

Megacasting and sustainability – driving new advantages for the automotive industry

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Abstract: Megacasting, a sustainable technique for the production of body-in-white and large structural components, is delivering huge advantages for automotive manufacturers. Could a sustainability focus deliver much more? What are the key strategies manufacturers can deploy and what benefits could it bring?

Keywords: Die casting; Megacasting; Sustainability; Giga-press

The evolution of die casting in the automotive industry

Die casting, the process of forcing molten metal under high pressure into a mold cavity to make repeatable parts, was first patented in 1849 for making movable type for the printing industry.

Die casting was first deployed in the automotive market in the 1920s (1), when mass production assembly lines adopted high-pressure casting as a means of creating high-strength repeatable quality parts. The automotive industry has been a driver for innovation in die casting ever since.

The latest evolution, megacasting, was initially driven by disruptive new car brands, looking to scale up production of mass-produced electric vehicles (EVs). Megacasting is now also being adopted by traditional internal combustion engine (ICE) vehicle producers.

Why megacasting?

Traditionally, in automotive panel production, individual component panels are steel stamped and then welded together using robots on an assembly line. Recent innovation from die-casting machine manufacturers like Bühler have created aluminum die-casting machines that can create larger pieces, to a higher quality, faster and more efficiently than ever before. This process of die casting larger pieces is known as ‘megacasting’.

With the range capability of new electric drive trains directly impacted by weight and a rising focus on sustainability, automotive producers have been searching for novel approaches to reduce the weight of vehicles, whilst improving manufacturing efficiency, sustainability

and cost. One area identified was ‘body-in-white’, or ‘underbody’. This is the stage of manufacturing in which a vehicle’s body frame is joined together.

What advantages does megacasting body-in-white deliver?

Megacasting presents the opportunity to replace up to 100 pieces of stamped individual steel parts in body-in-white assembly with a single aluminum casting (2). This enables the process to become simpler and faster because welding, gluing or riveting are no longer required. The joining precision of the overall structure is also higher, and quality assurance is easier to manage. Experts estimate that up to 300 robots per production line can be eliminated using this megacasting technique and that up to 30 percent less production space is required. The cost savings resulting from die-casting production are considerable, and investment costs are reduced.

Another area where advances in die-casting technology are relevant is in complex structural components such as shock towers and longitudinal beams. These too are traditionally made from steel. Replacing them with a single aluminum part can reduce weight and save time and money on complexity, logistics and assembly.

Defining the issues

Traditional automotive manufacturing and use have profound environmental impacts. From the extraction of raw materials to production, everyday use and on to vehicle disposal, every phase has implications for the environment.

Manufacturing processes have long consumed vast quantities of resources while producing a substantial amount of waste. Furthermore, the predominant use of ICE vehicles has led to significant greenhouse gas emissions, worsening global air quality and contributing to the ongoing climate crisis.

It is estimated that a car produces 10 percent of its CO₂ during production and five percent when it is disposed of; the remaining 85 percent is produced during the car's life (3).

Whilst the industry has made great strides in reducing its manufacturing impact over the last 15 years, it is estimated that on average, 5.6 tons of CO₂ are released during a petrol or diesel car's manufacture, and 8.8 tons are released when producing an electric vehicle (higher because of the emissions associated with battery production) (4). That equates to approximately 518 million tons of CO₂ emissions attributed to car production each year (5).

Working within a new regulatory framework

The pressure on companies to quantify and reduce their environmental footprint is increasing. First, new regulations have entered into force across the globe – the Corporate Sustainability Reporting Directive (CSRD) (6) and the recently adopted rules to mandate climate risk disclosures by the U.S. Securities and Exchange Commission (SEC) (7). As of September 2024, more than 7,000+ companies all over the globe have also voluntarily signed up to the Science Based Targets initiative (SBTi) and more than 5,000 have set up targets that align with a Net-Zero pathway (8).

The Corporate Sustainability Reporting Directive (CSRD)

The Corporate Sustainability Reporting Directive (CSRD) requires that, from 2025, European companies that meet two of three criteria – 500+ employees, at least EUR 20 million in total assets or more than EUR 40 million in turnover – “publish regular reports on the social and environmental risks they face, and on how their activities impact people and the environment” (9). In terms of climate issues, they will have to define their governance structure, climate metrics and targets, reduction strategy and quantified risk management.

Metrics and target reporting requires companies to:

- Calculate the Scope 1, 2 & 3 footprint according to the GHG Protocol.
- Set targets to reduce emissions.
- Build a climate transition plan to achieve

targets and track progress.

As more automotive OEMs and vehicle producers quantify and reduce their full GHG footprint, they will look for primary data and reduction measures from their supply chains and encourage suppliers to set science-based targets.

SEC climate risk disclosures

Shortly after being introduced, the new climate disclosure rules issued by the SEC have been temporarily put on hold, as of September 2024. This pause is due to ongoing legal action from certain states and business groups, with criticism about the rules being overly burdensome and exceeding the SEC's authority. The SEC, however, defends its position, believing they fall well within their remit to mandate information crucial for investor decisions.

The adopted rules intend to improve and standardize climate-related disclosures by public companies and in public offerings, responding to investor calls for more uniform, comparable, and dependable climate risk information. These disclosures are aimed at informing investors of the financial implications of climate-related risks on a company's business and the steps companies are taking to manage these risks, while also addressing concerns about the cost implications of compliance.

The Science Based Targets initiative

More companies are signing up to the Science Based Targets initiative (SBTi), which requires companies to quantify the GHG footprint and set targets that follow the 1.5°C or “well below 2°C” line (10).

In September 2024, over 341 manufacturers and OEMs from the global automotive industry had signed up to SBTi and 204 had approved targets, including major brands such as BMW Group, Ford Motor, General Motors and GKN Automotive (11).

What impact are regulation and compliance having?

Pressure for change is being driven by government regulation, such as the EU's ‘Fit for 55 package’ – a set of legislative proposals to reduce the EU's greenhouse gas emissions from the automotive industry by at least 55 percent by 2030 (12). This in turn raises awareness with consumers and other stakeholders such as investors, who bring pressure to bear around production emissions as well as product performance emissions and end-product waste and recycling.

In a recent survey, 52 percent of automotive companies stated they are navigating a rising tide of

product regulations, indicating a growing complexity and urgency in compliance and sustainability requirements (13).

How is the industry responding?

Sustainability in automotive manufacturing tends to be focused on end-user emissions, increasing the percentage of EV and hybrid vehicles produced and working towards zero-emission vehicles. Having said that, almost all major brands have a published sustainability plan that includes plans and targets to reduce manufacturing emissions, water consumption and waste. This puts pressure on all the manufacturing companies in the upstream part of the value chain.

Tesla, which solely produces zero-emission vehicles, is seen as trailblazer in environmental practices and manufacturing innovation. But other major brands have published plans to improve environmental performance in production, including BMW, Nissan, Volvo, Ford, General Motors, Audi, Hyundai, Mercedes Benz, and Toyota (14).

Quantifying sustainability for automotive production

Two main standards to quantify environmental impact are applicable for the automotive value chain: the Greenhouse Gas (GHG) Protocol and life cycle assessments (LCAs). See Figure 1 for the LCA of a die-cast part in the automotive market.



Figure 1: Life Cycle Assessment of a Die-Casted Part

The Greenhouse Gas Protocol (15)

A GHG assessment quantifies the CO₂e (CO₂ equivalent) impact of the entire business every year by splitting emissions into Scope 1, 2 or 3. This is both a regulatory and an SBTi requirement and can be certified to either the GHG Protocol or ISO 14064 (see Figure 2).

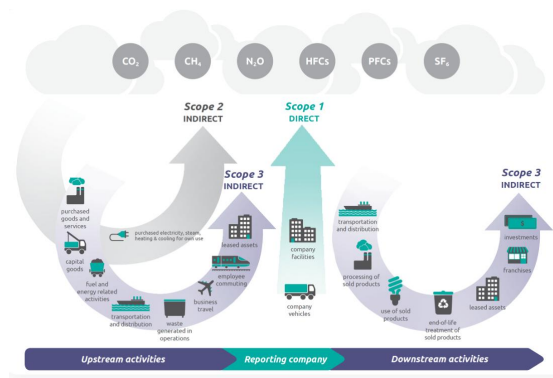


Figure 2: Scope 1, 2 and 3 emissions in the GHG Protocol

- **Scope 1** includes direct emissions by sources owned or controlled by an organization, e.g. emissions from combustion of fossil fuels in boilers and vehicles.
- **Scope 2** includes indirect emissions resulting from the generation of electricity, heat, or steam that an organization purchases. These are not controlled directly by the organization, but they can exercise control by choosing their electricity or heating plan.
- **Scope 3** includes all other indirect emissions from upstream or downstream activities, such as the production and transportation of purchased goods and services, employee commuting and waste disposal.

The Life Cycle Assessment (LCA)

The second method is the life cycle assessment (LCA), where assessments can be certified to ISO 14067 (16). An LCA measures the impact per unit of the final product, taking into consideration the impact across the entire value chain.

Using these methods to assess die casting

Defining functional units

For effective LCA in automotive production, establishing functional units is critical. These units are the benchmarks that allow for the comparison of inputs and outputs across the lifecycle.

For example, for manufacturing body-in-white components, they can be categorized across 'Raw material handling', 'Processing', 'Vehicle assembly' and 'Use phase and beyond processing'. The LCA can also take other metrics into account, such as electricity, water usage, land occupation and waste (see Figure 3).

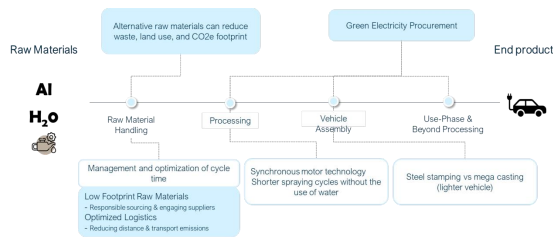


Figure 3: LCA categories for a body-in-white LCA

It's important to note that the composition of each vehicle is highly complex, with upwards of 5,000 parts and up to 40,000 processes. Vehicles have complex supply chains too, with an international/global structure covering anything from three to seven levels. Responsibility for Scope 3 emissions may be shared among many, and traceability and validation of supplier specific primary data can be hard to source.

Key determining factors such as EV or non-EV – affecting battery constituents – play hugely significant roles.

Using LCAs to understand steel stamping and aluminum die casting carbon hotspots

Using LCA's, it becomes possible to compare steel stamping and die casting, benchmarking the full manufacturing process for each. This is the first step in quantification; to map out which processes happen in which life cycles phases (see Figure 4).

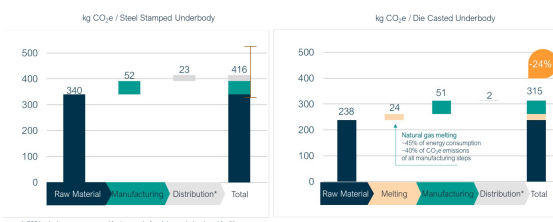


Figure 4: Example LCA for Steel Stamping and Die Casting an Underbody Part

Note: The error bar on the steel stamped graph represents the variability in the total value of a steel stamped underbody, which is highly dependent on various factors such as the specific material used, and the processing methods applied. We have established this error bar based on our calculations and corroborated it with findings from relevant research, indicating the minimum and maximum values observed.

Overall, a die-casted underbody can reduce emissions by up to 24 percent compared with steel stamping. This is achieved by optimizing the part design to achieve weight savings, in combination with the use of low-carbon aluminum alloys.

With both steel stamping and megacasting, raw materials make up 75 to 80 percent of emissions, which indicates the crucial role that low-carbon raw materials availability plays for both solutions. Distribution costs are lower in die casting than steel because the die-casting process is in a single location compared to numerous sites for steel stamping. Die casting can be located in the automotive plant, negating the transport emissions that occur with steel panel distribution.

Five key strategies for targeting sustainability in die-casting

Having seen the potential megacasting can deliver, there is an opportunity for auto manufacturers to use a sustainability lens to find more ways to reduce CO₂ emissions and improve efficiencies across the process.

To effect long-lasting changes, it is critical that producers take a strategic approach. These five steps present a logical path to reduced emissions in die casting.

1. Quantifying emissions

Implementing GHG protocol for accurate emissions measurement will undoubtedly form part of any automotive manufacturer's regulatory compliance, but it is also the essential starting point for improvement.

Alongside the GHG protocol, conducting a LCA will aid in identifying emission hotspots throughout Scope 1, 2 and 3, and relate the emissions to the end-product.

The process to measure, understand, report, reduce

In the collaborative process, Bühler experts collect comprehensive measurements and review key functional parameters such as vacuum settings and spraying, as well as performance and downtime data.

Working together with customer technicians, the team then works towards increasing OEE. It is important to note that it is usually the sum of many small things that contribute to ensuring a stable casting process, which in turn has a positive effect on part quality, leads to fewer rejects and has an overall positive impact on energy consumption during casting.

In collaboration with die-casting experts, the final step is to link energy usage sustainability monitoring with specialist Environmental Impact Services to continuously breakdown the manufacturing carbon footprint and to reduce costs and emissions together.

In one such exercise with an OEM that die-casts insulating plates, 156,000 kWh/year saving potential was identified, reducing CO₂e emissions by 89 tons/year and saving up to US\$32,760/year per plant (17).

2. Reducing Scope 1 & 2 emissions

Improving energy efficiency in Scope 1

Scope 1 includes all direct emissions from fuels (natural gas, refrigerants etc.). Where processes have thermal energy, electrification can reduce Scope 1 emissions.

Any emissions associated with production facilities are also relevant here. From electrifying site vehicles to more efficient use of heat and light, all of these considerations can help to reduce the overall CO₂ impact of every vehicle created. Newer plants are being designed to maximize natural light, significantly reducing the reliance on artificial lighting.

Optimizing Scope 2 emissions:

There are various technological innovations within the die-casting process designed to reduce energy usage and therefore bring down CO₂ emissions.

For example, Bühler's ServoDrive, a synchronous motor controlled at a variable frequency can significantly reduce cycle times, delivering a 40 percent energy reduction in casting, whilst reducing CO₂e emissions.

Similarly, Microspray technology, prevents thermal shocks to the die which reduces water consumption, also reduces cycle times and can result in a reduction of energy consumption of up to 64 percent in the spraying step, and up to 33 percent in thermal control, providing excellent overall sustainability improvements. Therefore, Microspray technology increases significantly the lifetime of the die.

Implementing Total Care and Digital Services

Total Care Services including digital services to identify untapped resources, analyze issues and create fundamental improvement plans can help to bring better outcomes in the long run. Simply optimizing plant performance throughout existing manufacturing processes can significantly reduce energy consumption, increase yield, and extend the lifespan of the existing assets.

This can be through digitalization of the process enabling downtime analysis and performance reports, as well as process optimization service, such as maintenance, and retrofits.

Switching to a dependable renewable energy supply

Switching to renewable energy in the manufacturing phase can reduce CO₂ emissions for a die-casting part by up to 22 percent, according to a Bühler value chain study (see Figure 5).

This can include energy from solar panels, wind

turbines, and other renewable infrastructure within facilities. Plus of course, a global electricity mix of hydro, wind, solar and geothermal.

3. Reducing Scope 3 emissions

The raw materials in die-casting that make up Scope 3 emissions are a hugely significant part of the process accounting for as much as 75 percent of all emissions (see Figure 5). The raw materials are primarily aluminum, with a small percentage of lubricants, nitrogen and water. Targeting improvements in this part of the die-casting production process can deliver significant improvements.

Sourcing sustainably produced alloy

Sustainability extends beyond environmental impact, entailing a delicate balance among the three pillars of sustainability: economy, environment (climate and biodiversity), and humanity (social aspects). As the aluminum alloy is the largest contributor to the raw materials emissions, sourcing sustainably can play a crucial role in reducing die-casting emissions while supporting a healthy balance between the pillars.

For instance, raw materials can be sourced from suppliers who adhere to strict environmental regulations and sustainable mining practices. These practices ensure minimal disruption to ecosystems and reduce the carbon footprint associated with raw material extraction.

In the example of the life cycle assessment shown in Figure 5, incorporating sustainably procured aluminum, such as Hydro REDUXA, can decrease CO₂e emissions by as much as 52 percent.

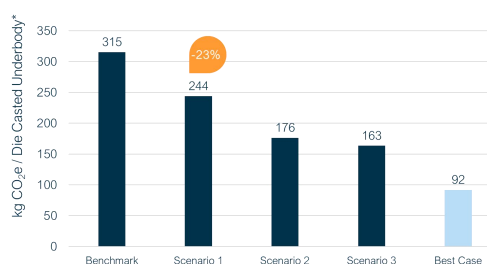


Figure 5: Best Case Die-Casting Sustainability Scenarios

Recycling secondary alloys

Aluminum die castings can be almost CO₂-neutral if low-CO₂ aluminum alloys are used for production and green electricity powers induction melting furnaces. Cells are also constructed to catch aluminum overflow and re-use it directly, avoiding transport emissions and recycling costs.

Additionally, using recycled secondary aluminum alloy significantly reduces environmental impacts

compared to virgin aluminum alloy. Recycled aluminum requires approximately 90 percent less energy to produce, resulting in a substantial decrease in CO₂ emissions.

Water consumption and waste generation are also markedly lower, as recycling processes use less water and produce fewer by-products.

By incorporating recycled secondary aluminum alloys, the automotive industry can achieve remarkable sustainability gains, while maintaining high-quality production standards.

Applied one-by one, the steps discussed above and shown in Figure 6, can deliver a step change in sustainability improvements. Further reductions using sustainably sourced alloys and recycled alloys could result in a best-case scenario for each underbody part producing just 92 kg CO₂e per underbody part – a 70 percent improvement.

Minimizing material waste in die casting

Material waste is a key component in automotive manufacturing. Raw materials are scarce, so efficient use is critical for sustainability. Storage, transportation, and eventual disposal of waste can also have cost implications for overall production.

The majority of waste in the die-casting process comes from production and handling of the raw materials (both hazardous and non-hazardous). According to the environmental product declaration from Alcoa, a leading aluminum smelter, the disposal of hazardous waste (HWD) and non-hazardous waste (NHWD) adds up to 2.02 tons of waste per ton of product (18).

The melting and alloy treatment process steps (described in Figure 7 above) also results in waste but die-casting cells are now extremely efficient. Continuous on-site remelting recirculates the waste back into the alloy and eliminating scrap back to the producer of the aluminium to 100%.

Logistics optimization

With up to 5,000 parts in each vehicle, often created within a complex global supply chain, reducing transportation sourcing from companies with strong sustainability credentials and reducing transportation between suppliers and to the automotive facility can play a part in reducing overall emissions.

End-to-end traceability introduced as part of any optimization process can also help to streamline logistics further.

4. LCA as a tool for improvement

The Life Cycle Analysis used to benchmark each model's

emissions profile should extend across the whole vehicle lifecycle, including indirect Scope 3 emissions.

It is the manufacturer's responsibility to critically assess design and build criteria that can reduce emissions in each vehicle's use and make recycling and recovery at the end of life easier and more effective.

The LCA should enable producers to set targets at every stage of the product's lifecycle, working throughout the value chain to constantly reduce impact on the planet at every stage.

The OICA, the voice for automation issues in world forum, whilst expressing caution about the ability to set a single standard for LCA approach in the industry, cites numerous successful examples of LCA's from leading brands, including Mercedes Benz, Renault, Toyota, Scania, Volvo and many more. (19)

5. Innovation in die casting

Innovation in the process or how we make vehicles and in the technology that supports that process consistently targets greater efficiency.

The die-casting industry is constantly evolving, using advanced technology to improve performance and reduce emissions, energy consumption, water usage and waste. Alongside digitalization and integrated cell management, one emerging technology is the use of advanced alloys.

Advanced alloys – a catalyst for sustainability

New alloys are constantly emerging that could deliver comparable or superior mechanical properties to alloys currently in use with reduced heat treatment requirement, or indeed, no heat treatment at all.

In 2018, the first prize at Euroguss for the optimized design of a casting, went to an automotive part which incorporated a weight reduction of 19 percent compared to the functionally identical part of the previous model. This was achieved with a high strength, highly flowable alloy in combination with a strength-optimized T6 heat treatment. The thin-walled design also saves a significant amount of material, thus contributing to a more sustainable value chain (20).

The benefits of sustainability

A drive for sustainability naturally brings benefits for our impact on the planet and our communities. But it can also deliver numerous commercial benefits too.

Cost reduction and affordability

In the emerging days of sustainability, there was perhaps a C-level opinion that efforts to comply with green

legislation and consumer demand was simply a costly exercise. These days, most C-level executives now realize that sustainability initiatives designed to use less energy, water and natural resources, reduce waste and improve recycling potential are synonymous with cost-saving too.

When it comes to die casting in the automotive sector, this is undeniably true.

In the best-case scenario using renewable energy and carefully chosen alloys (see Figure 5), the process produces 70 percent less emissions whilst using 83 percent less water, 35 percent less energy, and generating 39 percent less waste. All those improvements will cut costs in production and waste handling.

Sustainability as a competitive advantage

The report “Busting automotive sustainability myths” (21) looks at the key challenges for car manufacturers in relation to the rise of sustainable and digitized mobility. It found that 97 percent of sustainability-minded drivers would change brands for a more-sustainable vehicle. The report notes that automakers that fail to compete for the hearts and minds of sustainability-minded drivers will lose customers to competitors that have shown a stronger focus on and commitment to sustainability.

Innovation

Sustainability initiatives can also bring the stimulation of new ideas and processes to automotive production.

Bühler has been focused on the benefits of integrating more functionality through die-casting since the 1990s. The natural evolution of this process has resulted in the headline-grabbing changes to body-in-white megacasting now being adopted by numerous automotive manufacturers and OEMs.

But it’s worth remembering that a sustainability drive offers an opportunity to make incremental improvements throughout any plant, and for any vehicle.

Figure 6 shows how innovations throughout the die-casting process could reduce CO₂ emissions by as much as 95 percent, whilst saving significant costs on the energy required.

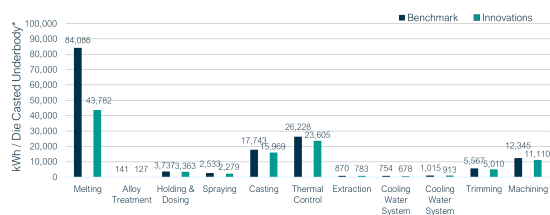


Figure 6: Applying Best Case Across the Die Casting Cell

Conclusion

The race is on to 2030. Many governments and companies have made bold commitments to quantify and reduce carbon emissions, aiming to avoid an increase in global warming of 1.5°C. With a growing die casting industry, there is an important role for manufacturers to play in the fight against climate change.

Regulatory requirements, e.g., the CSRD and the SEC, demand that companies have stronger oversight and communications in four key focus areas: governance, strategy, risk management, and metrics and targets. Metrics and targets require a robust quantification and pragmatic reduction plan, identifying the initiatives with the fastest ROI first.

Megacasting of body-in-white and large structural components is just one example of the many advantages a drive for sustainability can deliver for automotive manufacturers.

LCA assessments are a powerful tool in identifying and quantifying carbon hotspots and can focus reduction efforts and capture the value of sustainability by supporting downstream manufacturers. This will enable companies to create a competitive advantage and build a favorable business case for sustainable products. When sustainability is profitable, it will create impact at scale.

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