FIAT GROUP

Automobiles and
Light Commercial Vehicles

Assessment of the Environmental Impact of MACS and Investigation of its reduction drivers

LCCP analysis of MACS

VDA Alternative Refrigerant Winter Meeting

VDA Verband der Automobilindustrie

13. + 14.02.2008
Hotel Gut Brandlhof
Saalfelden / AUSTRIA

Roberto Monforte
Program Manager Alternative Refrigerants

Presentation Outline

- Background
- Main contribution to the LCCP
- TEWI and LCCP
- Investigation of the potential emissions reduction drivers effect
- Conclusion and Outlook

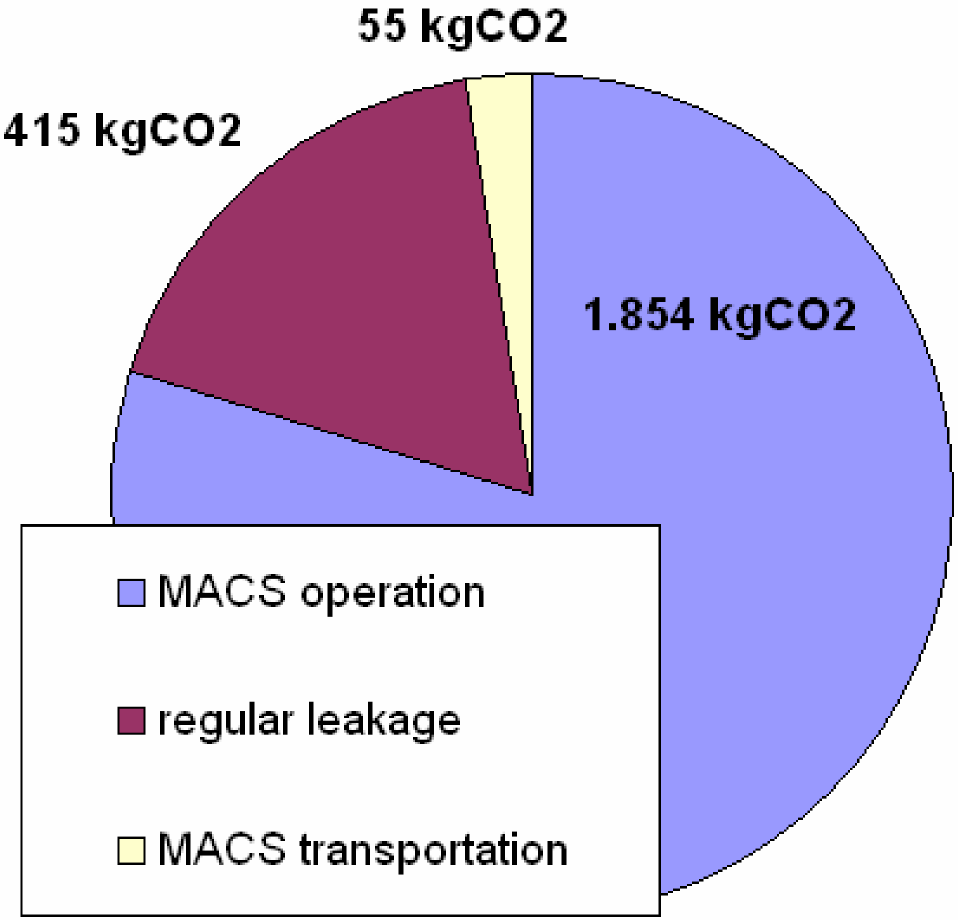
Background

- The consumers concern about the environmental impact of vehicles and the political parties' pressure (F-Gas Directive, 120 g/km issue) are growing in these last years.
- Both these factors are addressed by enhanced attention by the car manufacturers in their development process of the vehicles facing the market's expectation by the end of the present decade.
- The evaluation of the MACS environmental impact has been performed by FGA according to the LCCP approach, consistent to the GreenMAC LCCP tool in order to avoid any misunderstanding and unfruitful discussion.
- A particular stress has been devoted to the assessment of the TEWI:
  - indirect emissions related to the MACS operation: measurements
  - direct emissions: comparison of R-744, R-152a w/ SLS, HFO-1234yf

LCCP: TEWI and MACS transportation

The following assumptions have been considered:

1. 5 l/100 km base consumption
2. Phoenix Jul-07 approach for the real life overconsumption
3. Turin, 200000 km mileage
4. 13 g/y regular leak rate
5. 90% recovery in service & eol
6. 9 kg MACS mass
7. 0,1 l/100 km overconsumption per 100 kg load

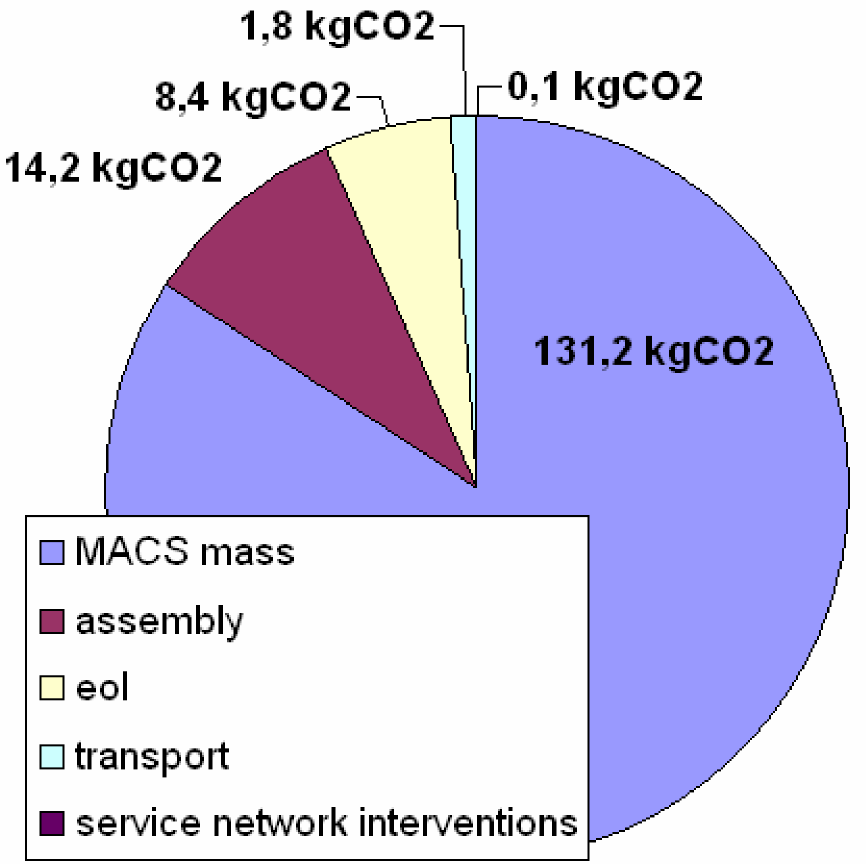


The TEWI and transportation of the MACS causes ~2300 kg CO_2 emissions over 200000 km (equivalent to ~15000 km mileage)

LCCP: Manufacturing of the MACS

The following contributions have been evaluated:

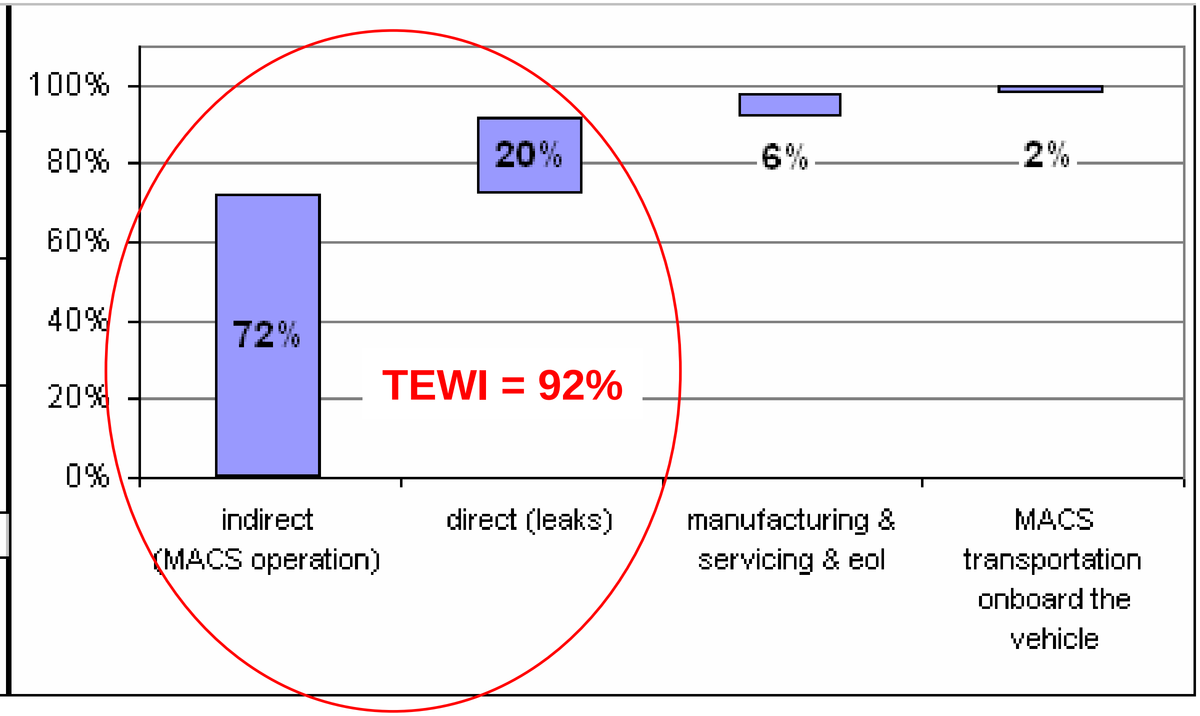
1. manufacturing of the MACS
2. transportation to the vehicle assembly line
3. assembly on the vehicle
4. service network interventions
5. end of life of the vehicle



The manufacturing of the MACS causes <160 kg CO_2 emissions, including service and e.l.v. (equivalent to 1000 km mileage CO_2 emissions)

LCCP: Comparison of the contributions

indirect (MACS operation)	1776
direct (leaks)	482
manufacturing & servicing & eol	140
MACS transportation onboard the vehicle	55
OA emissions during vehicle life ($kgCO_2$)	2452



The LCCP of the MACS accounts globally for 2500 kg CO_2 emissions (equivalent to 16000 km mileage CO_2 emissions)

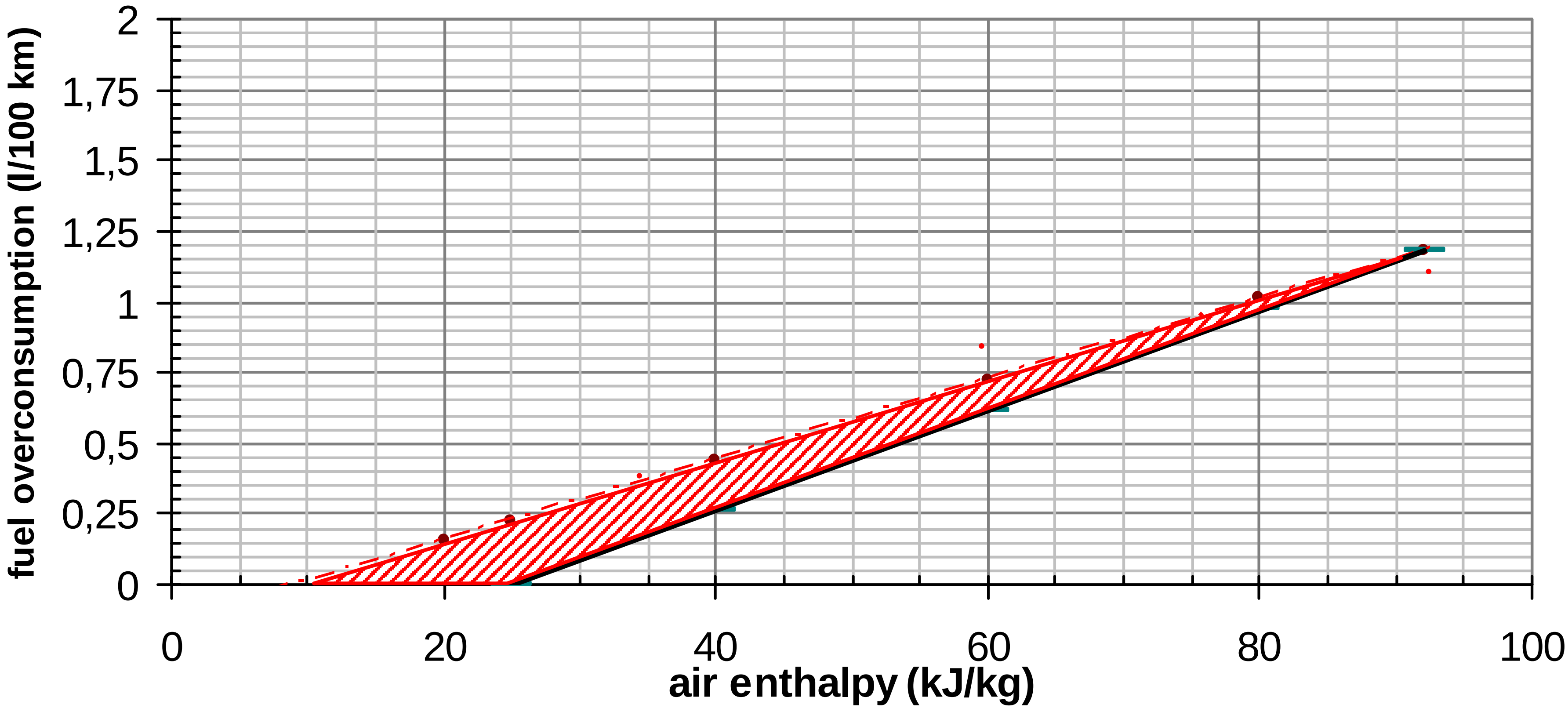
Investigation of the Reduction Drivers

The assessment of the potential emissions reduction drivers is featured starting from the TEWI (92% of the LCCP) as the remaining contributions are affected by a greater incertitude.

The following drivers will be analyzed:

1) effect of increased evaporating temperature
2) effect of an Intermediate Heat Exchanger
3) effect of PWM control on the fan
4) effect of a low GWP refrigerant:
    - HFO-1234yf
    - R-744
    - R-152a SLS

Effect of increased evaporating temperature



The adoption of an increased evap. temp. strategy helps saving 600 kg CO_2 emissions over 200000 km (equivalent to 4000 km mileage)

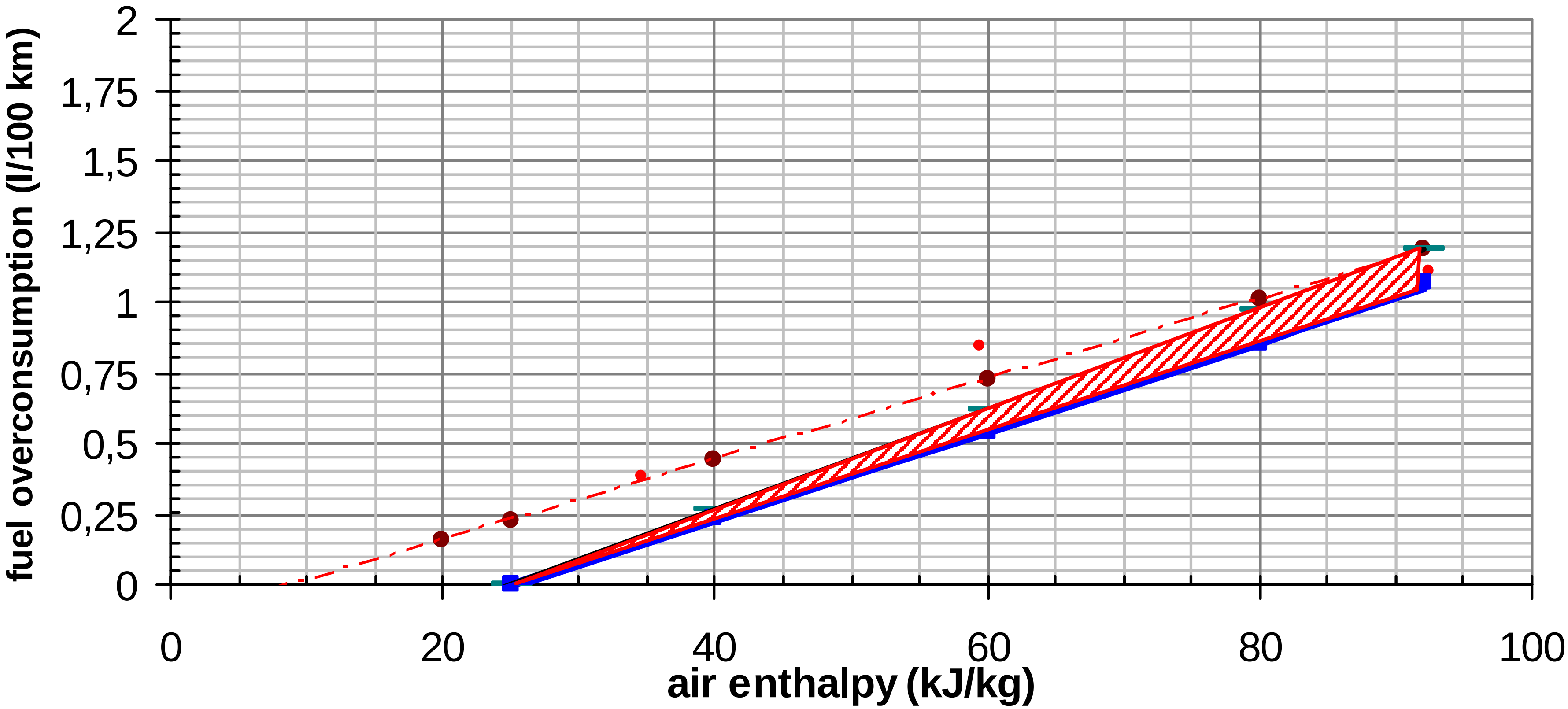
Effect of increased evaporating temperature

FIAT GROUP

town	enthalpy (kJ/kg)			fuel overconso		CO_2eq		avg indirect emissions	emissions over
	min	avg	max	l/y	%	g/km	kg/y		200 000 km
Munchen	-15	22	61	-10	-1%	-2	-32	-2 gCO2/km	-488 kgCO2
Stuttgart	-12	24	65	-11	-1%	-2	-33		
Hannover	-12	24	63	-11	-1%	-2	-34		
Dusseldorf	-10	26	62	-12	-2%	-2	-36		
Bruxelles	-3	26	59	-12	-2%	-3	-37		
London	2	28	64	-12	-2%	-3	-37		
Frankfurt	-11	27	65	-12	-2%	-3	-37	-3 gCO2/km	-592 kgCO2
Paris	-1	28	61	-13	-2%	-3	-39		
Valladolid	1	28	59	-13	-2%	-3	-39		
Turin	-9	31	78	-13	-2%	-3	-39		
Bursa	2	34	74	-14	-2%	-3	-41		
Ljubljana	-14	26	72	-14	-2%	-3	-41		
Athens	9	38	73	-19	-3%	-4	-59		
Phoenix	-1	40	80	-17	-2%	-4	-52	-3 gCO2/km	-613 kgCO2
Shanghai	-2	42	109	-11	-2%	-2	-35		
Belo Horizonte	28	53	86	-19	-3%	-4	-59		
New Delhi	13	56	109	-16	-2%	-3	-48		
Bombay	31	70	104	-11	-2%	-2	-34		
Calcutta	29	70	116	-11	-2%	-2	-34		

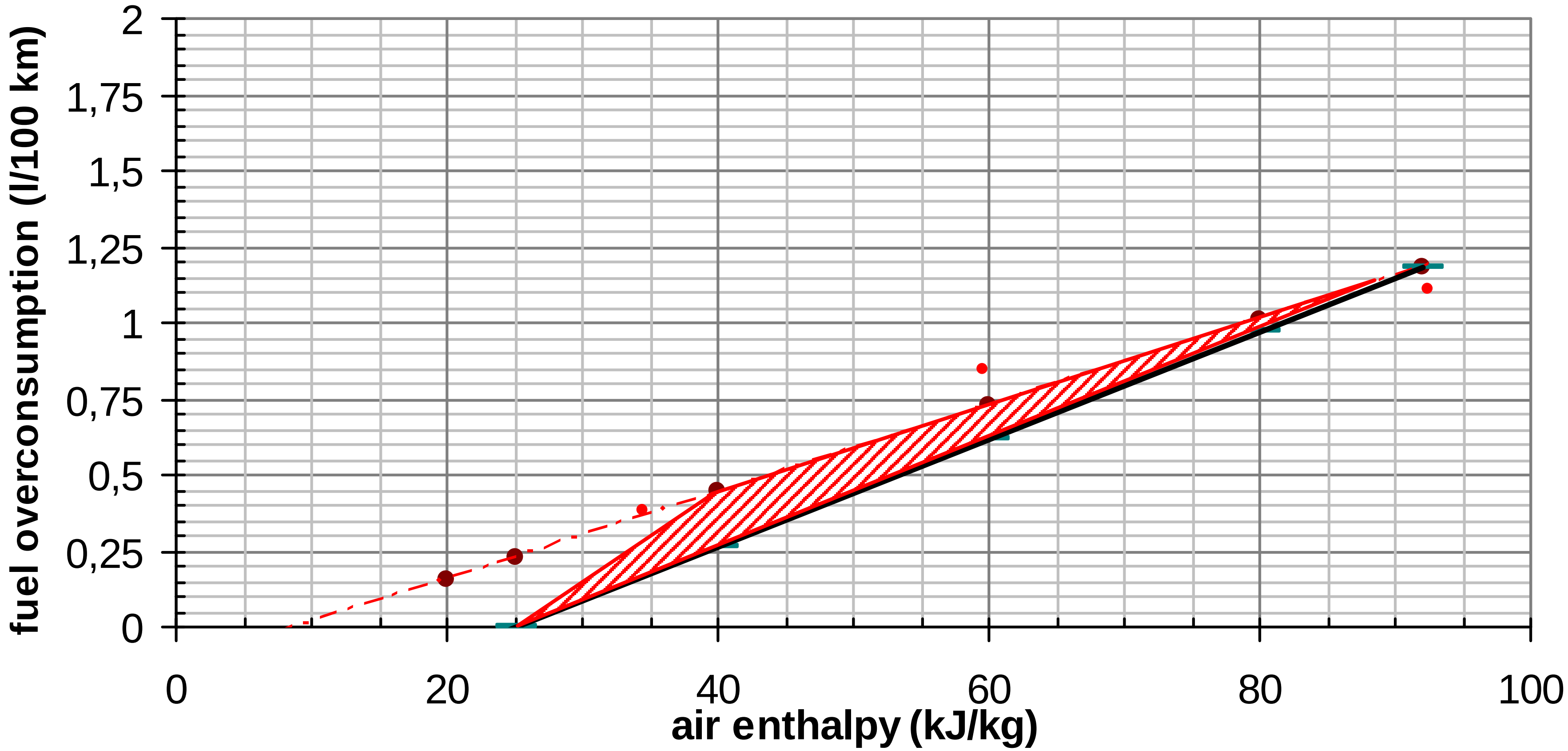
The “Phoenix table” applied to this driver allows to assess its effectiveness at different latitudes in the “real life” use

Effect of IHx adoption



The adoption of an IHx helps saving 500 kg CO_2 emissions over 200000 km (equiv. to 3200 km mileage)

Effect of PWM fan control



The adoption of a PWM fan control strategy helps saving 200 kg CO_2 emissions over 200000 km (equivalent to 1300 km mileage)

Effect of the refrigerant HFO-1234yf

town	enthalpy (kJ/kg)			fuel overconso		CO_2eq		avg indirect emissions	Δ(emissions) over
	min	avg	max	l/y	%	g/km	kg/y		200.000 km
Munchen	-15	22	61	0	0%	0	0	gCO2/km	-414 kgCO2
Stuttgart	-12	24	65	0	0%	0	0		
Hannover	-12	24	63	0	0%	0	0		
Dusseldorf	-10	26	62	0	0%	0	0		
Bruxelles	-3	26	59	0	0%	0	0		
London	2	28	64	0	0%	0	0		
Frankfurt	-11	27	65	0	0%	0	0	gCO2/km	-495 kgCO2
Paris	-1	28	61	0	0%	0	0		
Valladolid	1	28	59	0	0%	0	0		
Turin	-9	31	76	0	0%	0	0		
Bursa	2	34	74	0	0%	0	0		
Ljubljana	2	34	74	0	0%	0	0		
Athens	9	38	73	0	0%	0	0		
Phoenix	-1	40	80	0	0%	0	0	gCO2/km	-851 kgCO2
Shanghai	-2	42	109	0	0%	0	0		
Belo Horizonte	28	53	86	0	0%	0	0		
New Delhi	13	56	109	0	0%	0	0		
Bombay	31	70	104	0	0%	0	0		
Calcutta	29	70	116	0	0%	0	0		

The selection of a low GWP refrigerant helps saving 500 kg CO_2 emissions over 200000 km (equivalent to 3200 km mileage)

Effect of the refrigerant R-744

town	enthalpy (kJ/kg)			fuel overconso		CO_2eq		avg indirect emissions	Δ(emissions) over
	min	avg	max	l/y	%	g/km	kg/y		200.000 km
Munchen	-15	22	61	7	1%	2	22	2 gCO2/km	-79 kgCO2
Stuttgart	-12	24	65	8	1%	2	23		
Hannover	-12	24	63	8	1%	2	24		
Dusseldorf	-10	26	62	8	1%	2	24		
Bruxelles	-3	26	59	8	1%	2	25		
London	2	28	64	8	1%	2	26		
Frankfurt	-11	27	65	8	1%	2	25	2 gCO2/km	-95 kgCO2
Paris	-1	28	61	9	1%	2	26		
Valladolid	1	28	59	9	1%	2	27		
Turin	-9	31	78	8	1%	2	26		
Bursa	2	34	74	9	1%	2	28		
Ljubljana	2	34	74	9	1%	2	28		
Athens	9	38	73	13	2%	3	40		
Phoenix	-1	40	80	12	2%	3	36	2 gCO2/km	-430 kgCO2
Shanghai	-2	42	109	8	1%	2	24		
Belo Horizonte	28	53	86	12	2%	3	37		
New Delhi	13	56	109	11	1%	2	33		
Bombay	31	70	104	8	1%	2	25		
Calcutta	29	70	116	8	1%	2	25		

The selection of a low GWP refrigerant helps saving 100 kg CO_2 emissions over 200000 km (equivalent to 650 km mileage)

Effect of the refrigerant SLS R-152a

town	enthalpy (kJ/kg)			fuel overconso		CO_2eq		avg indirect emissions	Δ(emissions) over 200.000 km
	min	avg	max	l/y	%	g/km	kg/y		
Munchen	-15	22	61	-2	95%	0	-7	-1 gCO2/km	-254 kgCO2
Stuttgart	-12	24	65	-2	89%	-1	-7		
Hannover	-12	24	63	-2	87%	-1	-7		
Dusseldorf	-10	26	62	-3	81%	-1	-9		
Bruxelles	-3	26	59	-3	80%	-1	-8		
London	2	28	64	-3	77%	-1	-8		
Frankfurt	-11	27	65	-3	85%	-1	-9	-1 gCO2/km	-355 kgCO2
Paris	-1	28	61	-3	78%	-1	-10		
Valladolid	1	28	59	-3	80%	-1	-10		
Turin	-9	31	78	-5	87%	-1	-15		
Bursa	2	34	74	-5	83%	-1	-16		
Ljubljana	-14	26	72	-5	83%	-1	-16		
Athens	9	38	73	-6	92%	-1	-18		
Phoenix	-1	40	80	-7	90%	-1	-20	-3 gCO2/km	-819 kgCO2
Shanghai	-2	42	109	-8	87%	-2	-24		
Belo Horizonte	28	53	86	-12	87%	-3	-38		
New Delhi	13	56	109	-12	87%	-3	-37		
Bombay	31	70	104	-17	83%	-4	-51		
Calcutta	29	70	116	-17	83%	-4	-51		

The selection of a low GWP refrigerant helps saving 350 kg CO_2 emissions over 200000 km (equivalent to 60000 km mileage)

Comparison of the drivers' potentials

- The presented reduction drivers might be all applicable to the three alternative refrigerants but the Internal Heat Exchanger, which has already been introduced into the R-744 MACS to achieve the featured performance
- The overall benefit of the possible adoption those single measures, with their mutual interaction, might be assessed via an hybrid (virtual/test) tool; the possible tools are currently under investigation at ACEA SG-AirCo
- The potential benefit of the IHx is of the same order of magnitude of the R-134a direct emissions contribution to the LCCP
- Fuel Efficiency still missing to the R-744 MACS to reach the baseline level partially jeopardizes its beneficial effect on direct emissions abatement
- Potential further improvements of the R-744 have been investigated: despite the effort to fit our target vehicle with an improved technology compressor, tailored to a small engine, we are at a stalemate condition...

Conclusion and Outlook

- The presented assessment, referred to the data available to date, gave first useful comparisons among the all set of possible levers
- The evaluation of the potentials is featured on the basis of the TEWI to reduce the uncertainties' effect; a further step will be to adapt the presented approach to the LCCP assessment
- According to the available data at FGA, the R-744 MACS is "still" less efficient than an enhanced R-1234yf MACS: therefore, despite the R-744 lowest GWP, in terms of global environmental impact the R-1234yf would be the best solution
- The Secondary Loops would allow to exploit additional fuel saving opportunities (integration between the MACS and the engine control strategies) with any refrigerant!

Contact

Roberto MONFORTE

FIAT Group Automobiles S.p.A.

Engineering&Design - Interiors

HVAC - Advanced Design

C.so Settembrini, 40

10135 - Torino, ITALY

☎ +39.011.00.38188

✍ roberto.monforte@fiat.com