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Regulation of car HVAC systems

Heating, ventilation and air conditioning systems in passenger cars and light commercial vehicles (mobile HVACs) are by far the largest auxiliary consumers, increasing fuel consumption by up to 26%.

The efficiency of mobile HVACs remains unregulated in the EU. Fleet emission targets for OEMs, mandatory fuel consumption labeling for consumers, omit their energy consumption.

Substantially more efficient technologies (up to 54%) exist. Investment, implementation and demand remain elusive as current regulation favors the cheaper, convenient and uninformed status quo.

The operation of the A/C systems, at corresponding temperatures of vehicle and test chamber, must become part of the emissions-related type approval.

content

Abstract

Mobile A/C systems

Current regulation setting CO_2 fleet emission targets for manufacturers is based on the WLTP test procedure (EU 2019/631).
So is the mandatory car labelling directive, aimed to help consumers buy or lease cars which use less fuel and thereby emit less CO_2 (Directive 1999/94/EC, amended by Directive 2003/73/EC, Regulation (EC) No. 1882/2003 and Regulation (EC) No. 1137/2008)[1].

A/Cs are de facto standards in new vehicles: e.g., 92% of all new cars sold in Germany in 2018 had one.
Operation of A/C units for cooling (and heating in BEVs), as well as external temperatures, have significant effect on the fuel economy of a vehicle – on average, fuel consumption, and CO_2 emissions, increase between 10 and 15%. At 35° C, the increase is up to 26%.

Of the 475.4 Mt CO_2 emitted by passenger cars in the EU p.a., **between 6 and 9 Mt CO_2 per year are caused by operating the A/C units alone.**
That's a conservative estimate.

WLTP does not take the operation of A/C units into account. Tests are conducted at an ambient temperature of 23° C. Article 11 of Regulation (EU) 2019/631 („Eco Innovations"), as well as 3.2 of COM/2007/0019 ("supply oriented measures") have proved to be ineffective in bringing more efficient A/Cs about.

Current proposals for a revision of the EU CO_2 emission performance standards for cars and light commercial vehicles are based on an unaltered WLTP. Hence, any tightening of standards only will continue to omit the real-world emissions resulting from running an A/C in a car.

Refrigerant

R 134a, until 2017 the de facto standard refrigerant in A/C systems, has a GWP of 1,430. F-gas Regulation (EU) No 517/2014 mandates the phase-out of refrigerants with a GWP above 150.
DuPont/Chemours and Honeywell teamed up to develop, patent and promote R1234yf, successfully, as the new standard. It has a GWP of only 1 to 4.

R1234yf is convenient for manufacturers: a "near-drop in", it poses no need to change A/C systems or vehicle architecture. OEMs procure R1234yf at the same price as previously R134a.

R1234yf initially raised concerns regarding safety and toxicity in case of fires. But it is its propensity to **degrade into persistent TFA in the atmosphere** that has the German Environment Agency UBA calling for its replacement with a more sustainable solution.

Mobile A/C units leak about 10% of refrigerant each year and must be refilled about every other year to remain effective. "Near drop-in" also works in reverse, and R1234yf is six times as expensive (for consumers). Hence, R134a is finding its way back into European cars through a thriving black market.

One sustainable solution of the kind UBA called for would be refrigerant R744: it's both cheap and abundant, as it is a natural gas. It is environmentally neutral. Its GWP is 1. A/C systems running on R744 are incompatible to R134a or R1234yf (both of which are more costly anyhow).
Mobile A/C systems are up to 54% more efficient than current systems. R744 is also known as CO_2.

Including the operation of A/C systems in a revised WLTP would promote more efficient systems, help reduce CO_2 emissions – and potentially reduce TFA.

System

Air conditioning systems in cars are now standard: 92% of new cars purchased in Germany in 2018 were equipped with air conditioning. Among the used cars purchased, this was 88%.[2]

Air conditioning systems are by far the largest secondary consumer in vehicles: they lead to **up to 26% additional consumption and thus CO_2 emissions**.[3] Air conditioning operation is also not taken into account in the new WLTP test cycle.[4]

Consumption and emission data

The WLTP test cycle was introduced to generate more realistic consumption and emission values. It is the basis for passenger car energy consumption labeling[5], i.e. for the information on consumption and CO_2 emissions ("manufacturer's data").[6] This is supposed to enable car buyers to make informed decisions.

But car **buyers today are kept in the dark about significantly increased energy consumption** by operating the A/C system. They can neither obtain information on how high the additional consumption is due to the operation of an A/C system, nor compare these values for different models.
A crucial piece of information for the purchase decision – operating costs – is systematically being omitted.

The contribution to the climate crisis is also systematically presented more favorably by lower than realistic CO_2 values. This is misleading not only for environmentally conscious private consumers, but also, for example, for companies with corporate fleets and CO_2 balances.

Fleet emission targets

The test cycle is also the basis for setting manufacturers' fleet emission targets (EU Regulation 2019/631) - these also underestimate consumption by A/C systems and thus turn out to be more favorable for manufacturers.[7]

Article 11 of Regulation 2019/631 - "Eco-innovations" -, and 3.2 of Communication COM/2007/0019 - "Supply-side measures" - provide incentives for efficiency improvements outside the test cycle. The crediting of such instruments is capped at a total of 10g and 7g per manufacturer, respectively.

The incentives set do not have any effect regarding A/C systems: Firstly, current reference values would have to be specified for offsetting. This could have an unfavorable impact on the current (non-)regulation, which is advantageous from the manufacturer's point of view. Secondly, an effective efficiency increase would be significantly higher than the creditable (capped) values.

Cost, maximum applicable efficiency gain and potentially unfavorable regulatory impact are in an unfavorable relationship, rendering current regulation ineffective with regards to A/C systems.

Result

Currently, manufacturers achieve fleet limits more easily, avoiding fines and additional costs. Car buyers are being misled by claims of higher efficiency, lower emissions and lower operating costs.

A/C in cars are the big blind spot in car efficiency and CO_2 regulation: of the 475.4 Mt CO_2 emissions from cars in the EU per year, around 6 to 9 Mt CO2 could be attributed to car A/Cs alone.[8]

Refrigerant

While the **efficiency** of air conditioning systems does not receive sufficient attention from the public or policy makers, the **climate impact** of refrigerants is well known[9]. Fluorinated greenhouse gases are regulated by the F-Gas Regulation (EU 517/2014).

R1234yf

Since 2017, the previous refrigerant R134a (GWP 1,430) has been subject to[10] a phase-down - the "gradual restriction of the quantities available on the market."[11] It is being replaced by the new R1234yf (GWP 1 to 4).

R1234yf was jointly developed, patented and promoted as a successor solution by DuPont/Chemours and Honeywell. It is a "near drop-in" solution, so can be used in existing air conditioning systems. R1234yf requires no modification to the air conditioning system or vehicle architecture.

R1234yf is more environmentally harmful than its predecessor: it decomposes to 100% in the atmosphere to persistent TFA.[12] The increasing groundwater and drinking water contamination has been proven. TFA can only be removed again with considerable effort. (R134a decomposes "only" to 21% to TFA).

Safety debate

Before its introduction, the safety of the refrigerant was also controversial. The German Environmental Aid, among others, focused criticism on the flammability (fire acceleration) and the formation of hydrofluoric acid (highly corrosive) of the substance.

As a result, the German automotive industry opposed the R1234f solution and in 2007 initially opted for the refrigerant R744 (CO_2).[13] This was followed by years of wrangling with international manufacturers, the chemical industry, and finally the EU, with the result that R1234yf is the European and increasingly also the US and Japanese standard.[14] Über eine tatsächliche höhere Gefährdung von Insassen oder Rettungskräften bei Unfällen durch Flusssäure ist bislang noch nicht berichtet worden.

Black Market

During the negotiations, the patent holders and near-monopolists[15] DuPont/Chemours and Honeywell pledged to provide OEMs with the new refrigerant for the initial charge for the same price as R134a.

Up to 10% refrigerant escapes from a car air conditioning system per year.[16] It must therefore be refilled every three to four years. In the aftermarket (i.e., for vehicle owners), R1234yf costs about six times as much as R134a.

"Near drop-in" also means that the substantially cheaper R134a will also work in new car A/C systems. As a result, smuggling and the black market are flourishing.[17] – the industry association EFCTC estimates the share of the total EU market at one third.[18] Outside of Europe (where most used cars are ultimately exported), refilling with the less expensive R134a is also legal.

Results

The chemical industry retains a lucrative market. The better GWP of R1234yf comes with the greater environmental impact with TFA. The "near drop-in" property in combination with the significant price difference leads to illegal refills with the climate-damaging R134a on a massive scale.

Potentials

Car air conditioners are inefficient and cause an average of 10 to 15 percent[19] increased consumption. The refrigerant used in them is either harmful to the climate, to the environment, or both.

The global car population is rising continuously[20], as is the proportion of vehicles with A/C. With rising summer temperatures, these may also be switched on more frequently.

However, the electrification of the drive train and a European innovation show the potential for improvement.

Thermal pump

What consumption is to the internal combustion engine (ICE) vehicle, range is to the electric car (BEV). But while higher fuel consumption in ICEVs is a learned permanent annoyance, low or unreliable range in BEVs is an obstacle to purchase. This is leading to a surge in innovation in BEVs.

The electric motor does not produce sufficient waste heat to warm the interior in winter. First BEVs were equipped with energy-guzzling parking heaters.[21] Meanwhile, heat pumps are[22] common, which can both cool and heat.

These are generally more energy-efficient than air conditioning plus heating, but suppliers and manufacturers are often breaking new ground here: Volkswagen's ID.3 with heat pump showed 100% higher consumption. [23] A software update is supposed to amend this issue.

Octovalve

Since not only the interior, but also the battery and other components of a BEV require temperature control, thermal management is a challenge on both the software and hardware sides.

With Octovalve 2020, Tesla has set a new standard for the integration of thermal management[24] and thus **increased the range by 10%**. The Norwegian Automobile Association NAF regularly tests the winter range of BEVs: the Tesla 3 takes the top spot.[25]

CO_2-A/C system

Konvekta invented the car air conditioner running on refrigerant R774 (CO_2) and currently installs it in buses[26]. The German Federal Environment Agency (UBA) and the German Automobile Club (ADAC) already tested the technology in 2009 and **demonstrated the significant (up to 54%) energy savings in practice**.[27]

The UBA also found in 2010: "CO_2 is the most suitable new refrigerant for passenger car A/C systems ... In summer, the additional consumption is lower and in winter the air conditioning system can be switched as a heat pump. CO_2 is available worldwide at favorable prices. **CO_2 as a refrigerant has the greatest and most cost-effective reduction potential for greenhouse gas emissions in passenger cars worldwide**."[28] The GWP is 1.

CO_2 is a natural gas and cannot be patented. It is environmentally neutral.
CO_2 A/C systems are incompatible with R134a or R1234yf. There is no risk of reverse drop-in.
CO_2 air conditioners or heat pumps were introduced in 2017 in a few ICEV models.[29] and are now offered as expensive optional equipment in a small number of BEV models – as range extenders.[30]

Regulation

Lock-in

The current labeling and CO2 regulation undercuts actual consumption and emissions from air conditioning operation. It has no control effect on the market but keeps customers in the dark about additional costs[31] and higher emissions.[32]

It does not provide an effective incentive for automotive industry to increase efficiency and strengthens the chemical industry in the sale of its fluorinated refrigerants.[33]

The F-gas regulation neither considers atmospheric input of TFA, nor provides an effective remedy against reverse drop-in.

In their current version, efficiency regulation, the Passenger Cars Ordinance and the F-Gas Ordinance lead to a lock-in of the status quo. Yet the potential for efficiency and innovation is enormous: 6 to 9 million tons of CO2 per year are at stake.

Fit for 55

The EU wants to become "Fit for 55" by 2030 with the Green Deal – and use this to promote innovation and increase the continent's competitiveness.
Regulating mobile HVAC systems (car A/Cs and heat pumps) supports both goals.

Amend WLTP

The current proposals for tightening the European fleet emission targets [34] recognize the decreasing efficiency effect (e.g., with increasing electrification).

Nevertheless, they ignore the emissions caused by secondary consumers, blunting any tightening, no matter how strict.

At the same time, test procedures that take A/C systems into account are well known: in the discussion of how Real World Driving Emissions can be reliably measured by On-board fuel and energy consumption monitoring (OBFCM) devices[35], both test temperature conditions and operation of the A/C system are taken into account [36].

Effective tightening of fleet emission targets and efficiency targets require a realistic basis for all limits and measurements. An adaptation of the WLTP is required.

The operation of the A/C systems, at corresponding temperatures of vehicle and test chamber, must become part of the emissions-related type approval.

This way consumption figures, and efficiency labels will become realistic and fleet emission targets effective, leading to substantial, real world CO_2 abatement.

A subsequent revision of the F-gas regulation might improve rules and limits in view of the persistence of TFA or trifluoroacetate in the environment by halogenated refrigerants.

Comparison of current systems and refrigerants

	R1234yf systems (standard for new vehicles since 2017)	R744 systems (alternative available since 2015)	R134a system (Standard until 2017)
Refrigerants	2,3,3,3-Tetrafluorpropen	CO_2	1,1,1,2-Tetrafluorethan (Freon)
Patent	Honeywell/DuPont (Chemours)	natural gas, non patentable	Honeywell/DuPont
(GWP)	1-4	1	1430
Environmental properties	decomposes to 100% persistent TFA, increasing drinking water intrusion detected	natural gas, no environmental impact	decomposes to 21% persistent TFA
Safety	Conversion to highly corrosive, highly toxic hydrofluoric acid detected at high temperatures (accident)	No fire hazard, non-toxic for occupants and rescue workers in the quantities used	
Costs initial charge (= for OEM)	Comparable to 134a	low (mainly for logistics)	./.
Costs Aftermarket (= for consumers)	ca. 20 Euro per 100 gram	low (mainly for logistics)	3-4 Euro per 100 Gram
Compatibility with 134a systems	"near Drop-in"	incompatible	./.
System			
Pressure (bar)	High pressure level: 10-20 Low pressure level: 3-5	High pressure level: 60-130 Low pressure level: 30-50	High pressure level: 10-20 Low pressure level: 3-5
Adaptation vehicle architecture	No changes	necessary	./.
costs	No changes	30€ + compared to R134a system	./.
Efficiency, cooling	Up to 20% additional consumption/ range loss	approx. 5% additional consumption/ range loss*	20% additional consumption/ range loss
Efficiency, heat (for BEV, FCEV)	up to 10-30% additional consumption/ range loss. Only effective down to -15°C. Often separate heating	approx. 10% additional consumption/ range loss*	./.
*Estimation, current measurements missing			

Footnotes and Sources

[1] Some countries' labeling laws still reference the obsolete NEDC test regime, e.g., Germany's Pkw-EnVKV, but are currently being reviewed. In any case, a future review should create a uniform standard across the EU via a regulation, not a directive.

[2] https://de.statista.com/statistik/daten/studie/255284/umfrage/anteil-der-pkw-mit-klimaanlage/

[3] „Einflussfaktoren auf den Kraftstoffverbrauch:
Die Rolle der Klimaanlage", Präsentation von Helge Schmidt, TÜV Nord, 03.07.2012.
Messungen TÜV NORD im Auftrag der Bundesanstalt für Straßenwesen gemessen im damals aktuellen NEFZ.
Der theoretische Energiebedarf einer Autoklimaanlage wird mit 1500W und mit einem Kraftstoffmehrverbrauch von 1,97l Benzin bzw. 1,64l Diesel angegeben.
Der ADAC nennt „im Schnitt: 10 bis 15 Prozent Mehrverbrauch"
https://www.adac.de/rund-ums-fahrzeug/ausstattung-technik-zubehoer/ausstattung/auto-klimaanlagen/

[4] Im NEFZ wurde selbst das Gewicht der Klimaanlage nicht berücksichtigt (= sie war im Testfahrzeug nicht verbaut). Im WLTP ist sie verbaut, bleibt aber ausgeschaltet.

[5] https://www.gesetze-im-internet.de/pkw-envkv/BJNR103700004.html

[6] Momentan wird gemäß aktuell gültiger Pkw-EnVKV an Verkaufsstellen ein Pkw-Effizienzlabel (analog Weißer Ware) am Fahrzeug auf Basis von NEFZ gezeigt. Würde der Verbrauch der Klimaanlage berücksichtigt, würde jedes Fahrzeug ca. 1,5 Effizienzklassen schlechter bewertet müssen. Der Referentenentwurf des BMWK für die Novelle der Verordnung sieht keine Farbcodierung mehr vor.
https://www.bmwi.de/Redaktion/DE/Downloads/P-R/referentenentwurf-pkw-envkv.pdf?__blob=publicationFile&v=8

[7] Die Emissionsberichterstattung der Bundesregierung ist davon nicht betroffen. Sie basiert auf in Deutschland erfolgten Kraftstoffabsätzen, also z.B. den verkauften Mengen Benzin und Diesel. Aus den insgesamt abgesetzten Kraftstoffmengen können die CO_2-Emissionen anhand sogenannter Emissionsfaktoren in emittierte CO2-Mengen umgerechnet werden. Da die Berichterstattung auf den abgesetzten Mengen Kraftstoff beruht, besteht nicht die Gefahr, dass Emissionen nicht berücksichtigt würden.

[8] Unter der sehr konservativen Annahme, dass 50% aller Pkw in der EU mit einer Klimaanlage ausgerüstet sind und diese im Schnitt 3 Monate im Jahr in Betrieb ist. Hinweis: Diese Zahl erhöht *nicht* die Jahresemission Deutschlands: diese wird u.a. anhand von Treibstoffabsatz ermittelt.
https://www.statista.com/statistics/1236763/road-transportation-greenhouse-gas-emissions-eu-by-mode/

[9] Die Verwendung von FCKW in Spraydosen (Treibmittel) und Kühlschränken (Kühlmittel, Schäummittel für Isolierung), später FKW war schon in den 80ern Teil der westdeutschen öffentlichen Debatten, damals insbesondere bezüglich des Ozonlochs.

[10] Es war wiederum der moderne Ersatz für ozonschädliche Vorgänger

[11] https://www.umweltbundesamt.de/themen/klima-energie/fluorierte-treibhausgase-fckw/rechtliche-grundlagen/eu-verordnung-ueber-fluorierte-treibhausgase#VO5172014

[12] UBA Texte Persistente Abbauprodukte halogenierter Kälte- und Treibmittel in der Umwelt – Abschlussbericht:
https://www.umweltbundesamt.de/sites/default/files/medien/5750/publikationen/2021-05-06_texte_36-2021_abbau_kaelte-treibmittel.pdf

[13] VDA Pressemitteilung „Durchbruch in der Klimatechnik" vom 06. September 2007, ebenso VDA-Präsident Matthias Wissmann im Spiegel:
https://www.spiegel.de/auto/aktuell/vda-praesident-wissmann-muesliautos-interessieren-keinen-a-504526.html

[14] 2008 bot DuPont und Honeywell an, das Kältemittel den OEM zum gleichen Preis wie R134a anzubieten, die deutschen Hersteller schwenkten auch zugunsten eines Weltstandards ein. Später meldeten die Deutschen wieder stärkere Sicherheitsbedenken an, ein eigens zu

diesem Thema einberufenes Gremium des Weltverbands der Automobilingenieure verließen sie unter Protest.[14] 2013 gab zuletzt Daimler auch unter Druck der EU den Widerstand auf. Siehe auch: https://www.tagesspiegel.de/mobil/streit-um-kaeltemittel-fuer-klimaanlagen-daimler-bmw-und-audi-scheren-aus/7748300.html https://www.manager-magazin.de/unternehmen/autoindustrie/kaeltemittelstreit-worum-daimler-die-eu-und-us-konzerne-kaempfen-a-918195.html

[15] https://www.adac.de/rund-ums-fahrzeug/ausstattung-technik-zubehoer/ausstattung/auto-klimaanlagen/

[16] „Bis zu 10% der Kältemittelmenge gehen im Jahr durch poröse Leitungen, Lecks an den Verbindungsstellen und vor allem über das Lager der Verdichterwelle im Kompressor verloren. Tritt mehr Kältemittel aus, liegt dies in der Regel an Beschädigungen des Kreislaufs selbst, wobei sich der Blick vor allem auf den Kondensator richten sollte. Durch Steinschlag können dort kleine Löcher entstehen, über die das Gas entweicht. Durch den Hochdruck wird es praktisch hinaus gepresst." https://www.kfzteile24.de/magazin/werkstatt-service/klimaanlage-befuellen

[17] https://stopillegalcooling.eu/

[18] https://www.economist.com/europe/2022/02/25/an-eu-scheme-to-limit-the-use-of-dangerous-gases-runs-into-problems

[19] https://www.adac.de/rund-ums-fahrzeug/ausstattung-technik-zubehoer/ausstattung/auto-klimaanlagen/

[20] https://www.umweltbundesamt.de/bild/weltweiter-autobestand

[21] PTC-Heizelemente, wie sie auch in Heizlüftern verwendet werden.

[22] https://www.amz.de/von-der-klimaanlage-zur-waermepumpe

[23] Volkswagen hatte beim ID.3 kein glückliches Händchen:

[24] Dies betrifft auch die gedruckte Leiterplatte. https://cleantechnica.com/2020/08/03/teslas-octovalve-enabled-a-staggering-10-increase-in-range-for-the-model-y/

[25] https://nye.naf.no/elbil/bruke-elbil/test-rekkevidde-vinter-2022

[26] https://www.konvekta.de/produkte/klimaanlagen-fuer-busse/busklimatisierung/elektrobus-hybridbus/ultralight-500-700-co2-waermepumpe

[27] https://www.umweltbundesamt.de/publikationen/natuerliche-kaeltemittel-co2-klimaanlage-im

[28] https://www.umweltbundesamt.de/publikationen/natuerliche-kaeltemittel-fuer-pkw-klimaanlagen

[29] https://group-media.mercedes-benz.com/marsMediaSite/ko/de/9919575

[30] https://www.volkswagen.de/de/elektrofahrzeuge/id-technologie/waermepumpe.html

[31] Durch höheren Energieverbrauch und teureres Kältemittel.

[32] CO_2 durch höheren Energieverbrauch und TFA durch Leckage.

[33] Auch die Schwarzimporte von R134a werden hauptsächlich von Honeywell und DuPont/Chemours hergestellt.

[34] Agora Verkehrswende: Notes on the revision of the EU CO2 emission performance standards for cars and light commercial vehicles, 5. Februar 2021

[35] T&E: How can fuel consumption meters ensure car CO2 limits are met on the road, September 2020

[36] ICCT: Coming back to reality: A proposal for real world accuracy for vehicle on-board fuel and energy consumption monitoring, Februar 2022