



Natural refrigerants – CO₂-based air conditioning system put to practical testing

How mobile air conditioning systems damage our climate

The refrigerant commonly used in mobile air conditioning (MAC) systems is tetrafluoroethane, R134a for short. R134a has a high global warming potential (GWP), 1,300 times higher - according to more recent calculations by the Intergovernmental Panel on Climate Change (IPCC), even 1,430 times higher – than that of CO₂. A car equipped with air conditioning produces additional emissions corresponding to 7 grams of CO₂ per driven kilometre by the continuous release of R134a from the system. As a result, MAC systems have been veritable climate offenders up to the present.

Mobile air conditioning systems are the single most important source of fluorinated greenhouse gases, due mainly to high emissions during their operation and their large numbers.

More than 400 million vehicles worldwide are equipped with MACs. The climate experts of the UN IPCC expect that there will be nearly 1 billion air-conditioned vehicles by 2015. In 2015 alone, these will release refrigerant to the atmosphere on a scale of at least 270 million tonnes of CO₂ equivalent, contributing to climate change.

In Germany, almost 2,300 tonnes of the fluorinated refrigerant R134a were emitted to the atmosphere in 2006 alone. This is equivalent to almost 3 million tonnes of CO₂, which is as much carbon dioxide as is emitted via the exhaust gas of 1.7 million small-sized vehicles each driving 15,000 kilometres per year.

What is the European legislature doing?

In Europe, the route towards replacement of the high-GWP fluorinated refrigerant has been mapped out. European Directive 2006/40/EC requires that from 1 January 2011 new types of passenger car may only be approved if their air conditioning units contain refrigerants that are significantly less harmful to the climate than R134a. In fact,

the new refrigerant may not be more than 150 times as harmful to the climate as the same amount of CO₂. The automotive industry must now make important decisions: manufacturers must quickly start designing the new generation of air-conditioning systems.

The alternative: Protecting the climate with CO₂

In the 1990s, developers and engineers rediscovered a natural refrigerant which had already been known for more than a century: carbon dioxide (CO₂), known as R744 when used as a refrigerant. R744 is at least 1,300 times less harmful to the climate than the fluorinated greenhouse gas R134a. Carbon dioxide has a number of advantages as a refrigerant. It has a high cooling capacity, it is non-combustible, and available worldwide at low cost in the required quantities. Innovative plant technology using R744 is ready for serial production.

CO₂-based air conditioning systems are already at least on a par with systems using R134a in terms of performance and energy consumption. In some cars manufacturers have demonstrated clear advantages, such as quicker cooling of the passenger compartment and better fuel economy. Potential additional costs are also limited: A major manufacturer estimates that for a medium-sized car in serial production, the extra cost versus the current technology is less than 50 Euros.



The automotive industry now has the chance to move towards more climate-friendly cars by opting for CO₂ technology. There is no other place in a car where it is so cost-efficient to mitigate climate change.

Various organofluorine compounds made by chemical companies offer yet another alternative. Little is as yet known about these recently developed chemical substances. In particular, only spotty information is available on their toxicity, behaviour in the environment, long-term behaviour in the air-conditioning systems, and costs. These substances are certain to require additional development costs for all relevant industries and generate avoidable environmental impacts.

Therefore, in the opinion of the Federal Environment Agency (Umweltbundesamt, UBA), synthetic refrigerants such as R134a should be replaced by the natural refrigerant CO₂ (R744).

Global introduction of R744 necessary

To effectively reduce pressures on the atmosphere, an “island solution” with carbon dioxide - limited to Europe or even Germany - is insufficient. We need to act globally. A global switch to R744 provides manufacturers with a long-term sustainable, uniform technical solution. In addition, the contribution of mobile air conditioning systems to the greenhouse effect would fall significantly. Moreover, in CO₂-based systems, only CO₂ can be used as refrigerant for refilling – a significant advantage given that ozone-depleting CFCs are still being used in some countries for refilling MAC units.

CO₂ air conditioning system put to practical testing: Tests commissioned by the Federal Environment Agency

Critics of the CO₂ solution have repeatedly claimed that CO₂-based MAC systems consume more energy than systems with R134a. Experienced developers of MAC systems with carbon dioxide, on the other hand, have demonstrated in tests that these systems are more energy-efficient.

In a research project, the Federal Environment Agency had independent tests performed to see whether CO₂ air conditioning systems are also advantageous from the energy viewpoint. For this purpose, it commissioned Obrist Engineering GmbH to fit a federally owned vehicle with a CO₂ air conditioning system. This car was subjected to measurements on a chassis dynamometer both with the standard R134a air conditioning system

and the CO₂-based system. Initial results show the innovative edge of the CO₂ technology.

As another step in the project, the Institute of Thermodynamics (IfT) of the Technical University of Braunschweig will carry out comparative calorimeter measurements on the CO₂ air conditioning system and the standard R134a system, without the vehicle. Results are expected for late July 2009.

First results

Tests on a chassis dynamometer can provide information about the fuel consumption of a vehicle when fitted with different air-conditioning systems. In these measurements, testers need to ensure that measurement conditions for the two systems are fully identical.

Measuring cooling behaviour in the climate wind tunnel



Measurements in the climate wind tunnel

The aim of the cooling tests in a climate wind tunnel at the rta company in Vienna was to design the new CO₂ air conditioning system such that its cooling performance at 43° C is comparable to that of the standard R134a system. This makes it possible to ensure the comparability of the measurements with the two systems.

Measurements on a chassis dynamometer

Tests on a chassis dynamometer can provide information about the fuel consumption of a vehicle when fitted with different air-conditioning systems.

The UBA vehicle was tested on the chassis dynamometer of the SGS company in Vienna, first with the standard R134a system and subsequently with the new CO₂ air conditioning system.



Measurements on chassis dynamometer

After determining the vehicle's basic fuel consumption, i.e. with the air conditioning system turned off, consumption was measured with the air conditioning system turned on. The difference represents the fuel consumption of the air-conditioning system.

The measurements were carried out at select ambient temperatures of 20°C, 28°C and 35°C in the New European Driving Cycle (NEDC) as commonly used for type-approval of passenger cars. Measurements at 35°C simulate a very hot summer with intense solar radiation, i.e. conditions normally found only outside of Europe. This makes it possible to establish whether the air-conditioning system is also suitable for locations with a warmer climate.

The results of the realistic measurements on a chassis dynamometer show that additional fuel consumption is significantly reduced when using the CO₂-based MAC system as compared to the standard R134a air conditioning system. The difference in consumption is smaller at the high temperature of 35°C as compared to the middle and low temperatures of 28°C and 20°C (see Diagram 1).

In parallel with the tests in the research project, the ADAC carried out own measurements at 28°C and 35°C (see Diagram 2). Additional consumption at 28°C was also significantly reduced. Under very warm conditions (at 35°C), additional fuel consumption was somewhat higher in these measurements.

The tests on the vehicle on a chassis dynamometer demonstrate the suitability and effectiveness of CO₂ as a refrigerant for mobile air conditioning systems. They show that at average summer temperatures normal in Europe additional consumption by the CO₂ MAC is significantly lower than that of the standard R134a MAC system. Under very warm conditions, its consumption is roughly comparable to that of the standard air conditioning system when taking measurement accuracy into account.

As a further step in the project, calorimeter measurements will be carried out for precise technical characterisation of the systems.

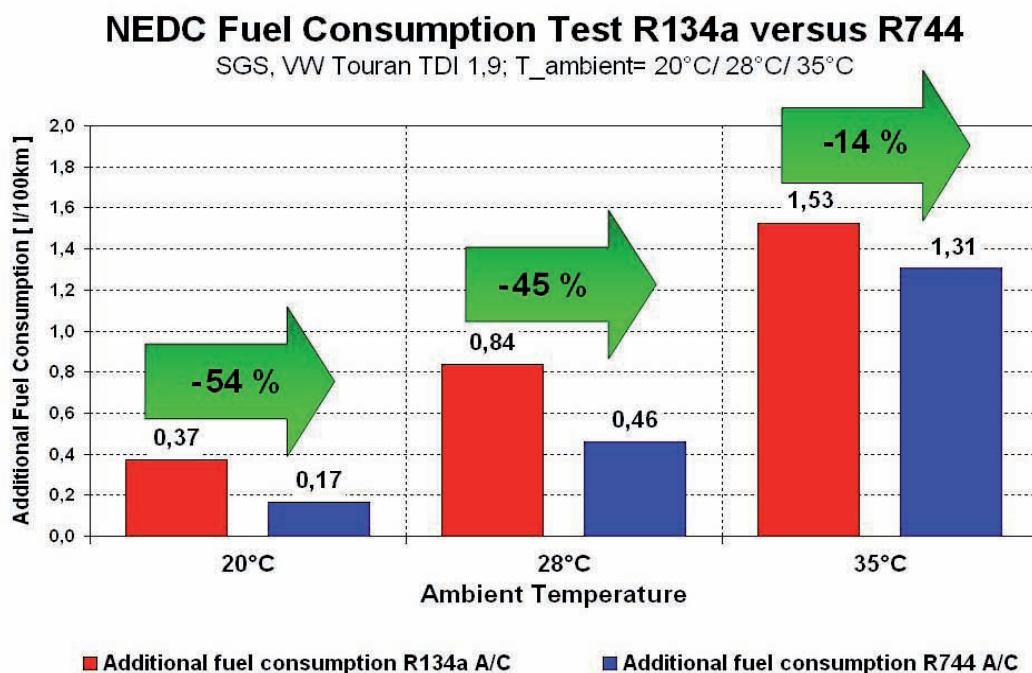


Diagram 1 – Fuel consumption of an R134a MAC and an R744 (CO₂) MAC at different temperatures (UBA research project)

NEDC Fuel Consumption Test R134a versus R744

ADAC, VW Touran TDI 1,9; T_{ambient}= 28°C/ 35°C

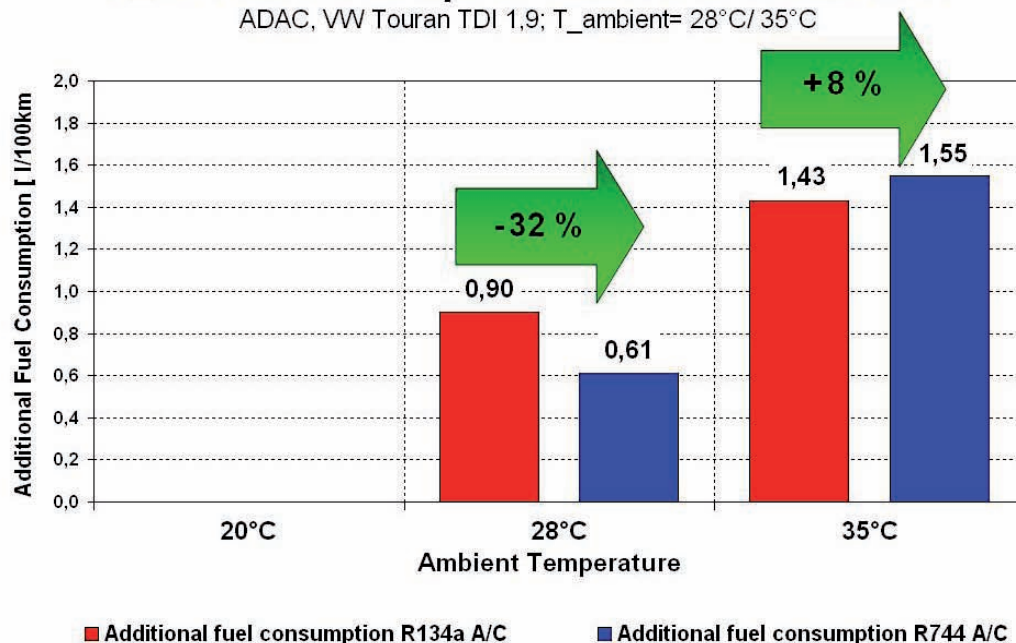


Diagram 2 – Fuel consumption of an R134a MAC and an R744 (CO₂) MAC at different temperatures (ADAC)

Conclusion

Taking a standard vehicle as an example, it was shown that the innovative mobile air conditioning system using CO₂ (R744) as refrigerant is favourable from the energy perspective.

With CO₂ (R744) as a refrigerant for mobile air conditioning systems, an overall climate-friendly solution is available.

What's ahead?

Another major advantage of the CO₂ technology results from the specific properties of R744 (CO₂), which allow the cooling process to be reversed. Even today, the engines of modern diesel vehicles and hybrid cars do not give off enough waste heat to heat the vehicles fast enough in winter. The supplier industry is already working on a future design for CO₂ MAC systems that would enable them to function as a heat pump to additionally heat the passenger compartment in winter.

An internet version of this flyer is available at www.umweltbundesamt.de/produkte-e/index.htm

EU Directive 2006/40/EC relating to emissions of fluorinated greenhouse gases from air-conditioning systems in motor vehicles is available on the Internet at <http://europa.eu/scadplus/leg/en/lvb/l24280.htm>

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