LOW-ENERGY COOLING CONCEPTION IN OFFICE BUILDINGS

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ABSTRACT

Air conditioning is widely used in the office building sector in the French Mediterranean region. Though often a «sine qua non» for renting office space, there is however a widespread feeling that operating and maintaining air-conditioning systems can be troublesome (unreliability, regulation and maintenance difficulties, non uniform comfort conditions, high prices are frequently lamented). With European support we aimed to explore how the market might adjust to these conflicting customer demands and provide actors in the Provence-Alpes-Côte d'Azur (PACA) region with improved tools (customised analysis and design, packages of retrofit solutions) which could lead evolution toward building stock of improved comfort, higher energy efficiency and environmental sustainability.

KEYWORDS

Energy audits and measurements, modelling and simulation, building envelope technologies, cooling load control, high efficiency lighting, market study, office building stock.

METHODOLOGY

The research consisted of two steps. In the first we developed an overview of the market for air-conditioning in the office building sector in the Provence-Alpes-Côte d'Azur region. A number of interviews were conducted with engineers, real estate agents and other professionals in the field in order to investigate the problems in promoting high performance solutions, provide a critical survey of existing technologies, and the likely trends of development.
In the second step, with the methodological guidance of the Politecnico di Milano, an analysis of summer cooling energy requirements of representative building stock in the Region was executed. Given that little data is available regarding specific energy consumption of air conditioning systems it was decided to perform a metering campaign of end use consumption and office space comfort levels. Selected buildings were subsequently modelled with DOE2 and the models calibrated against the consumption levels measured over the two/three week campaign period. Subsequently the models were used to simulate the thermodynamic behaviour of the buildings over an entire year allowing the energy saving potential of selected retrofits to be evaluated

RESULTS

1. Market study. Office buildings and air conditioning equipment in Provence-Alpes-Côte d'Azur Region.

Data available gives the floor space of office stock in Provence-Alpes-Côte d'Azur as: 13.6 million m^2 in 1989 and 14.7 million in 1994 (source BIPE and DRE).

Construction of new office space experienced a sustained growth during the latter part of the eighties followed by a serious recession beginning around 1992. According to all estate agents interviewed, though demand for new office space presently exceeds supply, constructions of new office space remains low (in 1997 100 000 m² for the whole region against 290 000 m² in 1990). In consequence the demand for « second hand » stock is increasing. However, according to professionals, this stock does not meet the market demand for quality office space (obsolescence or absence of air conditioning equipment, inadequate weather proofing, high maintenance costs, the presence of asbestos, poor location) and much restructuring is underway. The following table details the likely number of yearly retrofits.

TABLE 1

	Vaucluse	Aix - Marseille	Alpes-Maritimes
A) Stock immediately available for rent or sale as of 1/1/97*	17 600 m²	201 500 m²	165 000 m²
Part of A) built in the last year (calculation) *	2 500 m²	34 200 m²	50 000 m²
Part of A) which is second hand (calculation)	15 000 m²	167 300 m²	115 000 m²
obsolete buildings (in the second hand portion**	3 800 m²	50 200 m²	28 750 m²

Source: * Real estate observatory- ** Data from expert interviews, round figures

A review of building permits registered in the region shows the average floor space of reconstructed stock to be 460 m^2 in Vaucluse (Avignon), 610 m^2 in Bouches-du-Rhône (Marseilles) and 950 m^2 in Alpes-maritimes (Nice) (Data by DRE (Direction Régionale de l'Equipement), elaboration by ARENE). We thus estimate that there are a total of 300 office units in need of slight retrofitting and around 120 obsolete office units that would require major retrofitting. This figure is to be compared with the projects of new buildings in the region (258 projects started in 1995 and 250 in 1996). Any strategy for communicating information and giving advice on best practice should be designed/calibrated in respect of these numbers.
Important among the retrofit actions is the introduction of air-conditioning systems. Interviews with experts show that air conditioning equipment has become an essential criterion to rent premises. Given the pressure on the stock of old offices (and the scarcity of the supply of new stock), owners are slowly forced to take on the expense of this equipment in order to favour renting. Indeed according to all the professionals interviewed the percentage of air-conditioned office stock in Provence-Alpes-Côte d'Azur is much higher than at the national level.
Table 2 provides details of segmentation of the market for air conditioning in '95 and '96.

TABLE 2

room air conditioning			centralised air conditioning		
Type of machines	*Share of sales in 96*	*Share of sales in 95*	*Type of systems*	*Share of sales in 96*	*Share of sales. in 95*
Mobile	24,5%	22%	Water system	57%	51%
Fixed split-systems	50,5%	53%	Air system	40%	42%
Multi-splits	16%	14,5%	Dry expansion	3%	7%
Window systems	6%	6%			
Computer system room conditioning	1%	2,5%			
Floor mounted	2%	2%			

Source: data given by « Climatisation&Développement », 1996

It's worth noting that for room air conditioning, the split system remains the leading product on the market, however, the greatest sales' increase regards multi-splits as well as mobiles.
Using figures from the Bâtim Etudes survey and considering the office retrofits underway we can estimate (with a certain degree of approximation) the likely number of new installations in offices

in Provence-Alpes-Côte d'Azur in 1996.

- single room air conditioners: 10 000 installed units of which 6 800 in existing offices.
- centralised air conditioners : 525 construction sites

For the most part this market eludes professional designers, which raises serious questions about the quality of the installations and the effects on building comfort levels.
We can thus identify the chance and the importance of introducing quality cooling strategies in parallel with other retrofit actions in the « second hand » park.
Using these data, we built two scenarios of future development. In the first we extrapolate the current trend into the future, in the second we consider the introduction of strong incentives to implement best practice guidelines and high efficiency installations. The difference between the two prospective scenarios represents 80 million kWh per year. The significant savings possible highlight the importance of adopting a co-ordinated development strategy, which will also have significant benefits for user comfort.

The research proceeded with a review of present air conditioning technologies and the trends and strategies of the different market actors; the results of which are not included in this short paper.

2. *Energy audits and analysis of retrofit options of three representative buildings*

Three buildings were analysed in order to assess the size of energy savings achievable by means of system retrofit and improvements to the building envelopes. The analysis combined end-use energy audits with thermodynamic models of the building developed using DOE2.
Buildings were chosen in a number of regions with large areas of office space, each with a different climate. The buildings showed a variety of architectural styles typical of the regions in which they were located: In Nice, an old heavily laid building; in Aix-en-Provence, a new cement panelled block construction in an office/commercial development; in Toulon, a «glass» block ("high-tech" retrofitting of an old one). In Aix and Toulon space heating is provided using a heat pump, and in Nice mainly through the use of electric resistance heaters.
During summer 1997, energy audits and a two-week end-use measurement campaign were undertaken by two engineering offices: ADRET and GERES. Separate metering of the HVAC and lighting systems, office equipment as well as total consumption was made. External and internal air temperature in a number of selected rooms was also monitored. Meteorological data relevant to the measurement period and for a representative year was collected. Synthetic data produced through the audits and subsequent analysis are reported in Table 3.

TABLE 3

Toulon building					
ZONES	Area [m^2]	Volume [m^3]	Lighting load [W/m^2]	Office Equipment & other lo ds [W/m^2]	Max number of occupants
UNDERGROUND FLOOR	270	630	9,2	0	2
ZONE A	894	2770	22,6	2,8	45
ZONE B	413	1256	19,8	6,0	10
Nice building					
ZONES	Area [m^2]	Volume [m^3]	Lighting load [W/m^2]	Office Equipment & other loads [W/m^2]	Max number of occupants
NOT CONDITIONED	1600	6400	10,3	10,5	20
LILLA	242	970	12,6	10,7	7
ROSSA (Autocom)	27	108	0	27,8	0
VERDE	425	1670	11,9	16,4	14
PAC (Gestion)	309	1235	9,9	18,6	20
BLU (VRV)	861	3445	13,6	5,7	14
YELLOW	108	432	11,7	16,2	6

TABLE 3, continued

Aix-en-Provence building					
ZONES	Area [m^2]	Volume [m^3]	Lighting load [W/m^2]	Office Equipment & others loads [W/m^2]	Max number of occupants
CONDITIONED	834	2257	7,8	8,5	20

Using the architectural drawings of the buildings, together with information collected from the on-site surveys and energy audits, a DOE2 computer model was created and calibrated against the building energy consumption measured in the campaign period (modelling carried out by the Italian team). Following calibration, the the modynamic behaviour of each building was simulated over a year (in respect of the representative meteorological data), to provide values of annual end-use consumption.

Subsequently the DOE2 model was adjusted to reflect proposed changes in installed system types (e.g. improved lighting), improved system control procedures (e.g. better control of air-conditioning fans) and modifications to the building envelope (e.g. use of selective windows). With each proposed «retrofit», the model was again used to simulate building thermodynamic behaviour in respect of the same representative year in order to provide new values of annual end-use consumption. A brief synthesis of results is presented below.

First we consider the energy balance of each building in its present state (Base Case Scenarios or BC). We surmise these balances in respect of four categories of electricity use: Heating, Cooling, Lighting, Office Equipment.

As a first approach to proposed building retrofits we consider the development of so-called «New Base Case» (NBC) scenarios. These consist in simple modifications to the regulation strategies (on-off timing or temperature set point) which require zero or very low capital investment. It is interesting to note that in two buildings (Toulon and Nice), presently most of the HVAC systems are set to run during the night and on weekends. In Aix the systems are switched off during the night, but left on during the daytime at weekend.

The following table shows the size of savings (absolute and relative) on HVAC consumption, which can be achieved by simply using more rational regulation strategies (NBC scenarios). The ratio NBC HVAC/ BC HVAC qualifies the control strategy and management and assumes an acceptable value only for Aix.

TABLE 4

	TOULON	NICE	AIX
HVAC consumption in NBC scenario [kWh/y]	121354	106174	32212
HVAC consumption in BC scenario [kWh/y]	182318	215862	38660
ratio : NBC HVAC/ BC HVAC	0,67	0,49	0,83
total energy consumption in BC scenario [kWh/y]	287179	269330	51496

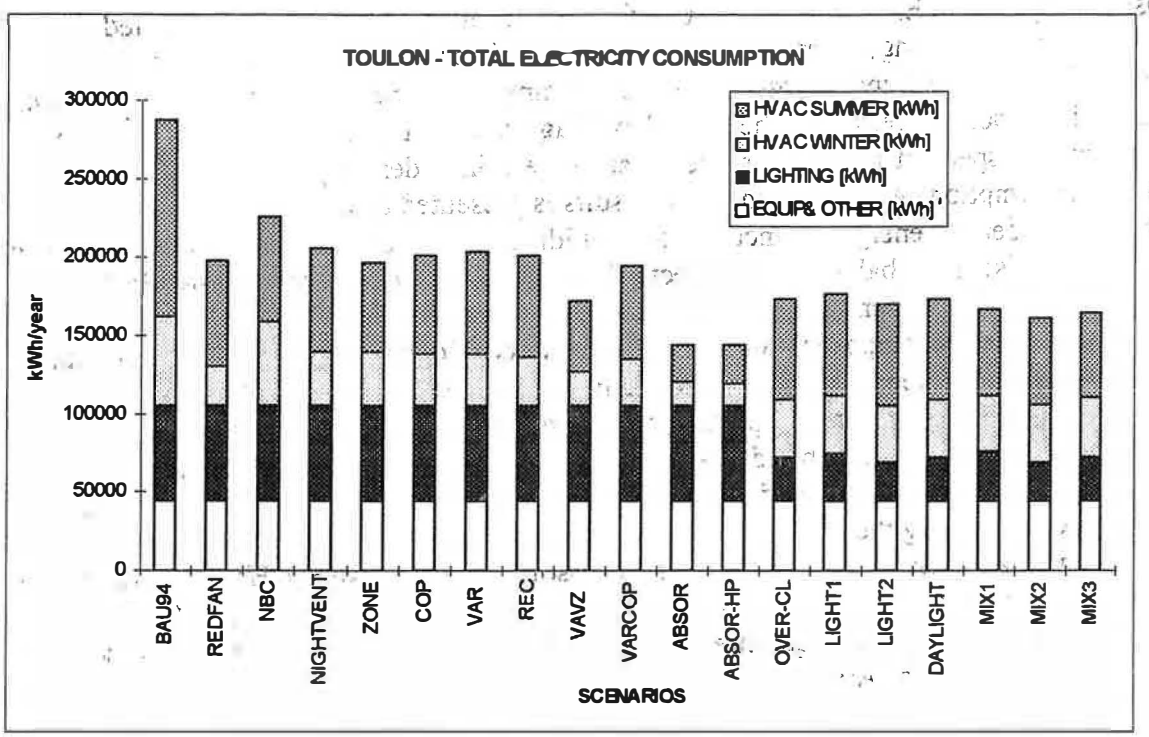
Starting with the NBC scena ios different sets of further interventions were assessed:

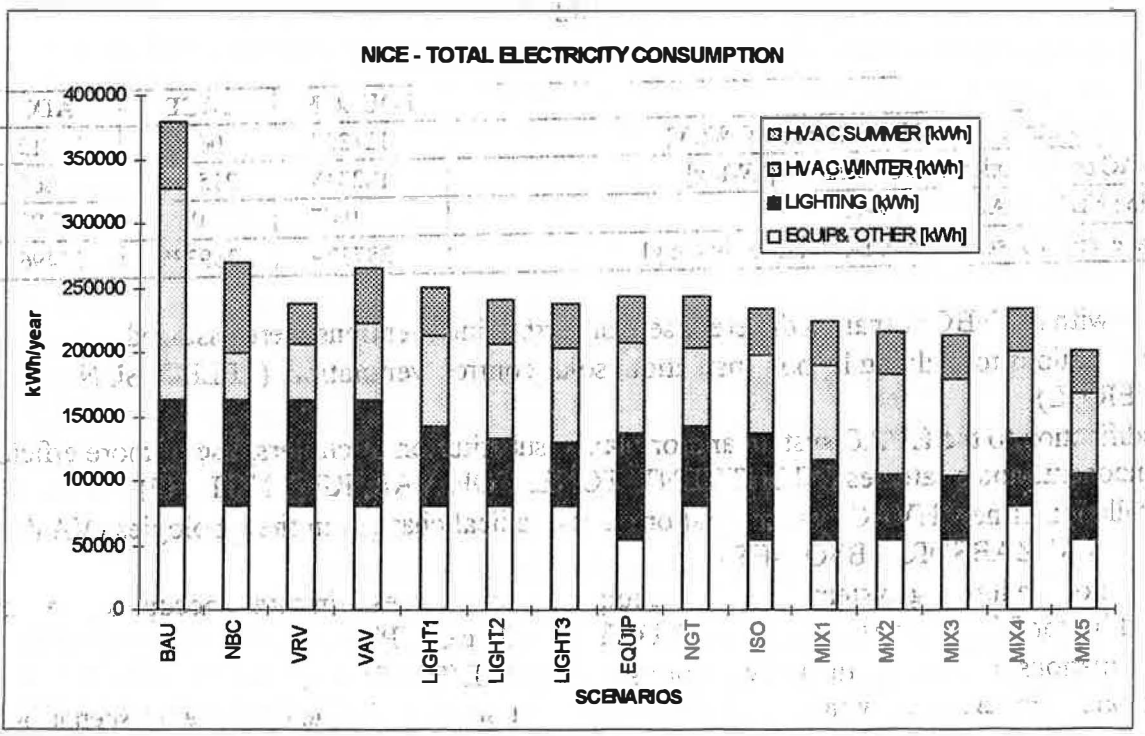
- modifications to building layout: insulation, solar control, ventilation (SELEC, SUN, OVER CL)
- modification to the HVAC system and/or plants: substitution of chillers, use of more efficient components and strategies (NIGHTVENT, ZONE, COP, VAR, REC, NGT, HP)
- installation of new HVAC systems and/or plants: radical changes in the typologies (VAV, V V, VAVZABSOR, ABSOR-HP)
- retrofit of the lighting system and office equipment: luminaries, dimming, occupancy sensors, stand-by for PCs, printers, etc. (LIGHT, DAYLIGHT, EQUIP)
- combinations of some of the above actions (MIX1, MIX2, MIX3, ...)

The graphs of Figure 1 show the results of the DOE2 simulation for the entire set of scenarios for

the three buildings.
An important point to note is that significant reductions in energy savings can be achieved even in respect of the NBC scenarios, that is even where a rationalisation of the regulation strategy has already been introduced. An economic assessment of each scenario has also been made.
However, given the diversity in the building stock studied (location, installed systems, usage patterns) it nevertheless is difficult to compare the achievable savings. A way to achieve a meaningful comparison is to consider the ratios between energy consumption and degree hours (either for winter and summer). In this way we can normalise the results with respect to climate (see Table 5). However, this method does not take into account many other climate factors such as temperature and solar radiation swings, wind patterns, etc.

FIGURE 1





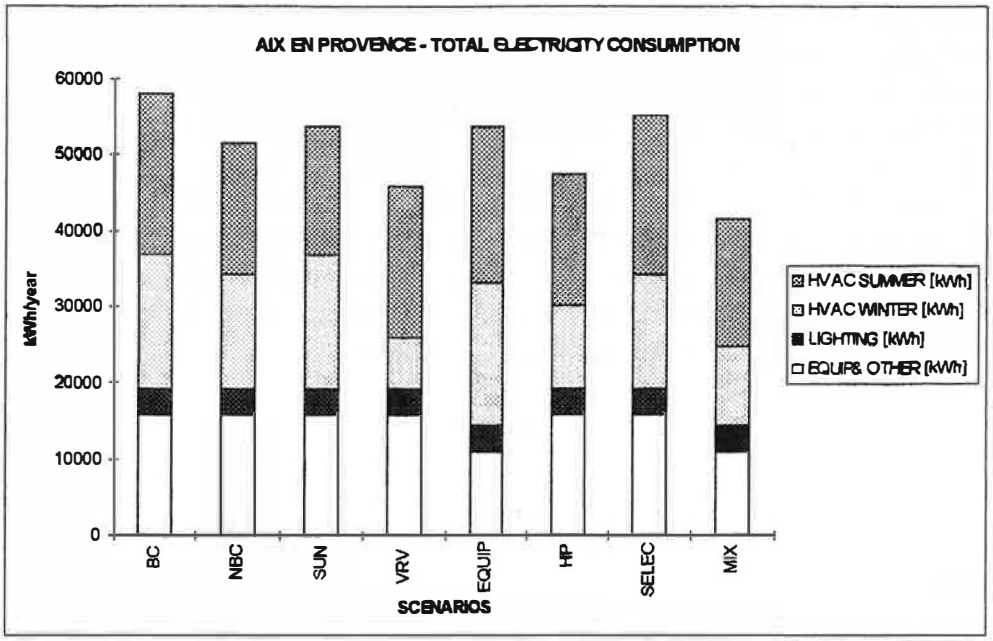


TABLE 5

	TOULON	NICE	AIX
degree hours Winter [°C h]	35155	40906	50394
degree hours Summer [°C h]	19881	24231	29362
total Degree hours [°C h]	55036	65137	79756
conditioned area (m^2)	1307	1972	834
Consumption Index: (NBC HVAC consump.)/(degree hours and area) [Wh/°C h m^2]	1,69	0,83	0,48

3. Conclusions

We explored the saving potential and the possibilities for a Regional Energy Agency to contribute to the development of a high efficiency air conditioning market. The work gave rise to a number of detailed pointers. i) Regulation is crucial for HVAC consumption; poor control procedures result in significant wastes of energy, which in the buildings examined could be resolved by relatively simple inexpensive measures. ii) Assuming correct system control, additional measures to further reduce energy consumption are available often providing good internal rates of return for the capital invested. More generally the choice of the correct mix of envelope, lighting and equipment measures is obviously related to the type of building, occupancy pattern, location and orientation. DOE2 proved a valuable tool for analysing and ranking these possibilities. However though the software does not present any undue complexity in use, developing a model of a building is relatively time consuming and might represents a relatively high overhead for projects of small office retrofits. In consideration of the potential number of projects requiring advice from the Agency, it would be more feasible to use DOE2 to model a number of representative buildings types. The incremental cost and energy savings per square meter achieved by a packet of retrofit actions would be determined in respect of the representative stock. Advice to small and medium offices would then consist in assistance on how to select and implement measures from the relevant package, thus reducing the costs and delivery time compared to completely customised design assistance.

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