Inspection of HVAC systems through continuous monitoring and benchmarking

www.iservcmb.info

Europe and Energy Efficiency in HVAC systems

Dr Ian Knight

iSERV Coordinator

www.iservcmb.info

SWEGON Air Academy

June 2012

Supported by INTELLIGENT ENERGY EUROPE

Why is Europe interested in the energy use of HVAC systems?

Equipment	Electrical consumption as % of total EU use in 2007
Air conditioning units and chillers	0.75
Fans in ventilation systems	3.34
Pumps / circulators	1.81
Space and Hot Water Heating	5.23
TOTAL	**11.13%**

EC Joint Research Centre, Institute for Energy, 2009

- A 10% saving would be worth over €3bn at €0.1 per kWh.
- Does NOT include savings from reducing fossil fuel energy use.
- HVAC systems must be a key contributor towards energy savings in the EU

What is the purpose of the EPBD?

- ➔The European Energy Performance of Buildings Directive (EPBD) arose because the market was not delivering the savings needed in the buildings sector to help meet long-term energy and environmental security concerns in Europe.
- ➔The EPBD, and its recast, is the primary legislation affecting all EU Member States' legislation aimed at reducing the energy used in Buildings

Implementation of the EPBD

- ➔ The UK's Part L legislation transposes the EPBD into legal requirements in the UK
- ➔ Introduced 2002, the EPBD became law on 04/01/2006
- ➔ The recast EPBD becomes law between 01/01 and 01/07/2013

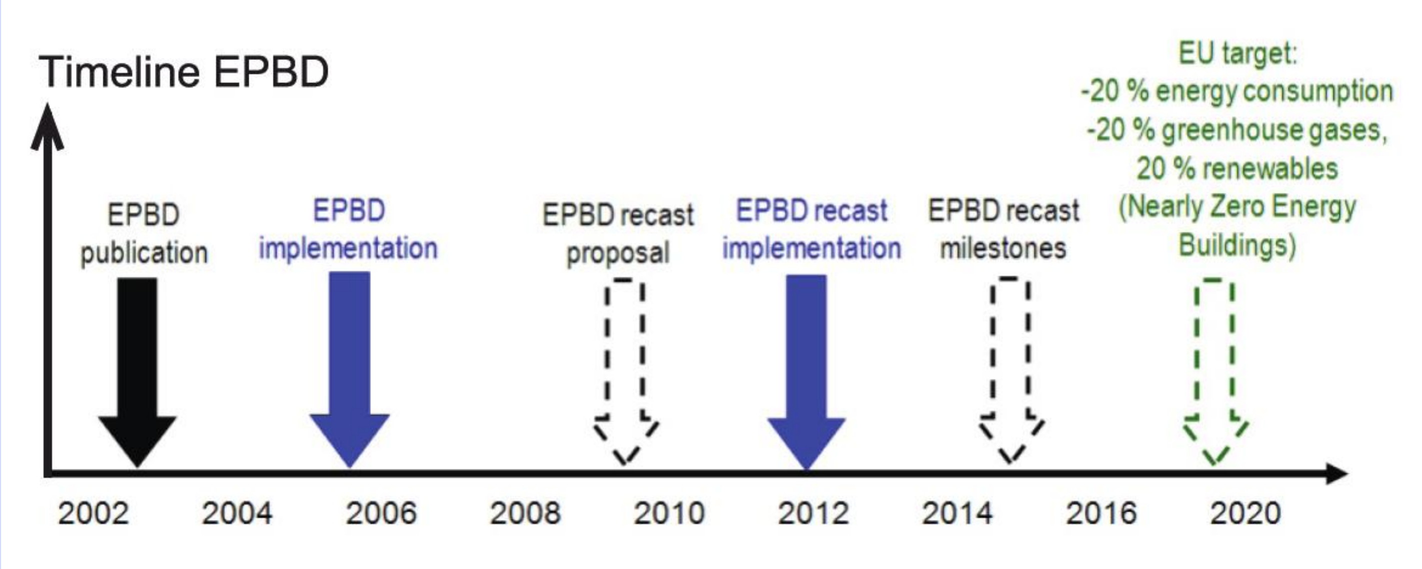


Figure 1. Timeline of the Energy Performance of Buildings Directive and its implementation.

- Taken from the REHVA Journal – March 2012

Which parts of the EPBD affect HVAC systems?

- ➔The EPBD has specific requirements for the treatment of HVAC systems within EU MS.
- ➔They are referred to as Technical Systems within the EPBD and have specific requirements for Inspection
- ➔There is also a requirement within the recast EPBD for all new buildings to be nZEB by 30/12/2020. This will have a major impact on HVAC systems, which will have a key role to play in achieving these targets.

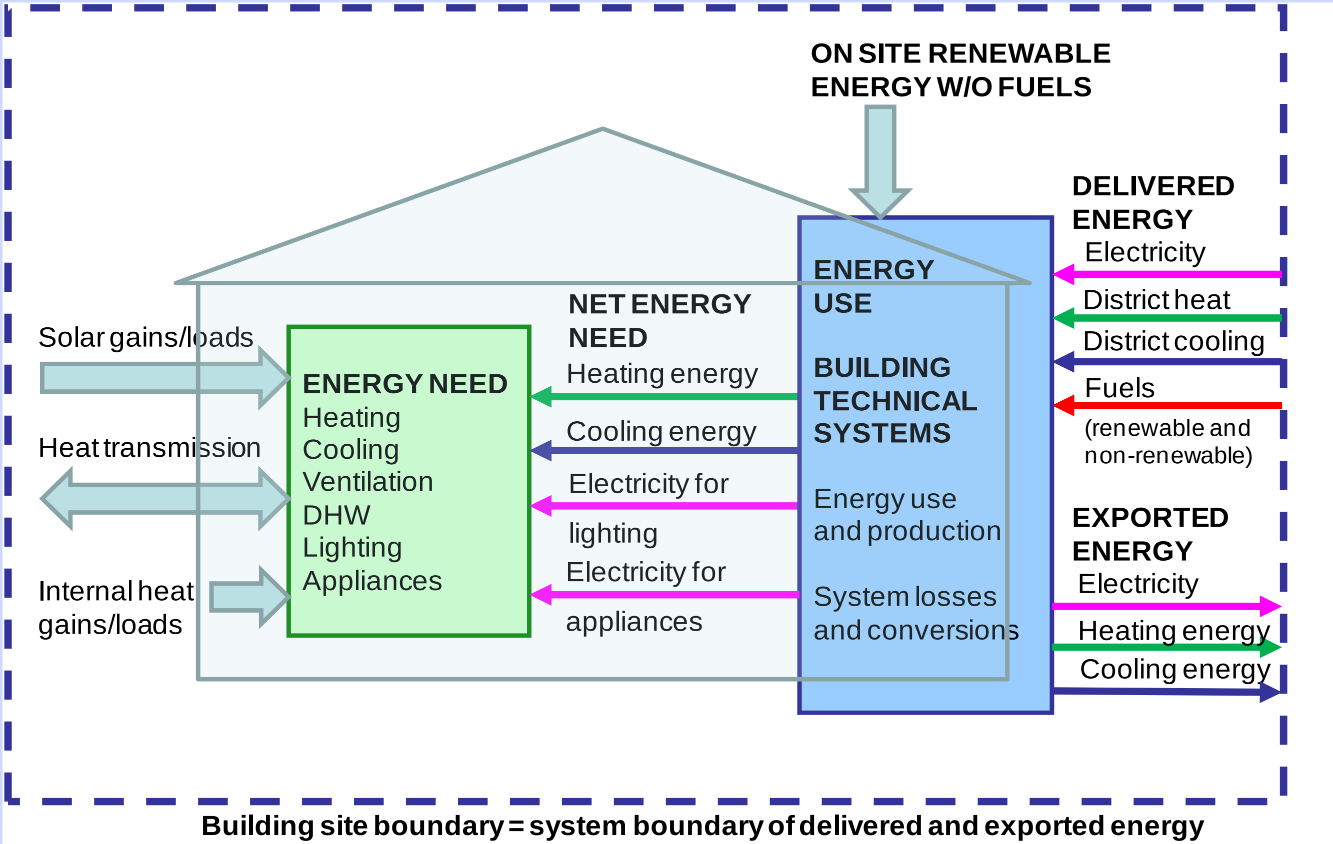
Future for HVAC energy use

- ➔The following slides briefly describe what is likely to be the definition of a nearly Zero Energy Building (nZEB), and how we are progressing towards such buildings
- ➔They show that in Germany we are heading towards 'plus energy' domestic buildings by 2020, i.e. buildings which produce more energy than they use
- ➔Progress in non-domestic buildings is meant to be led by the public sector who will need to be procuring only nZEB by 01/01/2019

nZEB from Jan 2021 onwards

➔ Near Zero Energy Buildings (nZEB) will be required from 2021

➔ Still not clear what the final definition of nZEB will be



- taken from REHVA proposals for nZEB definition June 2012

Are nZEB feasible?

- ➔ German housing energy use trends appear to suggest yes
- ➔ Not yet clear how far we can reduce energy use in non-domestic buildings due to the wide variety of activities

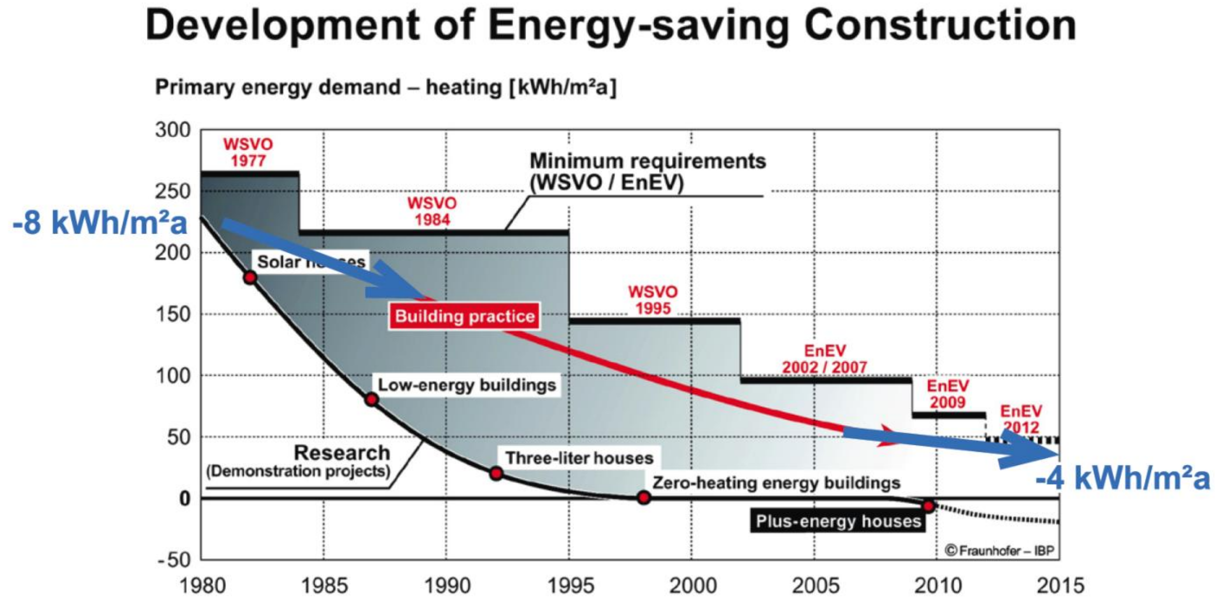


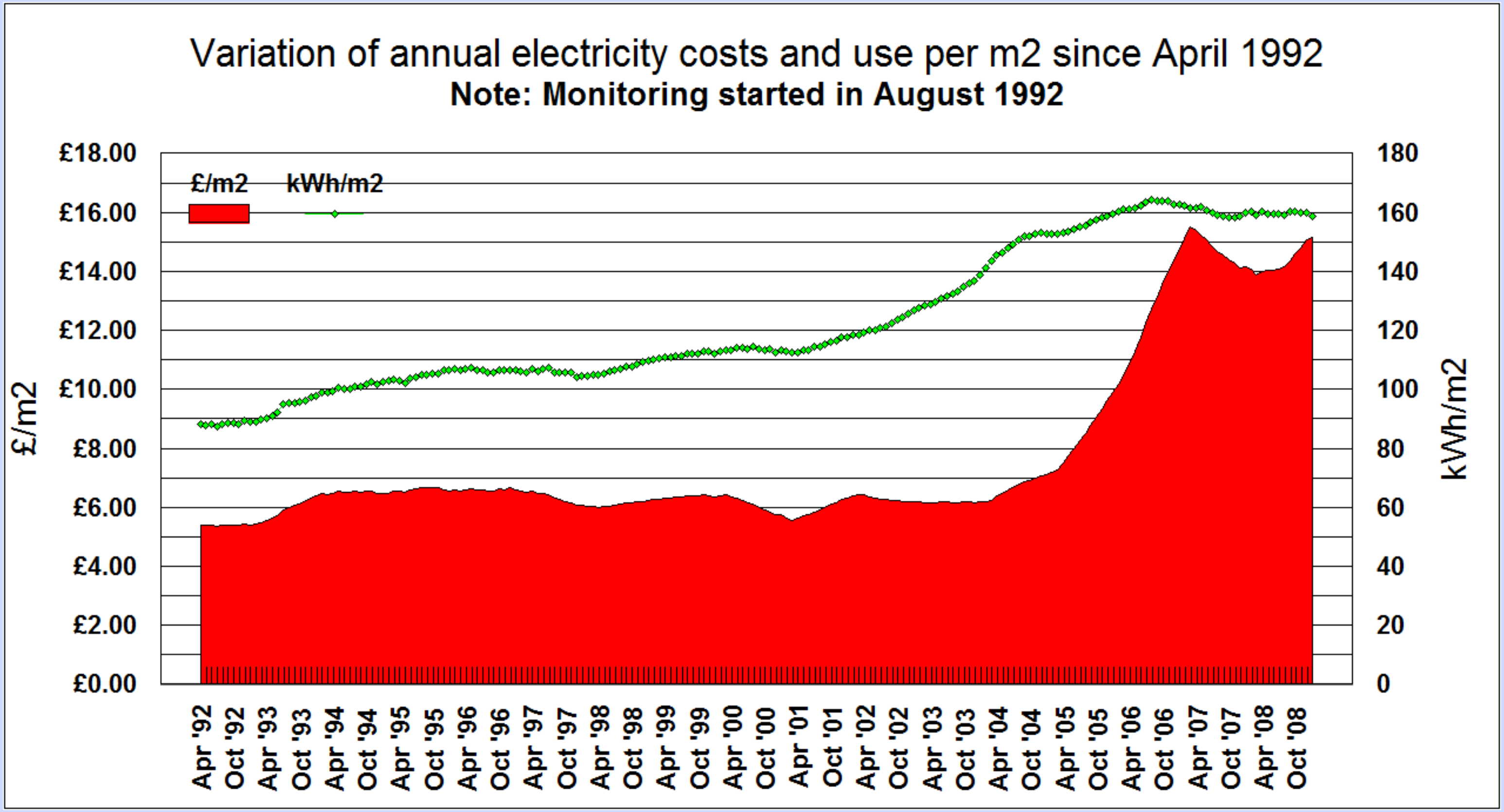
Figure 2. The development of the energy-saving construction in Germany showing the minimum energy performance requirements (upper line), the high performance pilot projects (lower line) and the innovative building practice (middle line) over the last 35 years.

- Source: REHVA Journal March 2012

Reducing energy use in HVAC systems – a practical approach

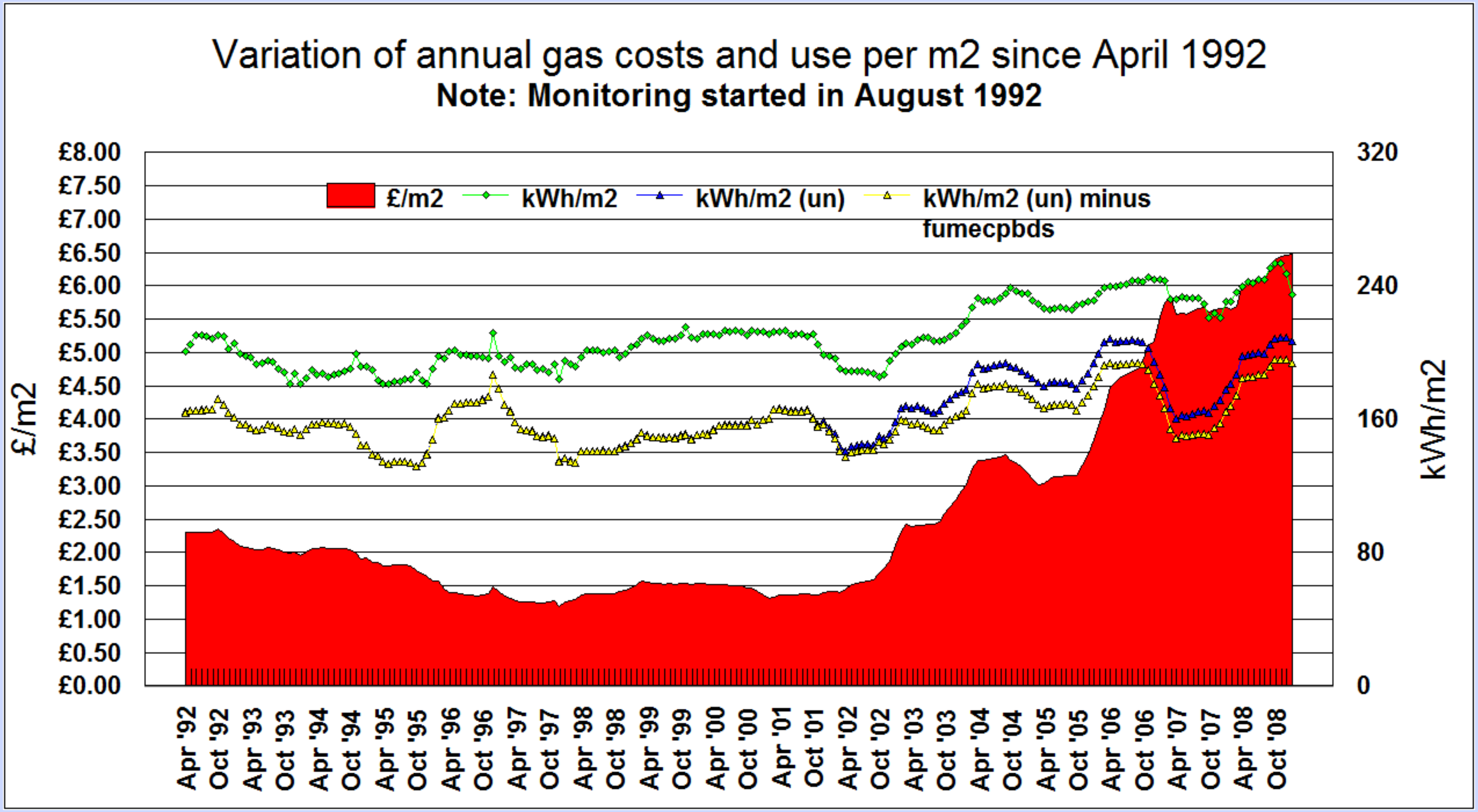
- ➔ So how do we achieve nZEB non-domestic buildings in practice?
- ➔ The rest of this talk examines a practical approach to reducing HVAC system energy use being trialled across Europe, starting with the history to the approach and a personal viewpoint.
- ➔ Whilst energy efficiency is primarily driven by monetary issues at present, paradoxically there is not a lack of money or will to invest. Rather there is a lack of understanding of where to invest to achieve long-term savings
- ➔ The next few slides examine experiences from 20 years of studying energy use in Cardiff University's buildings

20 years energy monitoring at Cardiff University - Electricity



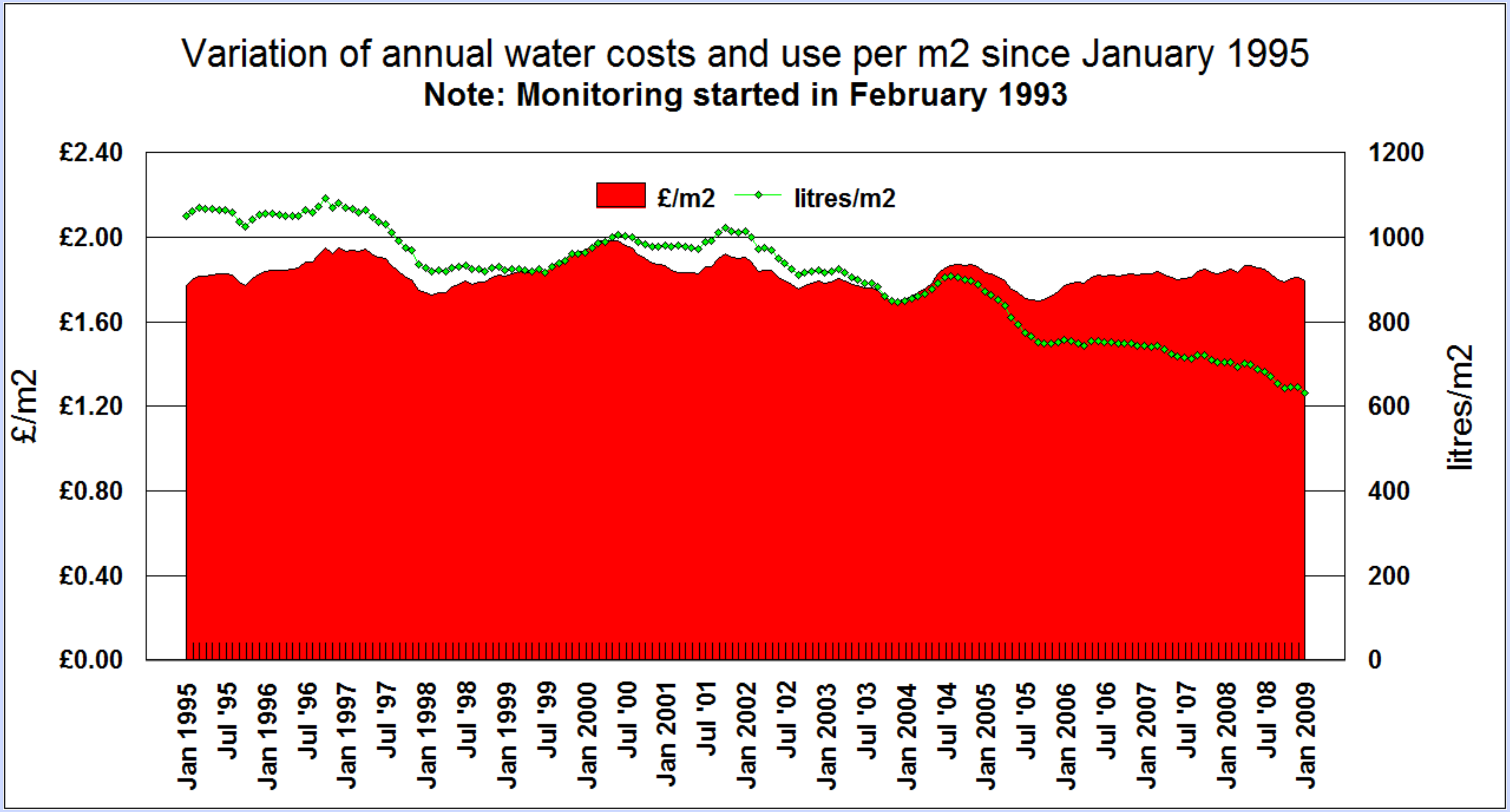
- ➔ Data stops end 2008 following migration to a new system
- ➔ Electricity increases mainly due to increased use of IT, greater research studies, and greater intensity of use of estate

20 years energy monitoring at Cardiff University - Gas



- ➔ Gas shows 10% reduction at first scrutiny, loss of savings over time when resource removed, savings recovered when focussed on again. Growth then due to acquisition of more intensive research facilities.
- ➔ Significant investment in more efficient services is lost in the other factors

20 years energy monitoring at Cardiff University - Water



- ➔ Data stops end 2008 following migration to a new system
- ➔ Major savings from finding leaks – many of which were over 10 years old…

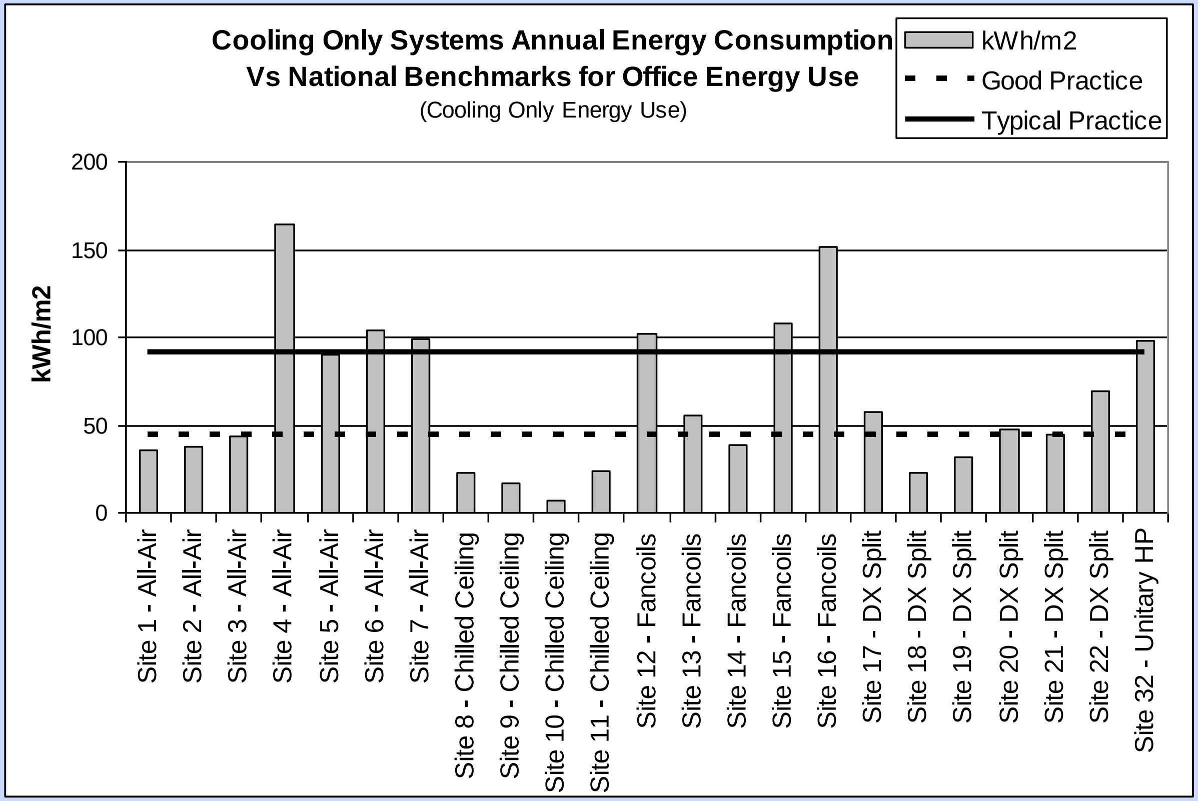
Cardiff University energy use

➔Observations and lessons learnt:

- Initial savings of 10 – 15% in gas use were quickly achieved from use of existing controls and attention being paid
- These savings lost when no longer paying attention
- Noticeable inability to prioritise investments and understand changes in the energy use profiles.
- We had the ‘effect’ (metered energy use) but not the ‘causes’ – what were the drivers for this energy use and was the energy use appropriate?
- Investment of manpower, money and time to save energy therefore difficult to achieve. So either follow ‘accepted wisdom’ or just do nothing.

Assembling the evidence for investment – first steps

➔ A study undertaken in 2000/2 into the overall energy use of AC systems into UK Office buildings suggested that choice of system could have an effect on overall energy use.

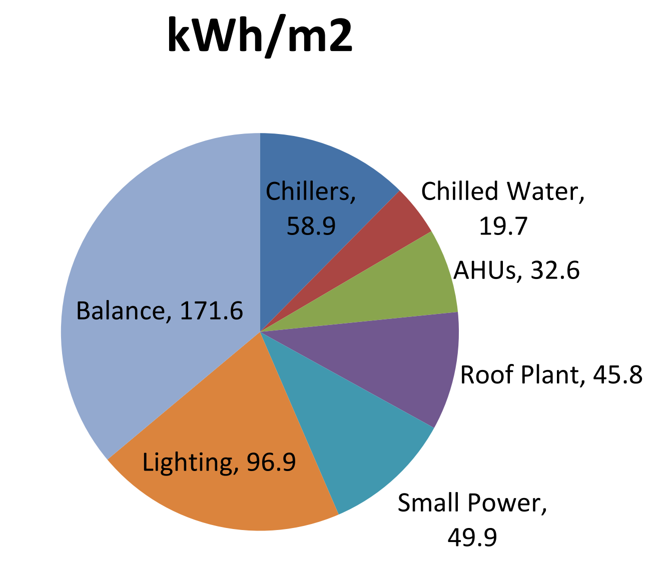


AUDITAC: 2005 - 2007

- ➔ AUDITAC was the first European project to look at the impact of the EPBD on HVAC systems – specifically the inspection of AC systems aspect
- ➔ AUDITAC reviewed the audit and inspection process for AC systems as required by the original EPBD
- ➔ It concluded that:
  - There was little independent information on the energy consumption of AC systems in use, or what affected it
  - There were insufficient high quality inspectors to undertake all the Inspections required in Europe.
  - Inspection unlikely to achieve savings predicted

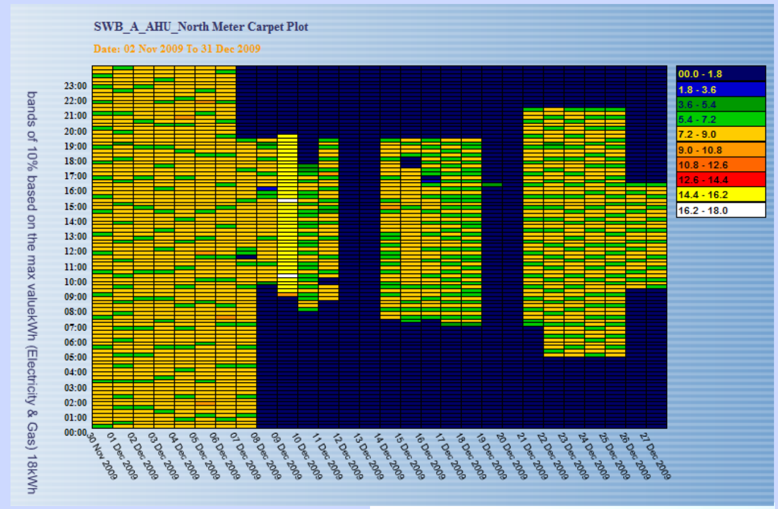
HARMONAC: 2007 - 2010

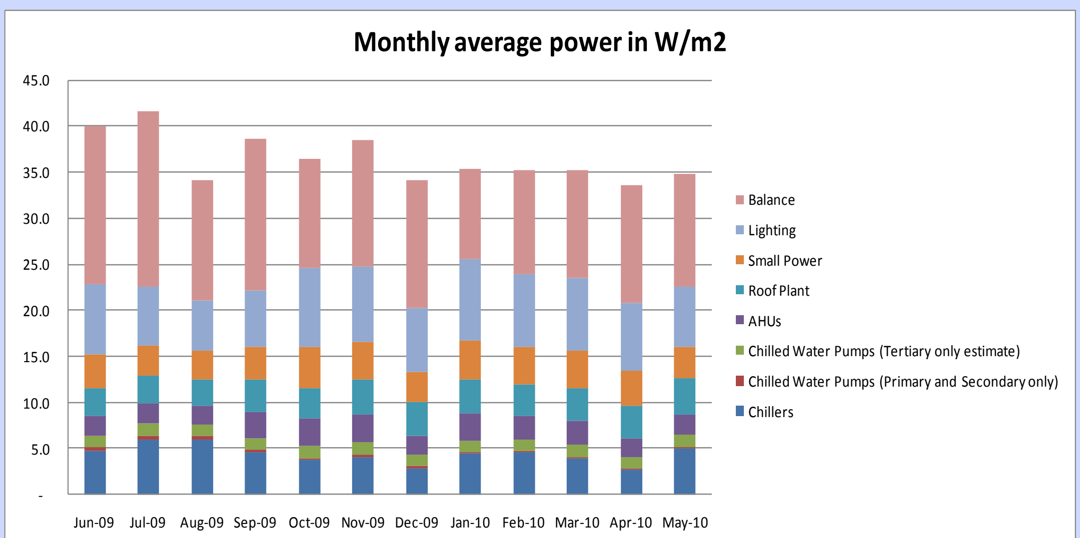
- ➔ A follow-on European project, HARMONAC, obtained sub-hourly information on energy use in HVAC systems from 42 Systems in the EU
- ➔ It showed the electrical energy use of HVAC systems is typically 30 – 40% of the building total electrical energy use.
- ➔ HVAC generally accounts for > 90% of non-electrical energy use
- ➔ First European data on in-use energy consumption in HVAC components
- ➔ All findings at: www.harmonac.info



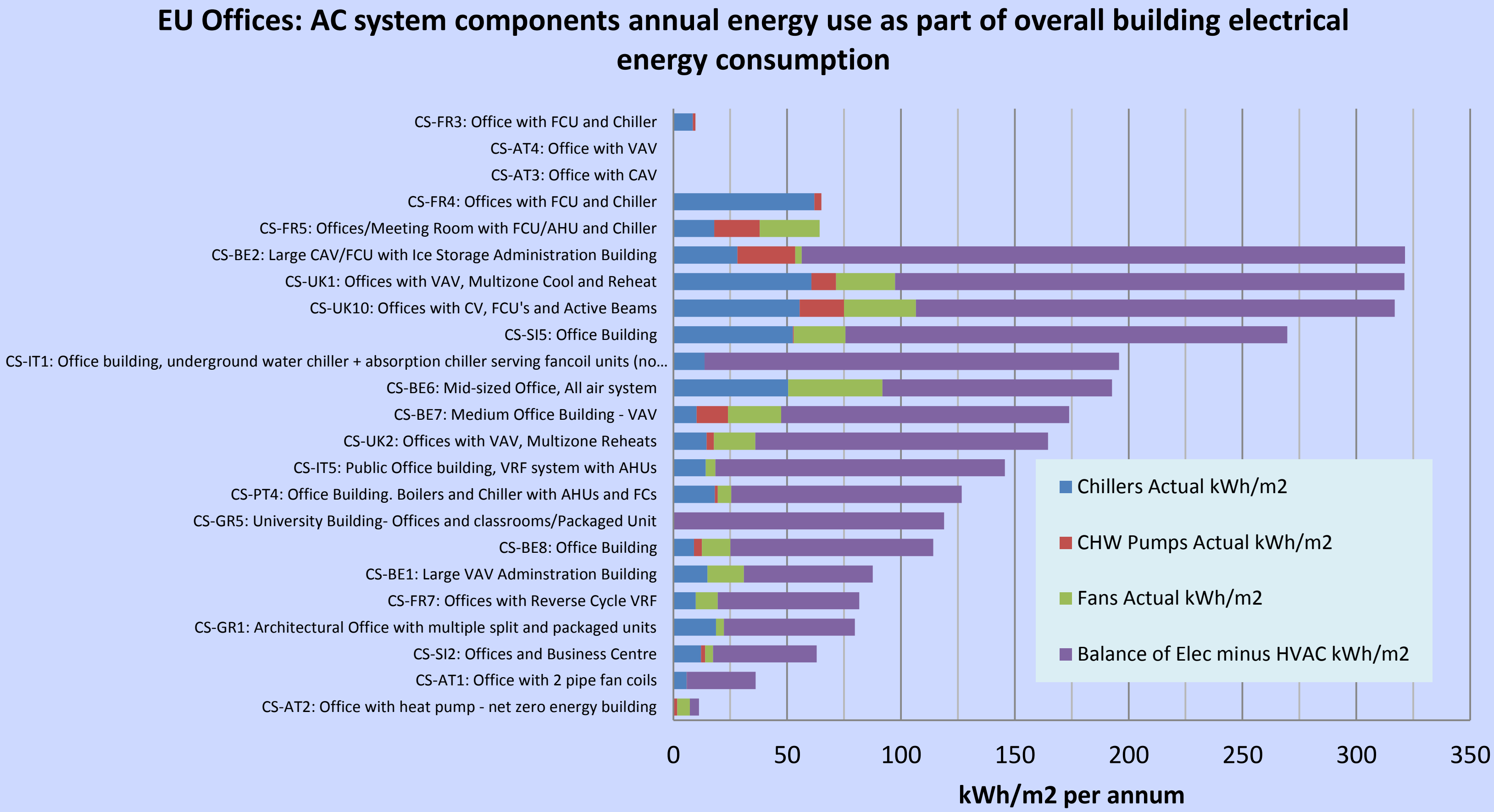
Annual energy balance – One Wood Street, London

Assessing buildings – end use and services in detail





HVAC system energy use in EU Offices – from HARMONAC



- Insufficient data to draw many conclusions at building level – **BUT…**

The crux of the issue…

- The two UK HQ Office buildings were very close in terms of occupancy type and activities.
- One was new at the start of monitoring and used the very latest 'advice' on trying to achieve a low energy design (variable speed drives, low fresh air rates, chilled beams, low energy daylight linked lighting, etc)
- The other was a 1988 building with that era plant and controls.
- They both used a nearly identical amount of HVAC energy per m^2.
- The benefits of 'energy efficient' HVAC **components** can potentially be negated by poor design and operating decisions.
- **Poor design choices can be locked into HVAC system energy performance for decades**

Operating HVAC systems efficiently

iSERV CMB

- ➔ Even when well designed, HVAC systems are often complicated and not explained well to operators.
- ➔ Sometimes they cannot be explained in a way that an operator can interpret with control actions should problems arise e.g. some are tied into the theoretical building demands and involve time lags. They therefore require faith that the building will stabilise.
- ➔ Result is that actions taken to rectify immediate complaints can have significant impacts on the actual energy use achieved.
- ➔ nZEB requirements run the risk of further complicating HVAC system design and operation

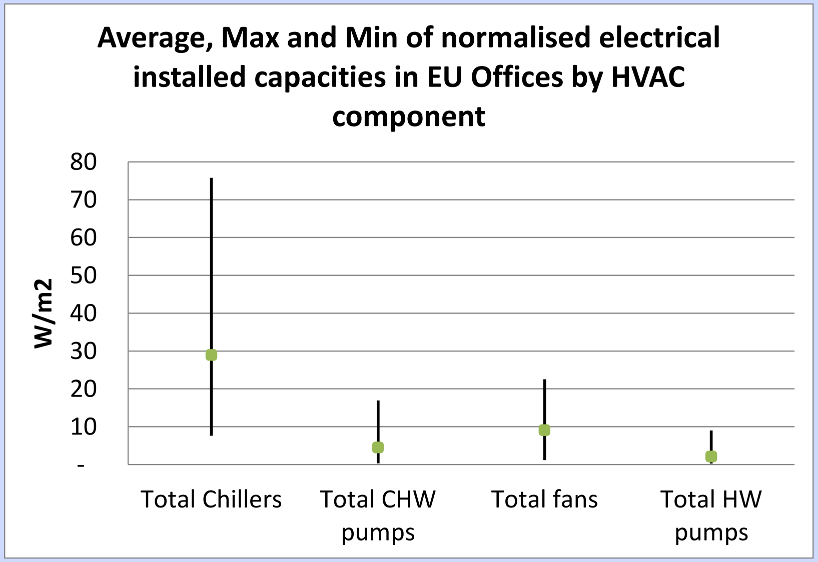
Current advice on achieving energy efficiency in HVAC systems

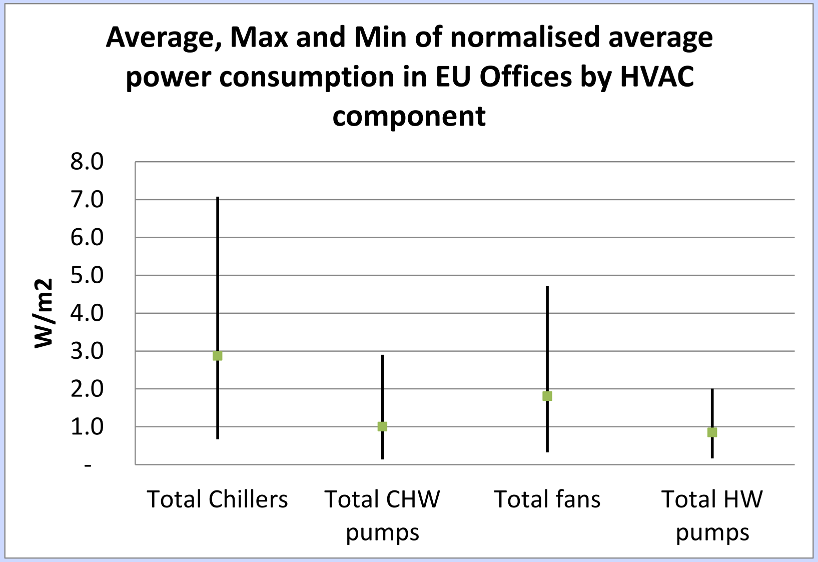
- ➔ With little information available on what makes an HVAC installation energy efficient in practice, then professional advice naturally tends to be based on theoretical considerations
- ➔ The history of HVAC systems until recently has been about providing the 'right' conditions, not reducing energy use, so we are starting from a low evidence base when trying to improve energy use.
- ➔ Large numbers of HVAC system types exist. How to provide advice?
- ➔ For an HVAC system to work **efficiently** the interactions between the heating, cooling, humidification and ventilation components are crucial, as are their interactions with the climate, building fabric and occupancy.
- ➔ HARMONAC showed that a major contributor to poor energy consumption was a lack of meaningful feedback on performance.

➔It is not yet possible to say "Just do this" and achieve an energy efficient HVAC system

Initial energy use ranges by HVAC component - HARMONAC

- ➔ HARMONAC also produced ranges of installed HVAC component loads per m^2, and the consumptions per m^2 recorded in the offices studied.
- ➔ The activities served in the Offices were not recorded in detail





HARMONAC Conclusions

- ➔ "HARMONAC… …reinforced what was already considered to be 'good practice', … …**necessary to have good operation, maintenance and control** of an AC system, as well as **good record-keeping** and **choice of the correct type and design of system for the end use activity**."
- ➔ "The **key to increased long-term energy efficiency… …rests with making it cheaper for the owner to run their systems efficiently**… . This implies… …there should be an alternative that rewards good energy management by allowing systems to avoid inspection if they achieve certain standards."
- ➔ "…there is **no real understanding in the market of the effect of AC system choice and design on the actual energy efficiency achieved** in practice"

Automatic monitoring – prospects for savings

iSERV CMB

- ➔ HARMONAC established, via metered EU Case Studies on 'real' AC systems, how many of the potential energy savings available in the systems studied were actually identified by Inspection procedures
- ➔ HARMONAC showed **Inspections identified about 37% of the energy savings shown to be present by the more detailed sub-hourly monitoring**
- ➔ The overall **average energy savings possible in the Case Study AC systems investigated were assessed as being between 35 – 40%**, or around 10% of the primary energy use of the buildings in which they were located
- ➔ Automatic monitoring allows **continuous feedback** on performance, thereby **achieving savings and, hopefully, maintaining them**.

HARMONAC Impact

- ➔HARMONAC's results led to requirements changing from Article 9 in EPBD to Articles 15 and 16 in recast EPBD i.e. allowing alternatives to physical Inspection based on automatic monitoring. The project also led to a more general emphasis on automatic monitoring and control systems in the recast EPBD
- ➔HARMONAC and iSERV are the two largest projects ever funded under the EC's IEE funding stream. They carry a great deal of weight.

HVAC Benchmarks

- ➔From all the previous slides, it can be concluded:
- ➔We should be using automatic monitoring systems more widely to achieve the maximum savings
- ➔We need energy use benchmarks by HVAC system for the activities they serve, i.e. relating the causes to the effects, for this monitoring to achieve the maximum impact.
- ➔We need to obtain more information on which HVAC systems deliver best energy performance in practice

Establishing credibility

➔ To make the benchmarks believable for investment purposes around Europe we should:

- Ensure data collection over a large number of real HVAC systems across Europe
- Provide a route and procedure for the continuous updating of benchmarks
- Allow any HVAC system in Europe to participate to ensure we get examples of practice from around the EU
- Provide clear reports on actual consumption against benchmarks and, where possible, reports on what actions can be taken to improve the energy consumption

iSERV – the continuous monitoring and benchmarking of HVAC systems

➔ www.iservcmb.info

➔ Three energy management axioms:

- You can't manage what you don't measure
- You can't control what you don't understand
- Data overload can prevent understanding the true picture

➔ For HVAC systems there is often little understanding by the people operating them of the HVAC system components, or the HVAC system design intent

➔ BMS and energy management systems are producing so much data that we struggle to see the important data.

iSERV – direct end user benefits

➔ Offers all HVAC system operators the opportunity to implement a monitoring and feedback approach to energy efficiency across their HVAC systems. iSERV:

- Deals with the data overload problem arising from trying to handle the outputs from many submeters in the building
- Links energy use @ HVAC component level to the activities served
- Provides regular feedback to help maintain savings achieved
- Provides analysis of monitored data and feedback on not only consumption achieved against benchmarks but also potential Energy Conservation Opportunities (ECOs).
- Reduces staff time spent analysing data freeing it up for implementing practical energy conservation regimes
- Will put monetary figures to all this data where possible

iSERV – indirect end user benefits

➔iSERV also provides:

- CIBSE and REHVA will publish benchmarks produced from iSERV as professional guidance i.e. the approach should become the accepted way to operate HVAC systems in practice across the EU
- Should establish the principle of the demonstrable good design, operation and maintenance of HVAC systems as being an acceptable complement to Inspection – with regular Inspection only being required where performance does not meet bespoke standards

iSERV aims

➔iSERV end goals:

- Establish a framework for describing, monitoring and benchmarking HVAC system components against the activities they serve
- Allow the HVAC sector and end users to take responsibility for reducing HVAC energy use long-term through rewarding good behaviour, hence reducing legislative burden and improving energy consumption
- Establish initial ranges of HVAC system component vs activity energy use benchmarks across Europe
- Allow these benchmarks to be upgraded regularly to reflect improvements in performance

iSERV – system basics

- ➔Involving the end user, along with the design of HVAC systems and choice of components are key elements in reducing HVAC energy use in buildings
- ➔HARMONAC showed end users will act if given information focussed on their systems
- ➔**A framework for describing systems and activities**
- ➔**Benchmark HVAC components against the activities they serve**
- ➔Building design and alterations are part of the potential iSERV ECOs to improve HVAC performance

What are the problems to solve?

- ➔ Owners want HVAC energy efficiency, but the market lacks the independent proof of likely performance.
- ➔ Establishing energy efficient HVAC solutions for specific activities served.
- ➔ To demonstrate clearly what is good energy performance for a given activity served, by providing the range of consumptions from which the benchmark is derived.
- ➔ Creating a common approach to demonstrating energy efficiencies available from HVAC components
- ➔ Enabling system operators to understand their specific HVAC system energy efficiency performance by providing bespoke benchmarks they should achieve

HVAC energy efficiency - practice

The basic question that iSERV tries to answer is:

Is the energy being consumed by an HVAC system reasonable for the activities it serves?

iSERV's approach will provide independent verification of **current** energy use possible at **HVAC component** level when serving given activities

How does iSERV propose to do this?

➔iSERV collates information in a way which is rarely (if ever) done for HVAC systems:

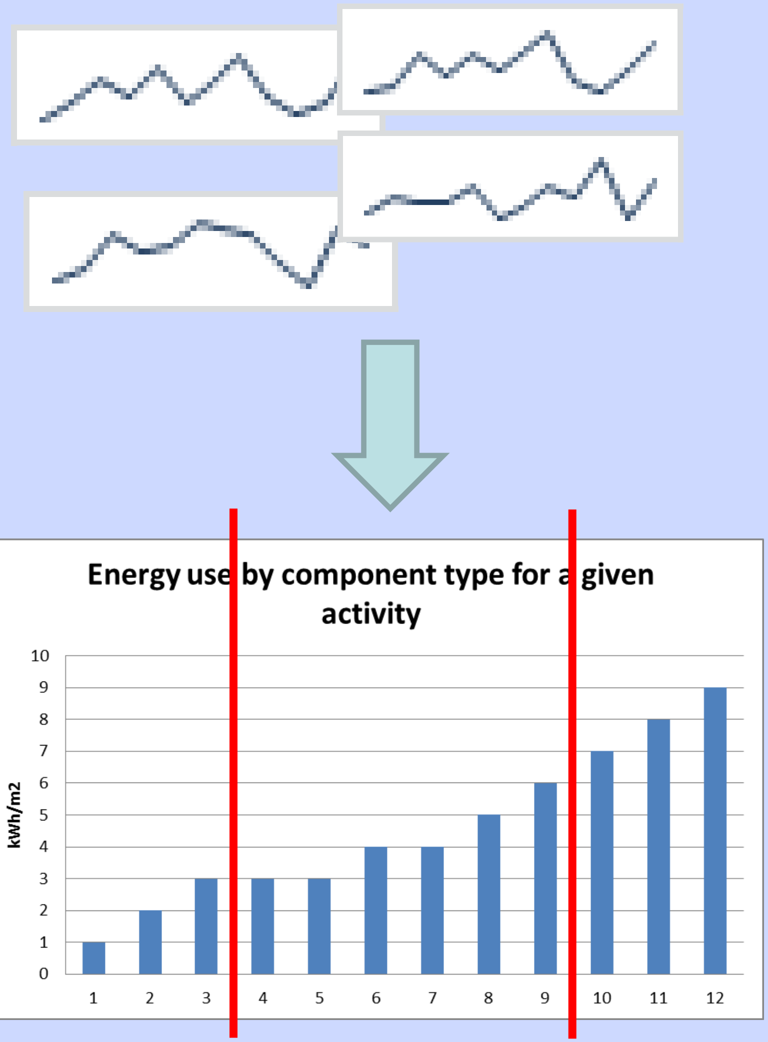
- It catalogues the HVAC components, meters and sensors
- It describes the spaces, areas and activities served by the HVAC systems
- It links all these elements together to describe the HVAC system components in terms of areas and activities served
- It provides a web-based system to collate all this information and to receive the sub-hourly metered data to describe the systems on-going performance.

Understanding an HVAC system

- We need to understand what an HVAC system comprises, and what it is meant to be doing, in order to improve its energy efficiency in a rational manner.
- iSERV provides tools and guidance to collect and collate the initial data needed. This usually need only be done once and is then available for Inspections and future system improvements.
- Approach is endorsed by CIBSE and REHVA and will be promoted heavily over the next 2 years

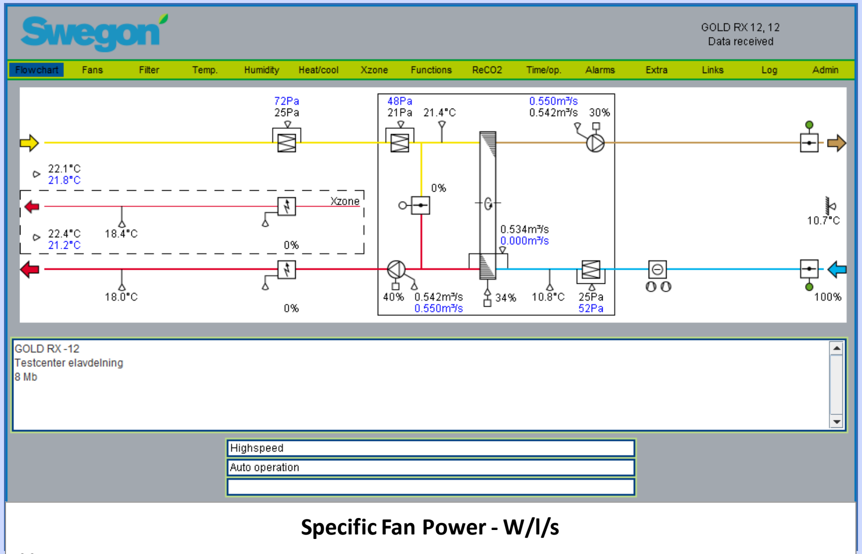
Where will the benchmarks come from?

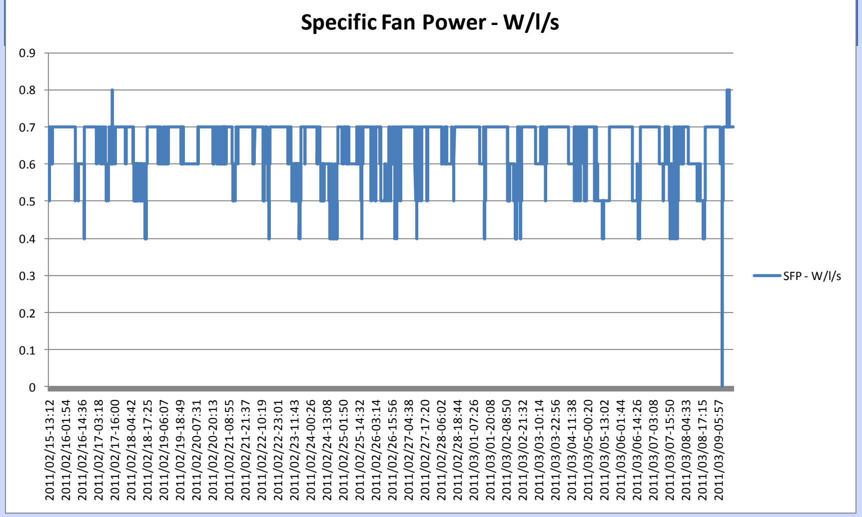
- ➔ By collecting energy use data per m^2 from HVAC component types servicing the same end use activity in different areas
- ➔ iSERV will collate this data by component and activity served
- ➔ These will be the first publicly available data on energy use per m^2 ranges for an HVAC **component** for a given activity served

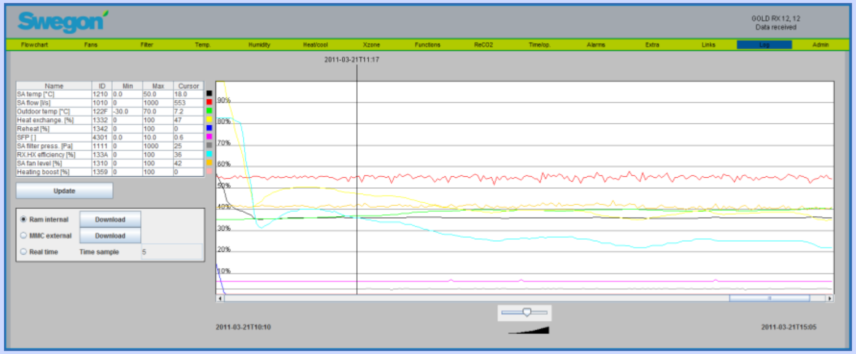


Data availability today

- These images show the type of data already available from some HVAC components, in this case SWEGON Air Handling Units.
- For energy accounting purposes only a subset of this data is needed







What type of benchmarks will be produced?

➔It is intended to produce ranges of benchmarks at the levels of:

- Annual energy consumption per m^2 ($kWh/m^2.a$)
- Monthly energy consumption per m^2 ($kWh/m^2.month$)
- Peak and average power consumptions in use (W/m^2)

➔Each one of these benchmarks should cover a range, not just a single figure, to allow performance to be assessed against the full spectrum of achieved use.

➔It is anticipated that range boundary figures will be presented for the upper and lower quartiles of the measured data in the first instance i.e. 25% and 75%

Use of benchmarks

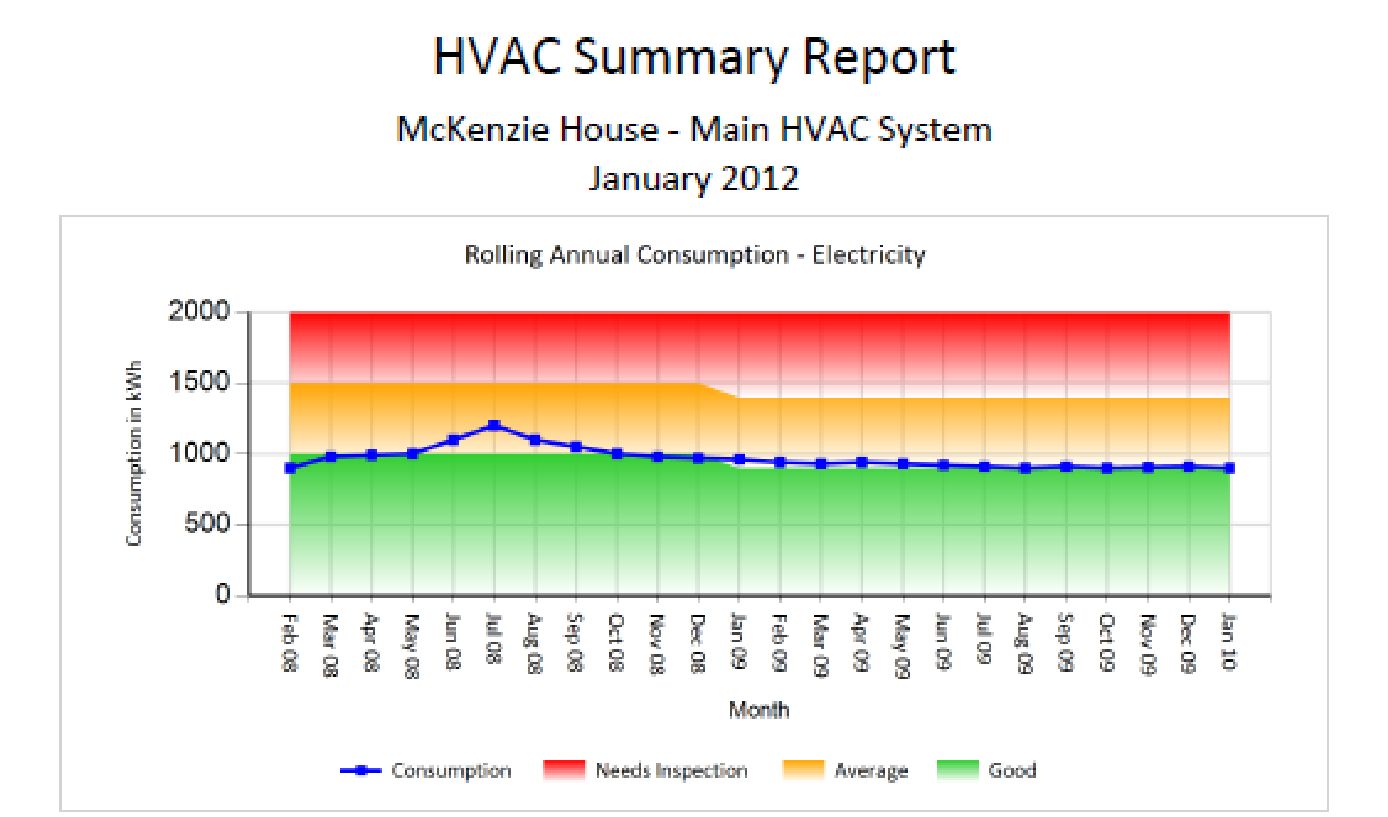
- ➔ These 3 different benchmarks cover all possibilities for assessing energy use
- ➔ The annual energy use is likely to be the benchmark for legislation
- ➔ The monthly energy use and power benchmarks are the most useful for diagnosing Energy Conservation Opportunities (ECOs)

What about a complete system?

- ➔iSERV will produce bespoke ranges of consumption for any combination of HVAC components used in a real system
- ➔To do this it need only know the end use activities served, along with (usually) the total floor area each activity type occupies.
- ➔The exact methodology used for the predicted ranges of consumption and 'sanity checks' will be derived during the project, but will include assemblage of component benchmarks in some form

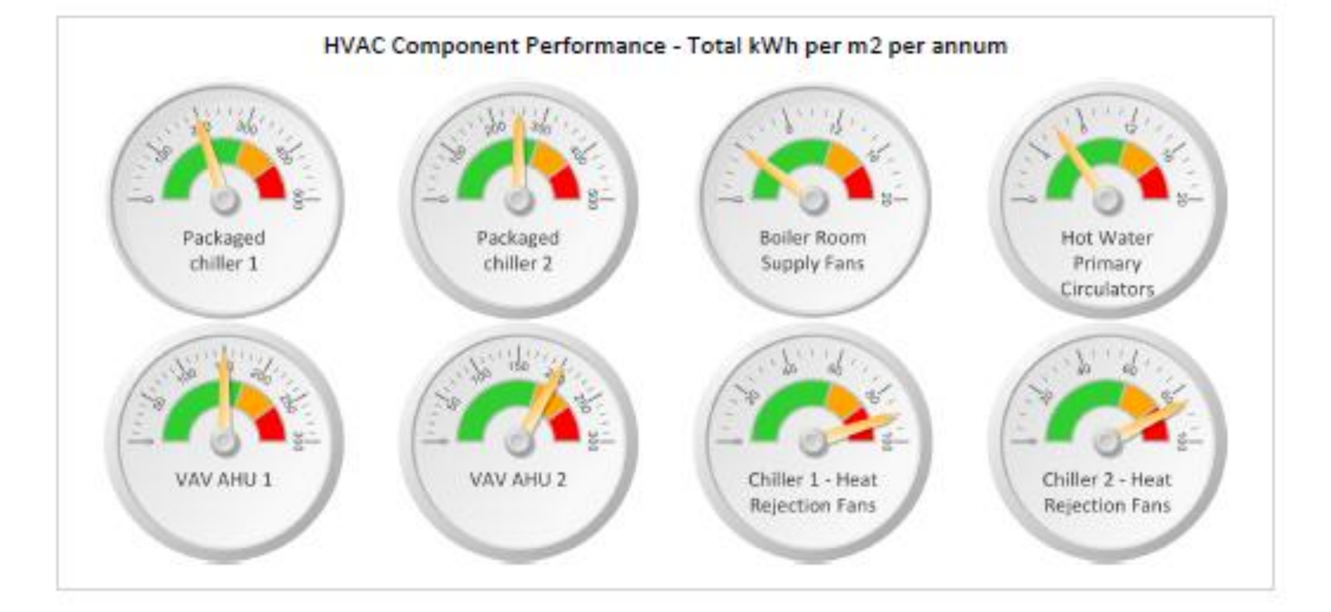
HVAC System Report

➔Overview of whole HVAC system performance against bespoke ranges for mix of activities served



HVAC Component Reports

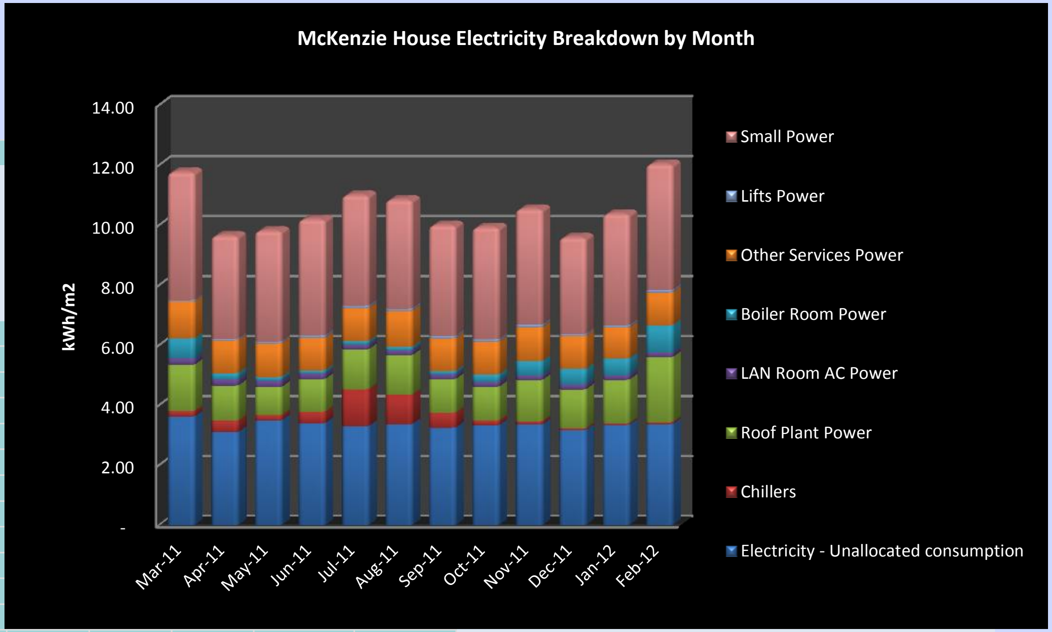
➔Overview of individual HVAC component performance against ranges predicted for mix of activities served



Energy Conservation Opportunity (ECO) Reports

- ➔Another unique feature of iSERV is its ability to take the measured data for the HVAC components and automatically suggest potential ECOs that could reduce the energy use of the HVAC system
- ➔iSERV will provide an indication of the likely energy and cost savings to be achieved for each ECO.
- ➔ECOs maximise the value of submeters, and reduce the analysis time needed by the energy manager to understand his HVAC system’s performance

Example outputs from iSERV data – monthly data



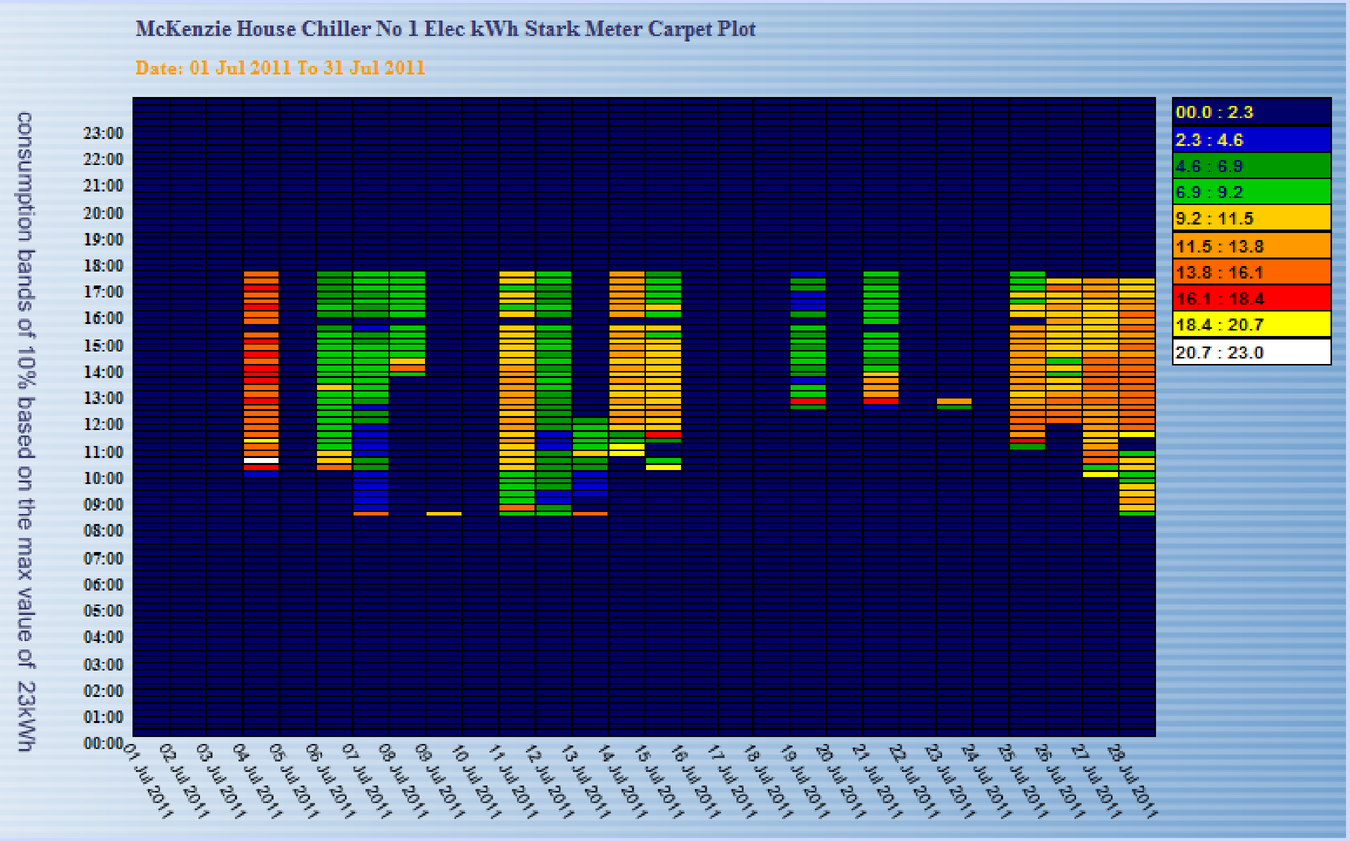
McKenzie House Conditioned Floor Area/m2 =		8434.93								
All Figures in kWh/m2										
Month	Electricity - Unallocated consumption	Chillers	Roof Plant Power	LAN Room AC Power	Boiler Room Power					
Mar-11	3.62	0.18	1.54	0.21	0.67					
Apr-11	3.10	0.38	1.17	0.21	0.21					
May-11	3.49	0.18	0.93	0.21	0.13					
Jun-11	3.39	0.39	1.09	0.18	0.11					
Jul-11	3.29	1.24	1.33	0.17	0.11					
Aug-11	3.36	0.98	1.32	0.17	0.11					
Sep-11	3.25	0.50	1.12	0.16	0.11					
Oct-11	3.33	0.15	1.13	0.17	0.25					
Nov-11	3.36	0.11	1.37	0.16	0.48					
Dec-11	3.17	0.06	1.30	0.17	0.52					
Jan-12	3.34	0.05	1.45	0.16	0.55					
Feb-12	3.37	0.07	2.16	0.16	0.90					
Total Mar-11 to Feb-12	40.1	4.3	15.9	2.1	4.1	13.3	0.8	45.0	125.7	257.0

Sum of Std_Month_ Consumption

Month	Blr 1 Cumulative	Blr 2 Cumulative	Blr 3 Cumulative	Chiller 1 cum power	Chiller 2 cum power	Clean Supply DB cum power	DB Floor 2 cum power	DB Floors 1&3 cum power	DB Ground cum power	Fire Panel cum power	Lan Room AC cum power	Landlords DB cum power	Lift 1 cum power	Lifts 2&3 cum power	Main Incomer CP	MCP 4th Plant cum power	MCP Boiler Plant cum power	MCP Central services	MCP Dining cum power
Mar-11	5,956.81	316,373.75	9,614.31	986	561	37	-	10,993	-	1	1,792	-	206	253	99,253	207	5,623	567	622
Apr-11	2,919.58	18,340.97	3,903.47	1,846	1,374	47	-	9,154	-	1	1,734	-	1	412	81,365	177	1,772	534	628
May-11	791.39	3,443.61	1,058.75	1,042	464	49	-	9,661	-	1	1,792	-	24	490	82,732	188	1,062	561	859
Jun-11	-	-	-	1,868	1,382	12	-	9,904	-	1	1,543	-	249	416	85,947	176	907	574	559
Jul-11	-	-	-	5,326	5,092	22	-	9,299	-	2	1,400	-	276	388	92,747	185	930	537	488
Aug-11	-	-	-	4,555	3,730	1	-	9,455	-	-	1,401	-	259	371	91,448	182	961	560	548
Sep-11	224.58	224.58	-	2,561	1,651	13	-	9,341	-	2	1,356	-	270	382	84,318	177	935	542	529
Oct-11	2,481.11	246,988.19	3,443.61	806	498	17	-	9,422	-	1	1,403	-	272	378	83,722	185	2,079	536	514
Nov-11	4,320.56	73,631.25	6,523.61	561	354	10	-	10,019	-	1	1,358	-	282	403	88,882	179	4,018	541	523
Dec-11	242,218.47	294,749.58	12,533.89	288	189	110	-	7,816	-	2	1,402	-	217	305	80,854	198	4,373	522	556
Jan-12	71,075.28	266,901.25	10.69	261	190	145	-	8,854	-	1	1,359	-	252	364	87,521	215	4,628	498	515
Feb-12	277,756.11	76,197.92	225,684.86	316	234	109	-	10,176	-	2	1,362	-	277	407	101,491	248	7,620	510	534
Mar-12	19,378.33	20,982.50	19,378.33	93	58	46	-	3,337	-	-	454	-	89	133	30,778	63	2,577	165	175
Grand Total	627,122.22	1,317,833.61	282,151.53	20,509	15,777	618	-	117,431	-	15	18,356	-	2,674	4,702	1,091,058	2,380	37,485	6,647	7,050

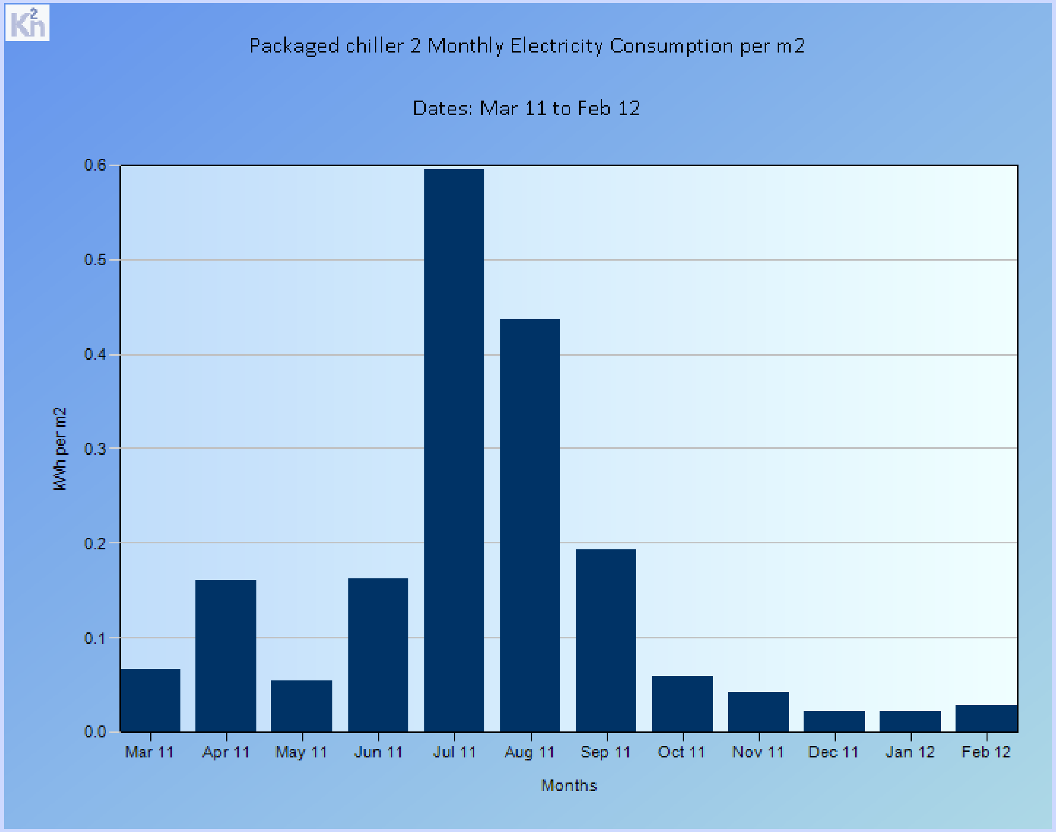
Example outputs from iSERV data – subhourly data

➔Example for Chiller 1 for July 2011 showing good control both inside and out of occupancy hours



Energy use by component

➔ iSERV will also calculate/estimate the consumption of individual HVAC components PER UNIT AREA SERVED and PER ACTIVITY where their supply meter is recorded.



iSERV project outputs and impacts

- ➔ Establish approach as a complement to Inspection
- ➔ Allow end users to access ECOs specific to their HVAC systems
- ➔ Rewards good system design and operation
- ➔ Electricity savings of between 5 – 60% per system anticipated
- ➔ Expecting 5 – 15% electricity savings on average
- ➔ Savings expected to be maintained c.f. Inspection reductions
- ➔ Establish that end users and manufacturers can help meet energy reduction goals with the correct support framework
- ➔ Reduce cost of doing business in Europe
- ➔ CIBSE and REHVA will be using this information to produce professional guidance.

FREE participation in iSERV

- ➔ Register on the iSERV website
- ➔ Notify the relevant iSERV Partner for your country that you wish to participate, so that they may give you the latest information and tips
- ➔ Download the iSERV spreadsheet and complete it for your HVAC system.
- ➔ Validate the spreadsheet and send to the iSERV Partner for checking and entering to iSERV database
- ➔ Check and validate your data collection with iSERV
- ➔ Start using iSERV to help manage your HVAC system

iSERV Summary

- ➔iSERV will produce 'benchmark' figures at HVAC component and activity level for the professions
- ➔iSERV is the only large-scale 'open' approach in this area at present in Europe
- ➔'Blind' to manufacturer and other potential bias
- ➔Allows rapid verification of novel HVAC approaches in real buildings
- ➔Allows owners to fully understand their systems
- ➔Essential for understanding HVAC system energy use in time to allow an orderly transition to nZEB

Already convinced and participating in iSERV…

The following organisations have already agreed to participate in, and to associate themselves with, iSERV:

Already convinced and participating in iSERV…

As are these:

iSERV CMB

Inspection of HVAC systems through continuous monitoring and benchmarking

www.iservcmb.info

Supported by INTELLIGENT ENERGY EUROPE

Thank you for your attention

Dr Ian Knight

iSERV Coordinator

knight@cf.ac.uk

www.iservcmb.info