

Auditing the European room air-conditioning systems and potential energy savings

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*ECEEE 2007 Summer Study
Colle sur Loup*



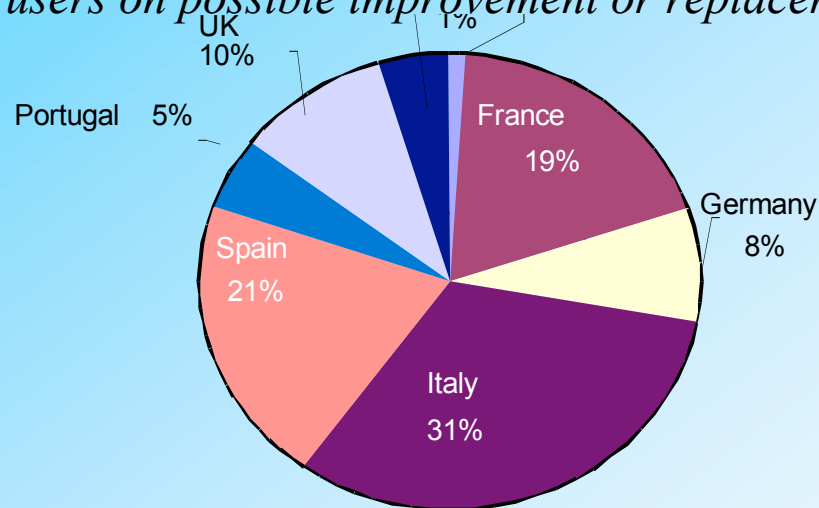
Focus on room air conditioning

DIRECTIVE 2002/91/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 16th December 2002 on the energy performance of buildings.

Article 9 - Inspection of air-conditioning systems

*With regard to reducing energy consumption and limiting carbon dioxide emissions, Member States shall lay down the necessary measures to establish a regular inspection of air conditioning systems of an effective rated output of **more than 12 kW**.*

This inspection shall include an assessment of the air-conditioning efficiency and the sizing compared to the cooling requirements of the building. Appropriate advice shall be provided to the users on possible improvement or replacement of the air-conditioning system and on alternative solutions.



The French stock was already important at that time, but its increase has been boost up after the extreme hot climate in 2003 that led to a rapidly market increase: +80% units sold in 2004

~ 400 000 unit sold in 2004

[ClimInfo 2205].

Common defects during operation

The defects identified by Breuker [Breuker1998] for packaged systems can be translated for room air conditioner equipment because of the similar structure of the two systems (air to air systems). The following defects were kept:

1. The refrigerant undercharge
2. The condenser fouling
3. The evaporator filter fouling
4. A restriction in the liquid-line
5. A worn compressor
- 6./7. Indoor and outdoor fans loss of performance

Chosen system characteristics

Rating Cooling Capacity (kW)	8.56
Rating Compressor Power (kW)	3.15
Rating EER	2.72
Compressor type	Reciprocating
Refrigerant	R22
Expansion device	Thermostatic expansion valve

Used Model: Oak Ridge Heat Pump model (MARK V)

<http://www.ornl.gov/~wlj/hpdm/>

Four indoor and outdoor conditions

Defects energy effects

Refrigerant charge reduction	-10%	-20%	-30%	-40%
$(EER - EER_{ref}) / EER_{ref} \%$				
T1 -35°C/27°C	-1.4%	-3.0%	-6.2%	-12.3%
T2 -27°C/21°C	-0.5%	-1.3%	-3.4%	-9.4%
T21 -35°C/21°C	-0.8%	-2.3%	-4.2%	-9.1%
T12 -27°C-27°C	-0.2%	-2.3%	-6.2%	-12.1%

Defects energy effects

Condenser fouling (surface Reduction)	-14%	-28%
	(EER-EERref) / EERref %	
T1 35°C/27°C	-5.6%	-14.8%
T2 27°C/21°C	-5.5%	-15.2%
T2 135°C/21°C	-5.2%	-15.1%
T1 2-27°C 27°C	-5.4%	-15.1%

Outdoor fan efficiency reduction	-16%	-27%	-40%	-49%
	(EEREERref) / EERref %			
T1 35°C/27°C	-1.5%	-3.2%	-5.1%	-7.2%
T2 27°C/21°C	-1.5%	-3.0%	-4.6%	-6.5%
T2 135°C/21°C	-1.3%	-2.7%	-4.3%	-6.0%
T1 2-27°C 27°C	-1.7%	-3.5%	-5.5%	-7.6%

Defects energy effects

Indoor fan efficiency reduction	-18%	-33%	-47%	-58%
$(EER - EER_{ref}) / EER_{ref} \%$				
T1 -35°C/27°C	-0.4%	-0.9%	-1.4%	-2.5%
T2 -27°C/21°C	-0.9%	-1.6%	-2.4%	-3.5%
T21 -35°C/21°C	-0.6%	-1.2%	-1.6%	-2.4%
T12 -27°C-27°C	-0.6%	-1.2%	-1.8%	-2.3%

Evaporator Airflow reduction	-12%	-24%	-36%	-48%
$(EER - EER_{ref}) / EER_{ref} \%$				
T1 -35°C/27°C	-0.2%	-1.0%	-2.2%	-4.1%
T2 -27°C/21°C	-0.8%	-1.6%	-3.6%	-6.0%
T21 -35°C/21°C	-0.4%	-0.7%	-2.2%	-4.4%
T12 -27°C-27°C	-0.4%	-1.0%	-2.0%	-4.6%

Defects energy effects

Compressor Volumetric efficiency reduction	-9%	-17%	-25%	-34%
$(EER - EER_{ref}) / EER_{ref} \%$				
T1 -35°C/27°C	-6.1%	-12.6%	-19.1%	-26.4%
T2 -27°C/21°C	-5.8%	-12.0%	-18.8%	-25.9%
T21 -35°C/21°C	-6.5%	-12.9%	-19.9%	-27.6%
T12 -27°C-27°C	-5.5%	-11.4%	-17.6%	-24.4%

Defects energy effects

Additional pressure drop (% of total pressure drop at T1 for reference case)	7%	14%	21%	28%	35%
	$(\frac{EER_{ref}}{EER_{ref}}) / EER_{ref} \%$				
T1 -35°C/27°C	0.4%	0.5%	0.0%	-0.4%	-1.2%
T2-27°C/21°C	0.2%	0.1%	-0.2%	-1.1%	-1.9%
T21-35°C/21°C	1.0%	1.1%	1.3%	1.4%	1.3%
T12-27°C-27°C	-0.3%	-1.1%	-2.2%	-3.5%	-5.1%

Literature comparison

Breuker, Mark S. and Braun, James E. « Common Faults and Their Impact for Rooftop Air Conditioners », HVAC&R Research, July 1998

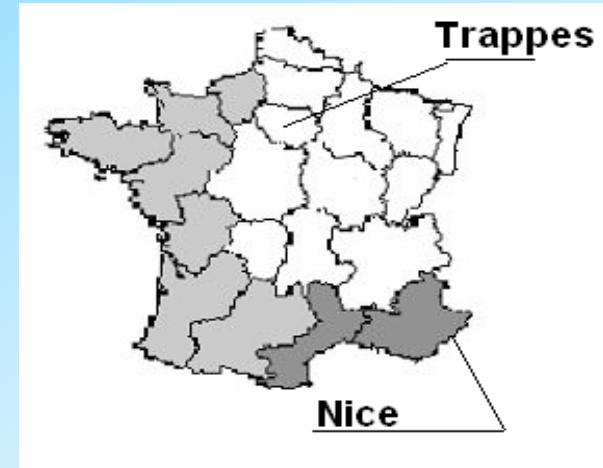
Impact on system parameters of the reviewed defects

Defects	pc	pe	Pc	Pfan	Pcompr	EER
Refrigerant Leaks	↓ (↓)	↓(↓)	↓(↓)	~	↓	↓ (↓)
Compressor Valve Leaks	↓ (↓)	↑ (↑)	↓(↓)	~	↓~	↓(↓)
Liquid-Line Restriction	↓ (↓)	↑ (↓)	~↑ (↓)	~	~↑	~
Condenser Fouling	↑ (↑)	~ (↑)	↓ (↓)	~	↑	↓ (↓)
Condenser fan efficiency	↑	↑	↓	↑	↑	↓
Evaporator Filter Fouling	↓ (↓)	↓ (↓)	↓ (↓)	~	↓	↓ (↓)
Evaporator fan efficiency	↓	↓	↓	↑	↓	↓~

Dynamic simulations

Building and climates

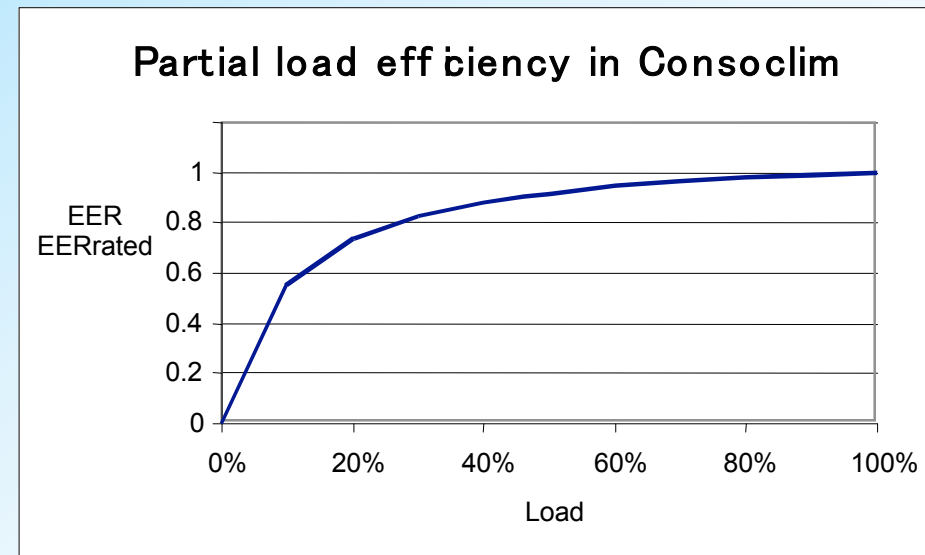
	Office	House
Total area (m ²)	1008	136
Cooled area (m ²)	762	85



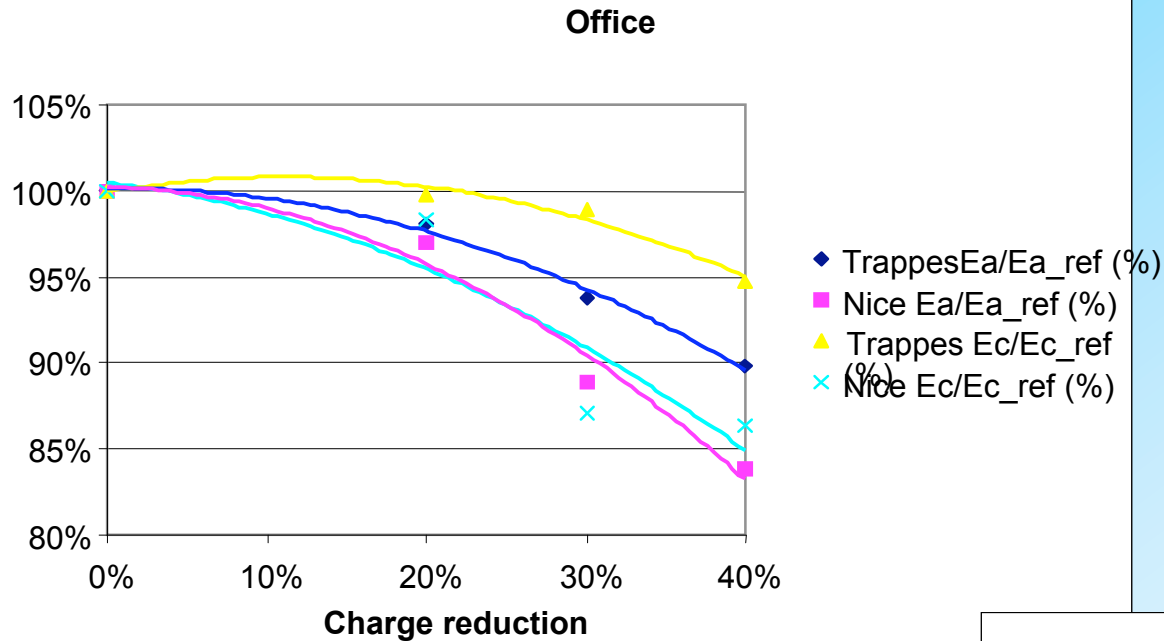
System characteristics

The dynamic simulation allows to take into account:

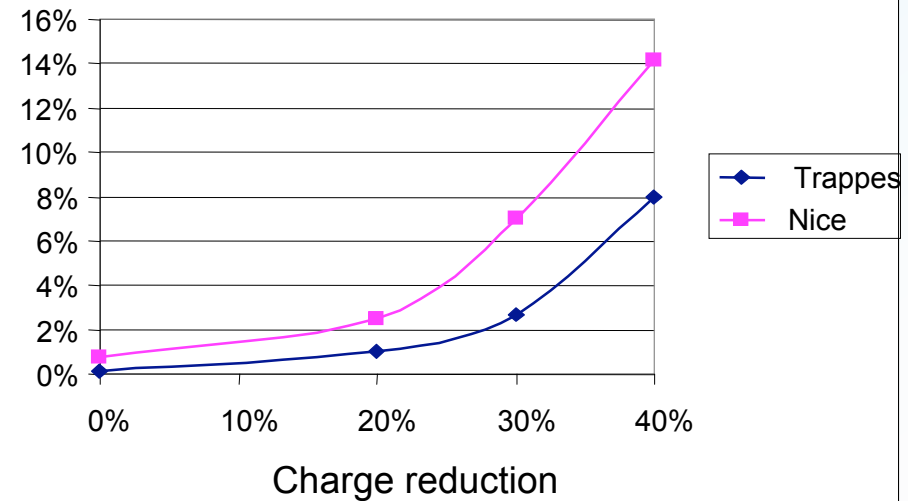
- Operation in non rating conditions
- Partial load behavior
- Building occupation and use



Charge effects on the buildings

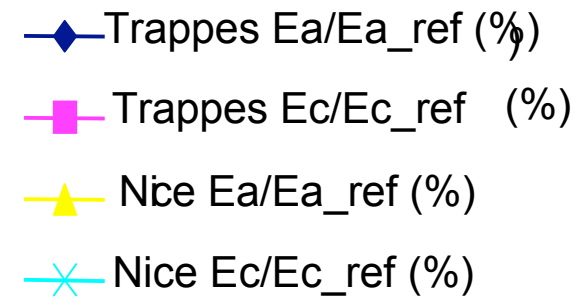
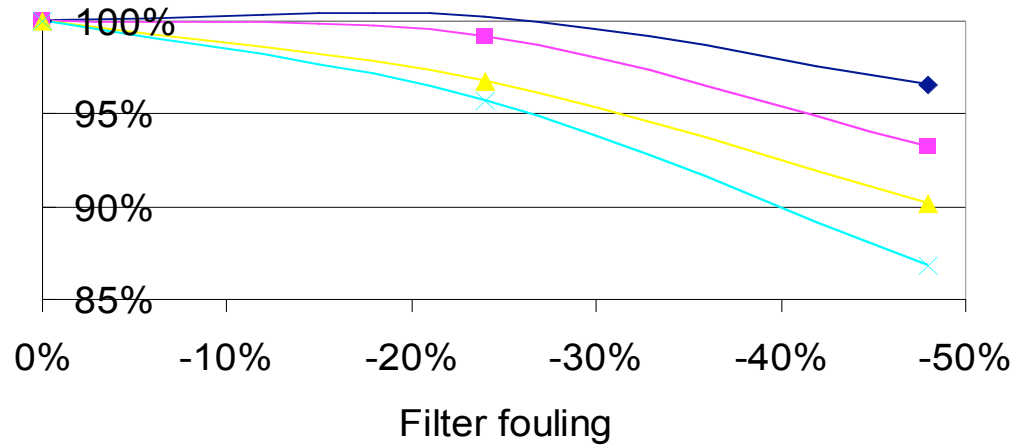


Discomfort hours/operating hours (%)Office

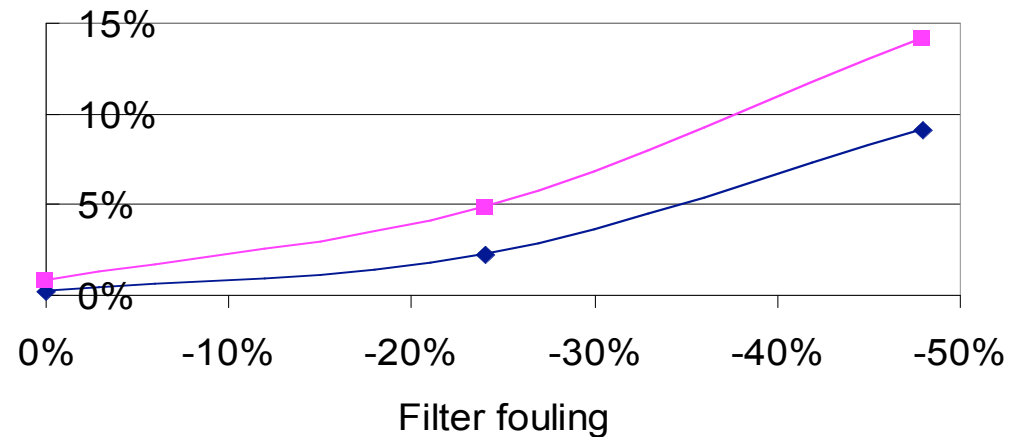


Filter fouling effects on the buildings

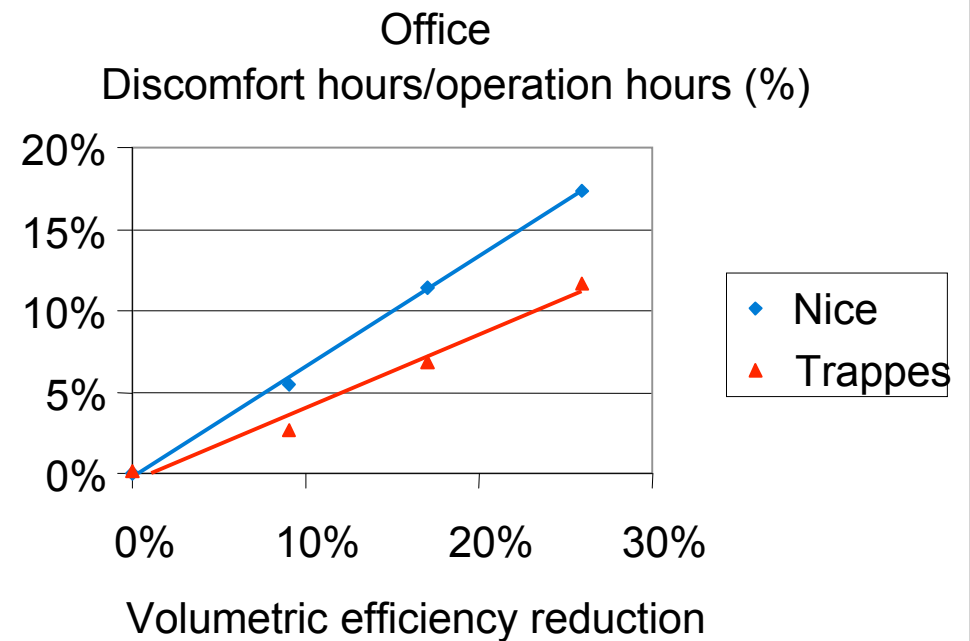
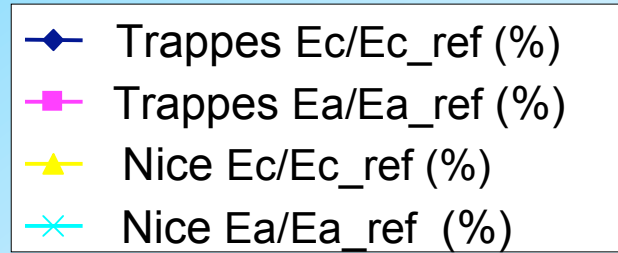
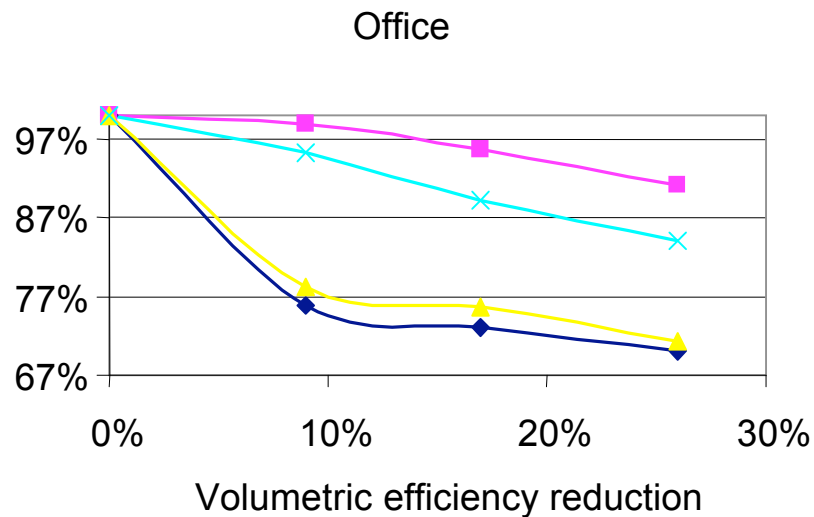
Office



Discomfort hours/operation hours (%)

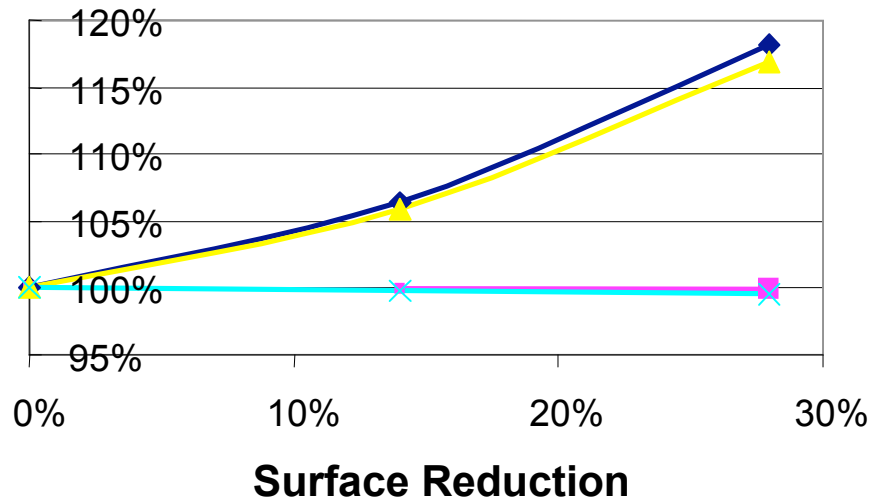


Compressor wearing effects on the buildings



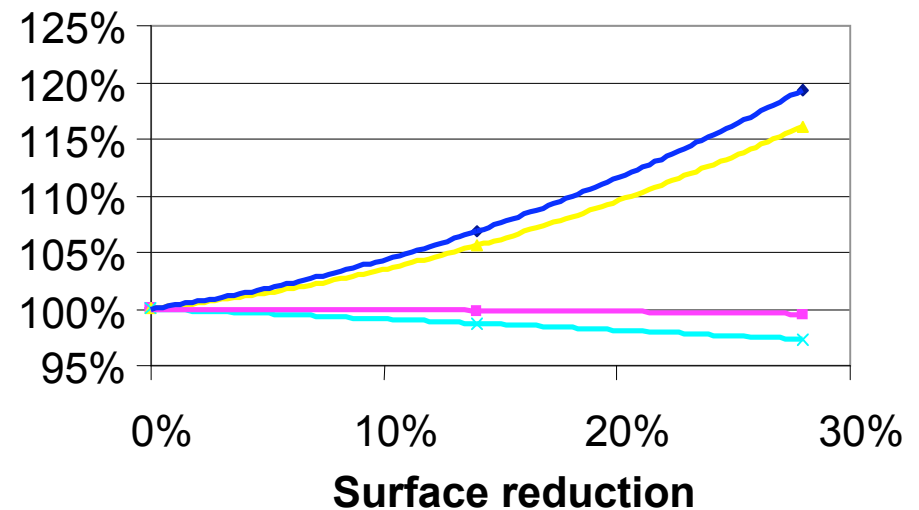
Condenser fouling effects on the buildings

House

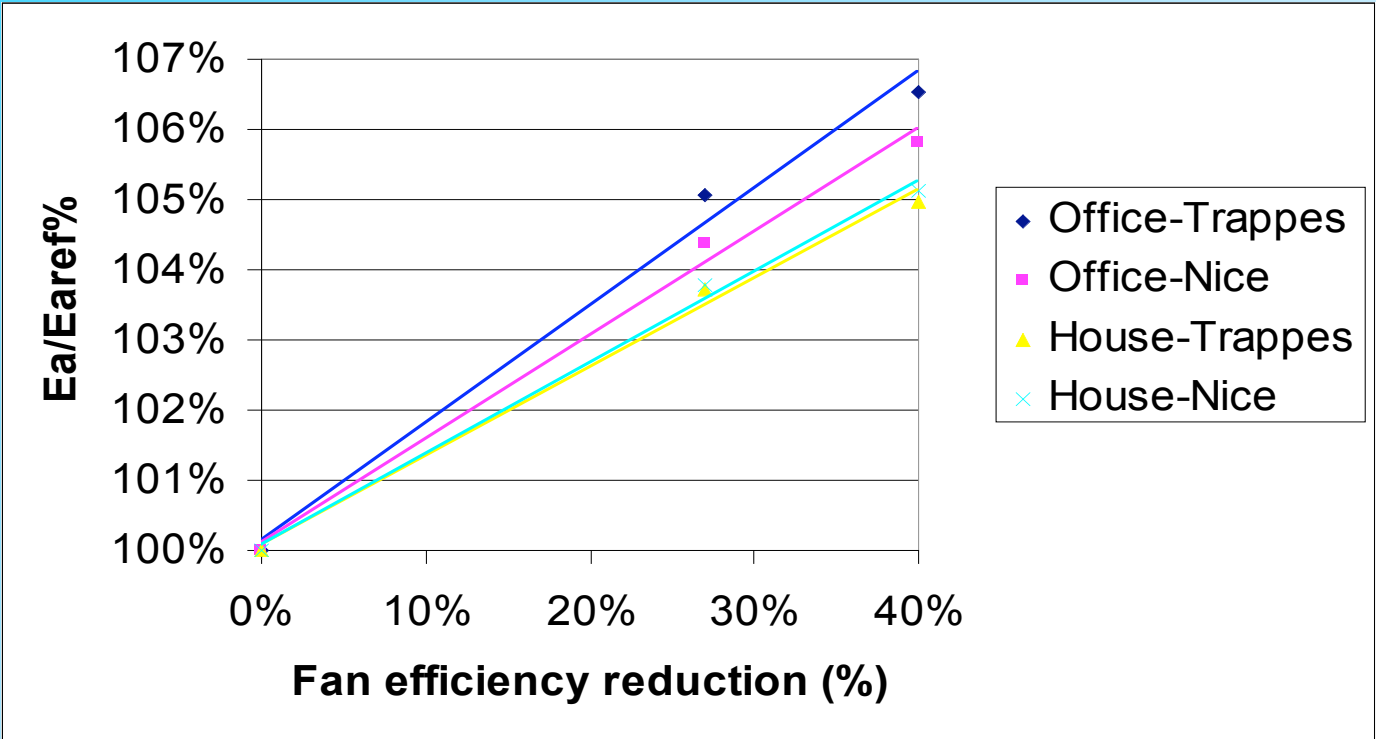


- Trappes Ea/Ea_ref (%)
- Trappes Ec/Ec_ref (%)
- Nice Ea/Ea_ref (%)
- Nice Ec/Ec_ref (%)

Office



Condenser fan wearing effects on the buildings



Conclusions

- Determine the defect that mainly worsen the AC room air conditioners efficiency:
 - defects that can be mainly source of over consumption as condenser fouling and outdoor fans loss of performance
 - defects that have main effects on the cooling capacity and comfort aspect (while the annual consumption can be found reduced) as filter fouling, compressor leaks, refrigerant leaks.
- The inspection procedure should focus on both these aspects
- Energy and comfort assessment would be necessary on the base of the inspector/auditor observations to promote the better maintenance

Conclusions

- We would recommend
 - Refrigerant leaks check should be a priority for the auditor (especially for old systems)
 - The condenser should be inspected with care because it has an important impact on the consumption level
 - Compressor problems are more difficult to detect
 - The status of the filter can be visually checked or estimated by asking the owner for a summary of maintenance operations
- More efforts should be done in order to extend this analysis to systems using different technologies or refrigerant fluids

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