Issues of the implementation of the EPBD article 9 : how and why to inspect all air conditioning systems all over Europe?

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Abstract

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”.

Despite the gigantic market of Inspection created by this measure, the real objective is to realise Energy Efficient Improvement and its achievements depend on the implementation Member States will select. The real objective will be realised or missed. Depending on those decisions, the huge cost of such an inspection will pay back in saved energy, or be lost in superficial approaches or heavy paperwork. The inspection implementation has to be a cost effective measure but also should be integrated in a framework of thought including more detailed Audits, better Operation & Maintenance and other measures for training of actors and sound decision making.

The paper is partly based on the ongoing work of a SAVE-EIE group called Auditac and including : ENSMP, France, coordinator, Eurovent, the EU manufacturers association, U. of Liège, Belgium, international experts on AC, INEGI- Univ. of Porto, Portugal, experts on AC systems, E.V.A., the Austrian Energy Agency, WSA, ABE, BRE, three UK institutions with

years of experience on the subject, POLITO, modellers and researchers on systems at Politecnico di Torino, UL-FME, leading the Slovenian effort in EE.

1- Opportunity and Timing

Over the last 20 years, the scale of application of air-conditioning in European buildings has greatly increased and, consequently, so has the importance of the associated energy consumption and carbon emissions. The age structure of the stock is such that a growing number of systems now need to be renovated or replaced (after 10-15 years of operation). This presents an opportunity to upgrade their efficiency. This can be seen from figure 1. By comparing the stock of systems in use in a given year (expressed in square meters served) with that 10 or twenty years before the number of such systems can be inferred . Out of the 2.200 Mm2 of air conditioned building area in use in 2010 in Europe, 800 Mm2 will be more than 15 years old

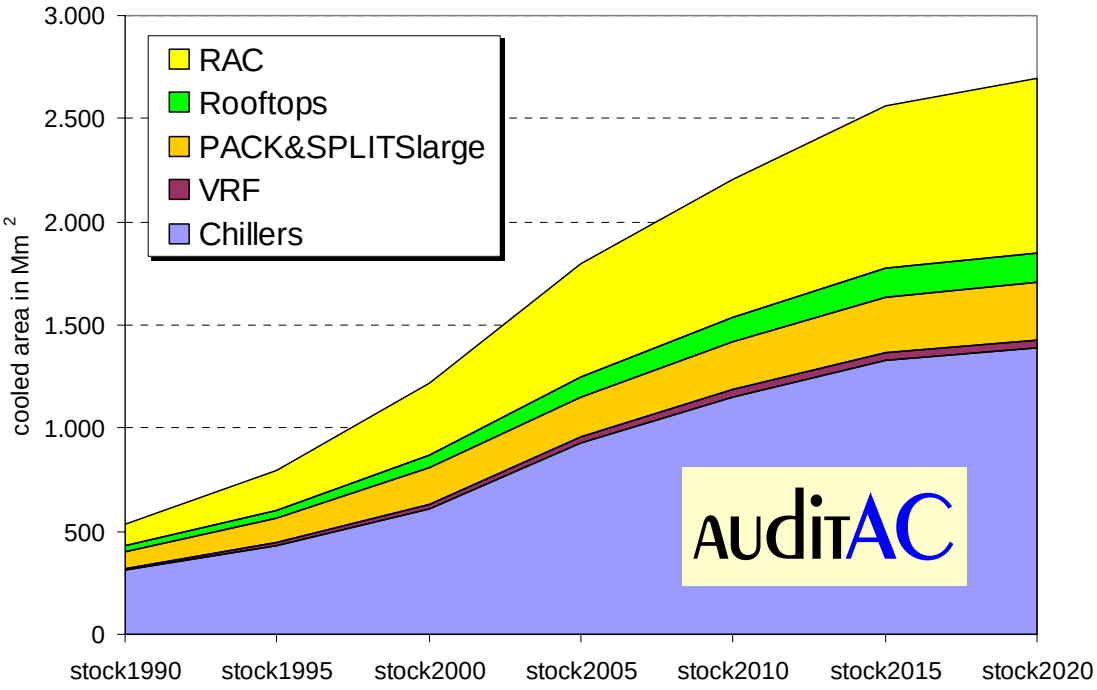

Figure 1. Cooled area (Mm2) in Europe (source EECCAC)

The age of installations is not a problem in itself, if they are of good performance and well maintained and efficiently operated. Unfortunately this cannot be guaranteed, since AC is still a relatively recent innovation and many professionals are not as familiar with the technology as they are with other building services. Building owners are often not as aware of the potential for energy savings as they could be.

In addition to savings from better operation and maintenance, the availability of systems and equipment today with much better performance than those on the market 10 years ago

provides a substantial saving potential. A SAVE Study (EECCAC) showed that this potential was of the order of 50 % of current consumption.

The rational approach

A rational actor will take the following steps to improve energy-efficiency:

- Manage and **benchmark** his systems and their consumptions. This can be done by every building-owner using very little information but well located indicators.
- The **pre-audit** (or inspection) is usually carried out either as part of some other process (such as a change of use, or within a maintenance operation) or because the indicators reveal a problem. It typically requires one or two days work, usually by a professional, supplemented by existing records and "spot" measurements and allows the identification of easily identifiable faults and possible improvements
- The **audit** (or detailed audit) is necessarily carried out by a professional, typically to further investigate opportunities identified by the pre-audit. It produces quantative estimates of the costs and saving to be expected It can take from several days (say 5 to 10) to several months (1 to 6) if long-term measurements are needed.
- If justified, investment in renovation or replacement of the system or components follows. Before a decision on investment is made, it may be necessary to obtain detailed quotations and make more detailed assessment of the likely savings. This we call an "**investment grade audit".**

This rational approach is not common, especially in the case of AC. It is well known that in order to generate financial savings, industries and building occupants' investment priority is their "core business". However, spending money to improve "utilities" is often pre-judged to be less rewarding: a serious barrier to energy-efficiency.

Clearly, from a business perspective, the financial criteria applied to investments in energy efficiency should be the same as those applied to other business investments. For many businesses, the loss of productivity that results from poor environmental conditions will be at least as financially important as energy costs. This aspect is not normally addressed by energy auditing, but could usefully be considered as part of a full audit.

For air-conditioning in buildings, the lack of established procedures for assessing the potential for savings and the shortage of visible precedents by other businesses are additional hurdles.

In comparison to industry, an additional difficulty with buildings is that there can be several persons with diverging interests: the building-owner(s), the occupant(s) and the operator(s) of the technical installations. This is called the problem of "split incentives".

Different motivations for different actors to carry out a pre-audit

- A **building owner who is also the occupant** and the operator of his building manages his energy consumption and monitors comfort level or total costs. The **detection of a problem** 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. Pre-auditing the building before sale by an independent expert (and resolving any problems) should improve the value..
- An **occupant, who is not the owner** of the building he uses, pays attention to comfort problems and to running costs (when he pays the energy bill). When the energy cost is part of the landlord services included in the lease, occupants can also be interested in a pre-audit of the building in order to negotiate that cost.
- 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 new compulsory inspection required by Article 9 is a type of pre-audit that is ruled by a national regulation.

The new compulsory AC inspection is timely because of the age of the stock and the lack of awareness of actors who can benefit.

The basic concept is necessarily constrained - it should: be possible in a relatively a short time, not require intrusive measurements, produce a precise list of defaults or possible improvements, be consistent between inspectors , be compulsory, be carried out regularly, …However, it is only the first – but very important - step that initiates the process leading to energy-efficiency by accelerating the replacement and upgrading of Air-Conditioning Systems.

Scope of inspection in Article 9

Article 9 of the EPB Directive takes care for the first time of the Inspection of existing air-conditioning systems. The idea of the European Union 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 (ad other actors) to make afterwards energy audits and maybe more.

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.

Many air-conditioning systems also provide ventilation, but nothing in the directive is said explicitly about “ventilation” (although there is a draft CEN standard on inspection of ventilation systems). While energy consumption of ventilation-only system can be significant, health and comfort issues relating to the provision of ventilation are very important.

Article 9 of the Directive focuses on the efficiency of air-conditioning systems and their sizing. (Over-sizing is financially wasteful but is not necessarily wasteful of energy for system whose peak performance s at part-load). The Energy Performance Certification requirements in other articles of the Directive should, in principle, encourage building designs that reduce the loads that systems have to satisfy – and should encourage passive design solutions.

However, the Directive is surprisingly silent on the issue of internal environment and comfort. Energy efficiency gained at the expense of poor indoor conditions may be a poor bargain. We have already noted that the productivity benefits (or losses) of poor performance are likely to be financially comparable or greater than the energy benefits. The optimal solution may involve a trade-off between, say, overheating risk, and system sizing or design. Although there would be some real difficulties in implementation, it would be desirable to enlarge the concept of "inspection" (and energy audit) in this direction

2- Implementation issues for mandatory inspection

The limits of application of Inspection are not completely defined in the EU directive. Member states have some latitude in the way that inspection is implemented. This section addresses some of the issues.

Definitions

The EPBD defines an 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 system. Only systems with an effective rated output over 12 kilowatts will be taken into account.
- 12 kW per temperature controlled zone. Every cooling system included in the same thermal zone (bound by a common control system) but with a total effective rated output of the zone over 12 kW is taken into account. (The rated output of each system can be lower than 12kW)
- 12 kW per building. Every cooling system included in the same building (bound by exterior walls) but with a total effective rated output for the building over 12

kW is taken into account. (The rated output of each system can be lower than 12kW)

- 12 kW per owner (or tenant) 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 (such as water loop heat pump systems) are not included in the scope, thus reducing 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 widens the scope under certain conditions. 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. 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 common , these large installations should be included into the scope but are excluded by the previous definition.

The third definition allows inspection to take into account any equipment included in a building even if its capacity is lower than 12 kW, since the total effective rated output of all systems is higher than 12 kW. The scope of regular inspection is thus widened but now takes into account some equipment for which the potential energy savings are low.

Although using the same technical definitions of the 12kW limit, the fourth definition takes into account the ownership of the building and systems. Indeed, it is very difficult to imagine that that owners of different parts of a single building will exchange technical information about their systems. With this definition, there are as many inspections as there are owners in a building, but we know who is responsible for the inspection : the owner. The definition allows us to define easily who is the responsible of the installation and links the inspection responsibility to those who can best take action on the results. Where buildings have multiple tenants whose leases include the provision of air-conditioning as a landlord service, this definition reverts to 12kW per building.

Globally, 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. For example, the fourth definition above provides an incentive for to provide each tenant with an installation of less than 12kW capacity (rather than a centralised system), even though the total installed capacity of the building is high. (It is an open question which solution would be the more energy efficient).

How happy you are when you have been inspected?

An inspection could be a “pass or fail” test or an inspection that you always “pass”. It seems to be the second case in the directive. The CEN draft standard tries to define conditions for repetitions of the inspection when the results are unsatisfactory, but this is not an easy

task. In that case, the penalty would not be to “fail” but to have to pay more frequently the auditor who would come again and report about the same thing. Obviously Member States are allowed to develop better, less arbitrary or more productive approaches. This could be the case for defects which existed at the time of initial installation and were prohibited by regulations at that time. In the existing projects, non compliance with regulations is not always reported.

Are thermal regulations useless when we move to inspection?

Neither the CEN draft nor national drafts on inspection rules make reference to any regulations in force at the time of inspection or, previously at the time of construction. 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 part of the technical basis of the regular inspection in order that future regulations will be applied more quickly to the existing stock. The same EPB directive requires Member States to introduce a thermal regulation of building renovations and an energy certification of existing buildings that may require pre-audits. Shouldn’t we look for a synergy when applying both articles of the same directive?

Many inspections will not be realised, should we just ignore that fact?

Local authorities have the list of buildings on their area and it could be 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 would need a costly local survey. After that, the update of the equipment database must also be made in real-time. This systematic approach may be too costly so that a simpler system will be used. A possible approach is to require proof of inspection at the time of the time of sale or lease, as for Energy Performance Certification. Some countries like France have AC as one item in the IPPC list. By changing the threshold (presently 50 kW elec. In the case of France) this powerful tool would help to provide a better coverage of inspection measures.

3- How to integrate compulsory inspection in the cycle of O & M of the plant?

When inspection is useful, it provides information at the time needed, in a useful form, acceptable to the people who will use it. Inspection needs information to become feasible.

In order to facilitate the inspection, it is necessary to have access to basic documentation, for example the building logbook. There are also potential benefits from sharing the information collected in fulfilment of the Directives inspection and certification requirements, and reducing the total workload. 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 most buildings so that the inspector have to spend time trying to obtain it. It seems then reasonable to require building owners create, use and update such a logbook

in order to facilitate the application of any existing or future building and energy related regulations. (In the UK, for example, Building Regulations compliance already requires the provision of a building logbook).

Inspectors and operators : partners or enemies?

One of the most cost effective outputs of the inspection is to question (thanks to an outside view) the way the AC system is managed and operated. On the one hand nobody knows the plant better than the operator (notably determining controls, modes and set points) or the maintainer (increasing reliability). On the other hand nobody is less interested in energy performance, reducing capacity, limiting equipment operation, etc. (except when an Energy Performance Contract has been signed, with profit sharing or fixed price arrangements).

So part of (all?) the inspection recommendations are to be transmitted by the owner to the operator, and a direct dialogue between the operator and the independent inspector is an opportunity for real world follow up. It is therefore very desirable for this direct dialogue to take place.

Collaboration between the inspector and operators/maintainers is essential for another reason. Should inspection certificates be issued for installations that we have not seen operating -and maybe cannot operate? No! So there is a need to put the plant ON even for a short time. If we want to inspect in Summer, the operator has to be present and generate an artificial cooling demand, (something that is not possible with all systems). Some systems cannot be technically inspected outside of the cooling season, but most can.

One of the outputs of the inspection, maybe the only one that the owner will always understand, is the implicit or explicit judgement on the O&M in place. As we have already discussed, there should be an obligation to maintain the “as-built” documentation and the log-book to avoid extra costs in the inspection process. The inspection report should say whether the maintenance regime in place appears to correspond to the contract or not. A good Inspection report will say where the contract can be improved. It is important to adjust Inspection time step to maximise this benefit (for instance one year after the start of a new O&M contract, one year before its end).

What is the inspector expected to discover about the plant?

A number of technical actions (benchmarking, checking of equipment references, checking of maintenance contracts, etc) could well be made at distance, via phone and fax. Inspection infers presence and visualisation, but the degree should be commensurate with the potential for savings, and it may not be cost effective to visually inspect all equipment.

Visible O & M errors, certainly. A 5-10% potential is quoted by « experts » for such errors, easy to correct if the diagnosis is expressed in the terms of the operator and takes into account the real operational constraints that the operator withstands.

Invisible O & M errors, difficult without short-term monitoring or use of BEMS data , and without some kind of modelling of the ideal behaviour of the plant to be compared with the real one. A 10-40% potential is quoted by « experts » for such errors, but the effort to (possibly) achieve this is clearly beyond that envisaged by compulsory inspection.

Benchmarking with other plants of the same type and age. This is certainly information that the owner would appreciate, and that only an independent inspector can bring. The knowledge is dramatically missing.

Improvements that can be made to the hardware. This needs a lot of expertise and engineering even to produce raw estimates. The (probably conservative) estimate of the potential for savings made in EECCAC is 50% of present energy consumption.

This brings us to projects like Auditac, supported by SAVE-EIE. AUDITAC is a project about the issues that follow after the national legislation to implement Article 9 of the EPBD. The focus of the project is to help the European A/C market to reach a higher overall energy efficiency, by taking benefit of good inspections, of improved audits, of best practice case studies, or of any other measure.

The only direct and certain benefits of implementation of article 9 are the discovery of visible operational errors. Beyond this, compulsory inspection can provide indirect help to the next stages towards achieving savings, by systematically documenting what has been inspected. It would be valuable for national implementations to require standardised documentation.

4- What can we expect the plant owner to do after a good inspection?

We can imagine four scenarios for a profitable effect of the compulsory inspection : identifying problems (scenario 1); assessing expenditure (scenario 2); a follow-on audit (scenario 3); preparation of a refurbishment (scenario 4).

The first benefit of the regular inspection for the building owner will be to generate an awareness that there is one (or various) more or less complex AC plants, a source of some potential problems **(scenario 1).** 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 its initial (or expected) efficiency can be due to:

- a dysfunction of air-conditioning induced by a fault 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

If we target the inspection at expenditure **(scenario 2)** the regular inspection could underline the economics of the possible complete or partial renovation of the air-conditioning installation or the change of mode of operation. If this looks significant it would become

relevant for the building owner to pay for an energy audit. But in order to enter into that circle the inspection report should identify the share of total costs (energy, O&M, investment) corresponding to the AC function. One could imagine that this is part of the Energy Certification of Buildings in the same EPBD, but it is unlikely to be (a breakdown of energy consumption by service is likely to be provided in some Member States, but is not a requirement). So only the inspection could start this financial approach. Any reference to costs will naturally increase the relevancy, the interest and the impact of inspection for building owners.

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 to invest after an energy audit. However, these subsidies depend directly on the Member States' policies. Last of all, the building owner may wish to improve the image of his firm or local authority. The "political image" is also an important parameter at the State level and 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. In contrast , the building owner can hardly detect an installation that operates normally but with a lower efficiency than current "best practice" standards of performance. Regular inspection is meant as a vector towards detailed energy audit and better energy-efficiency. We could expect that the inspector might advise the building-owner which additional indicators, such as sub meters (s)he should install and read.

At the same time, the requirement that the inspection is independent of installers, operators, etc in the Directive is not helpful to the provision of "energy services" as it seems to require the (few) owners that have already optimised their HVAC with good energy service contracts to pay again for something already done. This would be addressed if the requirement can be a satisfied by a system of independent auditing and checking of registered inspectors – who could be existing O&M or energy service contractors.

If Inspection is the real start of an equipment Audit **(scenario 3)** it should start by comparing the specific plant with state-of-the-art plants. An installation can work perfectly and be correctly operated and maintained without being energy-efficient. Actually, the term "energy-efficient" is absolutely relative and depends on comparison with a reference or level of performance. We can foresee three situations:

- A poor **initial** efficiency i.e. already lower than the average efficiency of products on the market when the equipment was originally installed. This could be due to poor sizing, a inappropriate choice of equipment or poor installation.
- A poor **present** efficiency in comparison to current average standards of performance even though performance was considered acceptable when originally istalled.. This is technical obsolescence.

- A less than ideal present efficiency in comparison to current best standards of performance (reached using most energy-efficient equipments) even though performance matches current average standards.

The inspection will thus highlight potential savings and – where economically justified - accelerate the replacement of air-conditioning systems or components by more efficient new ones. The inspection may focus on sizing that has to be closer to cooling requirements, on the appropriate choice of equipment, based on life-cycle costs (purchase + operation), on possible improvement of both process and building and finally on best available technologies on the market.

There is a fourth possible view on the benefits of a compulsory Inspection : preparation of a refurbishment **(scenario 4).** The methods should in that case also be adequate to the objective.

Flexible implementation: comparison between Article 9 and Article 8

Article 8, relating to the inspection of boilers and heating systems gives some explicit options for implementation. Article 9 does not do so, but Member States do have some latitude about a number of aspects of implementation. For example, they could adjust inspection to align with national O&M standards and coordinate it with other types of mandatory inspections on AC installations (F-gas, cooling towers). It may be possible to combine it with verification that safety regulatory requirements are met.

Article 8 (heating) has different inspection requirements for different situations. For air-conditioning there is no requirement to cover the full system at each inspection: it would be possible to have more frequent inspection of the cold or heat generating equipment and less frequent whole-system inspections. For example, there could be a one off inspection at the standard end of life of the system, or the frequency could vary with system capacity. For smaller equipment direct inspection might be substituted by some remote inspection.

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.

5- Costs and benefits of the inspection according to type and size of system and qualification of staff needed

The compulsory inspection of AC systems of more than 12 kW (EPBD article 9) is directed to energy savings: the primary aim is not to avoid breakdowns or to improve the security but to determine cost effective improvements. The details of implementation in each Member State will depend on impact assessments, which will include cost/benefit analysis.

What are the costs of inspection without targeting?

A recent study (Dupont, 2005) separated the market for air-conditioning between first installations and replacements . For example, with a (universal) 15 year system lifespan, the renewal market in year n is the difference between total apparent markets in years n and n-15. Figure 2 is extracted from this paper.

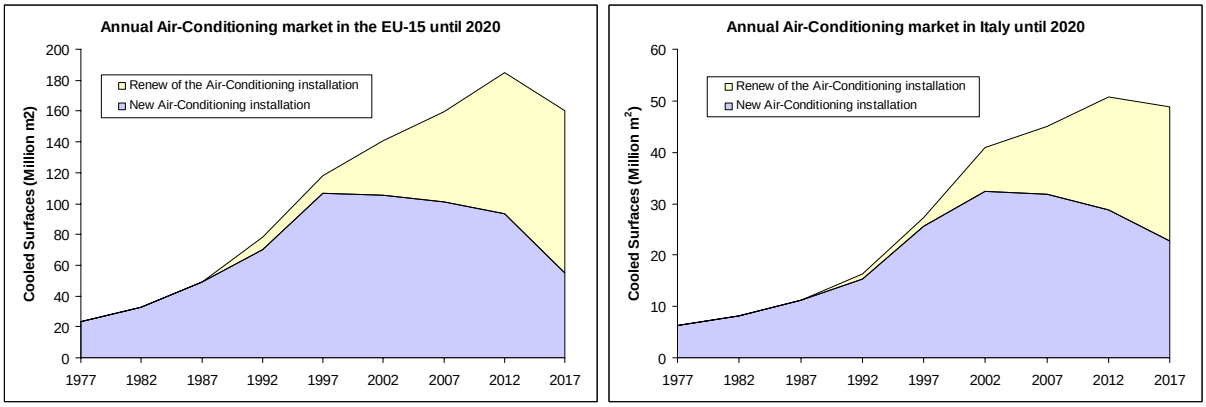

Figure 2. Prediction of annual Air-Conditioning markets in the EU-15 (left) and Italy (right) according to Dupont's paper at ECEEE

The size of the installed stock can be used to estimate the size of market for of audits and inspections. The breakdown of sales could be used to generate estimates of the demand for audits for older systems. The results for inspections are presented in tables 1 for five countries as numbers of "orders" per year. They were obtained using an interval of 3 years between two inspections and the 12 kW per building rule was applied. The inspection market is huge and as the inspection is compulsory, it is impossible for Member States to avoid it. Hence, there will be unavoidable costs associated with the identification of systems to be inspected, and the certification of inspectors and auditing of the process. Moreover, building owners will presumably bear most of the cost. The numbers of annual inspections and costs are substantial.

Table 1. Estimates of yearly inspection markets in selected countries. The total number of inspection is the sum of inspection of systems with a unitary capacity over 12 kW (CAC) and of buildings deserving inspection because they host various small systems (RAC)

	2007		2012		2017	
	RAC	**CAC**	**RAC**	**CAC**	**RAC**	**CAC**
Italy	628000	181900	828000	237000	962500	279600
Spain	405000	124400	490500	151100	545400	167500
France	311300	64300	405100	84200	477900	98600
Germany	239200	42400	322900	57300	384100	68000
UK	161700	54600	191300	64200	205700	69800

Inspection of air-conditioning installations is quite different from, for example, car safety inspection because it is focused on efficiency. Although good maintenance is part of good performance, there are other factors (behaviour, operation, adjustments, control system, equipment) that have large consequences on the efficiency of the system. All these factors

must be analysed and the inspector should give advice on possible improvements. The CEN draft focuses on visual observations without quantitative tests. We do not yet have standard procedures such as exist for car safety inspections. A balance has to be struck between the level of expertise required of inspectors and the scope of the advice that they can be xpected to give. To maximise energy-efficiency benefits, they need to be experts in air-conditioning and building. If the requirement for independence is interpreted to exclude installers and maintainers this will restrict the pool of possible inspectors, probably to HVAC consultants.

We can imagine two scenarios concerning the people in charge of inspecting air-conditioning 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 engineering expertise, it is possible that they spend the majority of their time on the periodic inspection. We can then make the following illustrative assumptions:

- 1 day on average to inspect a building
- 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 table 2.

Table 2. 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

The energy saving that will result from inspection is difficult to evaluate. There is a direct potential associated to the correction of visible defects limiting the operational performance, but also an indirect potential from possible consequent actions by the building owner. The indirect potential is especially difficult to estimate because it depends on the extent of the opportunities revealed by inspection and the proportion of them that building owbners are prepared to finance. 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 inspections, 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)

What are the benefits of the Inspection measure?

To our knowledge there are no published estimates based on field evidence because the information is lacking. The figures below are therefore hypothetical and should be revised on the basis of field data as soon as possible.

Estimated costs and benefits of the inspection are given in the table 3. The payback periods are longer than the expected intervals between inspections so (with these assumptions) inspection does not look directly cost-effective. Moreover, this 5-10% potential is likely to decrease with time because some defaults will be more often checked afterwards. Rising energy prices would have the opposite effect. In terms of climate change policy, the appropriate metric is cost per tonne of carbon emissions abated, but we have not examined this.

As we have explained, we have not assessed the indirect effects. If the direct cost of an audit were, say, twice that for an inspection and the potential savings were also doubled, the payback periods (ignoring investment costs) would be as in the table. In most cases, these are comparable with the expected life of systems so, when investment costs are added, it seems unlikely that the economics will be favourable. However, this analysis treats all systems as being identical.

Table 3. 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)**	**Simple payback (ignoring any investment cost) (years)**
IT	370.4	50.1	18.6	810	37.2 – 74.4	11-22
SP	407.7	81.5	33.2	530	66.4 – 132.8	4-8
FR	268.1	32.6	8.7	376	17.4 – 34.8	11-22
GE	185.3	22.8	4.2	282	8.4 – 16.8	17-34
UK	166.2	19.7	3.3	216	6.6 – 13.2	16-33

This illustrative analysis suggests that inspections and audits should be targeted. Inspection will be mandatory, but focussing the scale and frequency of inspection on systems

likely to offer the greatest potential would beneficial. Alternatively, including inspection within routine O&M would reduce the cost (the "independence" requirement would have to be met by independent auditing of registered inspectors). A similar argument applies to voluntary audits: inspection reports should help to focus attention. When systems or components are due to be replaced, the marginal investment costs for higher efficiency (over and above the unavoidable costs) and the marginal analysis costs (over and above design costs) should both be reduced and the expected future lifetime is long, so this seems to be an obvious target area.

How to adjust Inspection frequency according to plant size?

Several national implementations are trying to define the most convenient indicator of "size" in order to adjust frequency of inspection. Air flow is an indicator of size for air conditioning systems with all-air distribution (but not for water-based systems). Cooling capacity is the only parameter available without discussion, and on the plate on site. So it will certainly be the solution for definition of size, as it has been in the main text of the EPB directive.

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 seems strict and variations should be considered. Indeed, the energy saving potential by possible improvements in small equipment (RAC in general, split-systems) is low in absolute terms and an inspection every 3 years may be inappropriately expensive. On the other hand, it is usually considered good practice to inspect even small equipment for refrigerant leaks and to replace or clean filters more frequently than this, and the additional inspection requirements will be low. Alternatively the inspection frequency could be reduced and the requirement focused more on providing information about proper maintenance, availability of efficient systems and technologies and associated costs (purchase + operation) in case of a future replacement. Some actions could be made by telephone.

Our conclusion : the necessity to learn from experience

As will be apparent, there are many unknowns and much to learn from experience. The Member States in charge of this measure (and only body in charge of it) should try to learn from this unprecedented experience that they are conducting. Each of them will follow a distinct pathway. We recommend that they build a strong agreement on objectives (types of saving targeted, magnitude of expenses on average) and use at maximum their freedom on means to make that an experiment, with a common monitoring of field results. Then, the experience feedback would allow the creation of an harmonised procedure meeting the cost effectiveness criteria.

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