Ranking of Refrigerants by Different Assessment Methods

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Introduction

- All chemicals and products have impact on the environment e.g. energy consumption, toxicity…
- Life Cycle Assessment (LCA) has the goal to investigate and evaluate the environmental impact

→ Several approaches and methods developed

- Refrigeration is an important aspect of our life style

Aim: Exemplary process: *air-conditioning system* in cars, 11 refrigerants

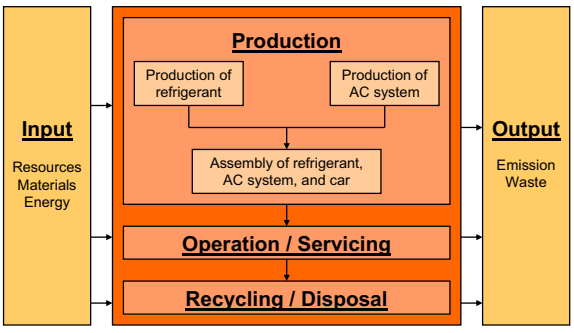
Comparison of 3 different LCA methods with the additional aim to find the most environmental suitable *replacement* for the presently used substance

Refrigerants applied to air-conditioning systems in this study

	Refrigerant	Chemical formula	Chemical name	GWP_{100}
Hydrochloro-carbon	**R30**	CH_2Cl_2	Methylene chloride	**10**[a]
Hydrofluoro-carbons	**R134a**	$C_2H_2F_4$	1,1,1,2-Tetrafluoroethane	**1410**[b]
	R152a	$C_2H_4F_2$	1,1-Difluoroethane	**122**[b]
Hydrocarbons	**R290**	C_3H_8	Propane	**20**[c]
	R600a	C_4H_{10}	Isobutane	**20**[c]
Di(fluoro)alkyl-ethers	**E125**	CF_3OCHF_2	Pentafluorodimethyl ether	**14800**[d]
	E134	CHF_2OCHF_2	1,1,1',1'-Tetrafluorodimethyl ether	**5760**[d]
Alkyl-fluoro-alkylethers	**E7000**	$CF_3(CF_2)_2OCH_3$	Heptafluoropropyl methyl ether	**450**[d]
	E7100	$CF_3(CF_2)_3OCH_3$	Methyl nonafluorobutyl ether	**410**[d]
	E7200	$CF_3(CF_2)_3OC_2H_5$	Ethyl nonafluorobutyl ether	**60**[d]
	R744	CO_2	Carbon dioxide	**1**[c]

[a] IPCC 2001, [b] IPCC 2006, [c] Devotta et al. 2005, [d] Tsai 2005

Life Cycle Inventory



Assessment Methods

1. Non-aggregated impact assessment: NAM
   → Separate categories
2. Aggregated method: Eco-Indicator 99
   → One indicator
3. Fast method: Total Equivalent Warming Impact
   → One index

1. Non-aggregated Method (NAM)

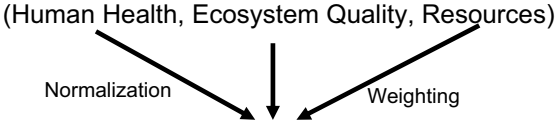
10 impact categories

- Primary energy demand
- Depletion of abiotic resources
- Global warming
- Ozone depletion
- Acidification
- Eutrophication
- Human toxicology
- Photo-oxidant formation (summer smog)
- Fresh water aquatic toxicity
- Terrestrial ecotoxicity

***Important*: NAM includes complete life cycle!**

2. Eco-Indicator 99

3 Damage categories
(Human Health, Ecosystem Quality, Resources)



EI99

***Important*: EI99 includes complete life cycle!**

3. Total Equivalent Warming Impact

Direct emissions of refrigerant

+

Indirect emissions of CO_2 and other greenhouse gases during energy production

↓

TEWI

***Important*: TEWI focuses on operation phase!**

Ranking from the NAM Assessment Method

Refrigerant	ADP	ODP	PE	GWP	AP	EP	POCP	HT	FAETP	TETP	AV
E125	5	3.5	8.5	11	1	1	1	1	9	9	**5**
E134	11	3.5	8.5	10	10	10	10	10	6	6	**8.5**
E7000	6	9	8.5	8	2	2	2	2	7	7	**5.4**
E7100	8	10	8.5	7	4	4	4	4	8	8	**6.5**
E7200	7	11	8.5	6	3	3	3	3	5	5	**5.5**
R134a	9	8	8.5	9	6	6	6	6	11	11	**8.1**
R152a	1	7	5	5	5	5	5	5	10	10	**5.8**
R290	2	3.5	1.5	3	7	7	7	7	2	2	**4.2**
R30	10	3.5	4	1	11	11	11	11	4	4	**7.1**
R600a	3	3.5	1.5	4	8	8	8	8	2	2	**4.8**
R744	4	3.5	3	2	9	9	9	9	2	2	**5.3**

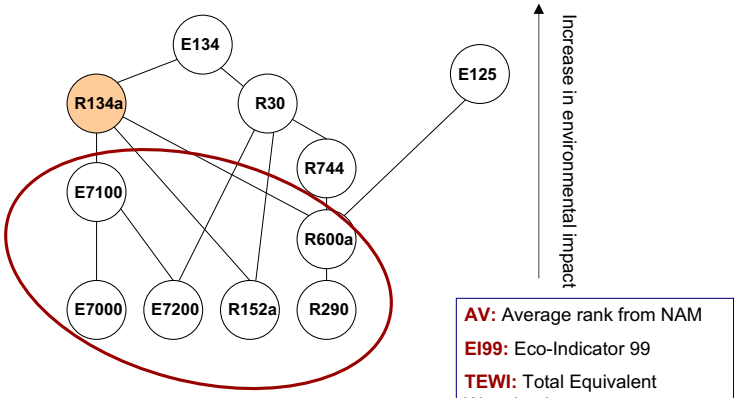
ADP – Depletion of abiotic resources (excluding primary energy); ODP – Stratospheric ozone depletion;
PE – Demand of non-renewable primary energy; GWP – Climate change; AP – Acidification; EP – Eutrophication;
POCP – Photo-oxidant formation; HT – Human toxicity; FAETP – Fresh water aquatic toxicity; TETP – Terrestrial ecotoxicity

Ranking from the different Assessment Methods

	NAM	EI99	TEWI
Refrigerant	AV		
E125	5	10	11
E134	8.5	11	10
E7000	5.4	7	2
E7100	6.5	8	3
E7200	5.5	5	1
R134a	8.1	9	7
R152a	5.8	4	4
R290	4.2	1	5
R30	7.1	6	9
R600a	4.8	2	6
R744	5.3	3	8

AV – average ranking of the CML02 method;
EI99 – Eco-Indicator 99;
TEWI – Total equivalent warming impact

Hasse Diagram: HD{AV, EI99, TEWI}

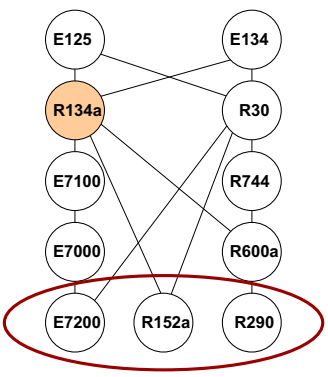


AV: Average rank from NAM

EI99: Eco-Indicator 99

TEWI: Total Equivalent Warming Impact

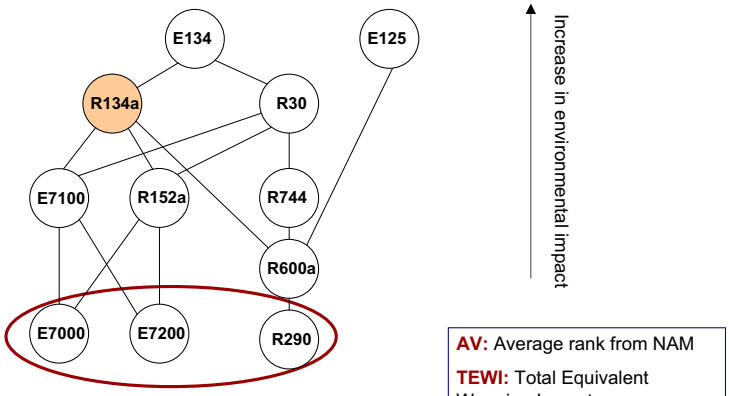
Hasse Diagram: HD{EI99, TEWI}



EI99: Eco-Indicator 99

TEWI: Total Equivalent Warming Impact

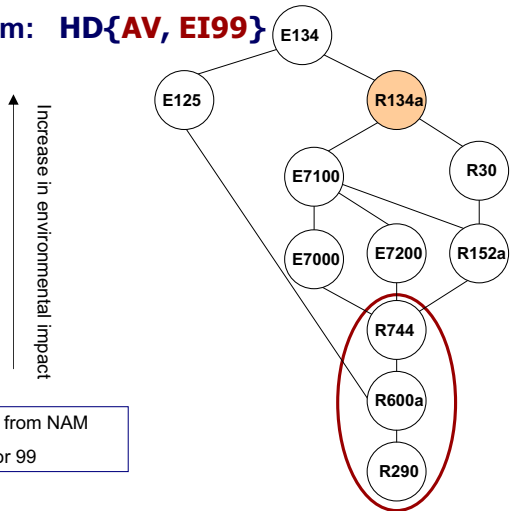
Hasse Diagram: HD{AV, TEWI}



AV: Average rank from NAM

TEWI: Total Equivalent Warming Impact

Hasse Diagram: HD{AV, EI99}



AV: Average rank from NAM

EI99: Eco-Indicator 99

Conclusions

- Different assessment methods can result in different rankings.
→ Different substances would be chosen as possible replacements.

- TEWI does not account for complete life cycle.
(Might be suitable for certain applications with low contributions from production and disposal phase.)

- NAM and EI99 account for complete life cycle, but give different results for some refrigerants.
→ Better to apply both methods and compare the results.

Conclusions cont.

-E134 (CHF_2OCHF_2) and E125 (CF_3OCHF_2) do not seem to be suitable replacements for R134a ($C_2H_2F_4$).

- Considering all three assessment methods:
7000-series ($CF_3(CF_2)_2OCH_3$, $CF_3(CF_2)_3OCH_3$, $CF_3(CF_2)_3OC_2H_5$), R152a ($C_2H_4F_2$), R600a (C_4H_{10}), and R290 (C_3H_8) have smaller environmental impact than R134a.

- Considering only two assessment methods: Helps to reduce incomparabilities.

- Considering only NAM and EI99: R744 (CO_2), R600a (C_4H_{10}), and R290 (C_3H_8) have smaller environmental impact than R134a and might be the most suitable replacements.

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and

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