Inspection and auditing of air-conditioning facilities in Europe – A new efficiency target

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Abstract

In coming years, the European stock of air conditioning equipments in use will partly become obsolete. In 2012, 50% of the Air-Conditioning market of EU-15 will be used to replace existing obsolete equipments (more than 15 years of operation) so that an opportunity exists to introduce higher efficiency systems. Indeed, the EPBD (European Energy Performance of Building Directive) introduced the technical obsolescence as a possible cause of replacement in addition to simple failure. A regular inspection of buildings equipped with Air-Conditioning systems is now obligatory.

First of all, the paper details the EPBD article 9 (European Parliament 2003) on the inspection and explains its scope, objectives and stakes. Indeed, too costly or too frequent inspections could create market distortions by leading building owners to prefer low capacity equipments that can be less energy-efficient. The paper focuses on the definition and the relevance of the 12-kilowatt limit and then on the type of installations included in the scope of that inspection. Despite problems, stakes are important in terms of energy savings because there is a strong link between the inspection and the audit, which is the first step toward Energy-Efficiency.

After that first phase, we model inspection and audit markets in the European Union, especially in the five biggest markets. The model shows that the Air-Conditioning market will increase a lot in the future and that present stock will become obsolete very soon. Inspection and audit markets are therefore enormous and Member States have to prepare the transposition as quickly as possible.

Last of all, standardisation is one way to accelerate the adoption process for this regulation. The draft standard (CEN 2004) developed by CEN (European Committee of Standardization) is a step in that direction but seems to be imperfect and several questions remain. However, facing with the quantity of buildings and the lack of time, several Member States could adopt that standard instead of developing their own more ambitious project, which could lead to less energy savings than forecasted.

Introduction

On January, 4 2003 the European Parliament and the Council of the European Union published Directive 2002/91/EC on the energy performance of buildings (European Parliament 2003), and Member States have to bring into force the necessary laws, regulations and administrative provisions to comply with the Directive by January, 4 2006. The requirements of the Energy Performance of Buildings Directive (EPBD) are expressed as several "articles" that relate to methods of ensuring the energy efficiency of buildings.

Among them, the Article 9 introduces a regular inspection of Air-Conditioning system with a capacity higher than 12kW during which the inspector will have to assess the efficiency of the system and suggest several possible improvements. Although this article seems to be simple, it needs a few definitions in order to understand well the scope, stakes and benefits of such a measure.

In a second part, we will then try to evaluate inspection and audit markets in the European Union and especially in its five largest markets that are Italy, Spain, France, Germany and the United Kingdom. After that, we will estimate what can be the workload, costs and benefits induced by such a measure.

Finally, as stakes and possible benefits are enormous, the European Union uses the way of standardisation in order to accelerate the process of transposition in national rights. However, we will introduce the CEN standard (CEN 2004) as presently drafted and evaluate problems that remain despite of it. This paper was written in 2004 based on information available at that time and its conclusions can be reversed by further decisions.

Who cares about existing Air-Conditioning facilities?

Before 2010, the stock of air conditioning equipment in use in Europe will partly become obsolete. Most systems will need renovation for the first time (after 10-15 years of operation) and an opportunity exists to introduce higher efficiency systems. Out of the 2200 million square meters of air-conditioned building area in use in 2010 in Europe, 800 million square meters will date by more than 15 years and will need urgent renewal (J. Adnot et al. 2003) in order to achieve objectives of the Kyoto protocol.

Several steps exist in the way to Energy-Efficiency:

1. Managing and benchmarking of the own technical installations and consumptions can be made by every building-owner using very little information.
2. The pre-audit (or walkthrough audit) is made by a professional. It allows to determine the existence or not of any defaults or on the contrary of any improvements in one or two days without any permanent metrology. Punctual measurements remain possible.
3. The audit (or detailed audit) is necessary made by a professional. It allows to determine quantitatively what can be improve on the considered installation and how much savings can be expected. It can take from several days (5 to 10) to several months (1 to 6) in order to make long duration measurements.
4. The investment in the renovation or the replacement of the system is the conclusion of the procedure. It often deserves an addition to audit result to get "investment grade" audit.

It is well known that in order to generate financial savings, industrials invest in priority on their "core business". To spend money to improve "utilities" is often judged less rewarding and that is the most important barrier to Energy-Efficiency. In comparison to industry, the difficulty is that there can be several persons in relation to a building with diverging interests: the building-owner(s), the occupant(s) and the operator(s) of technical installations included.

What can lead these different actors to have a given building audited ?

- A building owner that is also the occupant and the operator of his building manages his energy consumption and makes benchmarking on the comfort level or total costs. The detection of a problem during that phase can lead to a pre-audit by an independent expert.
- A building owner that is not the occupant of his building is interested by the value of his building in case of a possible sale. Any action that could improve that asset value is profitable so that he can have his building pre-audited by an independent expert.
- An occupant, who is not the owner of the building he uses, pays attention to comfort problems or running costs because he pays the energy bill. Occupants can also be interested in a pre-audit of the building they use in order to have their bill decreased.
- It is obviously profitable for an integrated operator, who is a third party, to make a pre-audit of a building before signing a contract with the building owner. Indeed, he can have information on the state of the installation in order to estimate his possible future costs for it.

Finally, every actor linked to a building can in theory be interested in a pre-audit. After that, each actor is free to invest in a detailed audit before any investment. The inspection is a type of pre-audit that is ruled by a regulation. It leads to the following limits: a precise list of defaults or possible improvements, necessary reproducibility of the assessment (independent from the inspector), possible in any seasons, obligatory, regular, punctual and non-intrusive measurements… The main stakes of the regular inspection is to initiate the process leading to Energy-Efficiency by accelerating the replacement of Air-Conditioning Systems. The idea of the European Commission was then to impose a certain type of pre-audit in order to launch the process. The compulsory inspection was therefore developed in order to incite building owners to make afterwards energy audits and maybe more.

The EPBD Article 9 makes regular inspection compulsory

Definitions

The Article 9 of the EPBD is named "inspection of air-conditioning systems". It stipulates that "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 kilowatts". Moreover, "this inspection shall include an assessment of the air-conditioning efficiency and the sizing compared to the cooling requirements of the building". Finally, "appropriate advice shall be provided to the users on possible improvement or replacement of the air conditioning system and on alternative solutions".

Scope of the regular inspection

The EPBD defines air-conditioning system as "a combination of all components required to provide a form of air treatment in which temperature is controlled or can be lowered, possibly in combination with the control of ventilation, humidity, and air cleanliness". Moreover, "the effective rated output (expressed in kW) is the maximum calorific output specified and guaranteed by the manufacturer as being deliverable during continuous operation while complying with the useful efficiency indicated by the manufacturer". However, even after defining those terms, article 9 remains unclear because the 12-kilowatt limit can be defined in several ways. Member States will have to define the meaning of the 12-kilowatt limit through a cost/benefit analysis.

That limit is associated on the one hand to an energy saving potential and on the other hand to a workload (number of inspections). The lower the limit (the wider the scope), the higher the workload but the higher the energy savings. One can understand the weight of consequences generated by that definition. There are 4 main ways to understand the boundary:

- 12 kW per cooling equipment. Only equipments with an effective rated output over 12 kilowatts will be taken into account.
- 12 kW per temperature controlled zone. Every cooling equipments (their individual effective rated output can be lower than 12kW) included in the same thermal zone (bound by a common control system) but with a total effective rated output over 12 kW is taken into account.
- 12 kW per building. Every cooling equipments (their individual effective rated output can be lower than 12kW) included in the same building (bound by exterior walls) but with a total effective rated output over 12 kW is taken into account.
- 12 kW per owner in a given building. Based on previous technical definitions, the scope may be extended to the real ownership in case of a share of the building.

The first definition is really simple and any building owner can easily determine eligible equipments by looking at nameplates. Indeed, any central air-conditioning (CAC) system is necessarily taken into account. However, most of room air-conditioning (RAC) systems and certain distributed air-conditioning systems (water loop heat pump system) are not included in the scope reducing as a consequence the energy saving potential of such a measure.

The second definition integrates installations based on low capacity equipment and equipped with a common control system. This new definition allows to widen the scope under certain conditions. Actually, in a water loop heat pump system, one (ore more) low capacity heat pump is installed in each thermal zone but its control is independent of another heat pump. These reversible heat pumps operate on a water loop the temperature of which is controlled by a heating system (boiler, heat recovery exchanger) during winter, by a cooling system (cooling unit, cooling tower) during summer or both during intermediate seasons. Although not very frequent, these heavy installations should be included into the scope but the previous definition does not make it.

The third definition allows inspection to take into account any equipment included in a one building even if its capacity is lower than 12 kW since the whole effective rated output of the installation then constituted is higher 12 kW. The frame of regular inspection is thus widened but now takes into account equipment on which the potential of energy savings is low.

Although using the same technical definitions of the 12kW limit, the fourth definition takes into account the property of the building and systems. Indeed, it is possible to consider inspection either on the building point of view or on its subdivisions in case of a building belonging to several owners. In the first case, each air-conditioning installation in a building is inspected independently of their ownership. It is the building that is subject to inspection. In the second case, there are as many inspections as there are owners in a building. This is the owner of a building (or of a part of) that is subject to inspection. The choice of the good scope has little influence on the workload. Indeed, in the first case, there are less inspections to do but with more equipment to check whereas it is the opposite in the second case. The latest definition allows to define easily who is the responsible of the installation and can facilitates and accelerates actions and investments from building owners.

Whatever the definition chosen, stakes of the regular inspection of air-conditioning systems are important. Initially, the inspection must avoid introducing distortions into the air-conditioning market. Indeed, too heavy, too long, too frequent and thus in short too constraining and expensive procedures for the building owner could lead him to buy equipment not covered by inspection. If the frame of inspection is not relevant, lower capacity equipments sales could increase in order to avoid inspection even if the final installation is less energy-efficient (which is an open question).

Benefits of the inspection

The first benefit of the regular inspection for the building owner will be to generate energy savings. Indeed, most of owners need evidence that the performance of their building is degradated before taking actions. The poor performance of an installation compared to the initial efficiency can be due to:

- a dysfunction of air-conditioning induced by a default on one piece of equipment
- a lack of operation or maintenance
- a control problem
- an improper action of the operating staff or occupants
- poor (obsolete) equipment compared with present standards

The regular inspection will underline the economic and environmental rationality of the possible complete or partial renovation of the air-conditioning installation or the change of mode of operation. In that case it could become relevant for the building owner to pay for an energy audit coming after the inspection.

Note that an installation can work perfectly, be correctly operated and maintained without being energy-efficient. Actually, the term “energy-efficient” is absolutely relative and depends on the reference installation. A low energy-efficiency must be judged in comparison to a reference so that 3 situations can be found:

- A poor initial efficiency i.e. already lower than the average efficiency of products initially on the market. This can be due to a bad sizing, a non-relevant choice of equipment or a poor installation.
- A poor present efficiency in comparison to present average standards of performance although performances were initially in agreement with past average standards. This is what we called technical obsolescence.
- A poor present efficiency in comparison to present best standards of performance (reached using most energy-efficient equipments) although performances are in agreement with present average standards.

The inspection will thus accelerate the replacement of air-conditioning systems by new ones more efficient when proving to building owners that their installation operates at a degraded efficiency level. The inspection may focus on sizing that has to be closer to cooling requirements, on the appropriate choice of equipment that has to be guided by the total cost (purchase + operation), on possible improvement of both process and building and finally on best available technologies on the market. Any reference to costs will naturally increase the relevancy, the interest and the impact of inspection for building owners.

The inspection is in addition the chance to highlight to building owners the importance of a good operation and maintenance (O&M) for most of processes. Indeed, without proper O&M, the efficiency of an air-conditioning equipment always decreases with time. That is why it is essential to focus on the existence or not of good O&M practice during inspection because building owners are not necessarily aware about that issue. One objective of the inspection is to make them improve operation and maintenance or contract a specialised company to do it.

Last but not least, the inspection is one way to make building owners apply the various existing and future building and energy related regulations. Indeed, the introduction of a check will allow to accelerate the application by the building owners of laws in relation to buildings in general but especially to heating, ventilating or air-conditioning systems (Thermal Regulation in France) that do not have a retroactive effect but can be applied voluntarily. The same EPBD requires Member States to introduce a thermal regulation of building renovations and an energy certification of existing buildings that may both require pre-audits and audits.

The CEN Standard for the transposition of the EPBD article 9

Usually, the European Commission let Member States transpose directives by themselves thanks to the "principle of subsidiarity". Indeed, European directives only define the objectives that Member States must reach but let them choose how to achieve them. However, each European directive is developed in association to several European studies that allow to accelerate the transposition and to help Member States in case of any problem.

Concerning the article 9 issue, the European Commission requested CEN to develop a standard defining the guidelines for inspection of air-conditioning systems. Independently of the quality of the document, the standard does not leave Member States develop their own experience. Nevertheless, the advantage of such a standard is to accelerate the transposition and to homogenise national laws on air-conditioning regular inspection.

Conscious of that problem, the philosophy of the CEN (CEN 2004) was only to impose a minimal acceptable standard acceptable by every Member States. As a consequence, the standard allows only a few measurements made with portable instruments or through possible existing metrology but obliges the inspector to make a list of essential verifications. The correction of any problem detected thank to that checklist is always cost-effective. Moreover, building-owners remain free to invest in voluntary best practices (GreenBuilding or detailed audits for instance).

In order to increase the impact of the regular inspection, the CEN widened the scope of article 9 to its maximum. Using EPBD definitions, cooling equipments (reversible or not), water and air distribution, air-exhaust systems and the control system must be inspected. So, mechanical ventilation (without mechanical cooling) and heating only systems are excluded. Moreover, the chosen 12 kW limit leads to the widest scope. Indeed, the effective rated output for a building is defined as the sum of the individual rated cooling capacities of the cooling systems in the building. Therefore, if the latter parameter is higher than 12 kilowatts, the building must be inspected.

Link with energy audits

The regular inspection is only the first step towards Energy-Efficiency and then energy savings. Indeed, possible actions following the inspection report depend only on the motivation of the building owner. In the best case, he will renovate his installations and will decide voluntarily to have his building audited. Nevertheless, if he decides not to improve his equipment, he will be at least warned about current defaults that occur on his installations. Therefore, he will be able to contract an HVAC operator (or improve the existing contract with), a maintainer or to simply establish a better internal follow-up.

Several factors can lead a building owner to have his building audited, especially for HVAC equipment. First of all, there is the will to decrease the building expenses by trying to reduce the energy bill. Moreover, the building owner can take advantage of financial incentives (ADEME subsidies, 5.5% VAT on works in France) to invest after an energy audit. However, these subsidies depend directly on the Member State economic conjuncture. Last of all, maybe the building owner needs to improve the image of his firm or local authority. The "political image" is an important parameter as well at the State level but also for its subdivisions (regions, departments or towns for France) before or during a political mandate. The "economic image" can be improved by actions towards "sustainable development" including Energy Efficiency.

Finally, the only rational incentive is the one that encourages the building owner to reduce the internal costs and so primary energy consumption. The others are only additional arguments to support the will to reduce internal costs. Nevertheless, the notion of "energy costs" is really relative and depends on the baseline. Indeed, any performance degradation leading to an increase of either the energy bill (efficiency decrease) or O&M costs (breakdown increase) is easily observable by the building owner and then can be corrected without regulatory measures. By opposition, the building owner can hardly detect an installation that operates normally but with a lower efficiency than present standards of performance. The regular inspection is meant as a vector towards detailed energy audit and more Energy-Efficiency. At the same time, the request that the inspection is independent from installers, operators, etc in the directive is not an opening in the direction of "energy services" and will request owners that have already optimised their HVAC to pay again for something already done.

Our modelling of the air-conditioning stock in use

Introduction

In some Member States, statistics about cooled areas are available. In some other Member States, annual equipment sales are regularly published in the specialised literature. Moreover, the recent project about Energy Efficiency and Certification of Central Air-Conditioners (J. Adnot et al. 2003) allowed to gather market statistics in the EU-15. As a consequence, air-conditioned areas were calculated thanks to all these data. The main steps of the model are detailed hereafter. The modelling is the same for every Member State but we only give here the results for France, Germany, Italy, Spain, the United-Kingdom that are the 5 larger markets representing 85% of the whole European Union in year 2000.

Analysis of statistical data

The analysis is based on equipment sales in 1998. Data for RAC are readily used. Data for distinct pieces of equipment are treated in order to reconstitute the centralised systems (generation, distribution, terminal units) called here CAC. Corrective coefficients are used concerning the:

- non representativity of data (wild imports of RAC, e.g.)
- average number of terminal units per installation
- oversizing of cooling equipment
- oversizing of terminal units
- average equipment capacities per range

Reconstitution of annual air-conditioning markets

The available data per type of equipment allowed to estimate annual growth rates before 1996 and from 1996 to 2000 as showed in table 1.

Table 1. Average Air-Conditioning growth rates of markets per type of equipment for considered Member States (J. Adnot et al. 2003) and grouping in CAC and A/C (total of CAC and RAC)

Market Average Growth Rates 1996–2000 / 1975–1996	FR	GE	IT	SP	UK
Split-System (>12kW)	35% / 30%	12% / 30%	3% / 3%	15% / 30%	15% / 15%
Chiller	6% / 6%	14% / 14%	10% / 4%	12% / 6%	0% / 6%
Packaged Unit	0% / 15%	0% / 15%	8% / 15%	11% / 15%	0% / 0%
Rooftop	20% / 15%	15% / 15%	10% / 15%	12% / 15%	0% / 0%
VRF (Variable Refrigerant Flow)	20% / 40%	30% / 40%	15% / 40%	15% / 40%	20% / 40%
CAC (5 previous systems)	8% / 9%	14% / 15%	11% / 7%	12% / 12%	3% / 7%
RAC	6% / 6%	14% / 14%	17% / 17%	12% / 12%	14% / 14%
Total AC (CAC+RAC)	7% / 8%	14% / 15%	14% / 11%	12% / 12%	7% / 10%

These growth rates allow to estimate annual air-conditioning past markets per type of equipment back to 1975 from the known market in 1998. This is important to estimate stock of equipment subject to ageing. A different treatment is needed from 1998 on due to saturation effects.

Translation of the market from quantity of equipments into cooled areas

The evaluation of market and stock after 2000 is made using a saturation model. This saturation is expressed in terms of areas so that we must translate our information of equipment quantity into cooled areas. In order to make such a translation, it is necessary to make sizing assumptions. We chose the following values:

- 120 W/m^2 for central air-conditioning systems (CAC) composed of split-systems (capacity > 12kW), chillers, rooftops, packaged units and variable refrigerant flow (VRF) systems.
- 240 W/m^2 for room air-conditioning systems (RAC).

The choice of this ratio for RAC takes into account the usual and important oversizing associated to installations based on such products. Indeed, occupants want comfort and a quick response to cooling requirements and then it is relevant to install a higher capacity than needed. Moreover, RAC systems are constructed in series so that only few capacity levels are available on the market (range effect). Furthermore, they are bought as units and capacity levels have a low influence on final price.

Calculation of annual air-conditioning stock

We assumed first that the average lifespan of an air-conditioning system is 15 years independently of the type of equipment. The sum of markets from years n-16 to n-1 is then the air conditioning stock for the year n.

The stock saturation model

The modeling of the stock in terms of cooled areas after 2000 is made considering the sharing of areas among the types of systems (and also the sharing among building sectors) remains the same as before 2000.

RAC systems are installed in the residential sector and in the other sectors and are treated separately from CAC systems in the present model. Global data of the Energy Efficiency of Room Air-Conditioners (J. Adnot et al. 1999) study were kept and included to the results obtained for the others air-conditioning equipments (CAC). Saturation forecasts are based a extrapolation of the Italian market data to other Member States.

About CAC systems (J. Adnot et al. 2003), we know the “stock of cooled areas” in 2000 is called S(0) and the market for the same year is M(0). The stock and market for year n are respectively S(n) and M(n). The stock of cooled areas S(n) is calculated after 2000 using the following laws:

The stock S(n) of cooled areas in square-meters for year n is given by:

$$S(n)=S(0).L_1(n).\frac{L_2(n)}{L_2(0)}$$

The L_1 term represents the growth of building (heated) areas in the tertiary sector of the considered Member State. The average annual growth rate k (in %) for this economic sector is known for each Member States (table 2) and is supposed to be the same for other sectors except for the residential sector:

$$L_1(n) = (1+k)^n$$

The $L_2(n)$ term is used to limit the growth of S(n) by introducing a “saturation”. Actually, $L_2(n)$ is a penetration rate i.e. the ratio between the stock of cooled areas S(n) and the building (heated) areas $S_h(n)$ in each tertiary sector. As S_h will grow with time thanks to the term, we divided L_2 by its value in 2000 in order to get independence. Then, L_2 will grow until it reaches its maximal value that we call the saturation. The penetration rate at saturation is $L_2(\infty)$ and obviously changes from one Member State to another because it reflects the sensibility of air-conditioning to the climate.

$$m(n)=L_2(n).b\left(1-\frac{L_2(n)}{L_2(\infty)}\right)$$

The b parameter is determined for each Member States in order to reach the saturation in 2030 with a 0.5% error. As expected, the evolution of the market will have consequences on the evolution of the stock and vice versa. The following recurrence law represents this link:

$$L_2(n+1) = L_2(n) + m(n)$$

That recurrence law reflects the evolution of the stock of cooled areas from the year n to the following due to the addition of the market of the year n and the subtraction of the market of the year n-15 (15 year lifespan). The m parameter is the difference between markets of year n and n-15 divided by the stock of year n. It is the actual addition to the stock, subtracting renovation.

Table 2 summarizes final penetration rates of air-conditioning extracted from the EECCAC study. Penetration rates at saturation reflect the sensibility of air-conditioning to the climate.

Table 2. Information about the stock saturation model for considered Member States

	FR	GE	IT	SP	UK
Assumed Final Penetration Rate $L_2(\infty)$ (%)	50%	30%	70%	70%	30%
Expected Building Area Growth rate k (%)	1.4%	0.6%	0.6%	2.3%	0.6%
Tertiary Sector Heated Areas S (Mm2)	641	900	631	432	646

In fact, penetration rates in 2030 in the South of Europe are supposed to reach, per sector, present penetration rates in the already saturated US market (J. Adnot et al. 2003). This comparison was made per type of climate so that we extracted 3 zones for Europe. Southern Member States (Italy, Portugal, Spain…) have an average final penetration rate of 70% and Northern Member States (UK, Germany…) have an average final penetration rate of 30%. France is too much divided in climate that it leads us to assume an intermediate final penetration rate of 50%.

Use of our stock model to determine inspection and audit markets

Preliminary remark on audits and inspections

The inspection is mandatory and must be applied to the whole stock of equipments operating in France. The quantity of inspections to do per year depends only on the choice of the frequency that will be fixed by Member States. It is totally different for audits because they are not obligatory but only advised for any refurbishment of an air-conditioning system. However, the building owner does what he wants. The quantity of audits used to determine simple improvements is hardly determinable.

Therefore, we must know the market (and the part of the renovation) in order to determine the maximal number of audits prior to any renovation or installation of an air-conditioning system. Indeed, for the first installation of such a system, the owner must have his building audited simply in order to size equipments. On the contrary, for a renovation, the building owner has experience in that domain and knows his consumptions as a reference so that he can invest in a whole energy audit in order to improve the operation of the future system (building, equipment and behavior of occupants).

Forecast of the air-conditioning market

The stock of air-conditioned areas before 2000 together with the results of the stock saturation model allow to deduce average markets per type of equipment. It is now possible to separate the market between sales due to a first installation of an air-conditioning system and sales for a renew of an existing installation. Indeed, with the 15 year lifespan, the market for the renew of an existing system in year n is the difference between total apparent markets in years n and n-15.

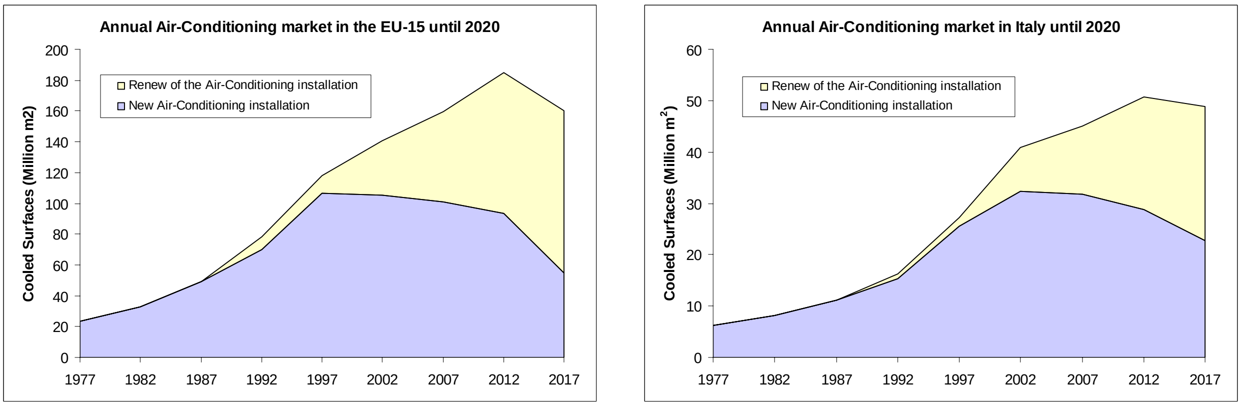

Figure 1. Prediction of annual Air-Conditioning markets in the EU-15 (left) and Italy (right)

After evaluating the two markets for each considered Member States, we compared our forecasts to other French studies (M-H. Foucard 2005) that evaluated the renew rate of Air-Conditioning installations as 10% of the whole market (RAC excluded) in 2002. The renew rate of CAC systems for France in 2002 is evaluated by our model as 29%. Chillers represent the biggest part of CAC systems and the 15-year lifespan may be underestimated for these equipments. In literature, some people say that the real lifetime is around 25 years for such equipments. Assuming that value, the renew rate for 2002 is estimated as 17%. This discrepancy is now in the range of acceptable uncertainties of a partial survey and we decided that those people are right. We applied this adjustment to all other Member States. The results of the adjusted model are presented on figures 1 to 3.

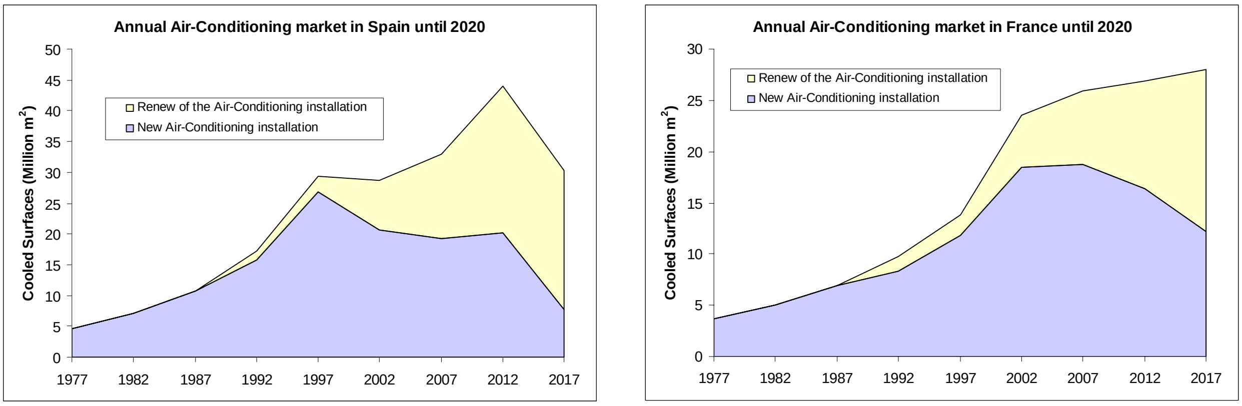

Figure 2. Prediction of annual Air-Conditioning markets in Spain (left) and France (right)

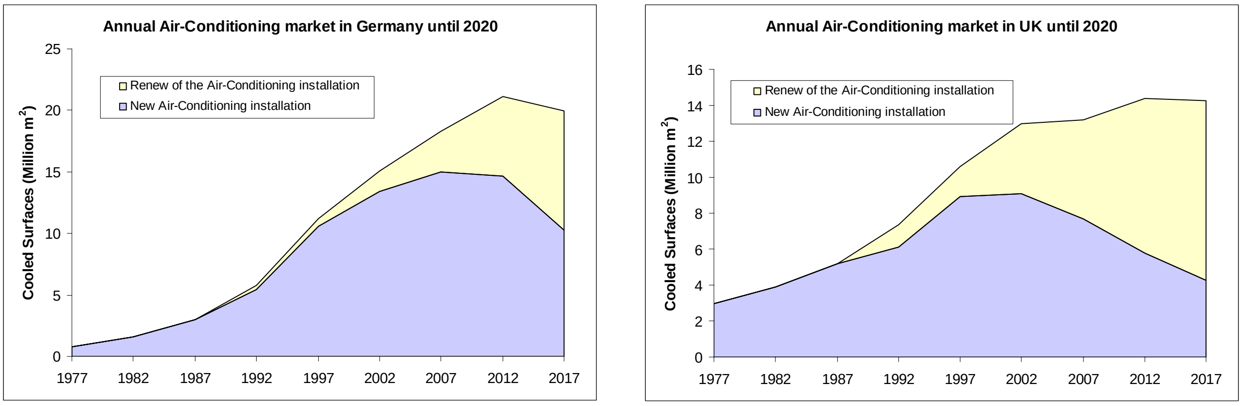

Figure 3. Prediction of annual Air-Conditioning markets in Germany (left) and in UK (right)

Inspection and audit markets

Thanks to the previous market and stock forecasts, it is now possible to evaluate inspection and audit markets. It is first of all necessary to come back to data expressed in numbers of equipments. The expression in square meters was necessary for saturation modelling. The average unit capacity per type of product presented in table 3 is used again.

For that estimate, we made several assumptions:

- The residential sector (22% of the annual market) is neither inspected nor audited. Indeed, in most cases, occupants have their own small capacity RAC that is not included in the scope of the regular inspection.
- A building is either equipped with CAC systems or RAC systems but not both.
- There is only one CAC per building. Actually, a French survey estimates that there are about 1 chiller, 3.1 VRF or 2.9 rooftops per building. By weighting with shares of the different systems for each considered Member States, we determined an average quantity of CAC per building.
- There are only 3 RAC per building.

Table 3. Average capacity of Air-Conditioning systems per type of equipment for considered Member States

		FR	GE	IT	SP	UK
Average Capacity (kW)	Split-System (>12kW)	22	23	13	24	17
	Chiller	110	140	71	130	231
	Packaged Unit	30	30	51	30	30
	Rooftop	40	40	51	40	40
	VRF	20	20	22	20	20
	CAC	66	66	60	96	60
	RAC	5.4	5.4	5.4	5.4	5.4
	AC	11	13	8	21	10

Analysis of the results

About inspection and audit markets

The results of the estimation of audits and inspection markets are presented in tables 4 to 8 as numbers of "orders" per year. They were obtained using an interval of 3 years between two inspections. The inspection market is huge and as the inspection is compulsory, it is impossible for Member States to avoid it. Hence, They will have to pay for the determination of buildings to inspect and the certification of inspectors and check of results. Moreover, building owners will have to pay for that inspection. The important number of annual inspections will have important consequences on Member States economy.

Despite the gigantic market, it is quite different for audits because they are not obligatory so that building owners are not obliged to invest in it. That estimate is then an upper limit of the audit market that will hardly be reached. However, the initiation of the process leading to Energy-Efficiency passing necessarily by audits was the main objective of such a measure so that the audit market will likely increase in the near future.

Table 4. Estimates of inspection and audit markets in Italy

	2007		2012		2017	
	RAC	CAC	RAC	CAC	RAC	CAC
Inspection	628000	181900	828000	237000	962500	279600
Audit (renew)	62800	16100	137700	20700	153800	29000
Audit (new)	121400	39700	98400	36800	33000	33100

Table 5. Estimates of inspection and audit markets in Spain

	2007		2012		2017	
	RAC	CAC	RAC	CAC	RAC	CAC
Inspection	405000	124400	490500	151100	545400	167500
Audit (renew)	53500	13900	94500	27100	86100	22000
Audit (new)	49300	17100	45400	17300	5000	5200

Table 6. Estimates of inspection and audit markets in France

	2007		2012		2017	
	RAC	CAC	RAC	CAC	RAC	CAC
Inspection	311300	64300	405100	84200	477900	98600
Audit (renew)	36900	5200	49000	9400	89100	11200
Audit (new)	60000	14300	48600	12600	16300	9400

Table 7. Estimates of inspection and audit markets in Germany

	2007		2012		2017	
	RAC	CAC	RAC	CAC	RAC	CAC
Inspection	239200	42400	322900	57300	384100	68000
Audit (renew)	24000	2200	46400	4600	63000	6500
Audit (new)	52232	11300	41500	11200	20200	8100

Table 8. Estimates of inspection and audit markets in UK

	2007		2012		2017	
	RAC	CAC	RAC	CAC	RAC	CAC
Inspection	161700	54600	191300	64200	205700	69800
Audit (renew)	20400	6400	39400	10400	34300	12000
Audit (new)	17700	6800	11600	4800	3800	2600

Limits of our model

We had to adjust the average lifespan to 25 years only for chillers keeping 15 years for other air-conditioning equipments. These lifetimes do not take into account of building renovations that often lead to a renewal (partial or total) of the existing air-conditioning installation even if it works correctly. As a result, life durations remain very uncertain. In certain sectors, especially the trade sector and horeca (hotel restaurant café), the interval between two building renovations is sometimes lower than 15 years but always lower than 25 years.

Moreover, the use of a saturation limit $L_2(\infty)$ is very sensitive for our model. A wrong estimate of that parameter can lead to wrong results especially concerning the renew rate and its evolution over time. That can be a cause of the possible differences observed comparing results of the model and real markets.

Finally, the sizing ratios (W/m2) were determined for CAC systems thanks to average European practice that can be very different from one Member-State to another. These practices and thus the ratios are likely to evolve a lot in the future in order to limit the environmental impact of air-conditioning. For RAC systems, the variability of these ratios is even more important because of direct purchasing by final users or installers

Necessary workforce for the inspection

We can imagine two scenarios concerning the people in charge of inspecting air-conditiong installations. On the one hand, if inspection requires "energy experts" or “air-conditioning experts”, Member-States will have to certify consultants for doing it. However, they will not be able to spend all their time on that activity. On the other hand, if inspection requires only “simple inspectors" without particular expertise, it is possible that they spend the majority of their time on the periodic inspection. We can then make the following assumptions:

- 1 day in average per building to inspect
- 200 inspections per year on average for a “simple inspector”
- 100 inspections per year on average for a consultant with a real expertise in air-conditioning or energy
- Inspection every 3 years

The number of persons necessary for the inspection resulting of our assumptions is given in the table 9.

Table 9. Estimate of the staff needed annually for the inspection per Member-State

	2007		2012		2017	
	Inspectors	Experts	Inspectors	Experts	Inspectors	Experts
IT	4050	8100	5325	10650	6210	12420
SP	2650	5300	3210	6420	3565	7130
FR	1880	3760	2450	4900	2885	5770
GE	1410	2820	1900	3800	2260	4520
UK	1080	2160	1280	2560	1380	2760

Costs and benefits of the inspection

The energy saving potential of the inspection is difficult to evaluate precisely. Indeed, there is a direct potential associated to the correction of defaults limiting the performances but also an indirect potential associated to the possible future improvements or even the replacement of the existing installation by the building owner. The indirect potential cannot be estimated because it depends on the will of the building owner as well as other parameters (financial, priority, unavailability of the installation...). Unfortunately, the most important savings are necessarily the consequence of important works on the installations and not only of simple correction of defaults. Therefore, the direct potential is unlikely to be larger than 5-10% of the Air-Conditioning energy consumption.

In order to evaluate the costs and the benefits of the measure, we made the following assumptions in addition to the previous ones:

- A consultant with a real expertise in air-conditioning or energy is in charge of the inspection
- The tariff (French practice for an expert consultant) for inspection would be 1000€ per day
- The price of the electricity in 2007 is between 20 and 40 €/MWh (current range on POWERNEXT, EEX, OMEL and UKPX)
- An average saving potential of 10% of the Air-Conditioning consumption
- Air-Conditioning consumption ratios (kWh/m^2) determined by simulation from the EECCAC study (J. Adnot et al. 2003)

Estimated costs and benefits of the inspection are given in the table 10. We can conclude that the measure seems to be costly for Member-States economics compared to the direct benefits only. Moreover, this 5-10% potential is likely to decrease with time because some defaults will be more often checked afterwards. However, there are indirect effects that could change the terms of the equation.

Table 10. Estimates of the costs and benefits of the inspection per Member-States for 2007

	Cooled Surfaces (.10^6 m^2)	Consumption Ratio (kWh/m^2)	A-C Consumption (TWh/yr)	Cost of Inspection (.10^6 €/yr)	Saving Potential (.10^6 €/yr)
IT	370.4	50.1	18.6	810	37.2 – 74.4
SP	407.7	81.5	33.2	530	66.4 – 132.8
FR	268.1	32.6	8.7	376	17.4 – 34.8
GE	185.3	22.8	4.2	282	8.4 – 16.8
UK	166.2	19.7	3.3	216	6.6 – 13.2

Points for further discussion

We have seen the CEN standard is a base to help Member States to transpose the EPBD article 9 but several questions still remain.

First of all, how can Member States determine which buildings must be inspected? How is it managed?

In a preliminary phase, it is essential to determine which buildings are eligible to the regular inspection at some time. To check enforcement a list of buildings is necessary. Local authorities have the list of buildings on their area and it is possible to crosscheck it with local taxes in order to determine the ownership. The existence of an air-conditioning system and the determination of the quantity in a building could be made by a local survey. After that, the update of the equipment database must also be made in real-time. This systematic approach will be costly so that a simpler system should be invented.

Who can become an inspector?

It is possible to make an analogy with “roadworthiness tests for motor vehicles” introduced by a European Directive. Roadworthiness tests are specialised on the safety of motor vehicles, in other terms on the efficiency of their safety parts but not on their intrinsic efficiency. A specialized metrology is used and limit values are fixed so that the inspector (a qualified mechanic) can directly judge if the vehicle passed the tests.

It is quite different for the inspection of air-conditioning installations because it is focused on the efficiency. Although a good maintenance is synonym of good performance, there are other factors (behaviour, operation, adjustments, control system, equipment) that have consequences on the efficiency of the system. We do not have yet a specialized metrology like for car safety. All these factors must be analysed and the inspector should give advise on possible improvements. The CEN standard is focused on operation and maintenance checking and few quantitative tests are proposed so that it requires a lot of experience from the inspector. Inspectors should therefore be experts in air-conditioning and building in order to get the authorisation to practice. Moreover, they must be totally independent so that HVAC consultants seem to be the best inspectors for the directive despite the fact that installers and maintainers have also a good experience of tuning and repair.

What about the 3-year interval? Has it to be adapted?

The CEN standard proposes a maximal 3-year interval that could be decreased if the building owner is advised to take actions. However, this frequency is far too strict and adaptations should be made. Indeed, the energy saving potential by possible improvements for certain equipments (RAC in general, split-systems) is too weak and an inspection every 3 years seems not to be the good way to reach energy-efficiency for those pieces of equipment. The frequency should then be reduced and the inspection should be more focused on information about efficient systems and technologies and associated costs (purchase + operation) in case of a future replacement.

Moreover, there is a strong culture of operation and maintenance in some countries like France (M. Dupont, J. Adnot 2004) so that a lot of companies provide long duration O&M contracts with obligation of results on costs or energy. These ESCOs implement the means that they judge necessary to obtain the contracted result. The main procedure is a regular inspection of the installation or of the building in order to make adjustments or to detect faults. In addition to that inspection, the analysis of the energy consumptions or costs allows to optimise maintenance and replacement of the whole or a part of the installation that ESCOs can finance. Building owners that can prove their building is subject to such a contract should be inspected less frequently according to our analysis.

Is a minimal documentation obligatory?

In order to facilitate the inspection, it is necessary to have access to a basic documentation, for example the building logbook. This logbook records any modification or work in the building itself or on any of its technical installations. However, this information is most of the time not available in the building so that the inspector will surely waste a lot of time to get information. It is then necessary to ask building owners in the frame of this regulation on inspection to create, use and update such a logbook in order to facilitate the application of any existing or future building and energy related regulations.

Concerning energy and building regulations, we observed the CEN standard on the regular inspection does not make any reference to the regulation in force now or at construction time. Obviously, regulations applied to buildings differ from one Member States to another so that it is impossible to quote them all in the text. However it seems logical that such an inspection should check if the building and technical installations included respect the regulation in force or not (at the time of installation or/and now). As these regulations are improved regularly, the inspection should also regularly propose improvements to owners in order their buildings reach the latest and stricter energy and environment standards. These verifications should in theory be the basis of the regular inspection in order that future regulations will be applied quicker.

Conclusion

The Kyoto objectives in terms of reduction of our CO_2 emissions are already ambitious for Europe but will obviously become more and more in the future. The EPBD is then a part of a whole package of directives developed and voted in order that the European Union reaches Kyoto targets. Although that measure is not as important as the European CO_2 market, its effects can be significant at the long term thanks to strong improvements of the European stock of buildings.

The philosophy of articles 8 and 9 of the EPBD was to limit the performance degradation of heating and Air-Conditioning systems and to accelerate their replacement by new more efficient ones. The idea is good but it will be difficult to achieve objectives because of the wide scope and the huge number of installations to inspect. However, it is important to warn building owners about current problems that occur on such installations and about energy waste then generated.

Moreover, the CEN standard allows to accelerate the transposition of the directive in national rights but it seems that several problems remain. Indeed, due to a lack of time and face to the huge number of building to inspect, Member States may concentrate on the implementation of the inspection but not on the quality of it. However, in that state, the CEN standard is hardly applicable because of the costs and the necessary workforce and hence needs adjustments. The risk would be that Member States use the standard without trying to improve or adjust it to their own market creating a lot of problems and leading to an abandon of the measure. The EPBD article 9 lets flexibility to Member-States so that they shall adjust (frequency, duration…) the regulation in order to make the inspection more efficient and applicable in practice.

Despite the problems, the idea of a mandatory inspection seems to be a good mean to launch the replacement procedure that goes on then with audits. As boilers, Air-Conditioning systems are complex and need a strong maintenance to operate correctly and at a good efficiency during their whole lifetime. The present development of energy services (ESCO) in Europe will surely support that orientation.

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