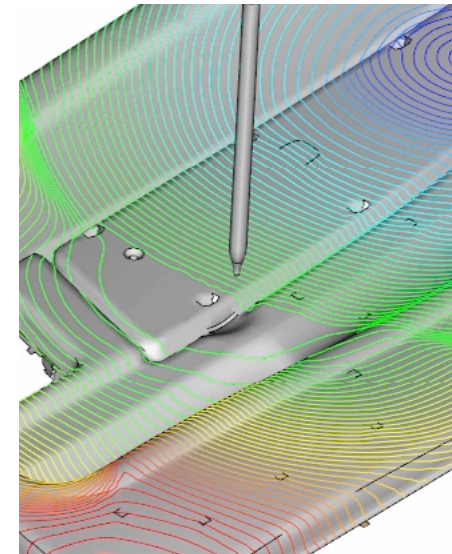
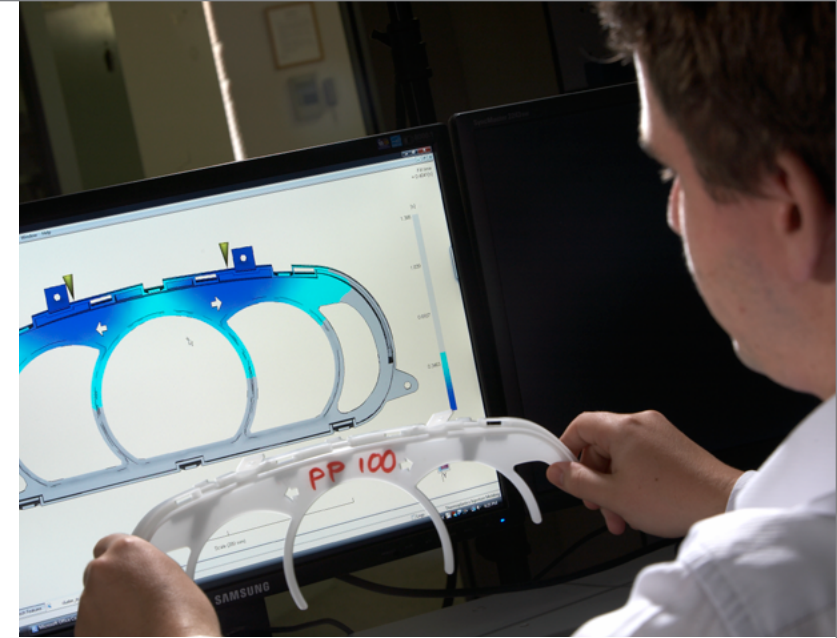
# Simulation: the key to successful manufacturing, testing, and use

In order to investigate different lightweighting opportunities within automotive designs, simulation software is essential. Physical prototyping and testing is very costly, time consuming, limiting, and generally not feasible due to the demands of the automotive industry.

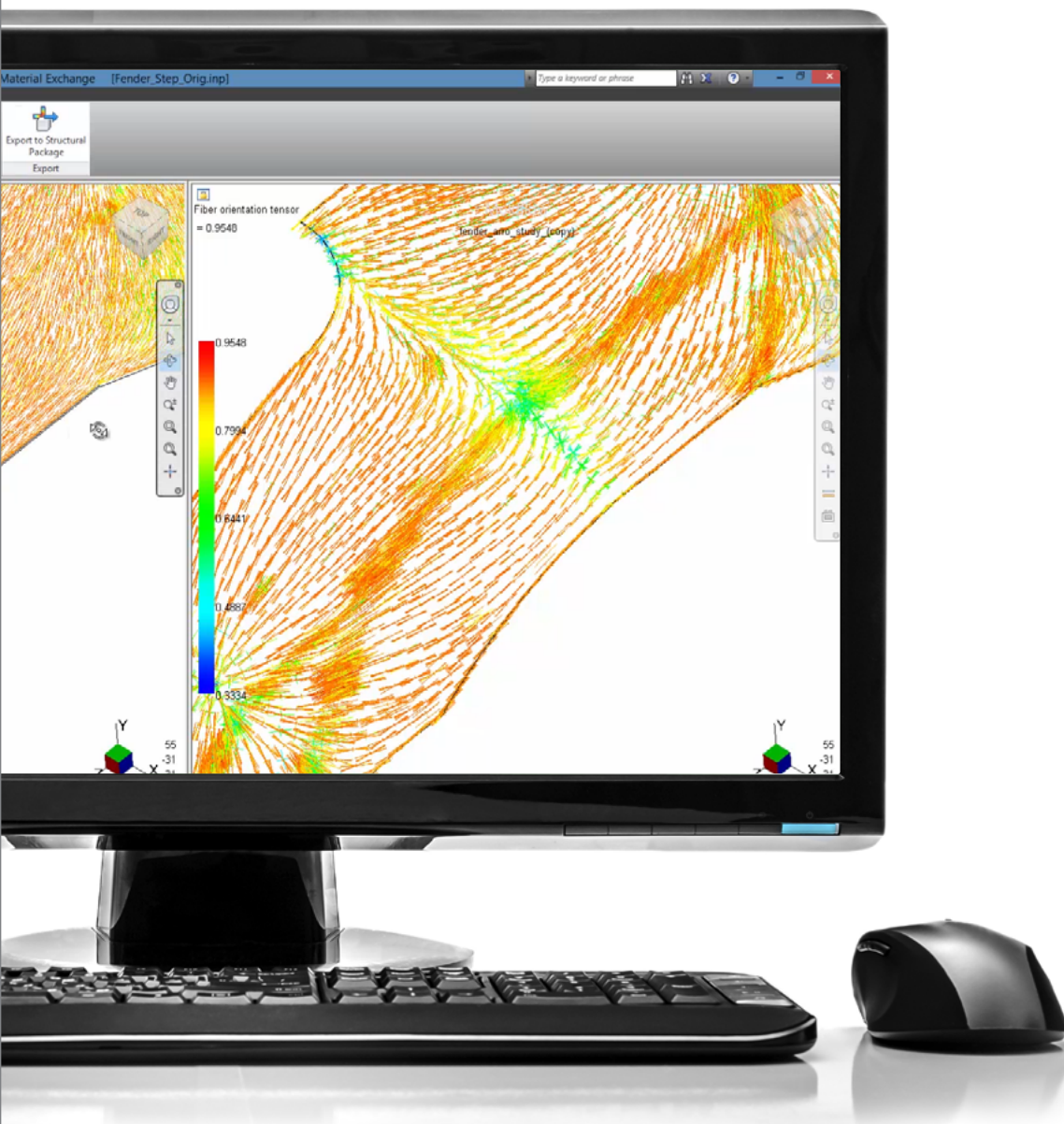
Proper simulation will help ensure the manufacturability of the part and optimize the manufacturing process, answering key questions during the design stage, such as:

- *How can cycle times be reduced?*
- *Will the mold fill?*
- *How will the part perform in practice, will it deform or crack under stress?*
- *Will the part meet safety requirements?*
- *Can the design be optimized for weight reduction?*
- *Are there other materials that are better suited for the application?*
- *Can the part be made stronger by manufacturing it differently?*
- *When the part fails, what is its mode of failure?*

Engine image courtesy of ADEPT Airotive (Pty) Ltd.







## Tools designed for advanced materials

In order to get accurate simulations of advanced materials (like composites), the simulation software application must understand the material properties driven by the manufacturing process. The designer must also be able to calculate the orientation of the fibers that result from the manufacturing process. Controlling the fiber orientations controls the strength of the part, so without accurate, as-manufactured material properties, the results from simulations will yield false information and provide little value to the engineer.

**Figure 4:** Calculating the fiber orientations of a reinforced plastic part ensures that the as-manufactured material properties are correct, resulting in accurate simulations.

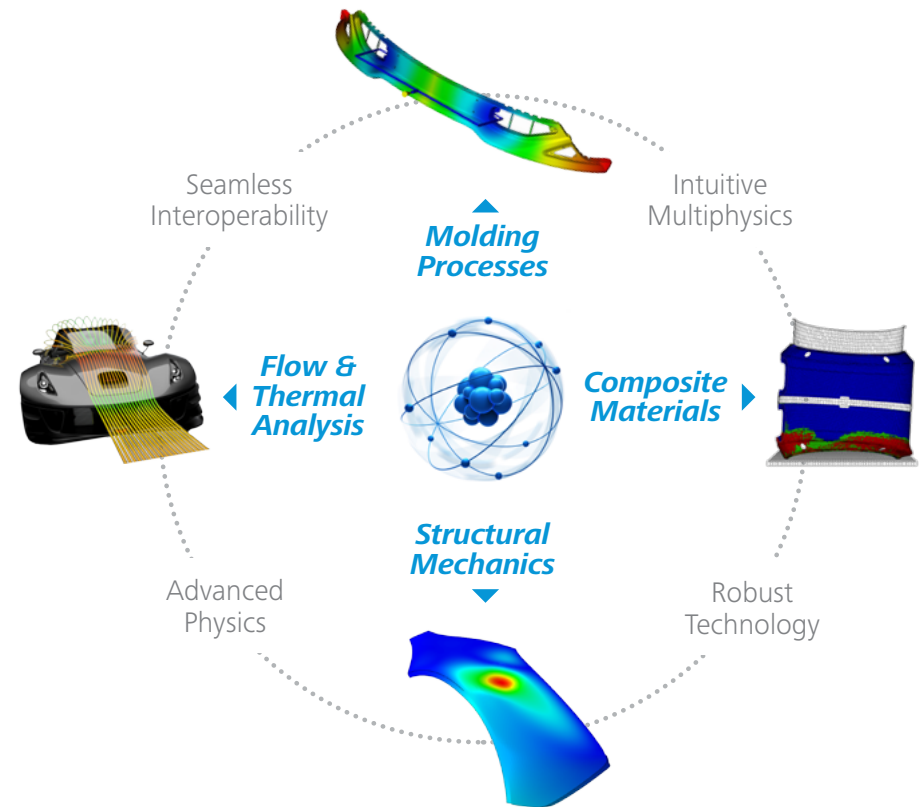


# Multiphysics/ multi-domain analysis for advanced materials

Working with advanced materials requires special simulation tools to make reliable predictions about the performance of a part. The construction of these materials causes them to behave very differently than traditional materials and requires specialized analysis tools.

For example, when loads are placed on continuous fiber composite materials, different failure modes can result, including matrix cracking, fiber breakage or crushing, and delamination. Capturing all of these failure modes *concurrently* within a simulation can be very important for correctly capturing the behavior of the laminate.

Accurately predicting how a part constructed from advanced materials will perform in practice can require analysis in more than one domain. For example, combining thermal, vibration, and composite analysis could be required to get accurate simulation results and predict a part's behavior in a particular scenario.



**Figure 5:** Connecting analyses from different domains is important to get simulation results that are accurate and reliable.

# Reducing the computational burden

Setting up multiple simulation studies using different materials and design iterations places heavy demands on your local computer resources. You may not even be able to utilize your computer during most simulation studies and the problem becomes exponentially larger as you increase the number of different materials and design iterations.

In order to reduce the computational burden on the local computer, you need flexible solving options to simulate where and how you want, based on your needs. Many professionals use their local resources to iterate and optimize their setup for an analysis. Then, when they are ready to kick off a longer, more computationally intensive simulation, they use the power of the cloud and free up local resources for other tasks.



**Figure 6:** Utilizing cloud-computing technologies reduces the computational burden on your local computer, allowing you to work more efficiently.



See how your local machine and the cloud work together to solve comprehensive simulations.



# *Autodesk Delivers*

Autodesk has been a market leader for more than 30 years. We offer the broadest and deepest portfolio of products in the design world and spend nearly a half-billion dollars annually on research and development. We collaborate with industry OEMs, academic researchers, government research laboratories, and application research centers so our comprehensive portfolio of simulation analysis products can support you with your lightweighting initiatives.



# Unlock lightweighting opportunities with Autodesk products

We offer powerful tools and capabilities to assist you with your lightweighting efforts. As outlined in this report, it is critical to have accurate, as-manufactured material properties to create accurate simulations. Our software tools and capabilities can assist you with creating accurate simulations you can trust for your lightweighting initiatives.

## Autodesk simulation solution strategy



### OPEN

Multi-CAD & Multi-CAE  
Customization & Scripting  
Heterogeneous Solutions



### INTEGRATED

Multiphysics  
Data & Process Management  
Results Visualization



### PURPOSE BUILT

Specific Tailored Solutions  
Broad Solution Coverage  
Upfront Analysis-Driven Design



### OPTIMIZING

Design of Experiments & Studies  
Parametric Optimization  
Lattice & Topological



### FLEXIBLE

Business Models & Licensing  
Asynchronous Productivity  
Elastic Cloud Computing



### ADVANCED

Advanced Materials  
As-Manufactured Properties  
Trusted & Validated Accuracy

# Simulation and analysis software

Our comprehensive portfolio of simulation analysis products easily and accurately integrates mechanical, structural, fluid flow, thermal, composites, and plastic injection molding into your design and engineering process. Validate, predict, and optimize your designs with the Autodesk Simulation portfolio.



## AUTODESK® MOLDFLOW®

Designers, engineers, and analysts use Moldflow® plastic injection molding simulation software to improve plastic part designs, injection mold designs, and manufacturing processes. **Find out more ›**



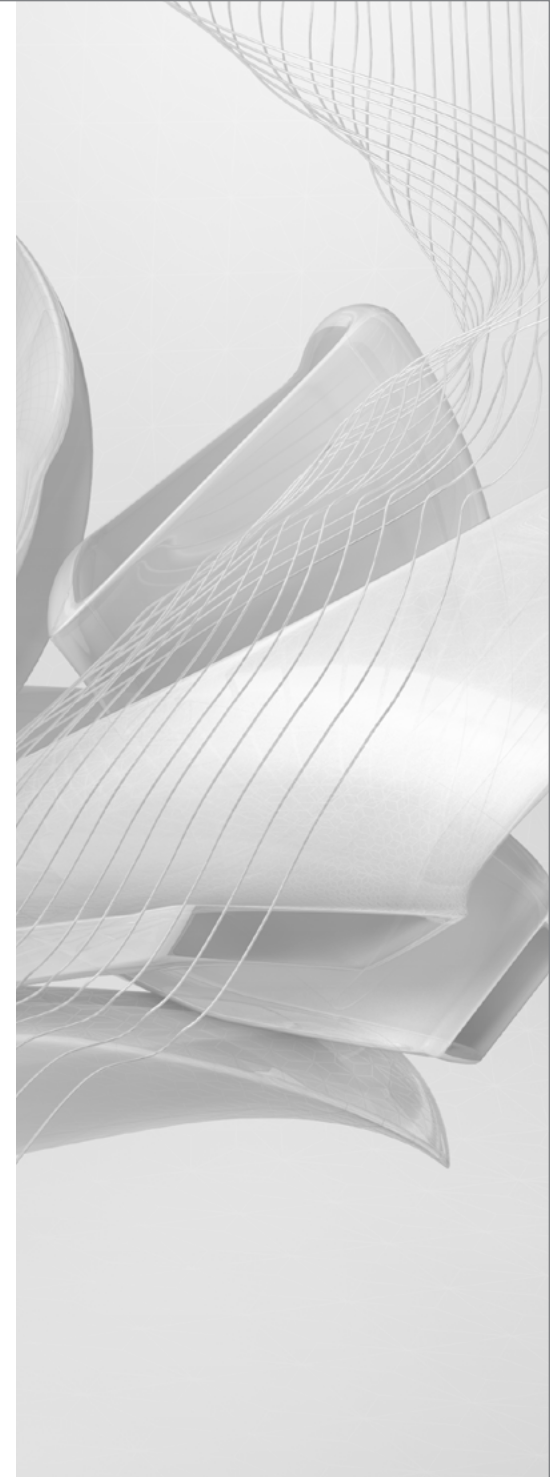
## AUTODESK® HELIUS COMPOSITE

Autodesk Helius Composite helps engineers size and build laminates for the conceptual design stage using a variety of intuitive and efficient simulation tools. **Find out more ›**



## AUTODESK® HELIUS PFA

Autodesk® Helius PFA software provides accurate and efficient nonlinear simulation of advanced materials to help reduce testing and shorten design cycles for plastic and composite structures. **Find out more ›**



# Additional capabilities

To highlight additional capabilities that are useful in supporting lightweighting initiatives, we've listed them here.

## Advanced Material Exchange

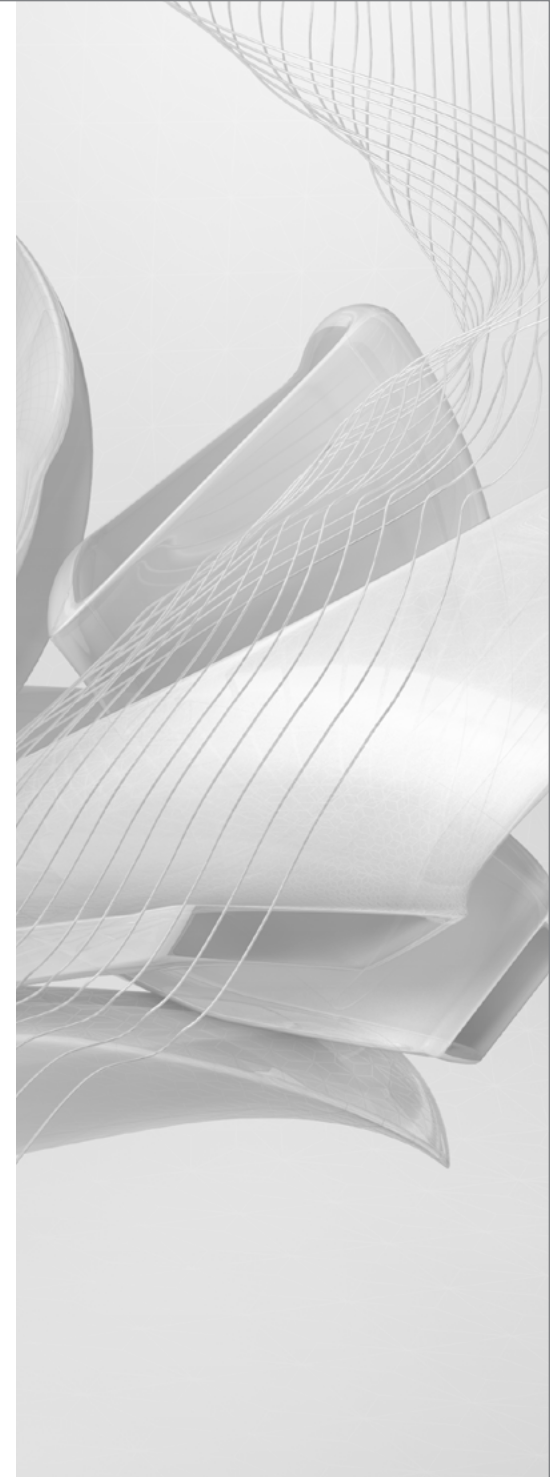
Advanced Material Exchange is used to map an Autodesk Moldflow analysis onto a structural finite element analysis mesh to accurately represent fiber orientations. **Find out more ›**

## Autodesk Moldflow Plastics Labs

Autodesk Moldflow Plastics Labs is a leader in material characterization for plastics processing. It has over 25 years of experience testing more than 8,000 grades of thermoplastic and thermosetting materials. **Find out more ›**

## Cloud Solving

Autodesk simulation products have a flexible, cloud solving option, which allows you to send multiple simulation studies to the cloud to be solved simultaneously. **Find out more ›**





# Get started and learn more

As automotive manufacturers race to meet consumer demand for more fuel-efficient vehicles and government CAFE standards, more and more OEMs are turning to lightweighting. Autodesk offers purpose-built simulation products and capabilities to support you with your lightweighting initiatives.

## Request a Business Process Assessment

Let our Autodesk team of experts help you identify tools and processes to achieve your lightweighting goals. We'll help you create specific plans to get more from the investment in the tools you already have, and recommend what gaps you need to fill to improve your design and manufacturing practices.

## Check out our Automotive Lightweighting Solution Center



# About Autodesk

Autodesk, Inc., is a leader in 3D design, engineering, and entertainment software. Customers across the manufacturing, architecture, building, construction, and media and entertainment industries—including the last 19 Academy Award winners for Best Visual Effects—use Autodesk software to design, visualize, and simulate their ideas before they’re ever built or created. From blockbuster visual effects and buildings that create their own energy to electric cars and the batteries that power them, the work of our 3D software customers is everywhere you look.

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<sup>1</sup> EPA light-duty automotive technology, carbon dioxide emissions, and fuel economy trends: 1975-2013.

<sup>2</sup> 2012, EPA report.

<sup>3</sup> Fisher, Michael PhD. “Enhancing Future Automotive Safety With Plastics.” Paper Number 17-0451.

<sup>4</sup> U.S. Drive (2013), [Materials Technical Team Roadmap](#), p.4. Accessed 4 February 2014.