Life Cycle Climate Performance [LCCP] in Mobile Air Conditioning

Matti Vainio, European Commission

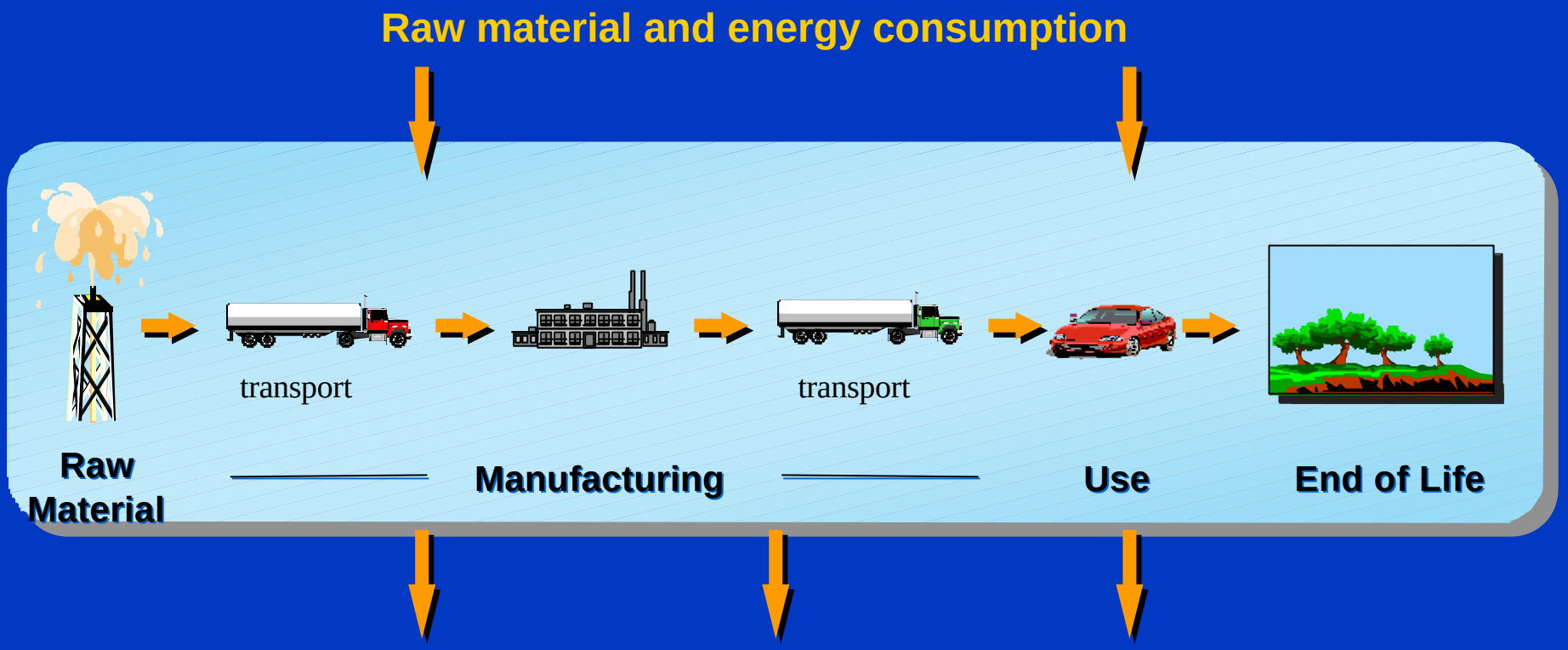
with contributions from

Stephen Andersen, Ward Atkinson, Denis Clodic, Rob Farrington, Jochen Harnisch, William Hill, Stella Papasavva and Winfried Schwarz

Purpose

- Based on the contributions of two presentations on greenhouse gas emissions from refrigerant (HFC-134a) and fuel consumption (CO2) complete the picture:
  - identify the life cycle climate performance of today's MACs in EU-15

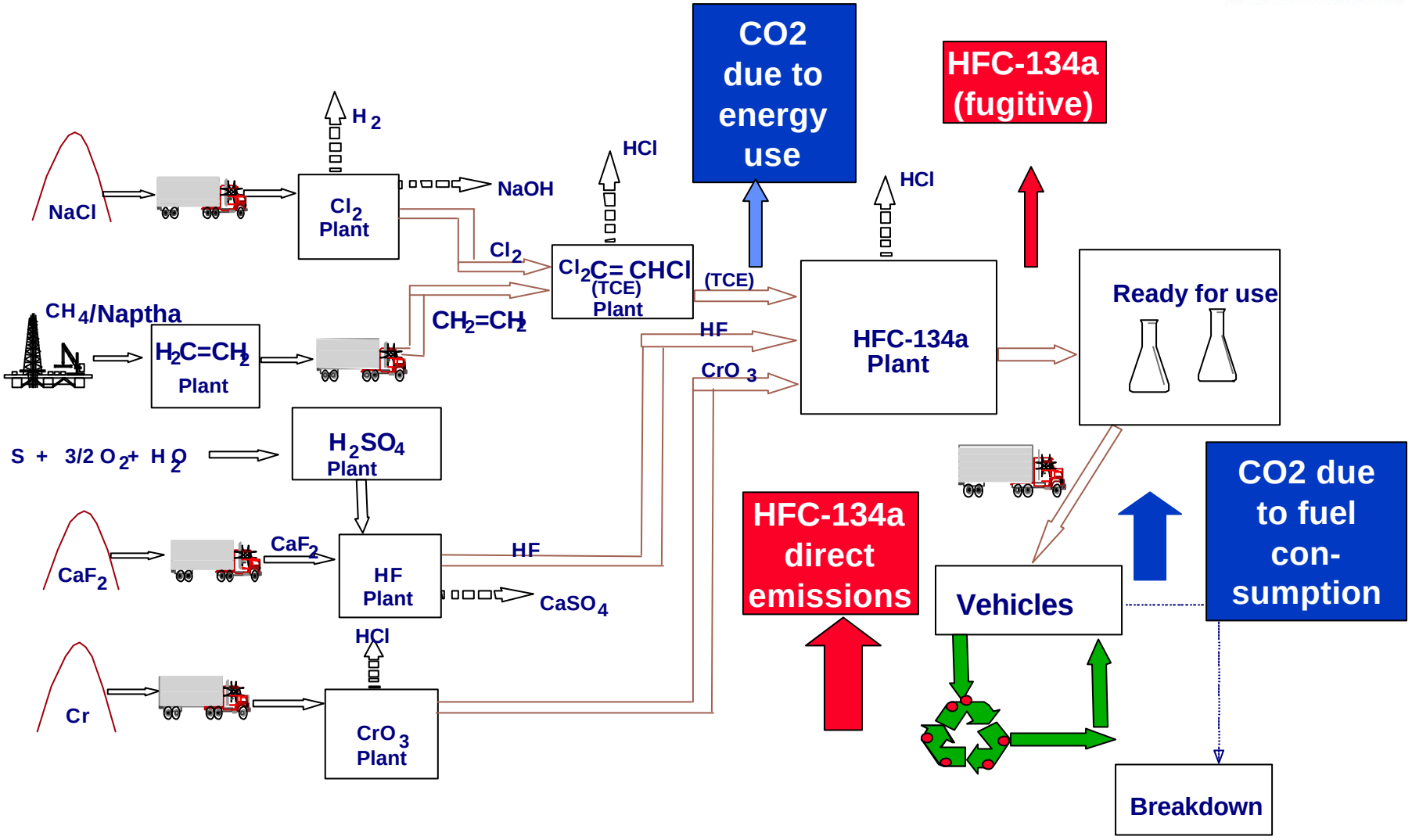
What is Life Cycle Climate Performance (LCCP)?



LCCP for MACs

- Includes AC operation only
  - Heater operation excluded (little data)
- Includes refrigerant components only
  - No plastic case parts or duct parts included
- Includes all energy emissions related to blower and cooling fan and an estimated energy conversion factor
- System components to be sized for equivalent performance
- Does not include engine/transmission efficiency variations
  - Should assume some nominal performance for reference
- Should be done according to ISO 14040-14044 standards for life cycle assessment

LCCP-Overview



Source: S. Papasavva, Ph.D Thesis, 1997, Tufts University "*Reducing the Risk of Global Warming from CFC Alternatives: A Scientific Basis for Policy Options*"

LCCP - Issues to address

- Decide why to carry out the LCCP
  - to get an order of magnitude (policy makers) or
  - to calculate differences between car makes (vehicle manufacturers)?
- Laboratory test data should be used based on difficulty of getting precise data from vehicle tests
- Different vehicle classes as well as regional driving cycles and ambient profiles should be used
- Conventional air pollutant emissions and their effect on AC operation are excluded
- CO2 emissions vary due to fuel mix differences

LCCP vs. Total Equivalent Warming Impact (TEWI)

Mac Summit 2003

Components to be included in LCCP

Emissions before MAC use

- CO_2 emissions due to energy needed to produce MACs
  - Raw materials used for producing MAC
  - Assembly energy
- Fugitive emissions and energy for manufacturing of refrigerant
  - Refrigerant emissions
  - CO_2 emissions
  - Initial charge plus lifetime re-charges

Emissions during MAC use

- CO_2 emissions
  - Mechanical and electrical energy
  - Affect of weight of MAC
- Direct emissions of refrigerant
  - "Controlled" leakage
  - "Uncontrolled" leakage
  - Emissions during service/repair

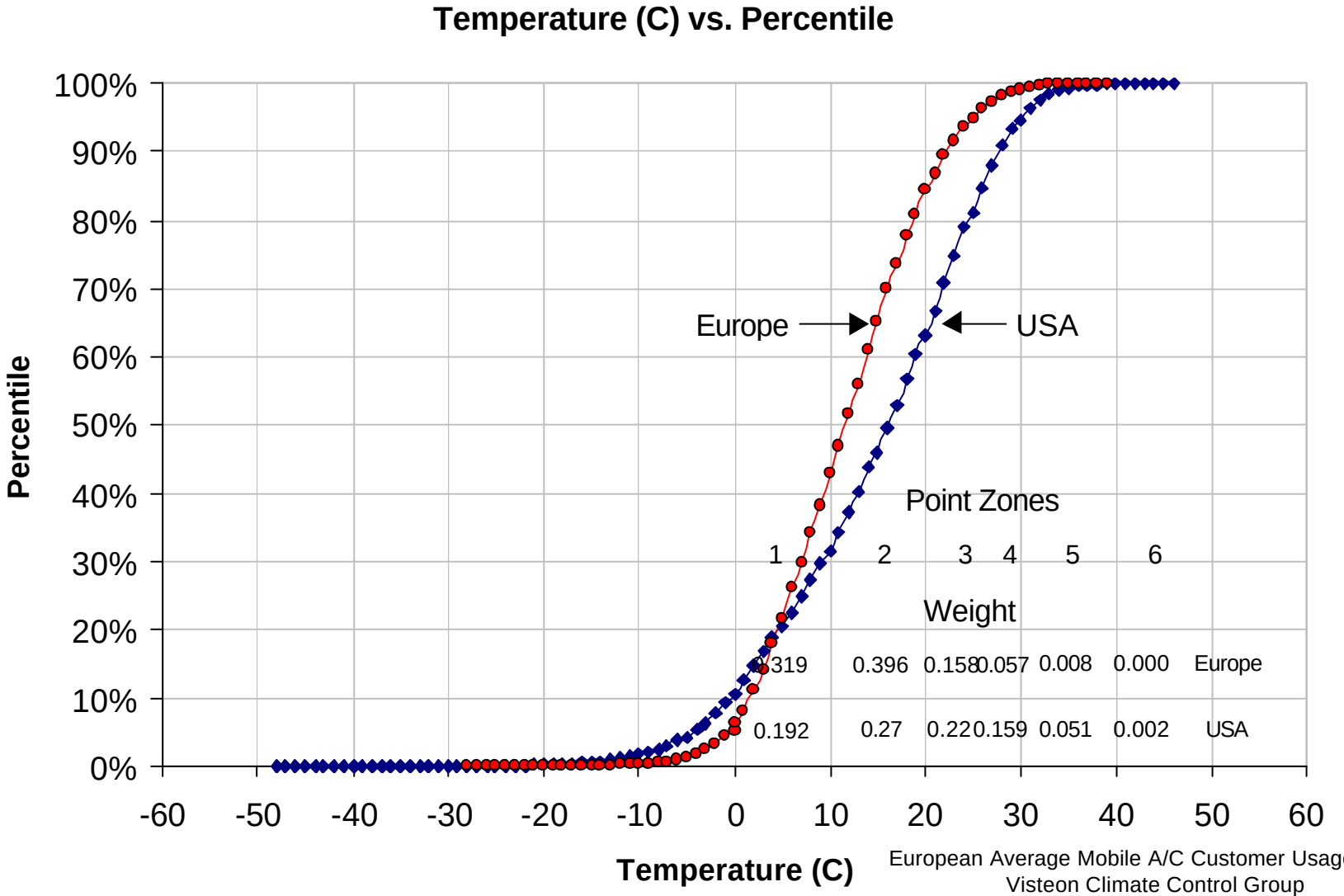
End-of-life of MAC

- Refrigerant losses during re-cycling
- CO_2 emissions due recycling and destruction of refrigerant (energy)

CO2 emissions due to energy needed to produce MACs

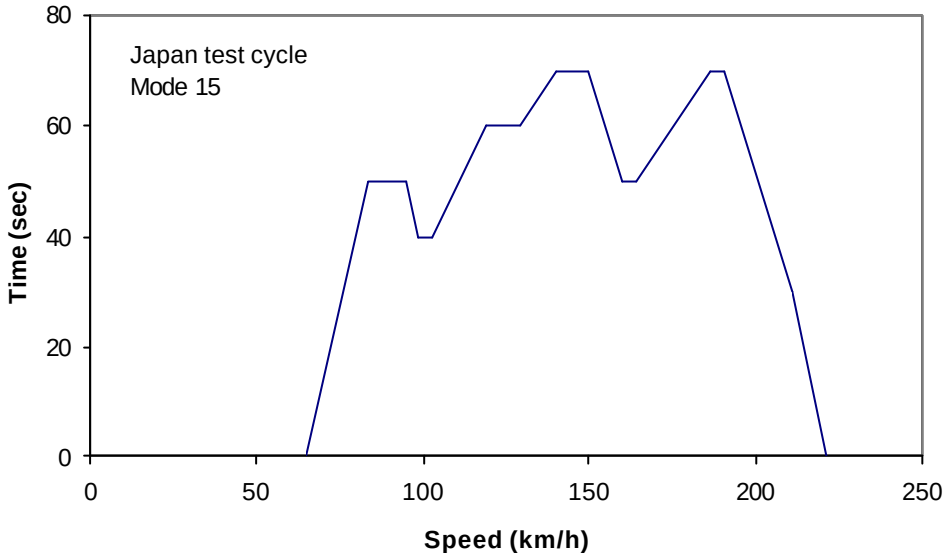
Energy Consumped and CO2-Equivalents Emitted from the Manufacture of A/C Components			
R134a/Baseline	Energy of Production (MJ/kg)	(kg)	(MJ)
Compressor		.4	603.0
Aluminum Casting		2.6	321.3
Aluminum Forgings		1.3	177.9
Elastomers	103	0.3	33.0
Steel Forging	22.5	1.0	21.6
Copper Alloys	55	0.5	28.2
Steel Castings	17	0.6	10.9
Plastics	80	0.1	10.2

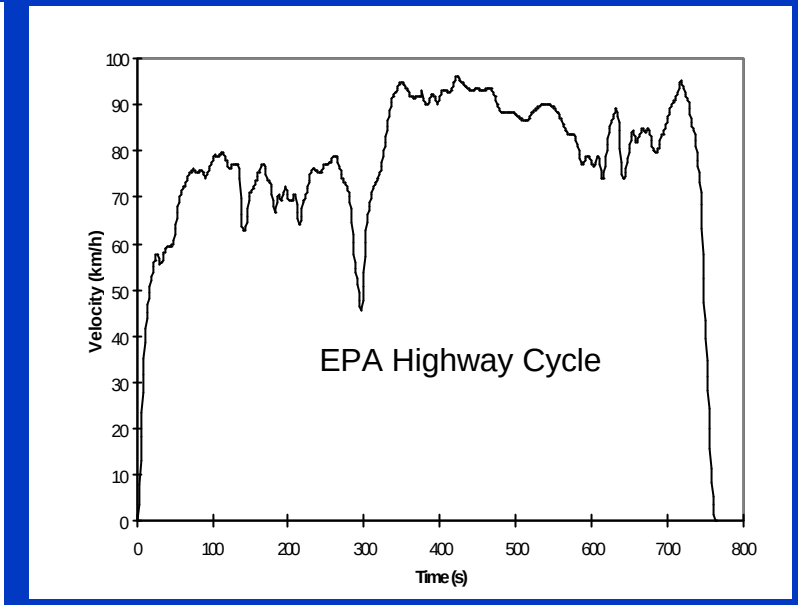
LCCP - CO2 emission “during use” depend on ambient driving conditions

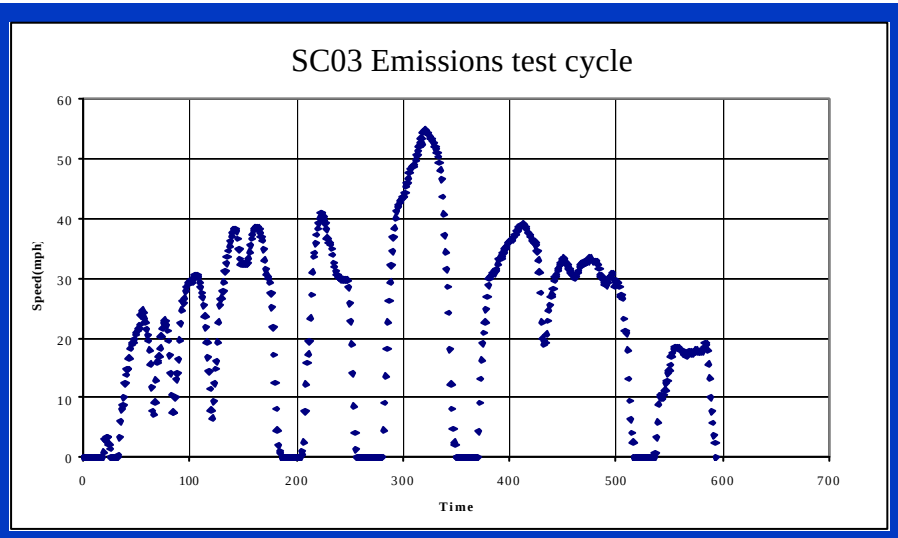


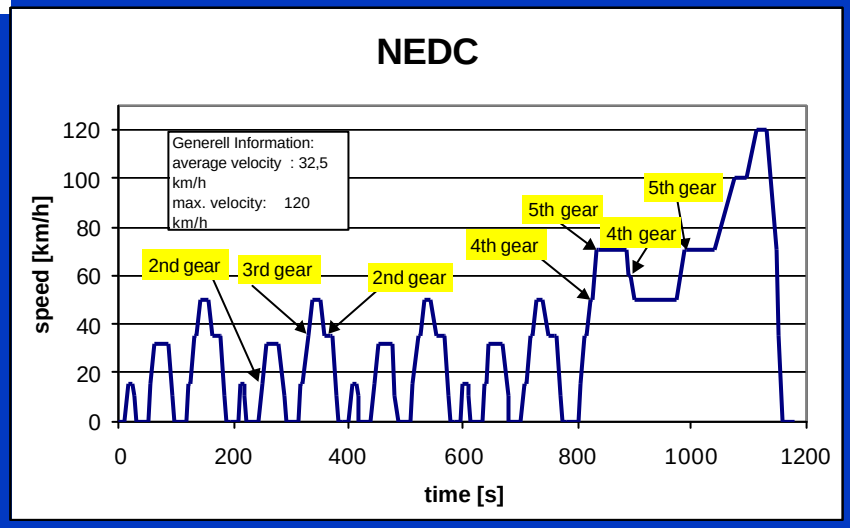
European Average Mobile A/C Customer Usage Model
Visteon Climate Control Group
Graham S. Duthie, Shane Harte, Vijit Jayasheela

… and driving cycles









Example: "Optimistic" case in EU15

Note: Assuming NO technological change...

Emissions before MAC use

- CO2 emissions due to energy needed to produce MACs
  - 1675 MJ
  - EU fuel mix 51,3 t kg CO2/MJ
- Fugitive emissions and energy for manufacturing of refrigerant
  - Refrigerant emissions (about 1%) (including "heels")
  - CO2 emissions (77 kg CO2/1 kg of HFC-134a)

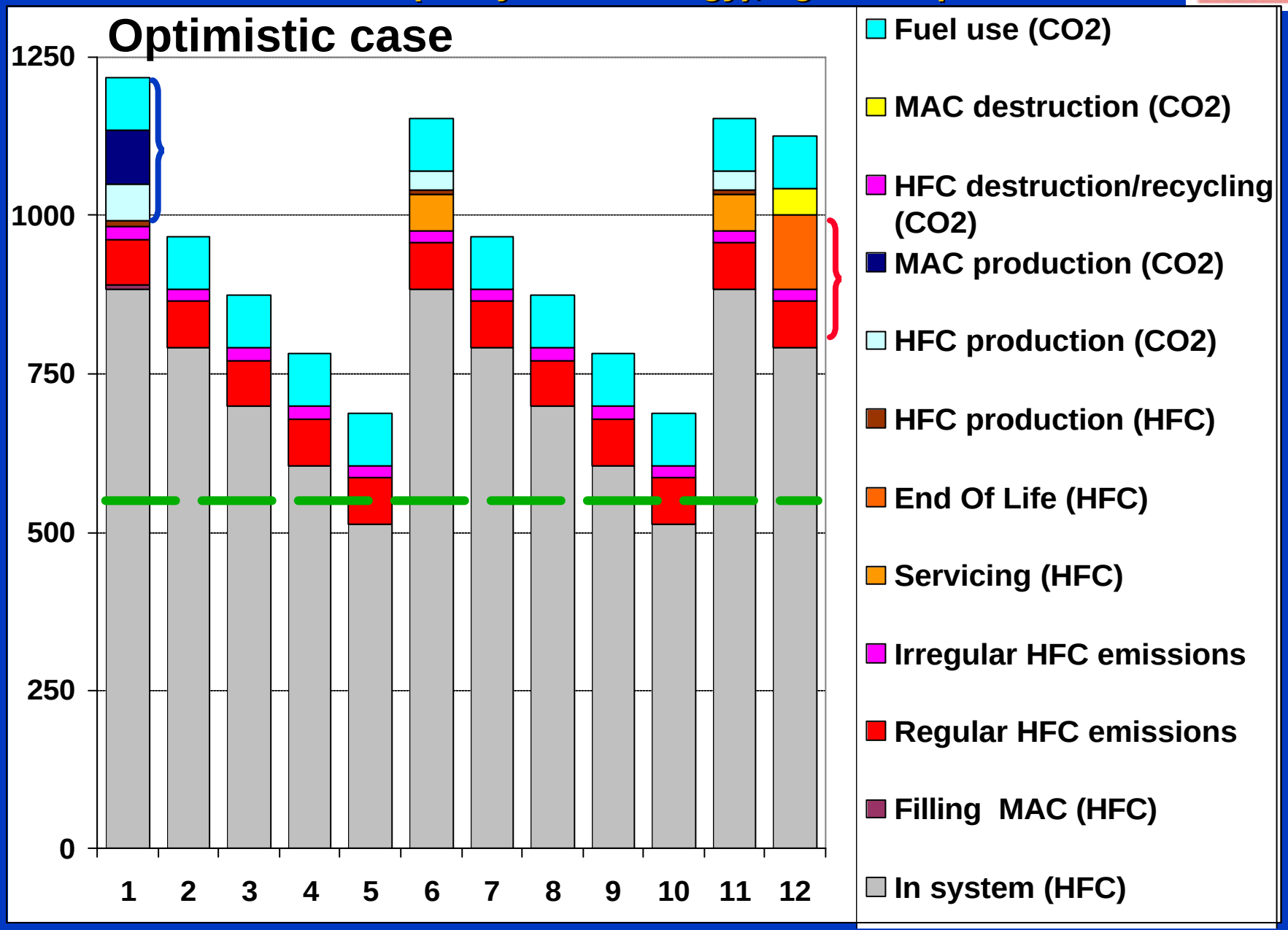
Emissions during MAC use

- CO2 emissions
  - 4% additional
- Direct emissions of refrigerant
  - "Controlled" leakage 57 g/ year
  - "Uncontrolled" leakage 1.9%/year
  - Emissions during service/repair
    - 6% of charge or 45 grams per service

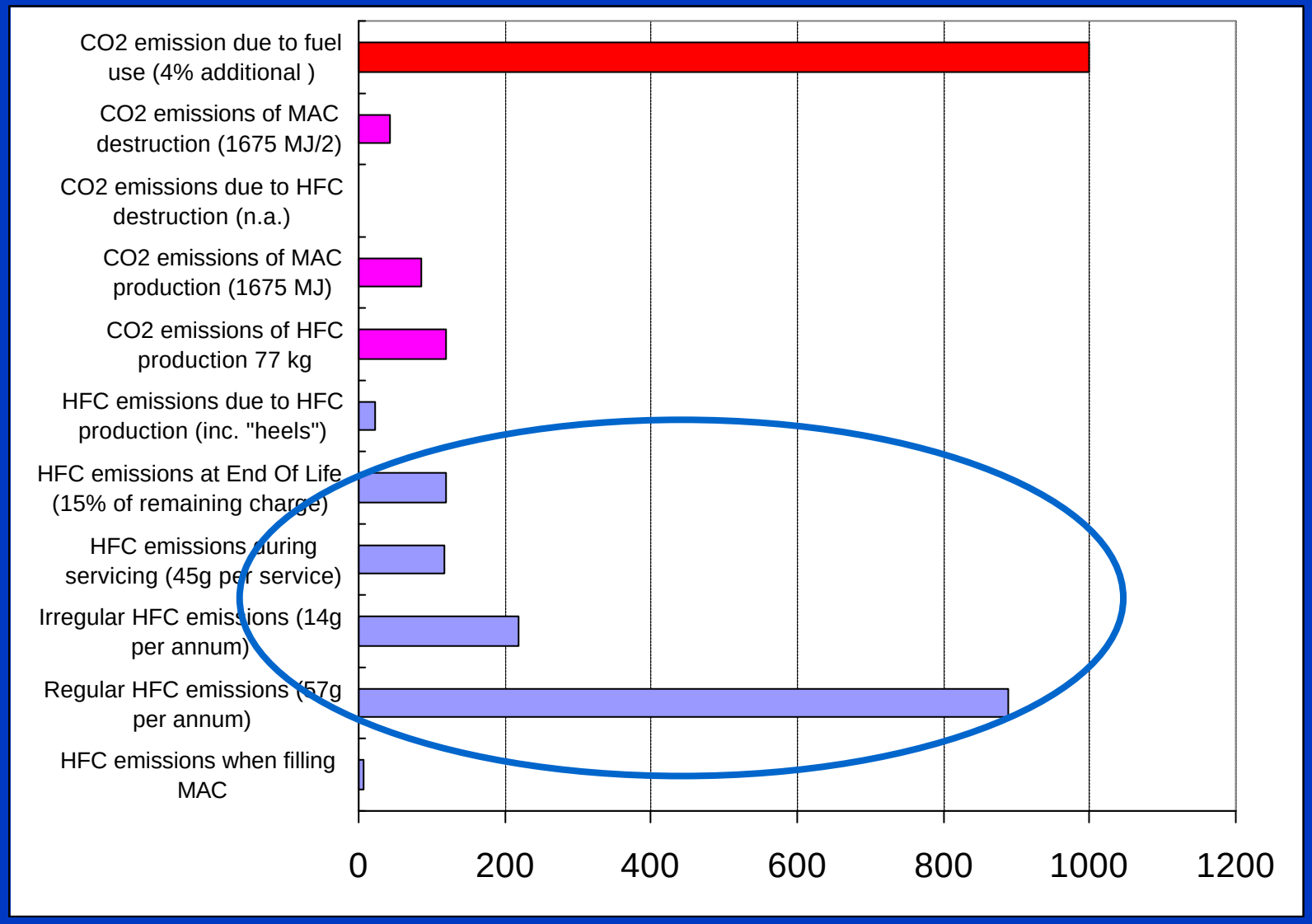
End-of-life of MAC

- Refrigerant losses during re-cycling (15%)
- CO2 emissions due recycling and destruction of refrigerant (energy) (n.a.)

Lifecycle emissions of a MAC in the EU car (today's technology), kg CO2 eq



LCCP of R-134a in the EU: "Optimistic" case (kg CO2 eq).



LCCP of R-134a in the EU: "Optimistic" case (kg CO2 eq) 17 g/km

Lifecycle emissions of an HFC-134a MAC	kg CO2 eq	Share
HFC emissions when filling MAC	7	0%
Regular HFC emissions (57g per annum)	889	34%
Irregular HFC emissions (14g per annum)	218	8%
HFC emissions during servicing (45g per service)	117	4%
HFC emissions at End Of Life (15% of remaining charge)	119	5%
HFC emissions due to HFC production (inc. "heels")	23	1%
CO2 emissions of HFC production 77 kg	119	5%
CO2 emissions of MAC production (1675 MJ)	86	3%
CO2 emissions due to HFC destruction (n.a.)	0	0%
CO2 emissions of MAC destruction (1675 MJ/2)	43	2%
CO2 emission due to fuel use (4% additional)	998	38%
Total	2620	100%

Example: “Realistic” case in EU15

Emissions before MAC use

- same as before

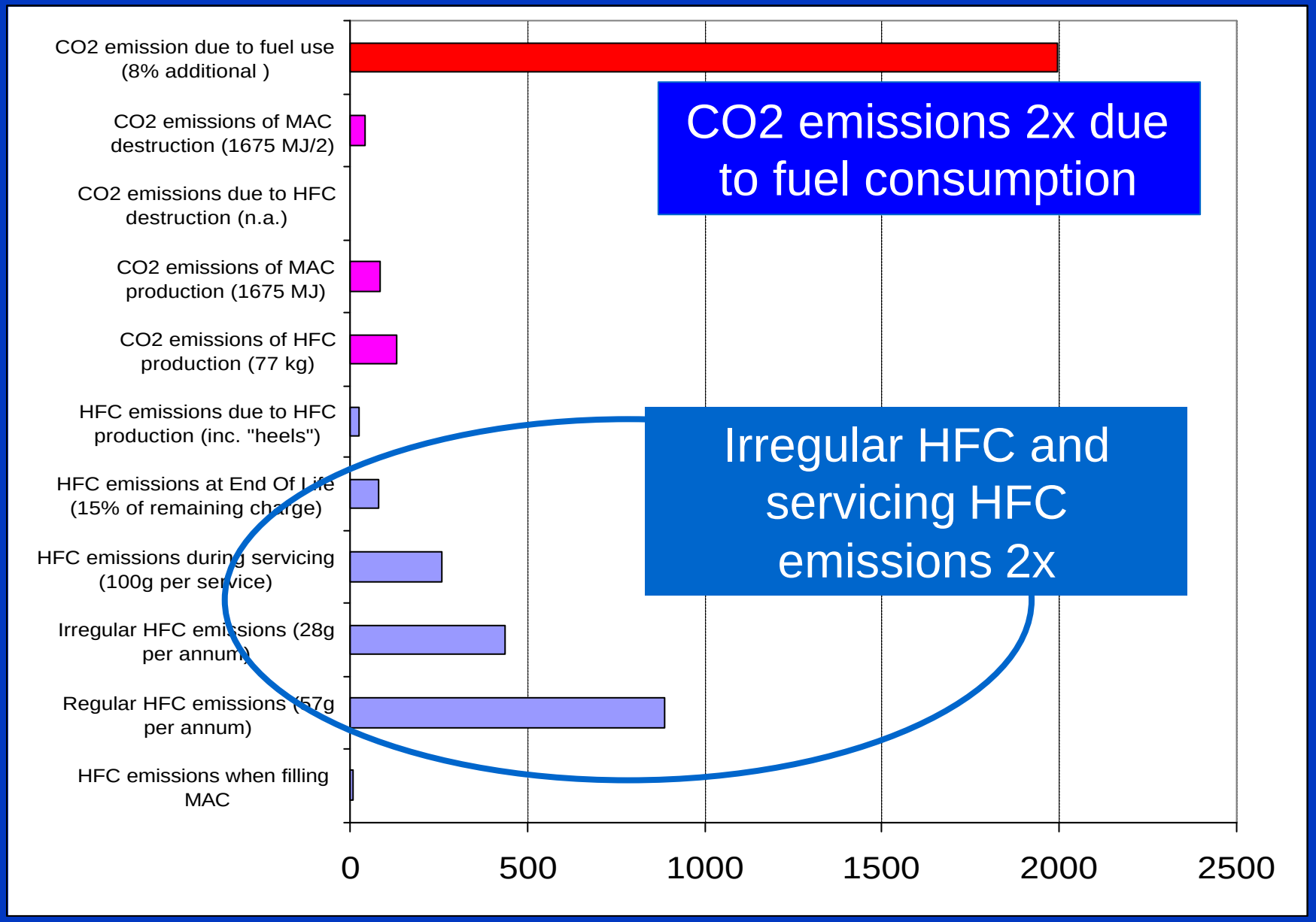
Emissions during MAC use

- CO_2 emissions
  - twice as high (8%)
- Direct emissions of refrigerant
  - “Controlled” leakage same
  - “Uncontrolled” leakage twice as high (3.8%/year)
  - Emissions during service/repair
    - over twice as high (100 grams per service)

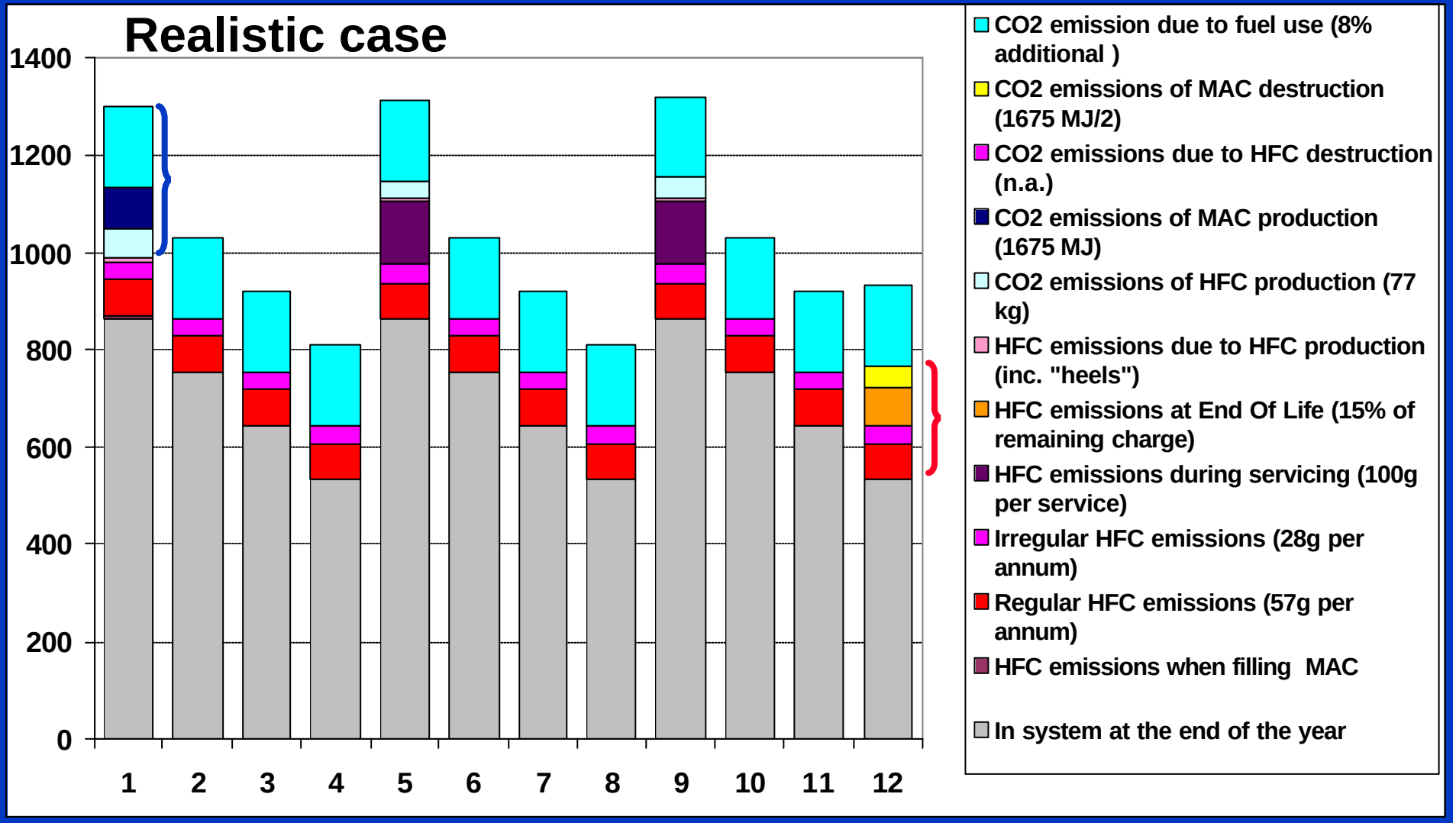
End-of-life of MAC

- same as before

LCCP of R-134a in the EU: "Realistic" case (kg CO2 eq).



Lifecycle emissions of a MAC in the EU car (today's technology), kg CO2 eq



LCCP of R-134a in the EU: "Realistic" case (kg CO2 eq) 25 g/km

Lifecycle emissions of an HFC-134a MAC	kg CO2 eq	Share
HFC emissions when filling MAC	7	0%
Regular HFC emissions (57g per annum)	889	22%
Irregular HFC emissions (28g per annum)	437	11%
HFC emissions during servicing (100g per service)	260	7%
HFC emissions at End Of Life (15% of remaining charge)	80	2%
HFC emissions due to HFC production (inc. "heels")	25	1%
CO2 emissions of HFC production (77 kg)	132	3%
CO2 emissions of MAC production (1675 MJ)	86	2%
CO2 emissions due to HFC destruction (n.a.)	0	0%
CO2 emissions of MAC destruction (1675 MJ/2)	43	1%
CO2 emission due to fuel use (8% additional)	1997	50%
Total	3955	100%

Policy relevance

- "Optimistic" case, LCCP of a MAC of 2.6 kg CO2 eq
  - if no technological progress
  - equal to about 17 g/km of CO2 eq
  - 32 Mt CO2 eq in 2010
    - assuming 70% of EU15 vehicles have a MAC
  - over 40 Mt CO2 eq in 2020
    - with 95% share

- "Realistic" case, LCCP of a MAC of 4.0 kg CO2 eq
  - if no technological progress
  - equal to about 25 g/km of CO2 eq
  - 48 Mt CO2 eq in 2010
    - assuming 70% of EU15 vehicles have a MAC
  - over 60 Mt CO2 eq in 2020
    - with 95% share

There is also a "pessimistic" case where emissions in 2010 would be over 50 Mt and in 2020 almost 90 Mt

Conclusion

- It is possible to get a good order of magnitude of the greenhouse gas emissions of today's MACs
  - In the EU, the good progress made to reduce CO2 emissions from cars by 25% up to 2008/9 is eroded by the increase of greenhouse gas emissions from MACs
  - It seems that about half of the projected gains would be lost due to MACs
- It is possible (but more difficult) to get the order of magnitude estimated for "tomorrow's" MACs
- It might be a good idea to standardize the definitions and terminology when LCCP is carried out
  - Issue to agree upon during VDA Winter Meeting?