



1st approach to reduce carbon footprint impact of lighting parts

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1. Abstract

To reduce the carbon footprint of lighting parts, engineers need to have a holistic approach of the system. Focusing on efficiency of system is important as it will be visible in the usage phase of the vehicle, but automotive lighting industry must also think about remanufacturing, repairing and recycling of these parts. A component reused or not produced is a component that will have a lower carbon footprint. Another solution is to design part with less raw materials. MuCell® technology is one of them. Study done in Renault group with this process will be presented: framing of application, advantages and drawbacks. Finally, to further reduce energy consumption in the usage phase, without safety compromise, some change in regulation should be explored.

Keywords: Sustainability, efficiency, carbon footprint

2. Introduction

After COP21 in Paris, Renault Group has adapted its strategy to reduce greenhouse gas emissions from its activities and contribute to limiting global warming significantly below 2°C and beyond, to continue its efforts to limit the rise in temperatures to 1,5°C. For 2050, the ambition of the Renault Group is to move towards net zero carbon emissions in the world and over the entire life cycle (and from 2040 in Europe).

Each of the group's four brands holds a promise around eco-design, in line with its brand territory: for DACIA, a frugal approach, for ALPINE, aim of lightness, for RENAULT, leading the race in low carbon materials and for MOBILIZE, employment of recycled materials.



In 2024, the Renault Group set new decarbonization objectives in absolute terms for 2030 compared to 2019: reduce scopes 1 & 2 emissions by at least 62.5% and scope 3 upstream (value chain) and downstream (use of vehicles) emissions by at least 27.5%. And the Renault Group continues its work plan to reduce emissions from each vehicle by setting targets for new projects commercialized by 2030, in comparison with the vehicles they will replace. These objectives are respectively declined for the reduction of emissions from the use phase, the production of components (materials, batteries and logistics) and for the emissions of factories.

Between 2010 and 2023, Renault Group has already reduced its carbon footprint per vehicle by -28%.

In 2024, Renault Group activities have generated 108 MteqCO₂. 78% are the usage of the vehicles sold including production of electricity and fuel required to use the vehicles. In 2nd position, equipment and services bought by the group represents 15% of the total.

Automotive lighting parts need to be part of the improvement to reach the target. Main levers will be presented to show potential progress that could be addressed.

3. Levers to reduce carbon footprint for lighting parts

Efficiency of lighting parts [1] is a key element when usage of vehicles is considered.

$$\eta_{system} = \eta_{electrical} \times \eta_{photoconversion} \times \eta_{optical}$$
$$\eta_{system} = \frac{\text{Flux of useful light on the road (lm)}}{\text{Electrical power at lighting part entry(W)}}$$

Below this simple formula, improvement of efficiency is shared between different stakeholders.

Electrical efficiency is priority of electronic suppliers of components to provide solutions to transform electrical energy of the vehicle in an energy usable for LEDs. Thus, we are talking about LED drivers' efficiency. Job has been done with very good results. Improvement of few percent more will not change directly the usage phase of lighting functions, but it will have consequences on thermal design and mass of thermal dissipators. The local reduction of mass has an impact at the car level with a reduction of chassis stiffness, braking system, engine power and so on. At the end, there is a direct consequence on vehicle's power consumption and carbon footprint.

Photoconversion efficiency is the job of light source suppliers. A big improvement has been done by replacing filament bulb or halogen bulb by LED. When H7 bulb was able to produce 1500lm for 58W, an efficacy of 26lm/W, LEDs are now able to reach 140lm/W. Luminous efficacy has been multiplied by 5, thanks to LED adoption.

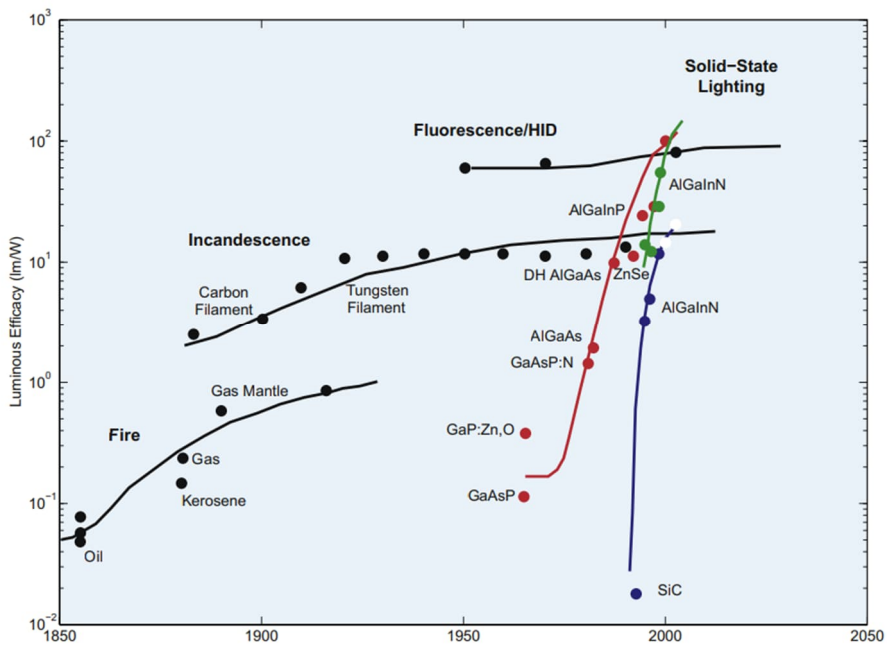


Figure 1: Trends in luminous efficacy for various lighting technologies [2]

Optical efficiency is clearly the weak point of the global system where all Tier-1s need to work especially with lighting styling trend to have very thin lighting modules.

But this global efficiency of lighting parts is just one aspect of the carbon footprint reduction. As the production of lighting parts has an impact [3], one of the best solutions will be to avoid producing components. That opens the need to offer higher possibilities of repair, remanufacturing and recycling of lighting parts.

Some initiative has been taken by Stellantis and Valeo and officialized in media in April 2025 with a specific line of **remanufacturing** LED headlamps for Peugeot 3008 and 5008. For reparation, a new way of designing lighting parts is required. A presentation of Volvo Trucks [4] has explained that LED lifetime is not sufficient compared to truck lifetime. Thus, designing a full LED headlamp without possibility of **repair** or of LED light source module replacement was not an option. Another example is the Renault 4 E-Tech with the cost-to-cost headlamps [5]. This part has been designed with the possibility of removing the 2 headlamps from the banner for a possible exchange.



Figure 2: Renault 4 E-Tech Electric cost-to-cost headlamps with replaceable headlamps

The cost of repairation is roughly divided by 3 as one or two of the components can be reused and reassembled on a new one for example. If the design was realized with a monobloc housing, RCAR rating and insurance for customer will be very high, and scratches' repair on outer lens would be too expensive for a B-segment vehicle.

These examples are for the moment local initiatives with specific motivation not directly link to sustainability and carbon footprint reduction. To go to a larger scale, regulatory pressure can give a momentum in good direction Today, designing for repairation or remanufacturing requires specific logistics loop, specific investments in dealer shops and remanufacturing plants. At the end, these repaired or remanufactured parts will be sold at a cheaper price than fully new ones produced on optimized lines of production. For the moment, only the extra-cost is visible.

The last axis is the **recycling**. To address the circular economy, at one hand, there is a need of recycled materials with good quality, affordable price and a reliable availability of raw materials. At the other hand, there is a need to collect and recycle efficiently parts to offer recycled materials. For an efficient circular economy, lighting parts must be designed by taking in account some basic rules: ease of dismantling, limitation of materials diversity and avoidance of non-recycle components like FR4 PCB. Some Tier-N manufacturers are proposing biodegradable and fully recyclable PCB [6]. This type of solutions must be evaluated and if cost is equivalent a large adoption will be possible for automotive industry.

Another approach is to limit the consumption of raw materials. This could be worked by carmakers by limiting size of lighting parts and choosing the lightest weight and efficient solution. But as lighting parts are a major vector of brand or vehicle image, this is not easy to apply.

4. MuCell® technology for housing materials

One solution validated in Renault Group is MuCell® injection process. A presentation of Headlamp's housing in PP-TD was done in Munich [7]. MuCell® injection process consists of incorporating a gas at a Super Critical Fluid state into a melted plastic raw material. The conclusion of this study was a mass saving of 28% compared to original component thanks to foaming effect of the plastic for 7% and lower viscosity which allows to design the part with a thinner thickness for 21%. This technology was also showcased by Hella Forvia, partner of our research, during CES 2024 with a sustainable headlamp using this MuCell® technology.

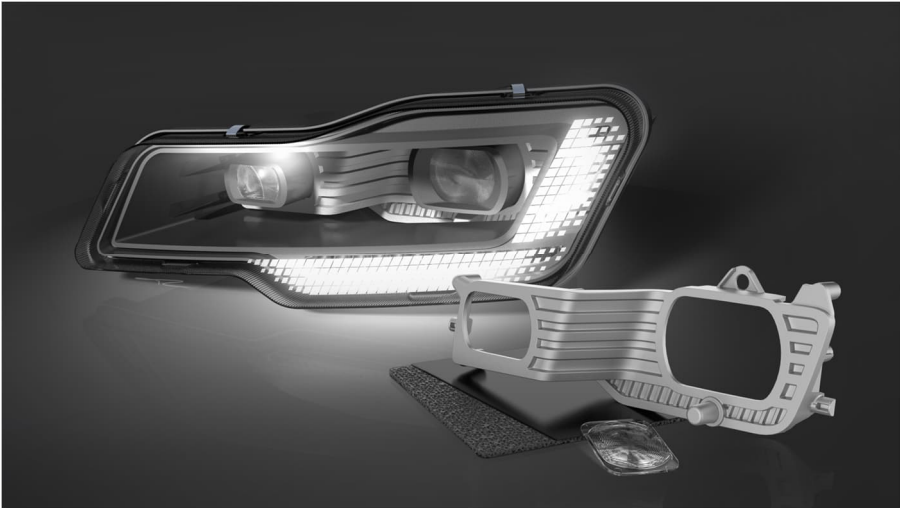


Figure 3: “Sustainable headlamp” concept of Hella-Forvia

Renault Group has continued to work on this injection process for rear lamps which uses other materials (ABS or ABS-PC grades). Welding interface was a point of attention to avoid any watertightness failure. Result of the study was a similar 27 to 30% mass savings achieved with a prototype based on the redesign of Renault Captur's fender rear lamp housing.

A last study has been conducted to evaluate recycled grades of PP-TD and ABS-PC for housing of headlamps and rear lamps. Results are also positive. The target to reduce mass of raw material and use recycled materials is achieved for the best carbon footprint reduction.

The limitation of this technology is the investment of two special equipment to allow the micro-cellular foam molding:

- The **SCF Metering system** with **SCF injector** that pressurizes, controls and injects the gases in a Super Critical Fluid (SCF) state.
- The **Mixing zone** that generates a single-phase solution of polymers and gas.

The main drawback is that the injected component is designed for MuCell® with specific thickness and cannot be injected with standard injection process. For the first application, the supplier must manage the risk with an additional standard injection process tool or with the support of experts in the design of the part and the tool.

MuCell® process has many advantages. The injection machine with its specific equipment can also be used for standard injection process. Due to lower viscosity, injection time can be reduced. During our test, injection time was drastically decreased with a time saving of 20%. Clamping force can be reduced. This opens the possibility to realize mold in aluminum with lower cost and reduced milling time compared to steel injection mold. Last point is the warpage and shrinkage. Quality of injected parts is better with less deformation. At the end, there is a real economic impact with less raw material and shorter injection time that must compensate the extra cost link to the investment of additional equipment. For sustainability point of view, less plastic will lead to lower carbon footprint, shorter injection time and lower clamping force will reduce energy consumption.

A housing component for a lighting part in PP-TD is ongoing for a serial application at that moment. The vehicle will be revealed in the next months and some achievement will be presented in detail during the Symposium ISAL2025.

5. A regulation change to minimize power consumption

During the last years, all regulatory changes have led to higher power consumption for more safety benefits. Among different items, main topics are:

- Mandatory Daytime Running Lamps in 2011
- Mandatory automatic switching of low beam according to ambient light level in 2016

The introduction of automatic high beam activation and adaptive driving beam gives a real safety advantage, but this is also a factor of increase of the power consumption.

As sustainability is becoming an important topic in the society and for the whole automotive industry, international lighting experts begin to push new ideas. The objective is not to add light everywhere but to have the right light at the right moment. Studies pushed by GTB have shown interesting potential improvements of the regulation with no compromise on safety and visibility at night but with a potential energy saving by changing the ambient light threshold of activation between Low Beam and DRL [8]. In the meantime, experts are also thinking of introducing a City Eco mode in the Adaptive Front Lighting System regulation frame that could be activated at very low speed in lit environments. To follow this movement, DRL function must be also reworked with variable intensity to adapt its minimum intensity to dusk or dawn conditions. A large proportion of the traffic in Europe is realized at dusk time with the commuters leaving their work and returning home.

Further improvements can be also done even if they have a more limited impact. Stop lamps or Turn Indicator lamps could be redesigned with possibilities to decrease intensity according to traffic density and ambient light conditions.

7. Conclusion & outlooks

We are at the beginning of a new way of thinking the lighting system. It is no more just a styling and safety topics. Carbon footprint reduction needs to have a holistic approach with consequences on regulation, technologies improvement, dedicated investment and new way of designing. Reaching a net zero carbon emissions will require to make difficult choices. Many levers are already on the table and must be activated to decrease our emissions. In the meantime, Stylists will continue to push engineers to realize unique and sometimes complex lighting parts. All the companies of automotive industries must focus on smart innovations with moderate cost to achieve great styles, with the best efficiency between emitted light and electric power consumption and a neutral carbon footprint to produce these parts. This will be the challenge to tackle in the future.

8. References

- [1] Valère Calais, François Bedu, “Sustainability, a new direction of optimization for future automotive lighting”, ISAL2023 proceedings (p198-213), 2023
- [2] Data from Tsao, Jeff T. Solid State Lighting, IEEE Circuits and Devices Magazine, May/June, pages 28-37, 2024
- [3] Betty Bou Abboud, Linda Granstrom Alpmann, Paul-Henri Matha; “Life Cycle Assessment (LCA) of Headlamp & Rear lamp”, ISAL2021 – proceedings (p198-213), 2021
- [4] Sara Engal, “Trucks shedding light on sustainable headlamps”, DVN Workshop Munich, 2025
- [5] François Bedu, “Front lighting of Renault R4 E-Tech electric, a piece of Art”, SIA VISION 2024, 2024
- [6] Recyclable and biodegradable PCB substrate, <https://www.jivamaterials.com/>
- [7] François Bedu, “Lightweight Design, Benefits of MuCell® technology for Headlamp housing”, DVN Workshop Munich, 2025
- [8] Dr. Rainer Neumann, Dr. Anil Erkan, “Energy Saving – Opportunities in Automotive Lighting”, ISAL2023 – Proceedings (p588-591)