Assessing electrical energy use in HVAC systems

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The iSERV project aims to collect sub-hourly HVAC system energy use data from around 1 600 HVAC systems in the EU Member States, analyse and compare this information through the development of benchmarks. iSERV is designed to show the ability for automatic HVAC system monitoring to reduce energy use in practice and compare this to the costs and savings of regular inspection.

Introduction

According to the EC's Joint Research Centre (2009), Heating, Ventilation and AC systems in the 27 European Union Member States were estimated to account for approximately 313 TWh of electricity use in 2007, about 11% of the total 2 800 TWh of electricity consumed in Europe that year (**Table 1**).

Table 1.
EC Joint Research Centre, Institute for Energy, 2009.

Equipment	Electrical consumption as % of total EU use in 2007
Air conditioning units and chillers	0.75
Fans in ventilation systems	3.34
Pumps	1.81
Space and Hot Water Heating	5.23

HVAC systems must therefore be a key contributor towards energy savings if the EU is to reach its target of reducing energy use by 20% by 2020.

The old adage 'you can't manage what you can't measure' is very apt for HVAC systems as there is a real absence of publicly available information derived from large scale datasets on the detail of energy consumption of HVAC systems in buildings.

This article explores an approach towards achieving a better understanding across the EU Member States of these important elements of European energy consumption.

A lack of information on which to base policy decisions and future legislation regarding achieving energy efficiency in HVAC systems is part of the reason behind the funding of an Intelligent Energy Europe (IEE) project on the Inspection of HVAC Systems through continuous monitoring and benchmarking (iSERVcmb). This project is addressing the problem of practically improving the energy performance of HVAC systems in EU buildings by producing benchmarks from sub-hourly in-use data obtained from HVAC systems around the EU. With a budget of €3.3M, iSERV is the largest project ever funded by the European Commission's EACI agency, with its predecessor project, HARMONAC, being the second largest.

The iSERVcmb benchmarks for energy performance by HVAC system components for specified end use activities will assist approximately 1 600 HVAC systems across 16+ EU Member states in understanding and reducing their energy consumption. It will do this through:

- Defining the HVAC system components, plus the spaces and activities it serves,
- Collecting and analysing sub-hourly data from these systems,
- Producing energy use benchmarks based on the HVAC components and the activities served,
- Providing reports back to the building owner that show how they are performing against their bespoke benchmarks, along with potential conservation actions they might take.

One of the bases for the iSERVcmb project is the findings from the IEE HARMONAC project that concluded at the end of 2010.

Figure 1, taken from HARMONAC, vividly illustrates the possible potential range of electrical energy consumption per m² in HVAC systems. This is derived from data taken across the EU for 42 HVAC systems energy use in real buildings. The figure also presents the total annual electrical energy use per m² of the building in which the HVAC system operated.

One of the observations to be made about **Figure 1** is that some major elements of HVAC system consump-

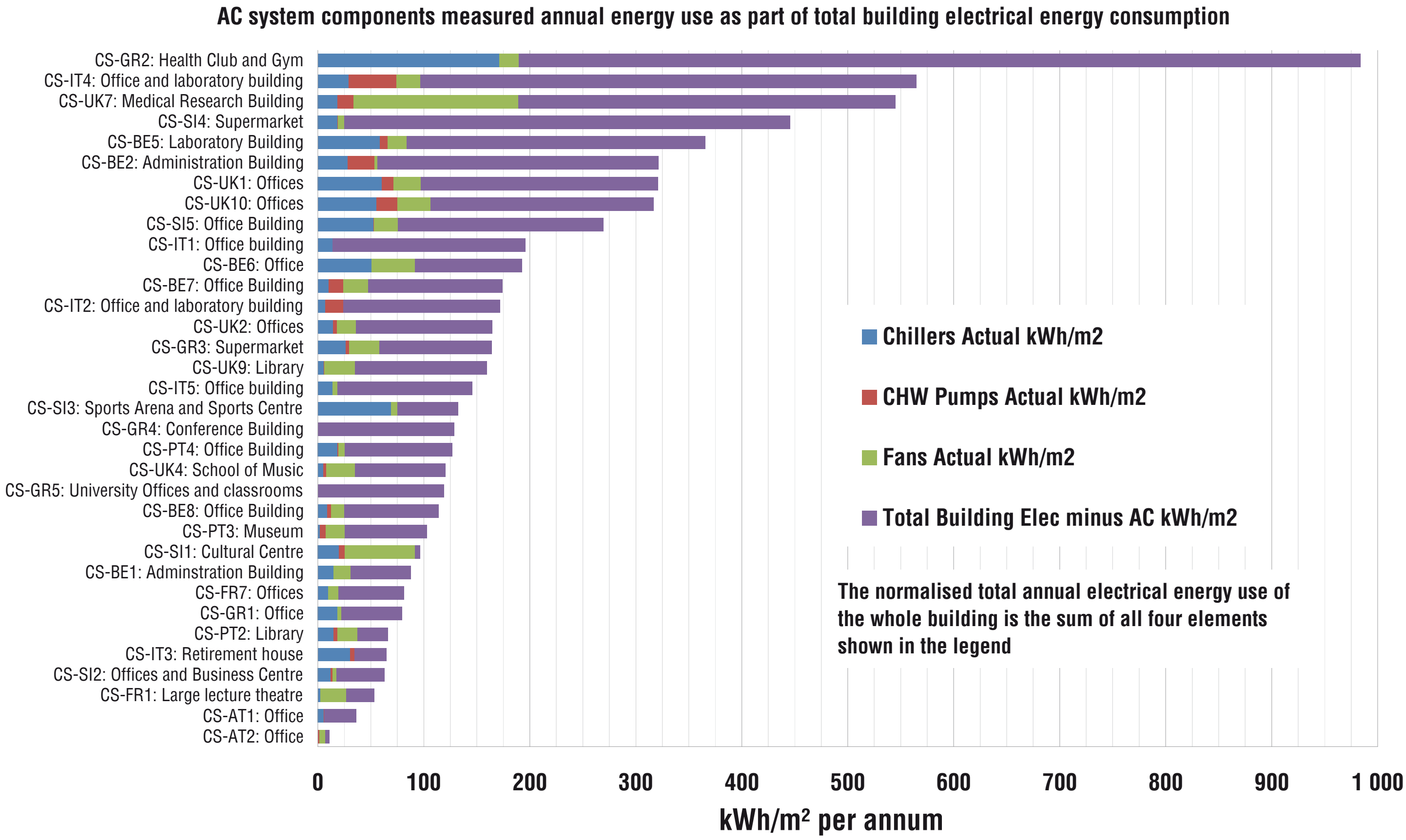

Figure 1. Overall annual energy use and total energy use in 33 HARMONAC buildings.

tion are missing for a few of the buildings e.g. the data may have Chiller electrical consumption and the main AHU's, but not Chilled Water pumps or Humidifier use. In addition, nearly all the systems monitored have some elements of electrical consumption unmetered e.g. electrical energy use in terminal fancoils or electrical terminal reheat systems. The point being made is that the energy use of HVAC systems is likely to be nearly always under-reported with current metering installations for buildings and HVAC systems.

Figure 2 shows how this metering problem manifests itself for One Wood Street in London, a modern (completed May 2008) prestige office block which is 'fully' metered to UK building regulation standards. It can be seen that, despite an apparently comprehensive metering strategy, nearly one third of the annual electrical energy use (labelled 'Balance') is unaccounted for. This building was one of the UK Case Studies in HARMONAC and was well documented, but still no-one was sure where this unaccounted energy was going. The author believes at least some of this unaccounted consumption is occurring in the HVAC system – potentially in the tertiary chilled water pumps for the chilled beams, and in the numerous fancoils in the core of the building. So, whilst HVAC systems apparently consume around one third of the annual electrical energy use in this building, it is entirely possible that their actual electrical consumption might be closer to one half of all electrical energy use in the building.

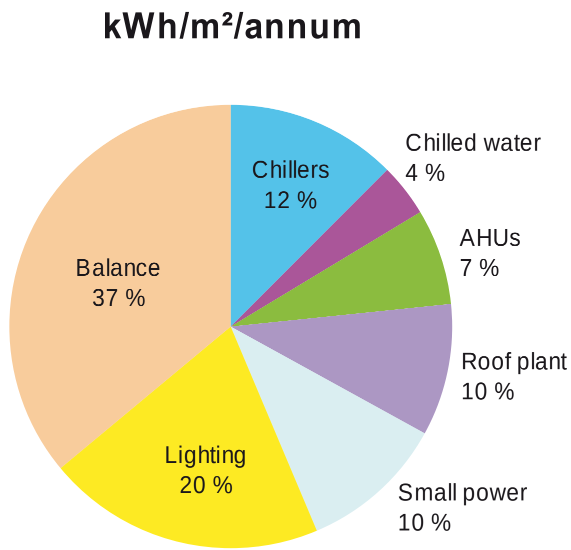

Figure 2. Annual electrical energy use in One Wood Street building, London. The Balance term denotes undefined electricity use in the building.

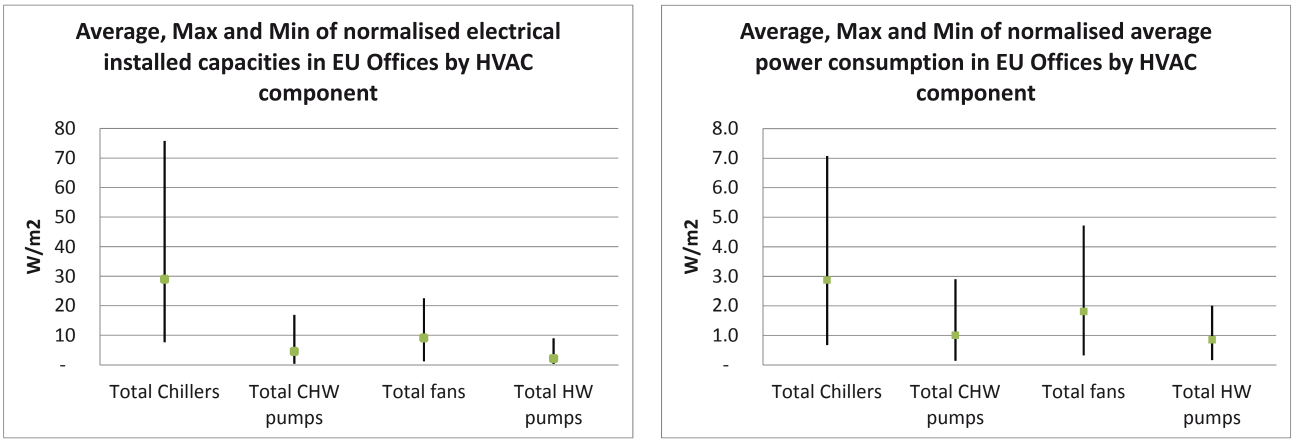

Figure 3. Average, Maximum and Minimum Installed and Annual Average Measured Power Demands normalized for floor area for Chillers, Chilled Water Pumps, Air Handling Units and Hot Water Pumps installed in EU Offices.

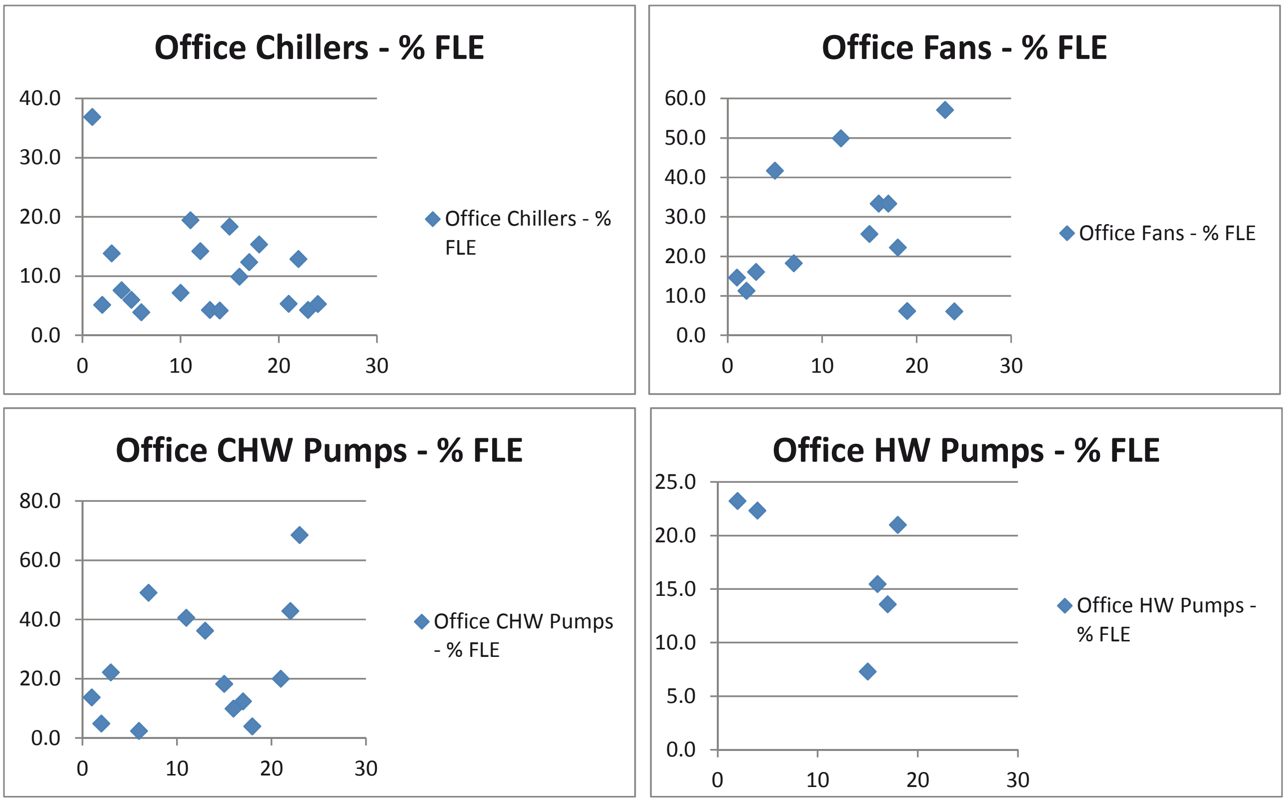

Figure 4. Measured average annual power demand by HVAC component as a percentage of the Full Load Equivalent for HARMONAC Case Study systems.

The next figure presented from HARMONAC is shown in **Figure 3**. This shows the ranges of installed electrical capacities in EU Offices by HVAC system component against the annual average measured power demand for those same HVAC system components taken from systems around Europe. The sample size for the components ranges from 14 to 23 systems.

It can be seen that the measured average power demand per unit area over the course of a year by the HVAC components follows the order of installed capacities by component, i.e. Chillers have the highest installed capacities and consume the most energy over the year, etc. In total the average power demand/m^2 of an HARMONAC Office HVAC system is around 6.5 W/m^2 or 56 kWh/m^2 per annum.

In terms of % of Full Load Equivalent (FLE) however, the order changes when we look at the ratio of the average annual power demand to the average installed loads. FLE is calculated as the power demand of the component assuming it runs continuously i.e. 8 760 hours per year. **Figure 4** presents the data by HVAC component type for each of the HARMONAC Case Study systems.

Taking the averages from the data used to produce **Figure 4**, the Chilled Water Pumps and Air Handling Units have the highest annual average power demand to % FLE ratio with an average power demand of 25% of their installed electrical capacity over the year across the sample. They are followed by Hot Water Pumps which consume about 17% of FLE (though based on a much smaller sample size), with Chillers consuming the least at around 11% FLE.

However, the range of % FLE's vary significantly for each HVAC component so, while we are able to look at an average for each component to obtain a first feel for the impact of installed load on likely annual use, it will not be until we obtain a much larger sample set from iSERVcmb that we will be able to present any statistically significant averages.

Future data on HVAC energy use

One of the main reasons for wanting to know about the energy use of HVAC systems in practice is to enable better prediction of what an HVAC system should consume in practice – this is important for both the operation and design of HVAC systems to achieve real-life low energy consumption.

The review of the HARMONAC data shows that iSERVcmb therefore has to obtain data on end use activities, HVAC components and operation hours when setting up a procedure that will allow a reasonable estimate for consumption in HVAC systems. The approach is similar to that used in the German VDI 3807 Guidelines and also the UK SBEM Methodology, with the intention being that data produced by iSERVcmb should be of value in informing these and similar methodologies.

Using an underpinning rationale that any procedure should be able to be related back to the actual HVAC equipment physically installed in a building, iSERVcmb requires data to be collected on installed HVAC equipment, including nominal power ratings. This will, over the course of the project, allow actual energy consumption data for various HVAC system components installed in real buildings, serving described end use activities, to be compared with their nominal power ratings and other characteristics. This data can then be used to benchmark best, average and worst energy consumptions for various end use activities served by HVAC system components.

From this data we should be able to predict with more certainty where HVAC energy use is likely to be occurring in systems serving stated activities in real buildings, and therefore where we should concentrate efforts on reducing this use.

Having a clear and supportable basis for obtaining these estimates also offers benefits in other areas, such as estimating energy use for Inspection purposes.

One aspiration for the iSERVcmb approach is that it can act as a complement to physical Inspections by helping target Inspections towards those systems most likely to receive real energy saving benefits as indicated by their current level of consumption for the activities they are serving. It should be noted that for the estimated benchmarks to continue to have relevance the iSERVcmb database must continue to obtain data, so that as improvements are made in HVAC component and system efficiencies the benchmarks evolve to reflect what is currently possible.

Collecting energy data for HVAC systems

As a first step towards collecting the data it requires for establishing targets and benchmarks for HVAC systems, iSERVcmb has established a spreadsheet for collating information about HVAC systems, activities and areas served in buildings. This can be downloaded from the iSERVcmb website www.iservcmb.info by anyone wishing to collate information on their HVAC systems in one place. This should be of great assistance in reducing the time and effort needed for both the owner and Inspector during an Inspection, as well as reducing errors and misunderstandings which can undermine the value of an Inspection. The spreadsheet requests the information shown in **Table 2**.

> *"The Excel spreadsheet developed by the iSERV project is a unique tool to structure and organise the information of HVAC systems... It aligns perfectly with the need to improve the value of HVAC system inspections by having collected and gathered pertinent information prior to the inspection…"*
>
> **Olli Seppänen, REHVA General Secretary**

Table 2. Data requested by the iSERV HVAC template data sheet.

Building	Utility Meter	HVAC sensor	HVAC system	HVAC component	Schedules of Setpoint&Occupation	Space
Building Name	Name	Name	Name	Name	Name	Name
Description	Description	Description	Description	Description	Description	Description
Organisation Name	Meter Type	Sensor Type	Main HVAC system	Component type	Time Control Method	Floor Area (m^2)
Site Name	Unit Type	Unit Type	HVAC type	Component sub-type	Date Range: Applies From	Sector
Sector	Multiplier	Duct/Pipe Area (m^2)	System Classification	Serves which HVAC system(s)	Date Range: Applies To	Activity
Address	Space Where Located	Unique Sensor ID	System Sub-Classification	Space Where Located	RH Range: Upper Limit	Served By HVAC(s)
Town	Unique Meter ID	Data Starts From	Data Starts From	Nominal Electrical Power Input (KW) OR/AND Meter Name	RH Range:Lower Limit	Utility Meter(s)
Postcode	Data Starts From	End Month	End Month		Heating Setpoint / Date & Time	Schedule of Setpoints, RH and Occupancy
Country	End Month		Sensor Name	Sensor Name	Cooling Setpoint / Date & Time	Sensor Name
Control of HVAC Temperature	Parent Meter Name		Meter Name	Data Starts From	Relative Humidity / Date & Time	Data Starts From
Construct Month			Control of Flow Temperature	End Month	Occupancy / Date & Time	End Month
Data Starts From				Parent Component		Control of HVAC Temperature
End Month				Nominal Heat Rejection Capacity (KW)		HVAC Component Physically located here
Property Reference Code				Coefficient of Performance (COP)		Utility Meters Physically located here
GPS - latitude				Energy Efficiency Rating (EER)		Space Notes
GPS - longitude				Seasonal Energy Efficiency Rating (SEER)		
Gross Internal Area (m^2)				European Seasonal Energy Efficiency Rating		
Conditioned GIA (m^2)				Manufacturer		
Schedule				Range		
Main HVAC				Model		
Building Notes				Serial Number		
				Year of Manufacture		
				Nominal Cooling Capacity (KW)		
				Nominal Heating Capacity (KW)		
				Nominal Heating Power Input (KW)		
				Maintenance contract		
				Maintenance trigger		
				Date of last maintenance visit		
				Date of next maintenance visit		

Cells in light red show data that is chosen from embedded lists

Cells in orange show data that is chosen from data entered elsewhere in the spreadsheet

Cells highlighted in grey colour acquire their content automatically from other cells.

Cells in green show data that can be sourced from the Eurovent Certification HVAC Database

Cells highlighted in blue colour show optional data, but which is still very useful to owner and iSERV

It can be seen that there are significant numbers of cells which are either selected from predetermined lists, previously entered data or which are 'optional'. The optional cells do however contain important information for the wider analysis of the data for both the HVAC system owners' reports, Inspection purposes and the iSERVcmb project. End users are therefore recommended to also complete this information where possible and where appropriate.

The spreadsheet also provides a mechanism to connect all this information together, as both an EPBD Inspection and any future analysis requires knowledge of how the HVAC components, HVAC systems, Building spaces, Utility meters, HVAC sensors and Space activities are connected.

"…CIBSE is participating in iSERV as the project offers practical help to those who operate and manage HVAC systems to reduce energy consumption, carbon emissions and, most importantly to many building operators, cost. The iSERV data entry spreadsheet is an invaluable tool for gaining an overall understanding of the HVAC system described and for collating information essential for Inspections"

Hywel Davies, Technical Director, CIBSE

Conclusions

The energy used in HVAC systems is a major proportion of the total energy use in Europe.

Within HARMONAC the electrical consumption of an Office HVAC system could vary from 18 kWh/m²/a to 106 kWh/m²/a, with an average of 55 kWh/m²/a. This data is only for systems where complete data was available for all major components. It is thought that two of the HVAC systems would have achieved consumptions of between 10 – 14 kWh/m²/a had they been fully monitored. Therefore the annual energy consumption achieved by HVAC systems per m² in Office buildings across Europe can be seen to vary by up to a factor of 10 times.

The data presented in this article also shows that the normalised ranges of consumption by HVAC **components** for 'Offices' can also vary by up to 10 times from one HVAC system to another. However, HARMONAC was unable to explore any more deeply the reasons for these differences existing in practice.

To make any major inroads into reducing this energy use it is important that we not only understand the ranges for actual energy consumption in HVAC systems serving various end-use activities, but that we also understand the causes of variations in HVAC system energy consumption for meeting the requirements of the same end-use activities.

This information will then allow more confidence in investment in improving the energy efficiency of poorer performing systems, as well as provide an understanding of how legislation should be framed to encourage better performing systems to be adopted.

iSERVcmb is a pan-European project which will collate into one place much of the data needed to underpin the achievement of the 10 – 50% savings HARMONAC indicated were possible in EU Air Conditioning systems. The approach will be fully detailed and the outputs derived will be discussed with all the main actors as the project evolves.

The outputs and findings from iSERVcmb will be reported in future REHVA Journal articles, the REHVA Annual Conference in Timisoara, Romania in April 2012, and future iSERVcmb workshops around the EU. Should you wish to know more, or to become involved in the project, please contact the project Coordinator via the website www.iservcmb.info.

Acknowledgements

The author wishes to thank all the contributors to the HARMONAC and iSERV projects who have helped produce the information which has enabled this article to be produced, as well as the European Commission for funding both projects.

Supported by INTELLIGENT ENERGY EUROPE

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