United Nations Forum on Climate Change Mitigation,
Fuel Efficiency and Sustainable Urban Transport

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Reducing the climate impacts of mobile air conditioning

Comparison of global warming effects among HFC-134a, R-744(CO_2), and HFO-1234yf by TWPG, CWP, and CEWN analyses

Akira Sekiya

National Institute of Advanced Industrial Science and Technology (AIST)

Background and targets

Climate Change Mitigation is the most important issue for environment.
Target (UNFCCC): "stabilization of greenhouse gas concentrations in the atmosphere"

Fuel Efficiency and Sustainable Urban Transport
- ⇒ Wide range of technologies are necessary. Power source, Urban system, ・・・・
- ⇒ Need to be analyzed by adequate methods.

Mobile Air Conditioning (MAC)
High GWP refrigerants have been used, however they have good properties in terms of energy saving.

History of refrigerants for MAC system

	CFC-11	→	**HFC-134a**	→	**HFO-1234yf**	HFC-152a	**R-744(CO_2)**
(GWP)	4,750	→	1,430	→	4	124	1
(energy use)			small		higher than 134a		large
(status)	phased out due to ODS		**in current use**		**under R&D**	--	**under R&D**

Comparison of environmental acceptability as refrigerant system is necessary.

This report

Mobil Air Conditioning refrigerants are evaluated in terms of global warming.

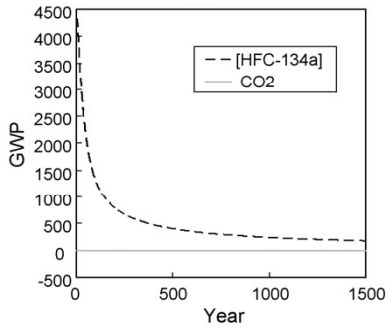
Warming Effects	
Indirect (Fuel Efficiency)	Direct (Refrigerant)
CO_2 >> HFO-1234yf > HFC-134a	HFC-134a >> HFO-1234yf > CO_2

1) Use JAMA's LCCP data for MAC (Mobile Air Conditioning) system.
2) Not only GWP, but also new indicators, TWPG, TTPG, CWP, and CEWN are used for the evaluation of global warming.
3) The most important technology is discussed by comparing these results.

LCCP : Life Cycle Climate Performance
TWPG : Total Warming Prediction Graph
CWP : Composite Warming Potential
GWP : Global Warming Potential
TTPG : Total Temperature Change Prediction Graph
CEWN : Carbon Dioxide Equivalent Warming Number

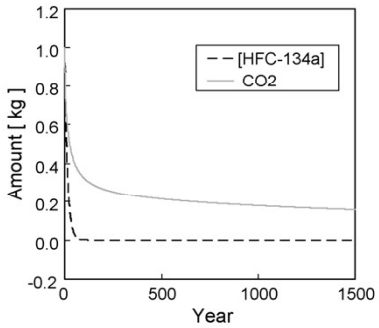
GWP and new indicators, TWPG and CWP

(a) GWP



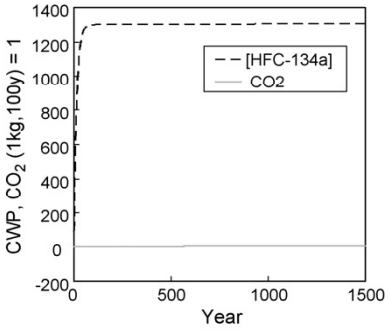
The relative direct warming effect values

(b) TWPG(kg)



The residual amount in the atmosphere

(c) CWP



The relative integrated warming effect, TWPG (W m^{-2})

GWP, TWPG (kg) and CWP evaluation for 1 kg release of HFC-134a and CO_2.

A. Sekiya, J. Fluorine Chem., 128, pp.1137-1142, 2007

A. Sekiya, United Nations Forum on Climate Change Mitigation, Seoul, March 16-17, 2010

MAC System*

Model framework and input assumptions for the evaluation

Car service life : 10 years
Car engine type : 1.5L Gasoline
4.3L Gasoline

Data points : Phoenix, Tokyo, Frankfurt
Data : Energy consumption, leakage rate, etc.

Refrigerant
- HFC-134a, CO_2, HFO-1234yf
- HFC-152a (simulated as secondary loop)
- DP-1 (NA : chemical structure unknown)

Direct emission (refrigerant leaks)
- Leakage from refrigerant production and transportation
- Regular emissions
- Irregular emissions
- Service emissions
- End-of-life emissions
  ← recovery rate of the refrigerant after 10-year-usage

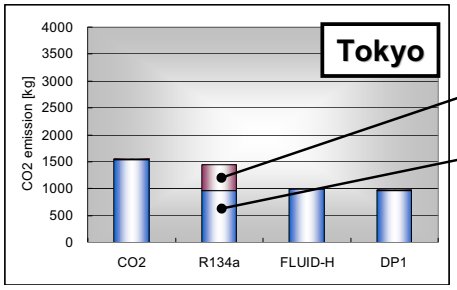
Indirect emission (Energy consumption)
- AC system and engine cooling fan operation
- A/C system manufacturing
- Refrigerant manufacturing
- Transportation of each component
- End-of-life recycling and recovery

*) JAMA, SAE 8th Alternate Refrigerant Systems Symposium, 17-19 July 2007

GWP due to the use of car air-conditioning

LCCP Calculation by JAMA*

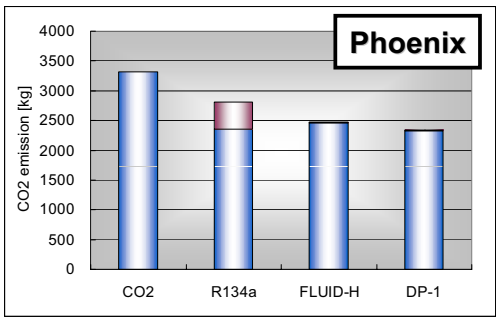
Compact Car (1.5L Gasoline Engine)

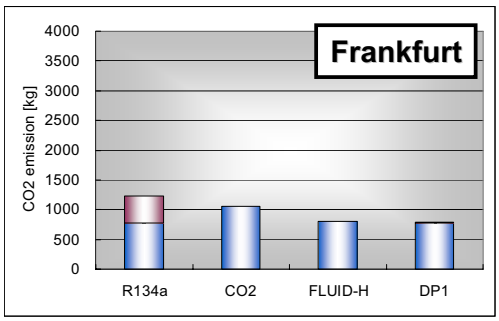


Direct emissions

Indirect emissions

R134a : HFC-134a
FLUID-H : HFO-1234yf
DP1 : unknown





*) SAE 8th Alternate Refrigerant Systems Symposium, 17-19 July 2007

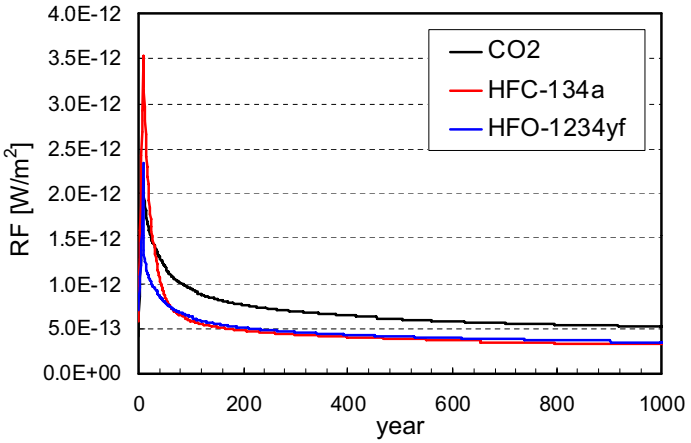
TWPG due to the use of car air-conditioning

Tokyo, Compact Car (1.5L Gasoline Engine)

direct emissions + indirect emissions

1 car is produced at the beginning

TWPG (Radiative forcing vs Time)



- duration of use : 10 years
- recovery rate of refrigerant after the use : 90%

direct emissions : leakage of refrigerant through the life of the car

indirect emissions : energy consumption due to A/C operation, manufacturing, recycling, etc.

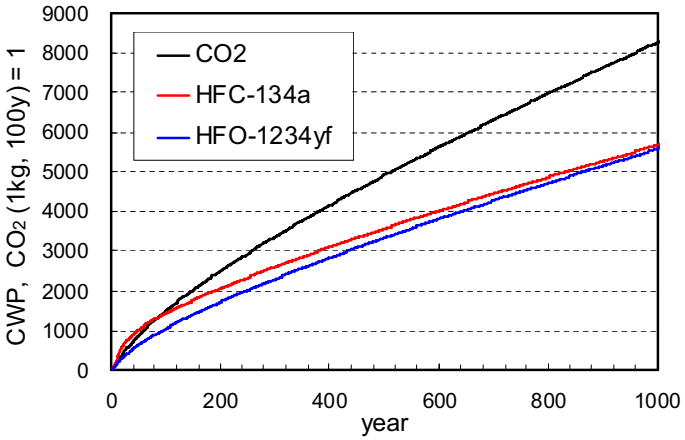
A. Sekiya, United Nations Forum on Climate Change Mitigation, Seoul, March 16-17, 2010

CWP due to the use of car air-conditioning

Tokyo, Compact Car (1.5L Gasoline Engine)

direct emissions + indirect emissions

1 car is produced at the beginning



- duration of use : 10 years
- recovery rate of refrigerant after the use : 90%

CO_2 >> HFC-134a > HFO-1234yf

direct emissions : leakage of refrigerant through the life of the car

indirect emissions : energy consumption due to A/C operation, manufacturing, recycling, etc.

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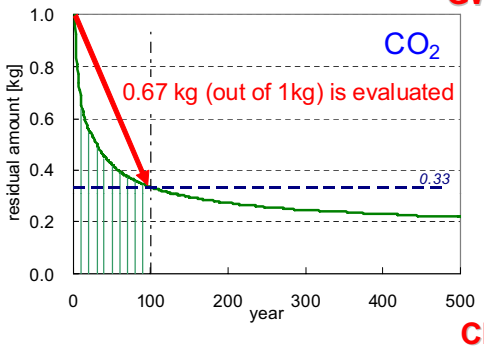
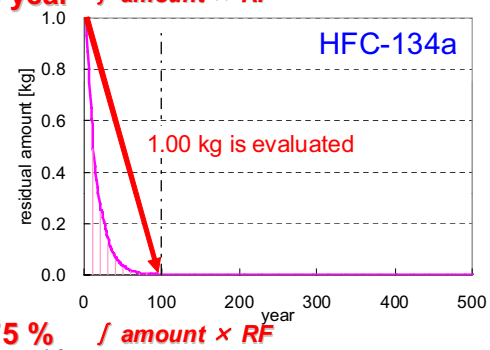
Difference between GWP and CEWN*

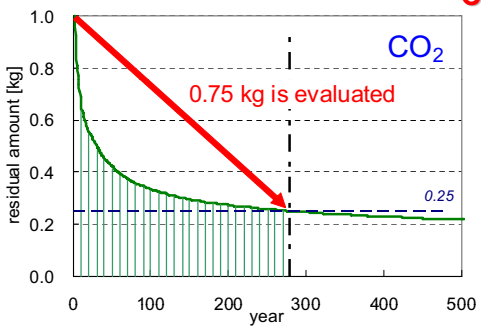
Decay after the **1kg release** of CO_2 and HFC-134a into the atmosphere

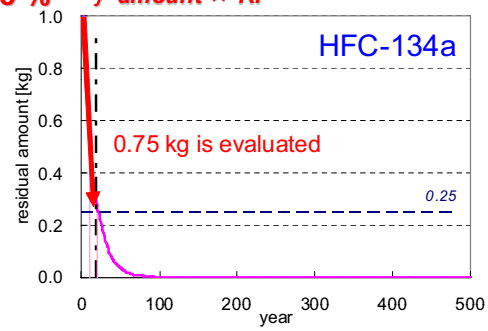
GWP 100 year ∫ *amount × RF*





CEWN 75 % ∫ *amount × RF*





CEWN: Carbon Dioxide Equivalent Warming Number

*) A. Sekiya, et al., J. Fluorine Chem., 131, pp.364-368, 2010

Feature of CEWN

	GWP_{100}	CEWN
concept	integrated warming values up to 100 years after the emission	integrated warming values up to equal removal rate from the atmosphere
evaluation period	100 years	lifetime-dependent
evaluation amount	long-lived gases : partial eval. short-lived gases : total eval.	equivalent quantity evaluation by unifying the removal rate
long-term evaluation	impossible due to uncertainty over long-term behavior of CO_2	longer evaluation is possible within the range where the behavior of CO_2 is clear
point (years, rates) settings	"100 years" is arbitrary	Higher rates are desirable. Progress of CO_2 research can be reflected.
relationship with climate impacts	weak	strong
characteristics of evaluation	one-sided evaluation	sustainability is evaluable

CEWN values

A. Sekiya, et al., J. Fluorine Chem., 131, pp.364-368, 2010

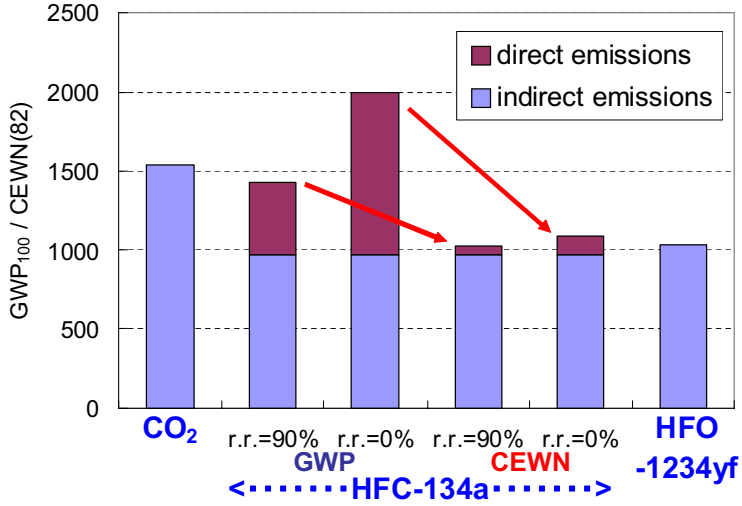
Common Name	Chemical Formula	Lifetime [years]	CEWN (75)	CEWN (80)	CEWN (82)	GWP_{100}*
Years until CO_2 decreases by the given removal rate [years]			279	728	1445	
Years until gas X decreases by the given removal rate / Lifetime of gas X			1.39	1.61	1.71	
Carbon dioxide	CO_2	-	1	1	1	1
Methane	CH_4	12	8.75	4.60	2.79	25
Nitrous oxide	N_2O	114	191	100	60.9	298
CFC-11	CCl_3F	45	1993	1048	636	4750
HCFC-22	$CHClF_2$	12	675	355	215	1810
HCFC-141b	CH_3CCl_2F	9.3	271	143	86.4	725
HFC-32	CH_2F_2	4.9	252	133	80.4	675
HFC-125	CHF_2CF_3	29	1352	711	431	3500
HFC-134a	CH_2FCF_3	14	534	281	170	1430
HFC-152a	CH_3CHF_2	1.4	46.4	24.4	14.8	124
HFO-1234yf	$CF_3CF=CH_2$	0.03	1.41	0.74	0.45	3.8 **
Nitrogen trifluoride	NF_3	740	53267	28017	16992	17200
PFC-14	CF_4	50000	1382736	727285	441104	7390
PFC-218	C_3F_8	2600	87502	46024	27914	8830

RF_{CO2} used for the calculation is 1.805×10^{-15} [W m^{-2} kg^{-1}]
The coefficients for concentration response function of CO_2 : the same as Shine, Climatic Change, 68, pp.281-302, 2005.
*) Quoted from IPCC Climate Change 2007. **) Calculated in the same way of IPCC 2007.

CEWN* and GWP due to the use of car air-conditioning

Tokyo, Compact Car (1.5L Gasoline Engine)
duration of use : 10 years
Recovery rate of refrigerant after the use
: 90% or 0%

	GWP_{100}	CEWN(82)
CO_2	1	1
HFC-134a	1,430	170
HFO-1234yf	4	0.45



*) A. Sekiya, et al., J. Fluorine Chem., 131, pp.364-368, 2010

Summary

- What is GWP, TWPG, CWP and CEWN ?
- Evaluation results by TWPG, CWP and CEWN using JAMA's LCCP data

GWP		TWPG, CWP, CEWN
Evaluation results of Compact Car (1.5L Gasoline engine)		
HFC-134a >>> CO_2 >> HFO-1234yf	⟷	CO_2 >>> HFC-134a > HFO-1234yf
Evaluation of future warming		
Not available	⟷	CO_2 >>> HFC-134a ~ HFO-1234yf
Effects of HFC-134a recovery on total warming		
significant	⟷	very small

CEWN results agree with those of TWPG, TTPG and CWP.

Sustainable MAC refrigerant: HFC-134a ≦ HFO-1234yf

LCCP by GWP shows only one side of global warming.
We may lead to serious problems in our future environment if we examine this matter with limited indicators, like GWP only.

Let's study the global warming using adequate and diverse evaluation methods.

A. Sekiya, United Nations Forum on Climate Change Mitigation, Seoul, March 16-17, 2010