# Sizing of Room Air-Conditioners for Minimum Energy Consumption and Peak Power


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## ABSTRACT

Important oversizing factors are observed for room air-conditioners leading to important energy wastes and costly summer peak demands for utilities. This article intends to show that sizing decisions should be based on dynamic simulation results and include an assessment of the air conditioner part-load performance. The sizing methodology established is applied to evaluate different oversizing levels for different types of buildings, climates and systems. This enables to compare our methodology to typical rules of the thumbs applied in France. By coupling these results to a stock model of room air conditioners, it enables to evaluate the potential benefits of better sizing in terms of energy.



## KEYWORDS

Air-conditioning, sizing, building simulation tool, Consoclim, residential and commercial sectors.


## INTRODUCTION

The European air-conditioning (AC) market is changing: the residential market is taking off and at the same time, efforts toward more efficient air conditioning systems gain ambition with the Energy Performance of Buildings Directive [EPBD, 2002]. This directive requires air-conditioning installations ranging higher than 12 kW to be periodically inspected. That inspection should include “an assessment of the air-conditioning efficiency and the sizing compared to the cooling requirements of the building”. Then, individual air conditioners for residences and shops are not in the scope. Since a major part of this market is nowadays sold in retail shops, several simple methods were developed to estimate the capacity of the system. We have so tested some sizing methods and compared them with a more accurate one through dynamic simulation. The sizing influence has been tested on two different control types of room air-conditioners: On/Off controlled compressor and a variable speed compressor. The field of investigation includes residential and commercial French buildings representative of the existing stock for two extreme French climates.

## REVIEW OF THE SIZING METHODS FOR ROOM AIR CONDITIONING SYSTEMS IN COMMERCIAL AND RESIDENTIAL BUILDINGS

Air-conditioning sizing methods are numerous and vary a lot especially for room air conditioners (RAC) depending on the activity sector and occupants behaviours. Let us have a look to different possibilities.

«Static» methods require only determining the peak cooling load to choose the capacity of an air-conditioner. For a private customer looking for sizing its AC system, non-AC specific sellers propose in general simplified methods based on capacity ratios per square meter (W/m²), leaving to the customer none or very few choices to characterize the room to treat. In some cases, sellers and manufacturers define the capacity by filling a calculation sheet including coefficients to apply to surface and other factors (such as number of occupants, electric appliances etc.) that result in a final sizing value. In the most detailed sheets, orientation and insulation factors are considered. Although still incomplete, these methods are more reliable than former simple ratios because they better adjust the size to the real needs. Usually, they do not consider climate factor because they are conceived for a fixed exterior temperature (European standard pr EN 14511) and often include ”margin” to be sure to satisfy cooling requirements in any climate conditions. More often, manufacturers, consultants or public institutions (as in the case of Office of Energy Efficiency of Canada [OEE 2005]) put on the web simplified methods and calculation tools to help in sizing RAC. These methods depend on the country, the manufacturer, the system etc…

For more complex projects or specific buildings, in general, a consultant or a designer is in charge of the sizing and usually they have internally developed specific methods. Rules of thumbs being seldom applied for RAC sizing and in general methods are increasing in complexity and details in order to fit to a better sizing and obtain lower energy consumptions without any loss of comfort.
Nevertheless, the more reliable sizing method is the “dynamic” simulation based on hourly data. Many application programs existing today to simulate the building and its AC systems and climate allowing to estimate cooling and heating needs or energy consumptions. Systems are introduced through simplified models more and more consistent with the real operation. All the building characteristics can be entered such as thermal properties or occupancy schedules. Finally, climate aspects can be considered through weather data in form of standard files. These “dynamic” methods (compared to “static” methods previously described) allow to precisely determine the optimal required cooling capacity to satisfy comfort requirements, avoiding the extra-costs of useless kilowatts and all secondary effects of oversizing (short-cycling for example leads to a quicker compressor wear). Unfortunately, such methods are not available for large public and can actually be performed only by professionals and trained persons.

## SPLIT SYSTEMS REGULATION: INVERTER AND ON/OFF

The split systems are small AC system, the characteristic of which is to be separated in two types of units: one or more indoor unit(s) include(s) a heat exchanger (evaporator), a fan, an expansion device; the outdoor unit includes a heat exchanger (condenser), an axial fan and a compressor. Their low capacities allow them to cool (and heat, for reversible models) one or few small rooms.
Two control types are available nowadays: on the one hand the ON/OFF controlled compressors, on the other hand the variable speed compressors also called Inverter systems. These two control techniques induce different part load behaviours: the ON/OFF controlled system efficiency increases with the load, and its nominal point

(European standard EN 14511) coincides with its maximal efficiency whereas the inverter controlled split-system efficiency reaches its maximum at lower capacity (Figure 1). The two behaviours have been deeply studied and explained in Anglesio et al. (2001). Parameters defining the system considered are: the nominal full load capacity, the nominal full load EER (in our study fixed at 2.5) and the OFF mode cycling consumption (10% of the nominal power) for both systems and the maximal efficiency point (defined at 40% load and 1.35 $EER_{nominal}$) for inverter systems.

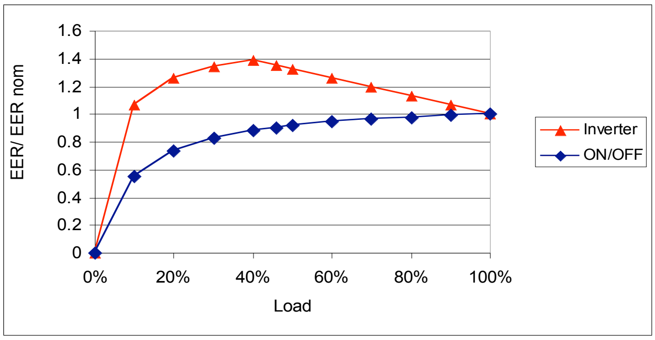


Figure 1 Partial load behaviour of ON/OFF and inverter controlled split.

For ON/OFF controlled systems, Figure 1 shows that the smaller the installed capacity, the lower the seasonal consumption, which is a clear indication oversizing is a systematic loss. For inverter split-systems, the low loads high efficiency could enable to optimise the seasonal consumption if oversizing enables to fit maximum efficiency and average operating conditions, near 30% load for a typical office building located in Trappes (Figure 2).

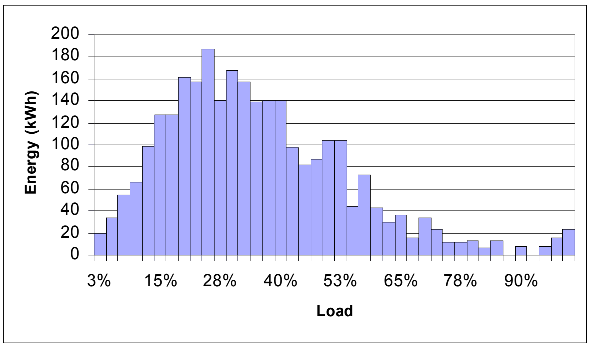


Figure 2 Cooling load profile of an office building in Trappes (France).

## COMPARISON OF DIFFERENT SIZING METHODS APPLIED TO RESIDENTIAL AND COMMERCIAL BUILDINGS

In this paper we want to describe the effect of different sizing rates on several types of commercial and residential buildings using RAC systems. Thus, an initial system size is calculated, performed through simulation with dynamic simulation software. This sizing method allows to fit the cooling capacity to the building cooling requirements that depend on its own characteristics (thermal properties, occupancy, lighting etc…) and climate.

We considered in our analysis four types of building (Table 1), the thermal characteristics of which are representative of the average existing building stock in France.

Table 1
Simulated building areas

| | Office | Mall | Hotel | House |
|---|---|---|---|---|
| Total area (m²) | 1008 | 12984 | 1541 | 136 |
| Cooled area (m²) | 762 | 10984 | 1280 | 85 |

For each building, two French climates are considered representative of two opposite weather conditions: Trappes as the typical North continental climate and Nice as the typical temperate Mediterranean climate.

The sizing method consists in two different steps. Firstly, the software calculates both internal and external heat gains of the building using weather files defined by the last French thermal regulation. This first step is an estimate of sensible peak cooling requirements so that a 20%-margin is considered to include latent loads. Secondly, once the installed capacity has been defined, the air-conditioning process has to be defined (2.5 EER split–systems in that study). A simulation for a typical yearly data file is performed with the initial sizing in order to check its validity. If the sizing is not optimal, cooling capacity is then adjusted to better fit the capacity to the required comfort and the local climate in a process of trial and error.

Thus, we examined several sizing criteria described previously and compared them with dynamic sizing results. As static methods are usually conceived for private owners and are not adapted to every building, we have restricted our analysis to the residential case. Several sizing ratios (W/m²) from different methods and the results of our simulations are showed in Table 2 for the residential building. We considered two different sizes for two spaces with very different configuration and loads: the living room (34m²) and the bedroom (51m²).

Table 2
AC size resulting from different sizing methods

| Sizing (W/m²) | Living-room | Bedrooms |
|---|---|---|
| Canadian Office of Energy Efficiency | 76 | 85 |
| French Manufacturer Method | 89 | 81 |
| UK Supplier method | 150-200 | 190-250 |
| French retail supplier | 86-110 | |
| | Dynamic method | |
| For Trappes | 100 | 50 |
| For Nice | 140 | 90 |

All the methods reviewed include information about:

- Cooled area
- Glazed area
- Orientation of the glazed surfaces and walls
- Occupancy.

In some more detailed methods, additional elements are included:

- Wall insulation (existence, type)
- Glazing type
- Additional internal loads (occupants, specific appliances).

Although our results show very different values for the two French climates, none of the ratio-based methods require climate information. For colder climates the oversizing can be important as for house bedrooms in Trappes. Moreover, while the Canadian method underestimate the sizing (because of the difference between Canadian and French climate), the UK supplier's method shows an important overestimate of the system capacity.

We can in general observe an effort by the French sellers and manufacturers to limit oversizing practices ; it should be added that the values observed seem more adapted to recent buildings better insulated respecting the stricter 2000 French thermal regulation levels.

## INFLUENCE OF SIZING PRACTICE ON ENERGY CONSUMPTIONS OF THE FRENCH SPLIT SYSTEM STOCK

Once the best sizing is established for our buildings, two different oversizing rates are considered that would lead to install systems with a cooling capacity equal to 150% and 200% of the real cooling needs. The effect of these oversizing is quantified through the simulation and an estimation of the impact on the French stock is performed.

French cooled areas per activity sector are extracted from the EECCAC (energy efficiency and certification of central air-conditioning) study (J. Adnot et al., 2003). The EERAC (energy efficiency of room air-conditioning) study (J. Adnot et al., 1999) updated by the CLIM-INFO CVC (2006) data allowed us to get the market of individual air conditioning including the 2003 heat-wave.

Simulations provided us energy consumption ratios (kWh/m$^2$.year) for each of the four building types and for two control strategies (ON/OFF and inverter). The inverter share in the French 2005 split-system market is 60%, the other 40% being ON/OFF controlled. However, inverter systems are supposed to represent only 25% of the 2005 French split-system stock because of their late development. We considered their shares were the same in every type of building.

Our simulations showed that annual energy over-consumptions of Inverter systems are as sensible to oversizing as energy over-consumptions of On/Off systems. The function linking the relative (to optimal sizing) over-consumptions of the French room air-conditioning stock to the relative oversizing (to optimal sizing) practice of professionals (installers, consultants) is linear and strictly increasing. Only annual consumptions differ and Inverter systems use obviously less energy. These savings remain equal to 30-35% whatever the building and climate simulated, considering the performance curves of Figure 1.

Considering that 2005 is a reference year characterized by the existing building stock air-conditioned by only split-systems commonly 20% oversized and using approximately 1423GWh, several improvements are possible:

- 7,5% energy savings are possible by keeping the same system mix (75% On/Off – 25% Inverter) in the stock and improving professional practices leading to reduce the oversizing (20% to 0%).
- 28% energy savings are possible by replacing the current system mix (75% On/Off – 25% Inverter) by only Inverter systems (this is occurring nowadays) and keeping the oversizing at +20% of the real cooling requirements.
- 33% energy savings are possible by replacing the current system mix (75% On/Off – 25% Inverter) by only Inverter systems (that tendency is really observed) and improving professional practices leading to reduce the oversizing (20% to 0%).

## CONCLUSIONS

The methods used for sizing individual air conditioners vary from sellers to installers, consultancies etc. In general the methods are based on simplified ratios. The dynamic method allows to estimate more precisely the cooling needs and the comfort satisfaction, and this method is tailored to each case including climate, building factor and comfort level. Moreover we have calculated the over-consumption due to oversizing for French commercial and residential sector cooled by split system with two different technologies: ON/OFF and inverter. These leads to the following conclusions:

1) As regards to our simulations, both systems -ON/OFF control and inverter- seasonal consumptions decrease with increasing oversizing.

2) sizing guides should be released to enable the customers to take benefit from those potential energy savings. Simplified web based guides as in Canada [OEE 2005] could be adapted by taking into account different climates and constructions habits. These guides could also give indication of energy consumption.

3) Energy savings can be reached with the replacement of ON/OFF systems with Inverter systems for the theoretical part load performance curves we have simulated (Figure 1). However, while part load performance curves are not required in EN14511, inverter energy conservation potential remains theoretical.

## REFERENCES


Anglesio et al., (2001). Anglesio P., Caon S., Caruso S., Determinazione delle prestazioni energetiche di condizionatori elettrici a due unità in aria invertibile : determinazione delle prestazioni energetiche, *CDA*.

EPBD, (2002). Directive 2002/91/EC of the European Parliament and of the Council of 16 December 2002 on the energy performance of buildings, *Official Journal* L 001 , 04/01/2003 P. 0065 – 0071.

OEE, (2005). How to Size a Room Air Conditioner, EnerGuide Room Air Conditioner Directory 2005 Natural Resource of Canada, Office of Energy Efficiency, http://oee.nrcan.gc.ca/publications/equipment/roomaircond/size.cfm?attr=4

J. Adnot et al., (2003), Energy Efficiency and Certification of Central Air Conditioners (EECCAC) for the Directorate General Transportation-Energy of the Commission of the European Union, May 2003

J. Adnot et al., (1999), Energy Efficiency of Room Air-Conditioners (EERAC) for the Directorate General Transportation-Energy of the Commission of the European Union, May 1999

CVC (2006). *CVC Chauffage, Ventilation, Climatisation* n°840, March-April.