Air-conditioning inspections: time needed and potential energy savings

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This paper presents the findings and observations to date from the IEE HARMONAC[1] project regarding the time taken by the various items of the HARMONAC draft EPBD Article 9 A/C Systems Inspection Methodology, and any potential energy savings identified to date. The HARMONAC methodology generally follows the CEN standard guidance[2] in this area.

The timings and energy savings presented are taken mainly from the UK Case Studies and Field Trials experiences, and are intended to be a first indication of the likely size and magnitude of the time:energy savings ratios to be found for each part of an Inspection.

This information is particularly important in assessing the on-going costs of system inspections for EU Member State countries, many of whom are anxious to maximize the cost:benefit ratio of such inspections.

Figure 1. *A large air handling unit for air-conditioning.*

The Inspection of A/C systems in buildings as required by Article 9 of the EPBD is designec to identify opportunities for the reduction of the energy consumption of A/C systems, and as such the Inspection Methodology used is critical to ensuring that these savings are identified. A secondary but equally important element of these Inspections is to ensure that they can be achieved in a cost-effective manner.

HARMONAC is assessing its own Inspection Methodology (based on CEN Standard EN15240[2] and CIBSE's TM 44[3]) in point-by-point Field Trials on real systems to assess which actions actually lead to practical energy savings in the real world. These Field Trials also assess the time needed to undertake each Inspection point, as this will be a major consideration for a number of Member

States in setting the on-going requirements for Inspection in their Country.

This article presents a summary of the initial main points arising to date from the HARMONAC Case Studies and Field Trials with respect to energy savings and timings.

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The HARMONAC Inspection Methodology is essentially divided into 3 sections - the collection of data on the building, the collection of data on centralised A/C systems, and the collection of data on packaged A/C systems. Due to space limitations in this paper these 3 areas are

Average times taken to undertake the building data collection inspection items. Ordered from longest to shortest.				
				Building data for all systems – longest to shortest times – notes
PI21	Annual energy consumption of the system	61.0		Sub-metering of energy consumed by the AC system and all its ancillaries allows benchmarks to be used as part of the assessment.
PI11	Current design loads per zone	56.4	4%–13%	Getting the installed cooling capacity correct can lead to savings of at least these amounts. Over 20% seems achievable[4].
PI22	Annual energy consumption of the building	45.5		Overall energy use by the building relative to the A/C system allows a further check on whether the A/C system use is excessive.
PI2	Documentation per zone	44.0	-	
PI15	Refrigeration equipment for each zone	43.0	-	
PI4	General zone data/zone	35.8	-	
PI1	Location and number of AC zones	35.0	-	
PI5	Construction details/ zone	27.5	-	
PI18	Cooling terminal units details in each zone	26.3	-	
PI3	Images of zones/building	25.1	-	
PI16	AHU for each zone	21.4	-	
PI9	HVAC system description and operating setpoints per zone	12.8		Knowledge of setpoints is important in knowing whether savings can be made from more accurate control to internal activities.
PI12	Power/energy information per zone	12.5	-	Internal gains are important in assessing amount of cooling capacity needed and type of cooling system that is suitable for the task.
PI8	Monthly schedule exceptions per zone	12.2	Up to 10% each month	Depending on control of each zone and exception days.
PI7	Occupancy schedules per zone	11.3	Up to 50%	Cooling only when needed can provide savings of up to 50%. Many systems in UK run all year, despite no demands for large periods[5].
PI10	Original design conditions per zone	10.0	-	Allows comparison with PI11
PI13	Source of heating supplying each zone	10.0	-	Needed to check that conflicts between heating and cooling are not occurring.
PI14	Heating storage and control for each zone	7.8	-	Control should be checked against heating and cooling supply.
PI6	Building mass/air tightness per zone	6.5		Reducing the infiltration rate can provide heating and cooling savings.
PI17	Cooling distribution fluid details per zone	5.7	-	
PI20	Energy supply to the building	4.1	-	To check the energy consumed by the building is fully accounted for.
PI19	Energy supply to the system	1.4	-	To ensure that energy use of A/C system is properly accounted for.
	Total average time (minutes)	515.3		

presented only in descending order of the time taken to complete the inspection items in each.

The tables presented are currently based on over 20 Field Trials and 10 Case Studies undertaken in the UK. The floor areas served by the A/C systems assessed to date range between 47m² and 18,153m².

It is anticipated that generally similar timings will be found across the HARMONAC Partners studies in Austria, Belgium, France, Greece, Italy, Portugal and Slovenia.

The potential percentage savings noted in the tables are drawn from past and present research work undertaken by the HARMONAC Partners and others, as well as from these Case Studies and Field Trials.

This section lists the average time taken to complete the general building data sections for all the system types assessed to date in both Field Trials and Case Studies. is ordered from the longest to the shortest times. The greyed out boxes indicate where savings are expected to be identified but no data is yet available. A full description of all the items in the table will be published by HARMONAC at a later date once the final methodology has been approved.

Packaged A/C Systems – Longest to

shows the average time taken in Fielc Trials and Case Studies to date to complete the various sections of the Packaged AC systems inspections. The times are displayec

Average times taken to undertake the Packaged A/C system inspection items. Ordered from longest to shortest.				
				Building data for all systems – longest to shortest times – notes
P15	Write report	68	-	
P6	Compare records of use or sub-metered energy with expectations	30	-	Overall energy use by the building relative to the A/C system allows a further check on whether the A/C system consumption is excessive.
P10	Check external heat exchangers	26		Damage or blocking of external heat exchangers can lead to a decrease in efficiency of between 7% and 7%
PP8	Design cooling load for each system	24	4%–13%	Getting the installed cooling capacity correct can lead to savings of at least these amounts. Over 20% seems reasonable taking distribution systems into account[4].
PP9	Description of the occupation of the cooled spaces	15	-	Allows checking of time and temperature setpoints are correct, as well as allowing the use of benchmarks when they become available.
P5	Compare size with imposed cooling loads	11	4% – 13%	Getting the installed cooling capacity correct can lead to savings of at least these amounts. Over 20% seems reasonable taking distribution systems into account[4].
P1	Review available documentation from pre inspection	10	-	
P8	Check for signs of refrigerant leakage	10		Refrigerant leakage can reduce the energy efficiency of an AC system.
P9	Check plant is capable of providing cooling	10	-	
PP6	Records of maintenance (control systems and sensors)	7	-	Can provide certainty that systems are well-maintained to go with visual checks. This could reduce time and cost of an inspection.
	Only the 10 most time consuming of 28 inspection items are shown			
	Total average time (minutes)	271		

from the longest to the shortest against each Methodology item. The greyed out boxes indicate where savings are expected to be identified but no data is yet available. Only the first 10 items of 28 are shown due to space limitations.

Centralised A/C Systems – Shortest to

lists the average time taken to undertake an inspection on centralised systems, rank ordered from longest to shortest. The data in this section are less robust than for Package systems due to the much greater diversity of design of Centralised Systems. The greyed out boxes indicate where savings are expected to be identified but no data is yet available.
Again due to space limitations only the first 10 most time consuming items of 59 are shown.

For many A/C systems much of the diagnostic equipment needed to assess their performance is already installed or could be readily installed. Perhaps the most important item to be installed if it does not exist is dedicated energy metering to the A/C system and its ancillaries.

In general, it is anticipated that the amount of portable equipment needed for an inspection will be minimal and restricted to non-invasive equipment to reduce both the cost and potential liability of inspections.

Figure 2. *Label on manometer provides physical indicator of when to replace air filter due to increased pressured drop.*

. Average times taken to undertake the Centralised A/C system inspection items. Ordered from longest to shortest.

				Building data for all systems – longest to shortest times – notes
C2	Locate supply to the A/C system and install VA logger(s)	161.7	-	Allows estimation of the power use of the system over monitoring period. Can help estimate a chiller or system COP.
C1	Locate relevant plant and compare details	77.5	-	
PC12	An estimate of the design cooling load for each system	47.7	4%–13%	Getting the installed cooling capacity correct can lead to savings of at least these amounts. Over 20% seems reasonable taking distribution system s into account[4].
PC1	Details of installed refrigeration plant	47.5	-	
PC2	Description of system control zones with schematic drawings.	45.3		Correct use of zoning can achieve savings.
C15	Visually check the condition and operation of indoor units	35.0	-	A dirty indoor unit would tend to indicate a poorly maintained system. Check also room layouts have not altered since indoor unit installed.
PC15	Monitoring to continually observe performance of AC systems	30.8	10%–20%	Energy M&T can identify early problems with A/C system s and help in a long-term maintenance programme.
C10	Check type, rating and operation of distribution fans and pumps	30.8	up to 50%	Variable Speed Drives on fans and pumps can provide savings of 20 – 50% fairly readily depending on system design and loading.
C24	Assess the controllability of a sample number of terminal units	26.7		
PC5	Floor plans and schematics of air conditioning systems.	26.5	-	
	Only the 10 most time consuming of 28 inspection items are shown			
	Total average time (minutes)	1017.9		

š shows graphs of the time taken to gather building data, and undertake centralised and packaged inspections from the work undertaken to date. The time is normalised to the floor areas served by each of the A/C systems.

From š we can produce an initial prediction of the time taken to inspect Packagec and Centralised A/C systems based on the floor area conditioned. These predictions are shown in There are blanks in the table where no surveys of that size have been undertaken for those system types.

The data shows that the collection of data about the building and its occupancy is generally as time-consuming as the Inspection of the physical A/C system itself.

It can be seen from the HARMONAC data to date that a complete Inspection can take from around 4 hours for the smallest systems up to 4.5 days for the largest systems inspected to date.

There is clearly a possibility of some significant time savings being made in subsequent inspections, provided the building and system details do not alter in the interim.

Two of the keys to this happening are:

- Ensuring that the Inspection data for each inspection provides clear information about HDFK LQVSHFWRQLWHP 2 SRWHQWLDO DVVHVVPHQW report template needs to be provided?

Figure 3. *Compressors, Variable Speed Drives, etc. should have on-board diagnostics monitoring their running hours and other performance variables.*

Figure 4. *Dedicated energy metering of the A/C plant helps identify exact annual usage and allows more accurate assessment of its overall performance.*

- Ensuring that the previous Inspection reports are readily available online.

Potentially, having the previous Inspection data available in a format that can be assimilated into subsequent reports could lead to time savings of over 80% for the Building Data. The potential time savings for subsequent physical systems inspections are likely to be less at perhaps only 10–20%, but these are nonetheless worth having.

Most common and largest savings to date

The most common and largest potential savings identified to date are shown in These savings represent the maximum savings that have been found for each inspection item, either from research work or from the Field Trials and Case

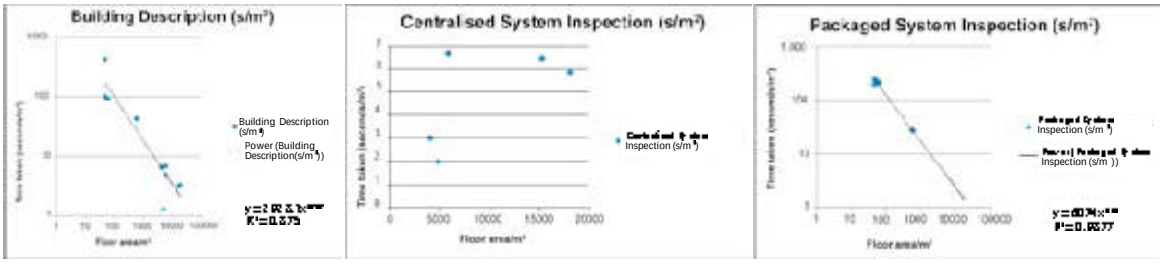

Figure 5. *Correlation between conditioned floor area and inspection time needed*

Predicted time in hours taken to complete inspections by floor area conditioned.					
40	2.1		2.9		5.1
60	2.4		3.1		5.5
80	2.6		3.3		5.8
100	2.7		3.4		6.1
150	3.0		3.6		6.6
200	3.3		3.7		7.0
250	3.5		3.9		7.3
500	4.2		4.3		8.5
600	4.4		4.4		8.8
650 to 5000	No data between these areas				
5,000	7.6	5.6		13.2	
6,000	8.0	6.7		14.7	
7,000	8.3	7.8		16.1	
8,000	8.6	8.9		17.5	
9,000	8.9	10.0		18.9	
10,000	9.2	11.1		20.3	
20,000	11.0	22.2		33.2	

Studies. They are only indicative at the moment until the HARMONAC project has completed sufficient studies to either support or question some of the savings shown. It should also be noted that each item is considered in isolation and that the savings are not additive. It is hoped that commonly occurring combinations of measures might have their cumulative effect identified as well.

From it can be seen that potentially a large amount of this data could be collected without ever visiting the site (those elements highlighted in yellow). It can also be seen that the majority of the large savings identified so far are primarily to do with control of the system, choice of system type and choice of system components. It is also anticipated that further significant savings will be associated with a regular maintenance regime. These will be demonstrated by comparison of poorly maintained systems with regularly maintained systems.

At this stage of the project, the savings and timings being shown are heavily biased by the UK experience as few Field Trials are being undertaken in the other Partner sites yet. The data shown is therefore still to be confirmed in more extensive testing of the Methodologies, particularly the updated Methodologies.

It was also noted from these first inspections that there were no specific inspection items dealing with humidity control in systems where this was part of the system design. This observation will be addressed in future HARMONAC meetings.

Overall, at this point in the project it appears that we can conclude:

- Some substantial savings can be identified by inspection procedures.
- Most of the major savings found so far appear possible to identify
- Most of the major savings appear possible to obtain
- There are technical savings that we will identify as the project proceeds, but the law of diminishing returns appears to apply here, i.e. the majority of the main savings can be identified quite quickly, but to identify all the potential savings will be costly in terms of time.

So what this means in terms of the Inspection methodologies being trialled to date is:

- ***Pre-inspection*** (the building related data) might eventually be the most productive

Most common and largest savings identified to date	
Description of method of control of temperature (system type)	Up to 60%
Method of control of periods of operation (time clocks, etc)	Up to 50%
Compare AC usage with expected hours or energy use	Up to 50%
Occupancy schedules per zone	Up to 50%
Check type, rating and operation of distribution fans and pumps	Up to 50%
Note the set on and off periods	Up to 50%
Monitoring to continually observe performance of AC systems	10%–20%
Design cooling load for each system	4%–13%
Compare size with imposed cooling loads	4%–13%
Monthly schedule exceptions per zone	Up to 10% each month
Building mass/air tightness per zone	
HVAC system description and operating setpoints per zone	
Annual energy consumption of the system	
Annual energy consumption of the building	

area of the Inspection in terms of identifying problems with the A/C system performance, but at this stage of implementation of the EPBD this data is also the most difficult to obtain, with many buildings simply not having information on their construction details, energy use of the A/C system, etc.

- The physical ***inspection*** is yielding clear Energy Conservation Opportunities (ECOs) for the A/C systems being inspected, but carries with it a significant cost in terms of time.

In the light of this report it is considered that the main outputs at the end of the HARMONAC project are still likely to be:

- A set of Inspection Procedures for A/C systems in Buildings are being assembled. These will be required whatever approach is taken to the A/C Inspections, as they will be needed wherever excessive consumption appears to be present.
- The % identifiable from in the Inspection and Audit Procedure.
- The required to undertake of the Inspection and Audit Procedures.

The tabulated energy savings and time taken in the final report will be backed by evidence and references.

Further details can be found at the website of the HARMONAC project www.harmonac.info.
More general information on the implementation of Article 9 of the EPBD can be found at www.buildingsplatform.eu.

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Harmonizing Air Conditioning Inspection and Audit Procedures in the Tertiary Building Sector (HARMONAC). IEE Project EIE/07/132/SI2.466705. www.harmonac.info

CEN Standard EN15240 - Ventilation for buildings - Energy performance of buildings - Guidelines for inspection of air-conditioning systems. www.cen.eu

CIBSE TM44: Inspection of Air-conditioning Systems. CIBSE, 2007 ISBN: 9781903287859 www.cibse.org/index.cfm?go=publications.view&item=372

Knight IP, Dunn GN and Hitchin ER– "Measuring System Efficiencies of Liquid Chiller and Direct Expansion", ASHRAE Journal, pages 26 – 32, February 2005. ISSN: 0001-2491

Knight IP & Dunn GN – "Carbon and Cooling in UK Office Environments", Proceedings of Indoor Air 2005, The 10th International Conference on Indoor Air Quality and Climate, Beijing, China September 2005. ISBN: 78-94-94830-6