GLASS FOR · EUROPE

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Advanced glazing systems to curb air-conditioning energy consumption

Through increased fuel consumption or decreased range (in electric vehicles), mobile air-conditioning is a significant energy consumer in vehicles. This energy load can generate considerable CO_2 emissions, depending on the vehicle's energy source.

Automotive glass manufacturers look for all possible means to contribute to minimising the environmental footprint of cars through their products and would like to draw attention to the positive contribution of automotive glass products. High-performance glazing technologies can contribute to reducing the need to use air-conditioning and subsequently save energy and decrease the CO_2 emissions generated by mobile air-conditioning systems.

Key facts and figures

- ✓ Advanced glazing systems can help reduce vehicles' air-conditioning energy loads for heating and cooling.
- ✓ **For Internal Combustion Engine Vehicles**, advanced glazing systems can help reduce the CO_2 emissions generated by mobile air-conditioning's energy load by 8.5%. This means cutting the emissions of an average light-duty vehicle by 1.2 gCO_2/km.

  The impacts of air-conditioning on Internal Combustion Engine Vehicles (CO_2 emissions) are not yet accounted for in official fuel consumption data and in the WLTP driving cycle. This should be corrected rapidly.
- ✓ **For Battery Electric Vehicles**, reducing energy needs with advanced glazing systems could increase a vehicle's range by 3% to 9%, depending on the models.

  The impact on energy consumption and range in Battery Electric vehicles is not accounted for in the official vehicle's data. It should be the case in the future to create a natural incentive for improvements.
- ✓ Upcoming legislative work should address the issue of air-conditioning energy consumption and all technologies substantially impacting it shall be incentivized.

Glass for Europe is the trade association for Europe's flat glass sector. Flat glass is the material that goes into a variety of end products, primarily in windows and facades for buildings, windscreens and windows for automotive and transport as well as solar energy equipment, furniture and appliances. Glass for Europe brings together multinational firms and thousands of SMEs across Europe, to represent the entire flat glass value-chain. It is composed of flat glass manufacturers, AGC Glass Europe, Guardian, NSG-Group and Saint-Gobain Glass Industry, and works in association with national partners gathering glass processors and transformers. European automotive glass producers supply advanced glazing systems to both Original Equipment Manufacturers and for the replacement market all over the world.

1. Mobile air-conditioning energy needs

When a vehicle without any solar control glazing technology is exposed to solar radiation, it can generate a greenhouse effect heating a vehicle's interiors to temperatures above 60°C on clear days[i]. In cold weather, unless solar radiation penetrates the car and naturally heats the cabin, the temperature of the vehicle's cabin can be similar to the outside temperature. In both cases, a solution to control the temperature is to use air-conditioning.

If the vehicle is overly cold, using the heat of the internal combustion engine permits to heat the cabin without generating additional CO_2 emissions. Yet, when considering Battery Electric Vehicles (BEV), which do not have a combustion engine, it is generally the mobile-air conditioning (MAC) which will be used. MAC can also be used when any type of vehicle is overly warm, to cool the cabin.

If one uses an Internal Combustion Engine Vehicle (ICEV), using MAC for cooling purposes increases fuel consumption and CO_2 emissions. If one uses a BEV, using MAC for both cooling and heating purposes increases the vehicle's energy consumption, which reduces its range. The CO_2 emissions generated by MAC use in BEV depend on the carbon intensity of the electricity used to charge the batteries.

The energy load needed by a vehicle's air-conditioning system depends on a variety of factors such as the glazing surface, outside temperature, exposure to solar radiation, or efficiency of the MAC unit. For ICEV, studies show that 5 to 15% of the annual fuel consumption of a standard car is due to MAC use[ii]. For BEV, studies showed that heating and cooling the vehicle can reduce the range by about 33%[iii]. Decreasing this air-conditioning load can be achieved through a combination of measures, e.g., increasing the energy efficiency of MAC systems and selecting the right type of glazing.

2. Advanced glazing systems can reduce the energy load of mobile air-conditioning

High-performance glazing products, e.g., windshields, rear windows, rooftop glazing, or side windows can help reduce the energy consumption of vehicles when integrated into advanced glazing systems.

- Solar control glazing can help reduce the variation in temperatures of vehicles' cabins[iv] which reduces the need for MAC.
  For ICEV, studies have shown that using solar control glass potentially improves overall fuel consumption efficiency by 1.7% to 3.4%[v]. Looking at the US (individual) vehicle fleet, it was evaluated that using solar control glass could permit MAC systems to cut 8.5% of their CO_2 emissions (1.2 gCO_2/km)[vi]. For BEV, it has also been evaluated that an optimized glazing system could increase the range of vehicles by 3% to 9% in urban conditions[vii].

- Electrochromic glazing permits to control the light transmission through the glass and offers adaptative solutions to reduce MAC loads in cold and warm weather[viii].

- Heatable glazing permits to directly control the heat of the windshield (rather than controlling the heat of the cabin) and increases the energy efficiency of defrosting and defogging operations.

Bearing in mind the thousands of new cars sold annually in the EU and overall CO_2 emissions and energy consumption generated by road transport, such an energy-saving potential should not be ignored. Today, air-conditioning impacts on ICEV's fuel consumption or BEV's energy consumption, are not considered in vehicles' official data (e.g., in fuel consumption data and in the WLTP driving cycle). There are also no legal incentives to optimize vehicles' glazing systems to increase vehicles' energy efficiency[ix]. This gap acts as a disincentive to car manufacturers from using these advanced glazing technologies, which explains why most new vehicles are not yet equipped with the above-mentioned technologies.

3. What can policymakers do?

Since glazing technology significantly influences the energetic impact of air-conditioning, Glass for Europe presses policymakers to take concrete actions in the framework of upcoming legislation on green mobility and calls for the following policy options:

- An ambitious target for reducing the energy impacts of air-conditioning vehicles should be included in regulations. Market mechanisms should also be adopted to encourage manufacturers' use of advanced glazing systems in light-duty vehicles.
- CO_2 emissions related to air-conditioning and the positive impact of advanced glazing systems should be correctly accounted for in vehicles' official data.
- A framework should be established to evaluate the environmental impacts of Battery Electric Vehicles which can account for all elements substantially impacting vehicles' sustainability.

In addition, regarding the current work on the definition of eligibility criteria for efficient MAC to be considered an eco-innovation, Glass for Europe calls for:

- Setting test procedures to calculate CO_2 emissions due to MAC systems that are unambiguous and provide a mechanism to account for the solar load, which affects the need for cooling.
- Taking glazing technology, surface area and inclination angle, into account in the MAC test procedure, e.g., by using the work already made on the topic (mandated by the EU Commission)[x].

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[i] Grundstein, A., Meentemeyer, V., & Dowd, J. (2009). Maximum vehicle cabin temperatures under different meteorological conditions. *International journal of biometeorology*, *53*(3), 255-261.
This study reports that in their test vehicle, the "maximum cabin temperatures, ranging from 41–76°C, varied considerably depending on the weather conditions and the time of year. Clear days had the highest cabin temperatures, with average values of 68°C in the summer and 61°C in the spring."
See also: Farrington, R. (2003). Stay Cool with Advanced Automotive Glazing. In *Glass Processing Days*.
[ii] Farrington (2003), see also:
Vale, J. P., Alves, P. G., Neves, S. F., Nybo, L., Flouris, A. D., & Mayor, T. S. (2022). Analysis of the dynamic air conditioning loads, fuel consumption and emissions of heavy-duty trucks with different glazing and paint optical properties. *International Journal of Sustainable Transportation*, *16*(10), 887-900.
This study reports similar results for a truck cabin: "windshields and side windows with transmissivity of 0.33 instead of typical 0.79 and 0.84, respectively, can reduce AC loads by up to 16%"
[iii] Lee, J. T., Kwon, S., Lim, Y., Chon, M. S., & Kim, D. (2013). *Effect of air-conditioning on driving range of electric vehicle for various driving modes* (No. 2013-01-0040). SAE Technical Paper.
"In general, air conditioning (i.e., cooling and heating) causes around about 33% average decrease in driving range."
[iv] Bharathan, D., Chaney, L., Farrington, R. B., Lustbader, J., Keyser, M., & Rugh, J. P. (2007). Overview of Vehicle Test and Analysis Results from NREL's A/C Fuel Use Reduction Research.
This study shows that the reduction in temperatures tested in a Cadillac STS exposed to the sun reached an average 7°C in the cabin, nearly 9°C at the driver seat and 14,6°C on the instrument panel surface.
[v] Farrington, R., & Rugh, J. (2000). *Impact of vehicle air-conditioning on fuel economy, tailpipe emissions, and electric vehicle range* (No. NREL/CP-540-28960). National Renewable Energy Lab.(NREL), Golden, CO (United States).
[vi] Rugh, J. P., Kreutzer, C., Kekelia, B., Titov, G., & Lustbader, J. (2018). US light-duty vehicle air conditioning fuel use and impact of solar/thermal control technologies. *SAE International Journal of Passenger Cars. Mechanical Systems (Online)*, *12*(NREL/JA-5400-70795).
According to this study, using Solar Control Glass in various vehicle configurations could cut CO_2 emissions related to air-conditioning in vehicles by 2 grammes per mile (it would decrease from 23.5 g/mi to 21.5 g/mi)
[vii] From tests made on a single-passenger car, Favoino et al. (2020) provide estimations of range gains for different types of BEV driving at 30 km/h.
See also: Rugh, J., Chaney, L., Venson, T., Ramroth, L., & Rose, M. (2013). *Impact of solar control PVB glass on vehicle interior temperatures, air-conditioning capacity, fuel consumption, and vehicle range* (Vol. 1, No. NREL/CP-5400-57489). National Renewable Energy Lab.(NREL), Golden, CO (United States).

Authors show that the EV range of a 2011 Toyota Corolla can be increased by 1.5% in city conditions and 0.7% in highway conditions only by using a windshield with solar-absorbing PVB.

[viii] Favoino, F., Raheli, E., Ramirez, D., Pilosio, F., Tavernese, S., Simonetti, M., ... & Masoero, M. (2020). Impact of glass technology on future electrical individual transportation: the Pop. Up case study. *Glass Structures & Engineering*, *5*(1), 117-131.

Marshall, G. J., Mahony, C. P., Rhodes, M. J., Daniewicz, S. R., Tsolas, N., & Thompson, S. M. (2019). Thermal management of vehicle cabins, external surfaces, and onboard electronics: An overview. *Engineering*, *5*(5), 954-969.

Electrochromic glass cannot be used for any vehicle parts. For instance, a section of the windscreen must have high light transmission performance to reach the necessary visibility requirements and ensure drivers' safety. The technology can yet be used for rooftop windows and improve the sustainability of air conditioning vehicles.

[ix] For instance, the eco-innovation scheme is focusing only on ICEVs and is not designed to include energy-efficient glazing systems since MAC emissions are not considered. This shall change as of 2025, with the possible inclusion of efficient MAC in the scheme, but there is yet no certainty that the measurement method to evaluate efficient MAC will consider the impact of solar radiation and its possible attenuation through using adequate glazing.

[x] European Commission, Directorate-General for Internal Market, Industry, Entrepreneurship and SMEs, Samaras, Z., Vonk, W., Hausberger, S. (2015). *MAC performance test procedure : co-ordination of the pilot test phase and follow up towards the drafting of the regulatory text : final report*, Publications Office.

This report shows that it is feasible to apply accurate correction factors on fuel efficiency based on the 'total transmitted solar energy' through the glazing, the so-called 'TTS scale'. With this tool, each technology is assessed in a fair manner and its benefits are reflected in the vehicle's MAC consumption.