Power demands of heating, ventilation and air conditioning components in EU Buildings

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Keywords: air conditioning, ventilation, heating, measured energy use, EU buildings. AHU, chiller, pump, hat pump.

The importance of understanding energy use at HVAC component level

A previous paper in the January 2104 REHVA Journal (Knight, 2014) proposed that detailed monitoring of energy use at HVAC component level was likely to be a key element in achieving sustained reductions in energy use in EU buildings. To use this detailed monitoring to its full potential it needs to have benchmarks against which it can be compared, and Power Demand benchmarks are a key component for identifying Energy Conservation Opportunities.

The iSERVcmb project (www.iservcmb.info) is producing what is believed to be the first public dataset of measured energy and power consumption of HVAC components operating in European Buildings. This paper presents a brief overview of a subset of this data, normalised Power Demands, to illustrate some of the forthcoming outputs from the project this summer.

The Power Demands presented here are from **measured** data obtained during the iSERVcmb project. It was taken from 1700+ HVAC systems and components drawn from across Europe, which are servicing a variety of activities and floor areas. This measured data is a key element in the HVAC system benchmarking process proposed and tested by iSERVcmb across 16 EU Member States.

With such a large dataset it is inevitable that the data covers a wide range of years, and as such will continue to be analysed at finer levels of detail before the end of iSERVcmb to explore different ways of examining the data. However, the full dataset present at the time of this paper is used to provide the largest data source possible for analysis here.

Due to the analysis work still to be completed, this paper therefore provides only an overview of the ranges of Power Demands being found in practice by HVAC Component Type normalised by Area serviced by that component. Note that this floor area is derived from the iSERV spreadsheet and is therefore much more accurate than simply relating power demand to total building floor area.

Measured Energy Use by HVAC components

The iSERVcmb process philosophy is based around physically quantifiable parameters i.e. energy, space, activity types, and HVAC system components. A HVAC component could be, for example, a fan, pump, air handling unit, cold generator, etc. There are subcomponents of these component types too e.g. different pump end uses such as primary or secondary circulation pumps.

This paper considers only the electrical energy use in the following component types, defined as:

AHU – Air Handling Unit fans and controls only, including supply, extract and combined units. No pumps, humidification, heating or cooling loads.

All-in-one unit – packaged air conditioning unit capable of heating and cooling. Includes fans, pumps, controls, compressors.

Cold Generator (Chiller) – compressors, integral heat rejection fans, integral pumps, integral controls

Heat Pump – Compressors, Outdoor unit fans, Controls, Circulation Pumps, Defrost section

Pumps – stand-alone circulation pumps including primary and secondary hot and cold pumps, condenser water pumps and Domestic Hot Water Pumps

Terminal Units – these are the fans, electrical reheat, pumps, etc that deliver the air, heating and cooling into the occupied spaces.

The benchmark ranges being proposed by iSERVcmb as the core of the iSERVcmb process, all have the measured energy or power demands as a key element. These are then normalised by the actual floor area and activity type serviced by each HVAC component. There are 7000+ combinations of HVAC sub-component and activity type benchmarks used in iSERVcmb.

This large number of potential combinations means that, despite obtaining data from over 1500 HVAC systems around the EU, the data obtained from iSERVcmb will only provide a first overview of the actual energy and power demands/m² occurring in operational HVAC components and sub-components when servicing these end use activities. It cannot be considered statistically robust yet at the level of individual activities or sub-components.

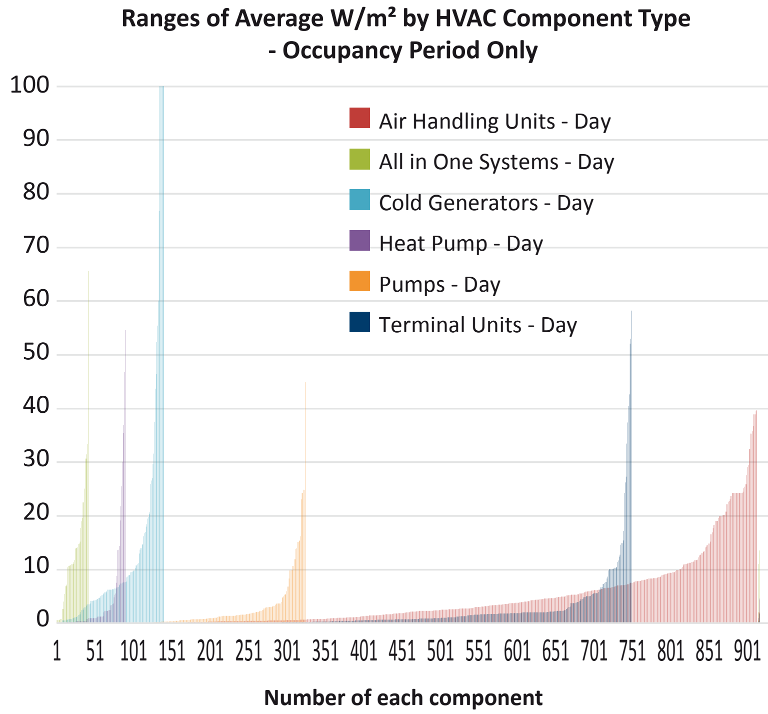

Figure 1. Ranges of Average Electrical Power Demands/m² by HVAC Component during Occupancy Period. The graphs are composed of individual component power demands but some of the individual bars are too small to be seen due to the scale of the vertical axis and the sample size.

This paper presents the data from the larger sample sizes available for the electrical power demands of those HVAC component types for which we have data at the time of writing this paper. Power demands are an important indicator of component sizing and operation within buildings, and being separate from time issues allow comparison between components in buildings with very different occupancy periods.

The completion of the iSERVcmb project in May 2014 will produce additional data for HVAC components not yet published once there has been an opportunity to study it in more detail.

This short paper is only an overview of the type of data that will be produced from the iSERVcmb dataset at the end of the project. All data findings will be revisited before publication of the final project reports in July 2014, as data is still coming into the HERO database.

The data shown in the rest of this paper provides a unique insight into the range and level of normalised power demands occurring in European building services components when in operation. The data is obtained from individual meters covering periods from a few months to a few years. The majority of the data for each component covers both winter and summer periods and can therefore be considered representative of the range of demands likely for that component.

Average Power Demands by HVAC Component Type

Figure 1 shows the range of normalised AVERAGE power demands being measured by HVAC component type in operational HVAC systems across the whole of Europe. The sample size for each component can be estimated from the X-axis, and the Y-axis is limited to 100 W/m² to enable the ranges to be seen more clearly. The largest average Cold Generator power demand recorded is 362 W/m² in a Server Room.

It is clear that there are, as might be expected, a significant range of AVERAGE power demands/m² serviced for each HVAC component type. The graph shows that Cold Generators incur the largest average power demand/m², followed by Air Handling Units, Pumps and then Terminal Units. The separate categories of All-in-One Units and Heat Pumps show similar average power demand ranges in use to Pumps and Terminal Units.

A closer examination of the data (not presented here) for the higher average consumptions shows that they tend to occur for specific activity types – underpinning the need to separate power demand ranges into activity types served, as used in the iSERVcmb process.

Maximum Power Demands by HVAC Component Type

Figure 2 shows the range of normalised MAXIMUM power demands being measured by HVAC component type. The general shape of the graph is very similar to the Average graph shown above, and the Y-axis is limited to 200 W/m² to enable the ranges to be seen more clearly.

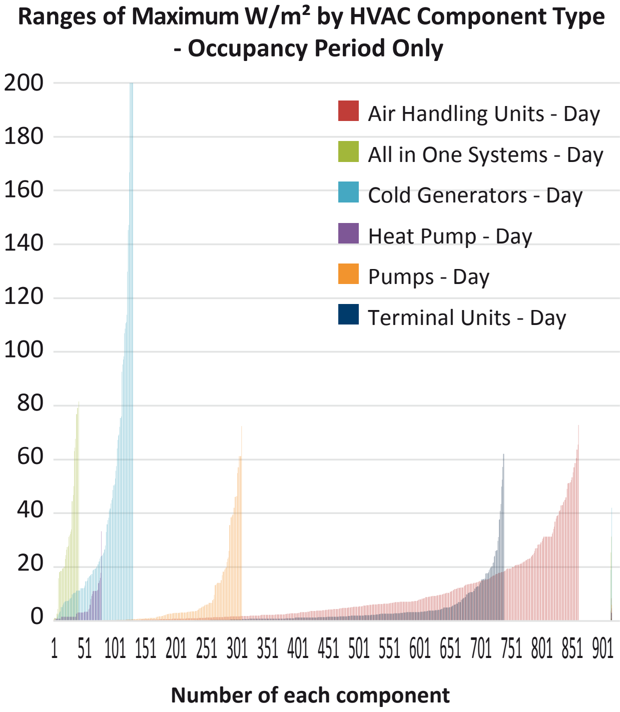

Figure 2. Ranges of Maximum Electrical Power Demands/m² by HVAC Component during Occupancy Period. The graphs are composed of individual component power demands but some of the individual bars are too small to be seen due to the scale of the vertical axis and the sample size.

What can be seen is that for all HVAC Component types other than Heat Pumps there are instances in Europe where the peak electrical demand is 50 W/m² or more at some point in the year. As with the average power demands, it appears that these peaks generally occur for significant loads such as IT server rooms.

All data will be rechecked before the project end as the detailed analysis of any large dataset obtained on real world conditions always raises questions which need to be answered to provide further confidence in the findings.

Table 1 and **Figure 3** present the **median** figures by HVAC component type for the average and maximum ranges shown in these two graphs. The median is taken, rather than the average, to reduce the influence of the extreme data values which are not considered to be typical of most HVAC component operation in buildings.

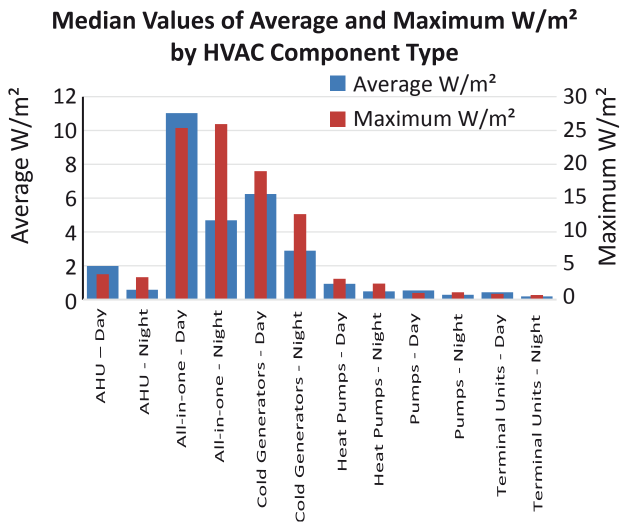

Figure 3. Median values for Day and Night Average (axis on left) and Maximum Power (axis on right) Demands/m² by HVAC Component.

Table 1. Median values for Day and Night Average and Maximum Power Demands/m² by HVAC Component.

Median values	AHU – Day	AHU – Night	All-in-one – Day	All-in-one – Night	Cold Generators – Day	Cold Generators – Night	Heat Pumps – Day	Heat Pumps – Night	Pumps – Day	Pumps – Night	Terminal Units – Day	Terminal Units – Night
Average W/m²	**1.99**	0.58	**11.03**	4.69	**6.24**	2.89	**0.94**	0.49	**0.55**	0.29	**0.43**	0.20
Maximum W/m²	**3.76**	3.33	**25.39**	25.95	**18.98**	12.63	**3.09**	2.36	**0.99**	1.09	**0.84**	0.70

Each component type is sub-divided into approximate Day (08:00 to 20:00) and Night (20:00 to 08:00) periods to examine the degree of variation between day and night, and to minimise the effect on the average figures of HVAC systems being turned off at night.

Examining the ratio of the maximum to average power demands for individual items of equipment in the HERO database shows that the median turndown ratio from peak to average power demands during the day varies from 50% for the Terminal Units, through 45% for Pumps, 44% for AHU's, 40% for All-in-one systems, down to 27% for Cold Generators and 24% for Heat Pumps.

The importance of good part-load efficiency for Cold Generators and Heat Pumps is reinforced by this data, as the Peak Demands measured do not represent the installed capacity. Previous research (Dunn, 2005) noted that installed capacity is frequently around twice the peak demand found from measurement.

Dunn also found that the systems studied operated at 8 – 44% of Installed Capacity on average, with 8 – 21% being the value for 3 of the 4 systems. Whilst we have yet to look at complete system capacities within the iSERV data, this does seem to agree with the data being obtained in iSERVcmb which, using Dunn's findings of component maximum demands generally being less than 50% of installed capacity, suggests the iSERVcmb HVAC components are operating at 14 – 25% of their installed capacity on average. This has implications for the in-use energy efficiency of such components, as efficiency has a tendency to drop off markedly below 30% of installed capacity for many HVAC components.

iSERVcmb will produce further data on the relationship between measured power demands and installed capacity for all the HVAC Component types as the data continues to be analysed.

The data also shows that, if the median figures are representative of the wider population as a whole, then the maximum normalised electrical demands occur from heating or cooling equipment (Cold Generators and All-in-one equipment) as might be expected – though the heat pumps in this sample (predominantly split systems) appear to be used in places with small loads. This is unexpected and will be checked further.

Over a full year, the median HVAC **system** in our sample (either an All-in-one system or an HVAC system composed of AHU, Pumps, Terminal Units and Cold Generators) ranges from an average electrical power demand during the day of between 9.2 to 11.0 W/m², and 4.0 to 4.7 W/m² at night, with the Cooling Demand being the major component of this average load. The median MAXIMUM demands range from 24.6 to 25.4 W/m² during the day and 17.8 to 26.0 W/m² at night.

Extrapolating this data up to a full year, implies an annual electrical energy consumption range of between 58 to 68 kWh/m² for an 'average' HVAC system in the iSERVcmb project, which compares with the 'Good Practice' 44 kWh/m² and 'Typical Practice' 91 kWh/m² measured for cooling only systems in UK Office Buildings from 2000 to 2002 (Knight,2005). As the iSERVcmb project covers all types of end use activities this figure seems to be in line with this previous study.

The iSERVcmb annual energy use figures will be further refined by the end of iSERVcmb through comparison with actual annual consumption figures for those HVAC components and systems where annual consumption data is available.

The figures presented have shown the range of measured power demands being found in practice for operational HVAC components. From a practical viewpoint these figures are too coarse for use in predicting the likely power demand ranges to be found in specific buildings, as the ranges are dependent on the end use activities being serviced in practice.

We will produce data on the ranges of power demands by component servicing given end use activities, where available, in the Final Reports from iSERVcmb.

Conclusions

This paper has shown the ranges of normalised electrical Power Demands being achieved by HVAC component type in Buildings throughout Europe. The data shows that current median **average** Power Demands figures being achieved by HVAC systems in non-residential Buildings in the EU are contributing up to about 11 W/m² of a building's total Power Demand during the average working day. The median electrical maximum Power Demands are up to 25.4 W/m². ■

References

Please see the complete list of references of the article in the html-version at **www.rehva.eu** -> REHVA Journal