



Budapest University of Technology and Economics

Federation of European Heating, Ventilation and  
Air-conditioning Associations

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# Energy saving of HVAC system with continuous monitoring



REHVA Seminar, Aqua-Therm, Praha, 5 March, 2014

# Acknowledgements

iSERV      Inspection of HVAC systems through  
continuous monitoring and  
benchmarking

[www.iservcmb.info](http://www.iservcmb.info)

Co-ordinator: Prof. Ian Knight

Cardiff University, UK

2012 - 2014



# iSERV Partners and Steering Group

<p><b>Welsh School of Architecture, Cardiff University</b> Building energy use experts</p>		<p><b>K2n Ltd</b> Energy database experts</p>	
<p><b>MacWhirter Ltd</b> Installation, Maintenance and Energy Inspections</p>		<p><b>National and Kapodistrian University of Athens</b> Indoor Air Quality experts</p>	
<p><b>University of Porto</b> HVAC and Engineering experts</p>		<p><b>Politecnico di Torino</b> HVAC and Engineering experts</p>	
<p><b>Université de Liège</b> HVAC and Modelling experts</p>		<p><b>Univerza v Ljubljani</b> HVAC and Engineering experts</p>	
<p><b>University of Pecs</b> HVAC and Engineering experts</p>		<p><b>Austrian Energy Agency</b> Dissemination and Legislation</p>	
<p><b>REHVA</b> HVAC Professional Body</p>		<p><b>CIBSE</b> HVAC Professional Body</p>	
<p><b>SKANSKA</b> Building Developer</p>		<p><b>Camfil Farr</b> Filter manufacturer</p>	
<p><b>SWEGON</b> AHU System manufacturer</p>			

# EU Directives

- Energy Performance of Building Directive  
EPBD 2002/91/EC
- Ecodesign of Energy Using Products Directive  
2009/125/EC
- Energy Labelling Directive 2010/30/EU
- EPBD „recast” 2010/31/EU
- Energy Efficiency Directive EED 2012/27/EC

# Outline/Agenda

- Long-term energy savings in buildings
- iSERV process
- Potential savings, results

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

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

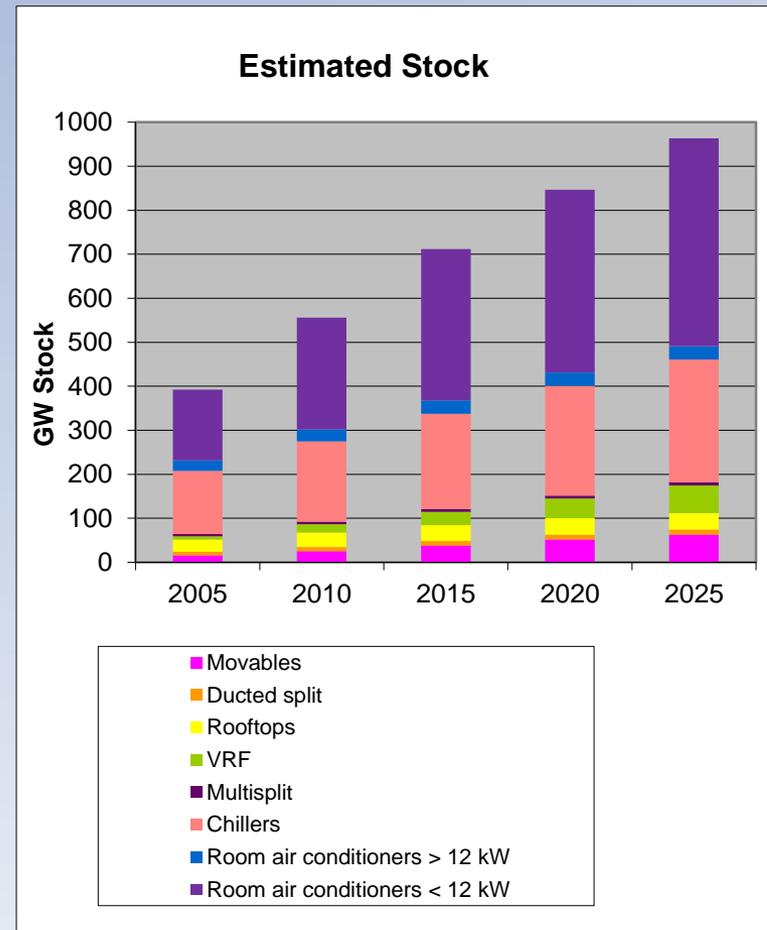
EC Joint Research Centre, Institute for Energy, 2009

At this level of energy consumption, HVAC systems must be a key contributor towards energy savings being sought in the EU

# Context: European A/C Market

- European ownership of air conditioning is increasing
- This trend is expected to continue as Europe is currently well below US levels of ownership for similar climates

Reference: Roger Hitchin, Christine Pout, Philippe Riviere “Assessing the market for air conditioning systems in European buildings”, Energy and Buildings, Volume 58, March 2013.

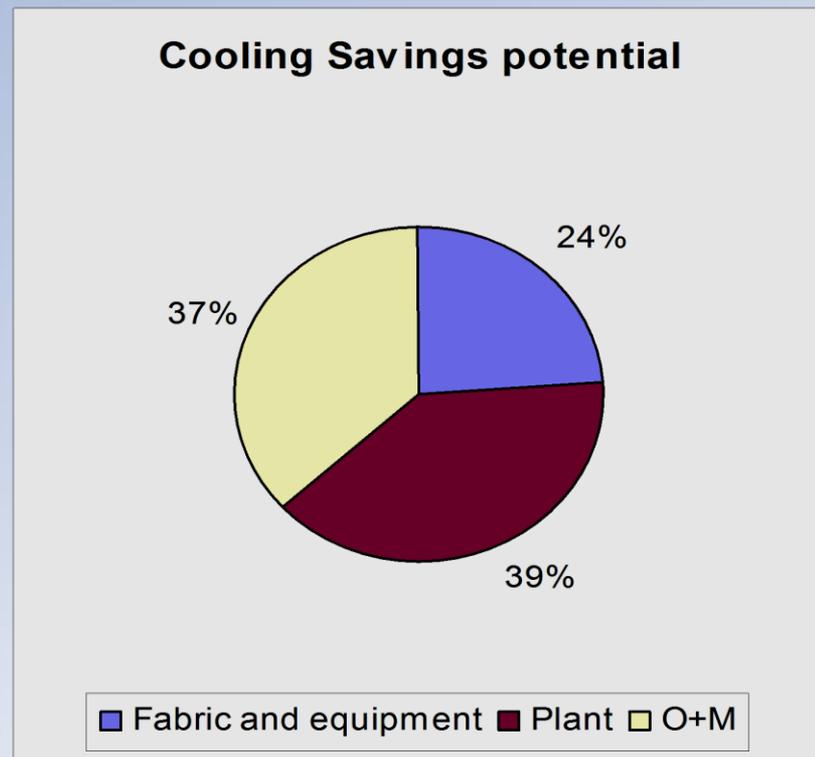


# Context: Potential Energy Saving

Potential for savings through:

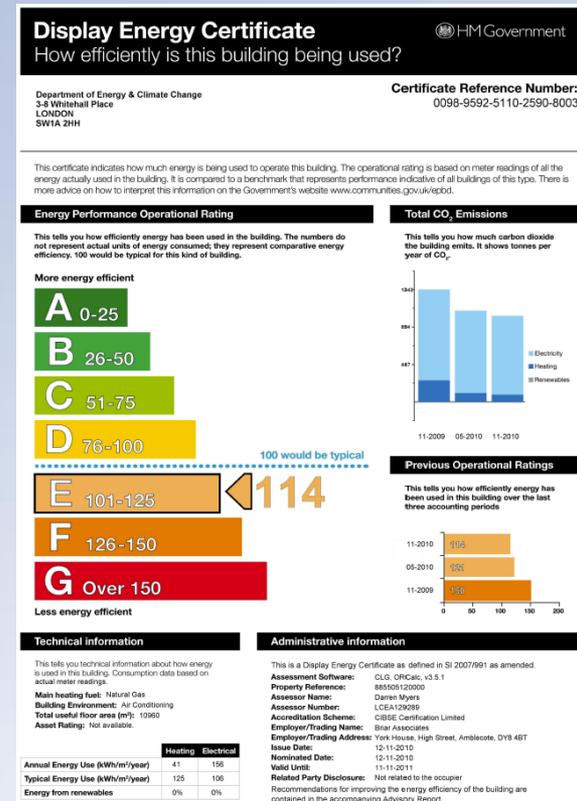
- Load reduction (24%)
- Improved efficiency (39%)
- Better operation (37%)

Source: HarmonAC project results. <http://www.harmonac.info/>



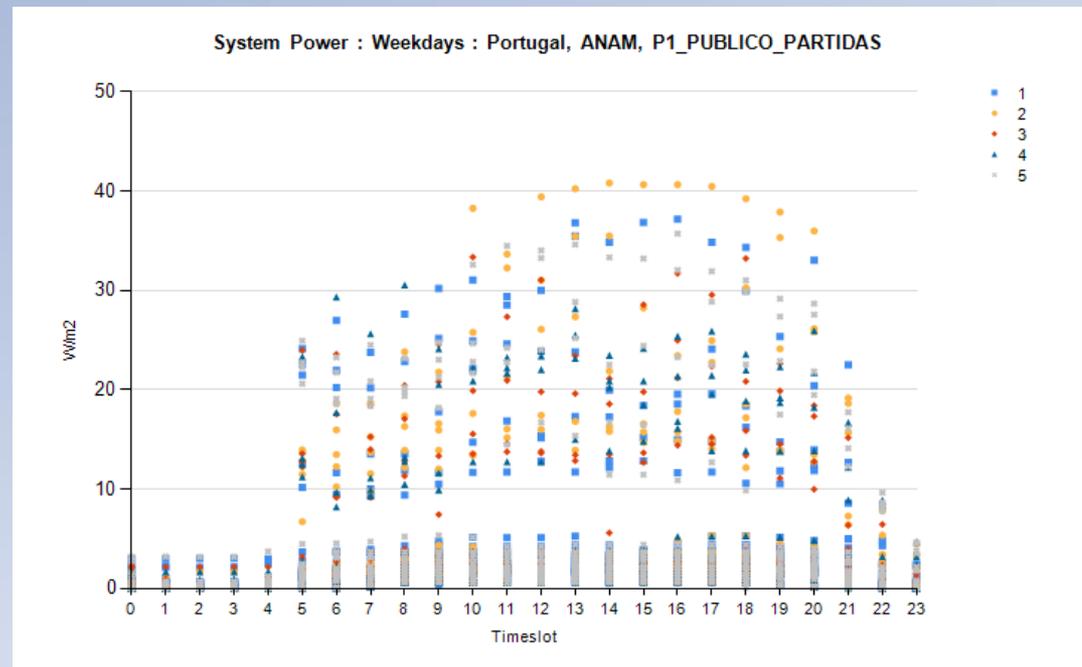
# A 20<sup>th</sup> Century approach to a 21<sup>st</sup> Century problem

- Most EU MS Legislation aimed at reducing energy use looks at whole buildings and annual energy use due to the availability of billing meters for most buildings.
- So we know WHAT we are using, but not WHY we are using it.
- Current processes do not show what is possible to achieve with our actual existing building and activity mixes.
- Most organisations JUST comply with legislation, i.e. they spend time and money on compliance exercises but not improving their energy use in a robust manner.



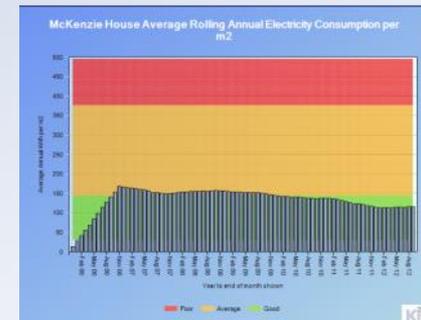
# A 21<sup>st</sup> Century approach to a 21<sup>st</sup> Century problem

- New data sources now allow us detailed insights into how energy is used at sub-hourly intervals and by end uses.
- This level of detail is sufficient to provide confidence in what needs to be done to reduce energy use.
- iSERV utilises these new data sources to show how such a new approach might work - from defining the buildings through to how it might work with legislation.



# iSERV

- A way to show owners of real buildings the energy savings possible **FOR THEIR BUILDINGS**, by comparing their use with the performance of other real buildings using the same equipment to service the same activity and floor area.
- iSERV uses an empirical process based on physical items that can be measured and found in all buildings.
- This means that reports can refer to actual items in a building.
- Gives confidence to the owner/operator that the information is relevant to them.
- Reduces RISK – therefore enables **INVESTMENT**.

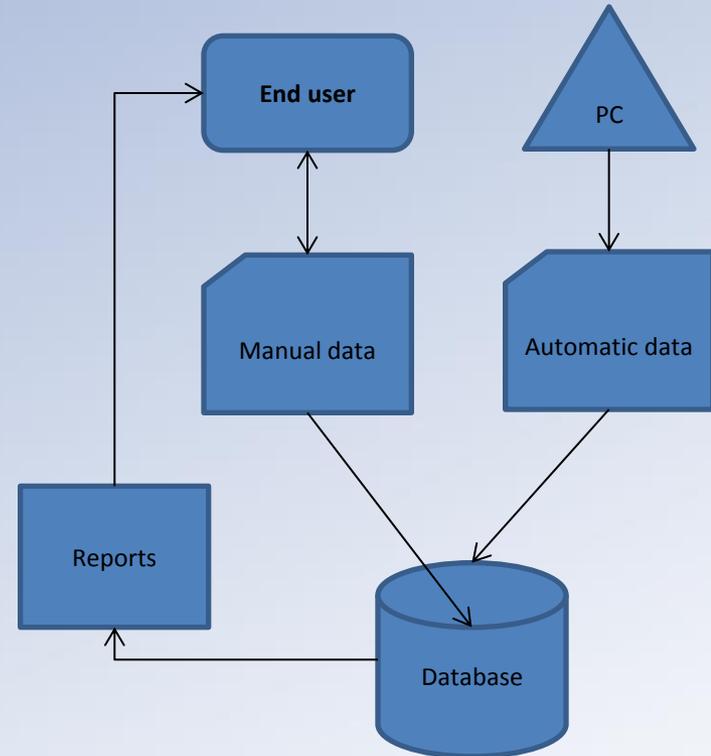




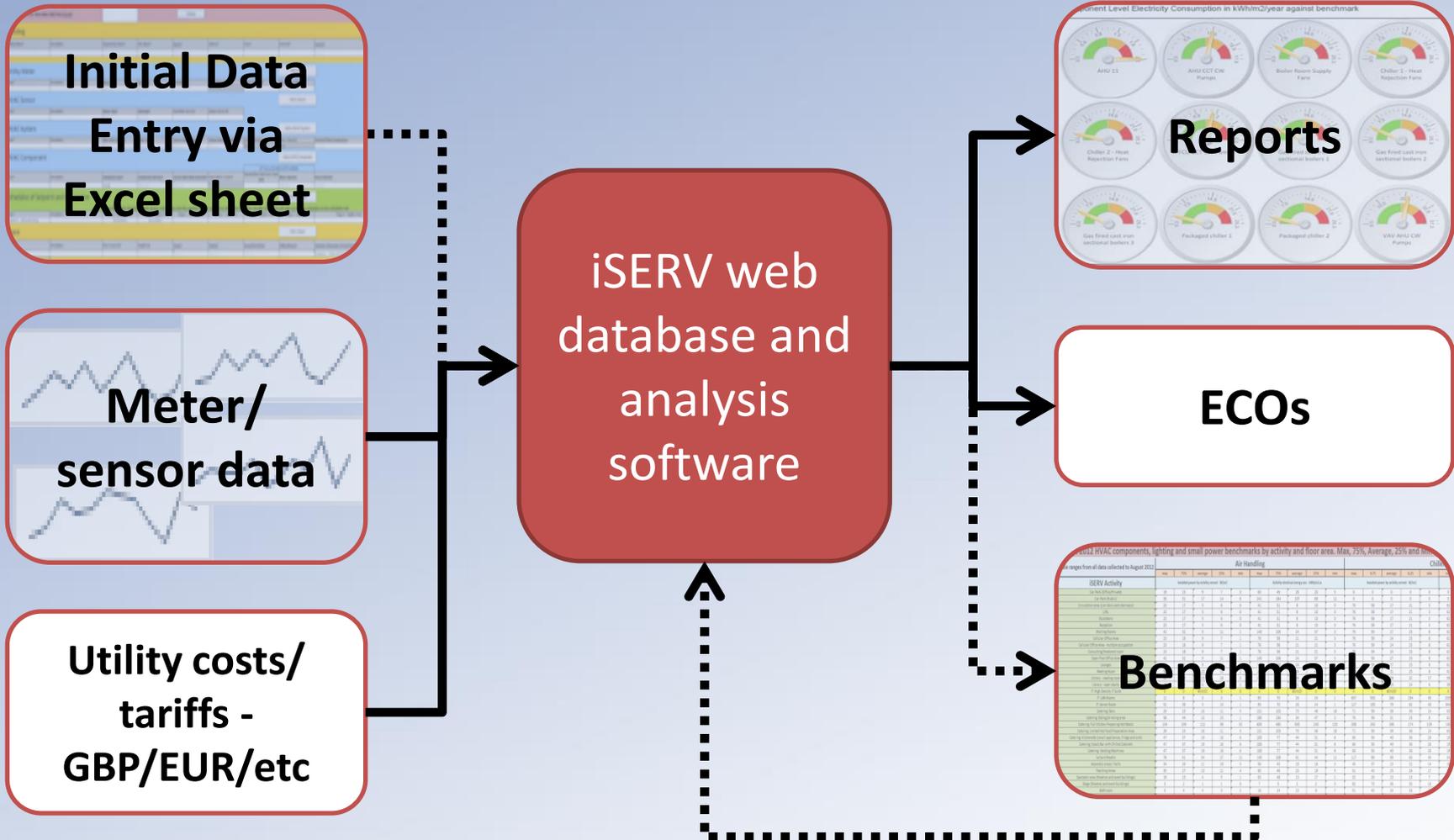
# What iSERVcmb is doing

Remotely monitoring HVAC systems across Europe

- Target 1600 HVAC systems of all types in EU countries.
- Range of building sectors.
- Sub-hourly data for individual HVAC components.
- Mostly using existing or easy-to-add monitoring.
- Collating and analysing all data in a web-based database.



# Overview of basic process



# Collect information on the building

- Floor area and activity for each space in the building
- Networked utility meters and sensors, and where they serve
- Unique Identifiers for the sub-hourly data to be collected from these meters and sensors
- All HVAC Components and where they serve



# Collate information on the building

- iSERV has set up a spreadsheet to act as a data collection focus for the building, meters and services physical elements
- The spreadsheet also acts as a means of **connecting** all the elements together

Data applies from this date (dd/mm/yyyy):

### Building

Building Name*	Description	Organisation Name*	Site Name*	Sector*	Address*	Town*	Postcode*	Country*	Control of HVAC Temperature*	Construct Month*	Property Reference Code	GPS - Lat
<Ctrl-1>				<Ctrl-1>				<Ctrl-1>	<Ctrl-1>			

### Utility Meter

Name*	Description	Meter Type*	Unit Type*	Multiplier	Space Where Located	Unique Meter Id*	Main Incomer	Shared Meter	Parent Meter Name
<Ctrl-1>		<Ctrl-1>	<Ctrl-1>				<Ctrl-1>	<Ctrl-1>	<Ctrl-1>

### HVAC Sensor

Name*	Description	Sensor Type*	Unit Type*	Duct/Pipe Area m2	Unique Sensor Id*
<Ctrl-1>		<Ctrl-1>	<Ctrl-1>		

### HVAC System

Name*	Description	Main HVAC System*	HVAC Type*	System Classification*	System ID*	Sensor Name(s)	Meter Name(s)	Control of HVAC Temperature*
<Ctrl-1>		<Ctrl-1>	<Ctrl-1>	<Ctrl-1>	<Ctrl-1>	None	None	<Ctrl-1>

### HVAC Component

Please check HVAC component data with Euroox

Name*	Description	Component Type*	Component Sub-type*	Series which HVAC System(s)*	Space Where Located	Nominal Electrical Power Input (KW)	Meter Name(s)	Sensor Name(s)	Parent Component	Nominal Heat Rejection Capacity	Coefficient of Performance (COP)	Energy Efficient Rating (IEE)
<Ctrl-1>		<Ctrl-1>	<Ctrl-1>	<Ctrl-1>			<Ctrl-1>	<Ctrl-1>	<Ctrl-1>			

### Small Power System

Name*	Description	Meter Name(s)*
<Ctrl-1>		<Ctrl-1>

### Lighting System

Name*	Description	Meter Name(s)*
<Ctrl-1>		<Ctrl-1>

### Other System

Name*	Description	System Type*	Meter Name(s)*
<Ctrl-1>		<Ctrl-1>	<Ctrl-1>

### Schedules of Setpoint and Occupation

To configure the schedule details please enter dates into the applies from or applies to cells below and then double click - this will take you to the schedule on the schedules tab

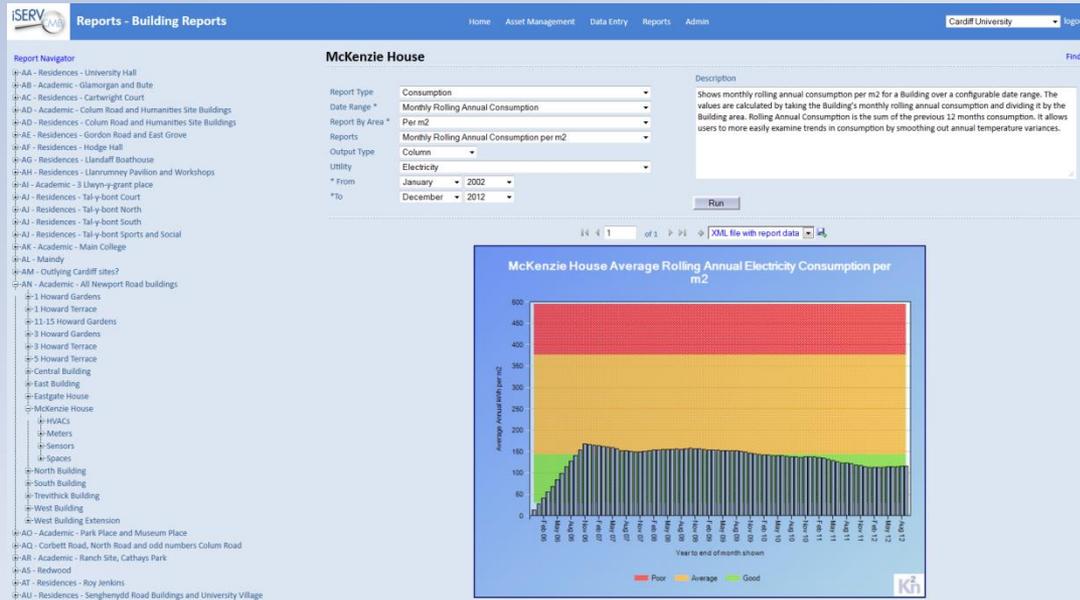
Name*	Description	Range 1 - Applies From	Range 1 - Applies To	Range 2 - Applies From	Range 2 - Applies To	Range 3 - Applies From	Range 3 - Applies To	Range 4 - Applies From	Range 4 - Applies To
Schedule 1- Whole Building		0101	3112						

### Space

Name*	Description	Floor Area (m2)*	Height (m)	Sector*	Activity*	Served By HVAC(s)	Small Power System(s)	Lighting System(s)	Other System(s)	Schedule of Setpoints, BH and Occupancy	Sensor Name(s)	Control of HVAC Temperature
				<Ctrl-1>	<Ctrl-1>	<Ctrl-1>	<Ctrl-1>	<Ctrl-1>	<Ctrl-1>	Schedule 1- Whole Building	<Ctrl-1>	<Ctrl-1>

# Database

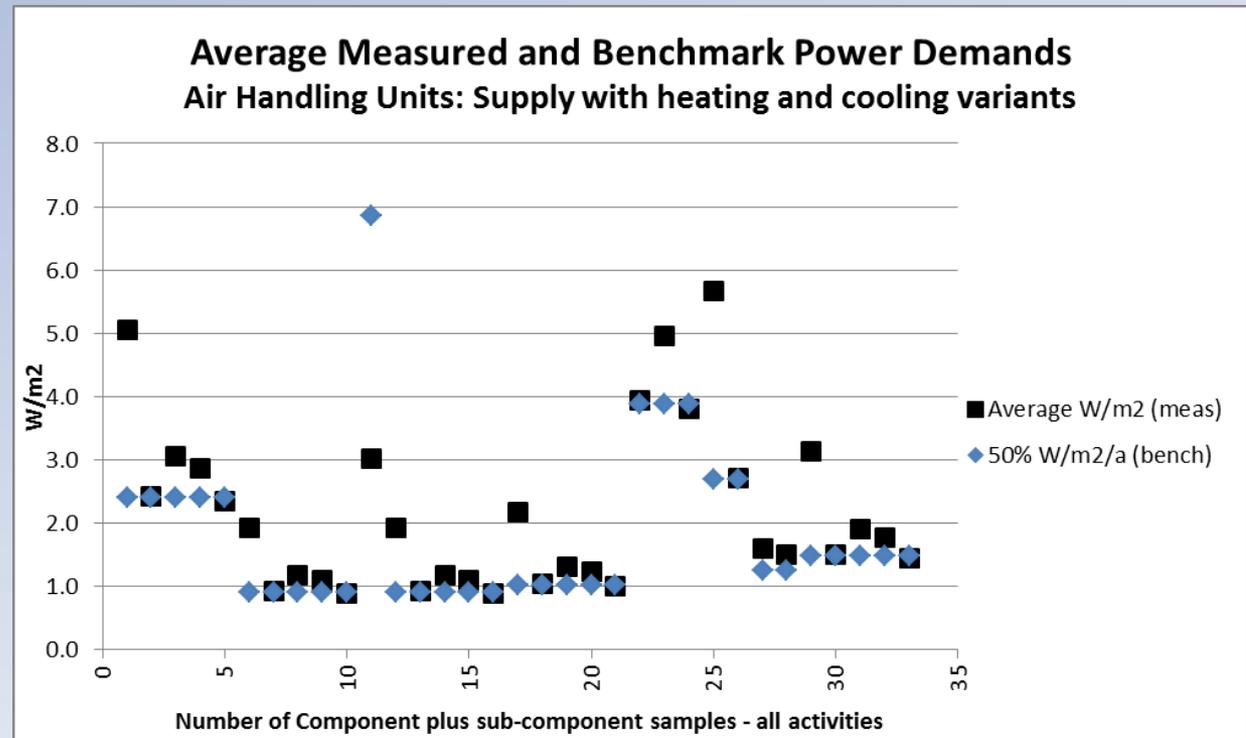
- A bespoke database has been written for the project
- Based on a commercial product
- Acts as the focus for the iSERV project elements:
  - Data collection
  - Benchmark use
  - Benchmark generation
  - Reports
  - Energy Conservation Opportunity algorithms



# Benchmarks

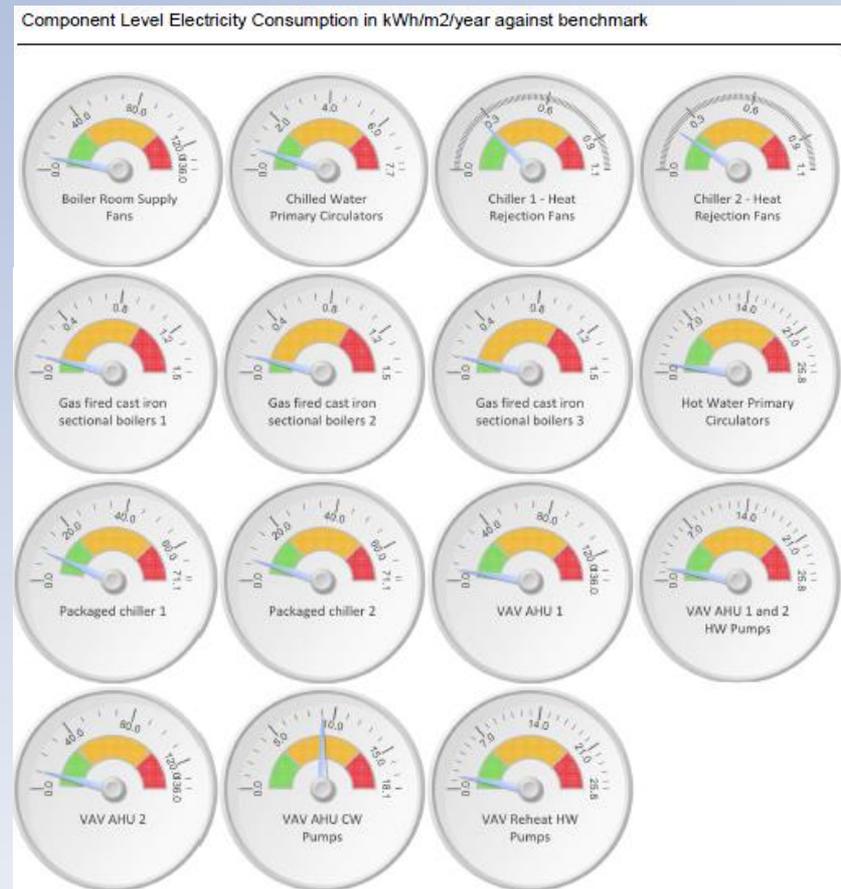
Three types of benchmark being produced and explored:

- Annual energy/m<sup>2</sup> – kWh/m<sup>2</sup>.a
- Monthly energy/m<sup>2</sup> – kWh/m<sup>2</sup>.month
- Power demands/m<sup>2</sup> – W/m<sup>2</sup>



# Three ways to save energy – regularly show performance

- Regularly show performance against benchmarks derived from the spreadsheet description of the building and services
- Benchmarks will evolve over time as the buildings / components providing data change their performance – so benchmarks always reflect current practice

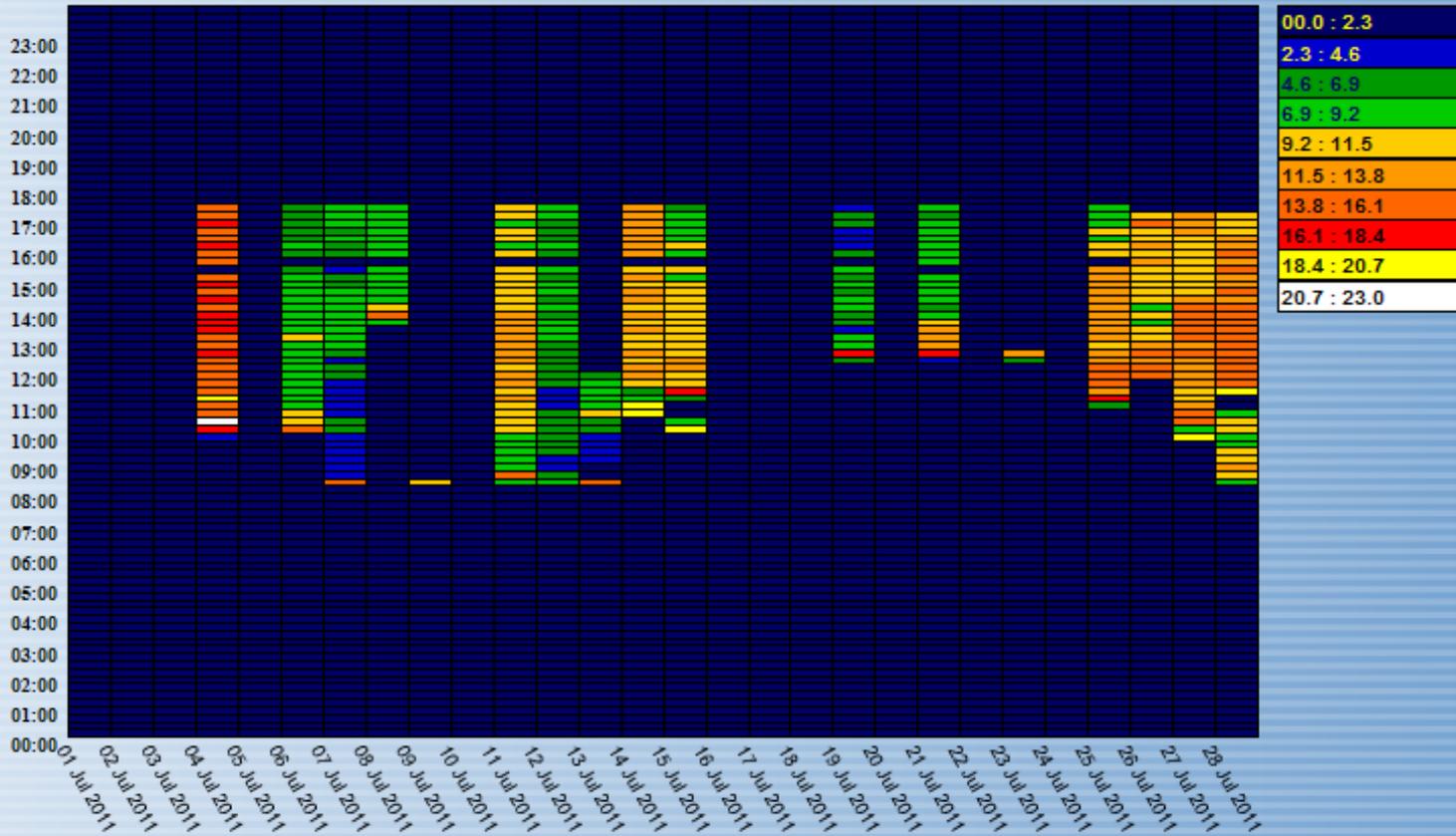


# Identification of Energy Conversation Opportunities (ECOs)

McKenzie House Chiller No 1 Elec kWh Stark Meter Carpet Plot

Date: 01 Jul 2011 To 31 Jul 2011

consumption bands of 10% based on the max value of 23kWh

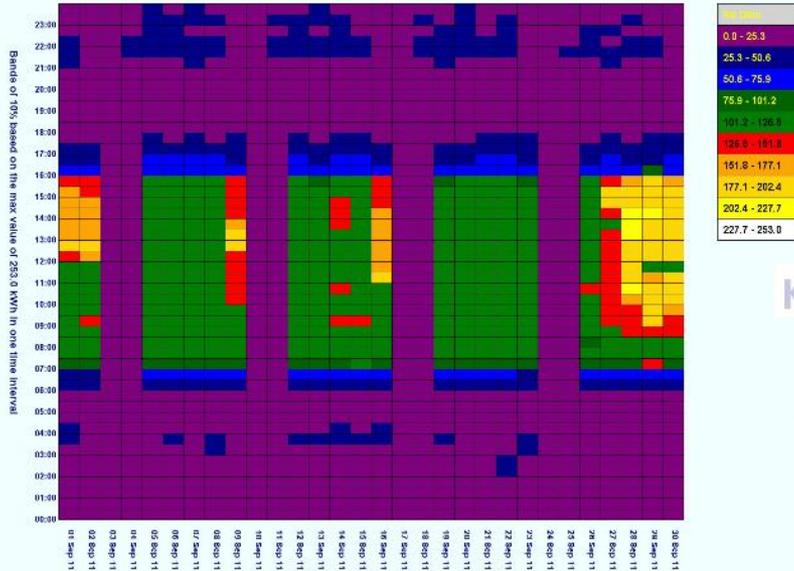


# Carpet Plots – McKenzie House

K<sup>2</sup>

## Main Electricity Billing Meter

Date range for plot: 01 Sep 11 to 30 Sep 11

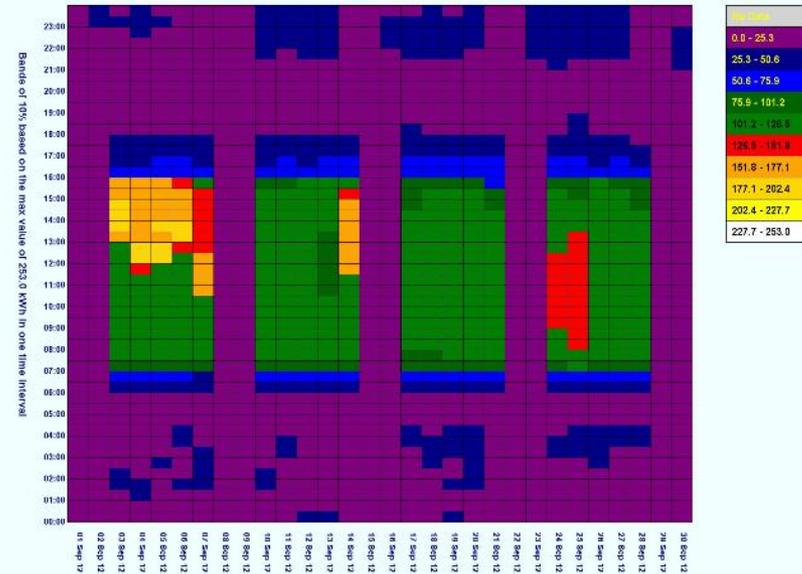


www.k2nenergy.com

K<sup>2</sup>

## Main Electricity Billing Meter

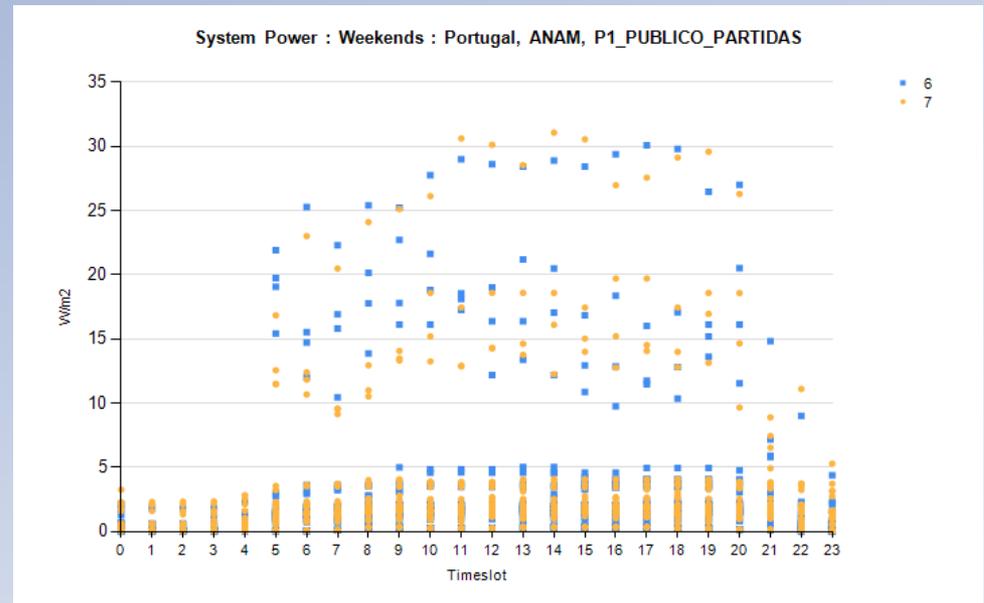
Date range for plot: 01 Sep 12 to 30 Sep 12



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# Three ways to save energy – better control of existing plant

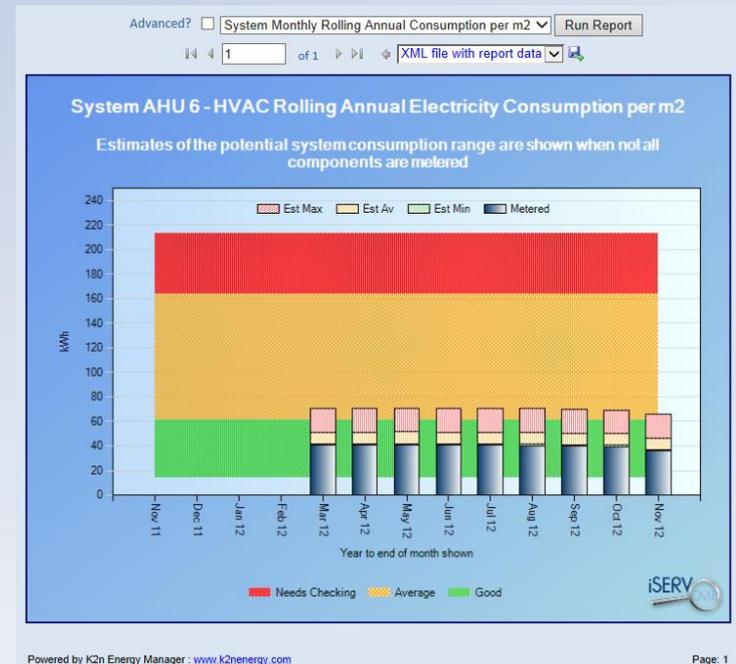
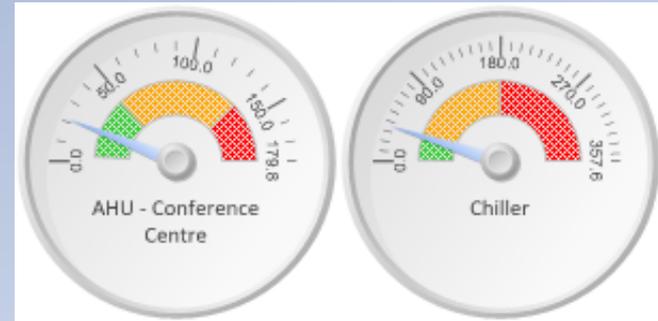
- Better control of what you already have e.g. use of ECO algorithms or scatter graphs/carpet plots to identify when systems and components are running outside of expected hours



- Clearly shows what could be controlled better
- Can use the data directly to calculate potential savings

# Three ways to save energy – install more efficient equipment

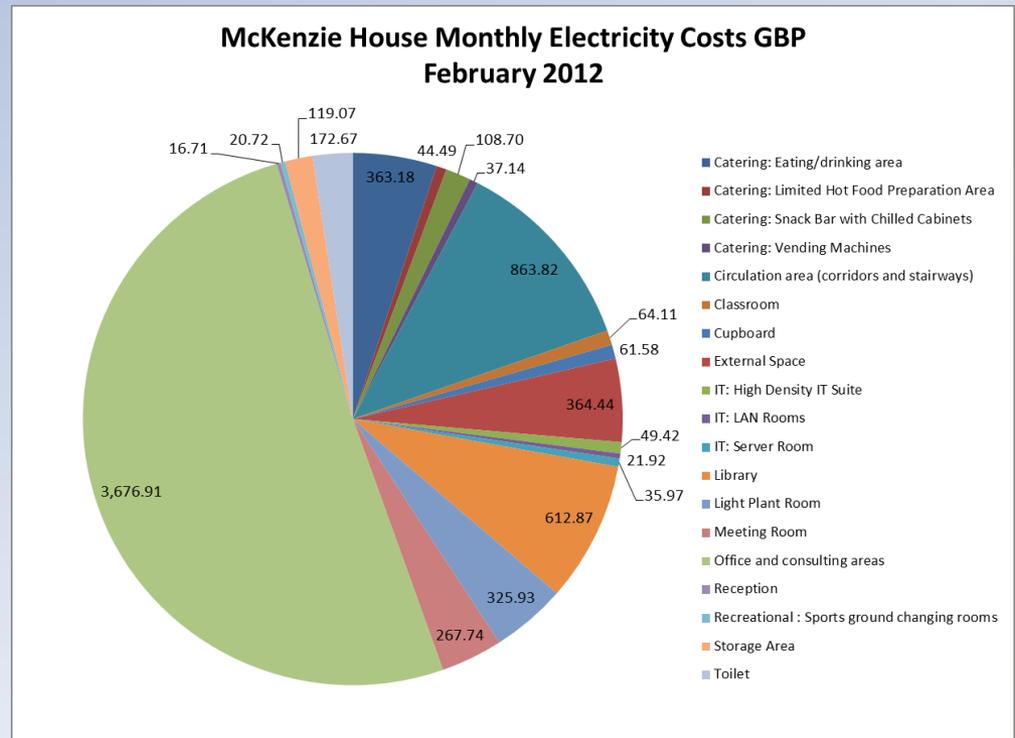
- **Install more efficient equipment.** Even if equipment is well controlled it may well require more power when in use than more modern equipment
- Benchmarks based on power demands when in use can help show this difference and when equipment might benefit from being upgraded



# Energy cost by activity

- Energy cost by activity can be calculated from the whole building energy consumption (monthly cost shown here)
- This can also be broken down into HVAC and Occupant costs by activity per month

The graph shows the estimated electricity costs in February 2012 for the activities undertaken in the building



# Reports

- The key is to not just present meter data but to interpret it with respect to the situation in the real building
- A number of report sets are being trialled to see which provide the information in the best form to allow

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## McKenzie House Cardiff University

Cardiff, United Kingdom

Inspection of HVAC Systems through continuous monitoring and benchmarking

Weather Analysis

MON	TUE	WED	THU	FRI	SAT	SUN
9°C						
9°C						
9°C						
9°C						
9°C						

51.5N 3.2W CF24 ODE

### Monthly Overview

Monthly kWh Consumption

November 2012: 3500 kWh (-13% since last month, -45% since 10th month participation)

Monthly kWh Comparison

October 2012: 3820 kWh, November 2012: 3500 kWh

Monthly CO<sub>2</sub> Emissions

November 2012: 10 kg CO<sub>2</sub>e (-10% since last month, -35% since 10th month participation)

Cost Analysis

October 2012: £60, November 2012: £50

Comparison with peer systems around Europe

McKenzie House uses 100% more energy than an efficient peer system in Europe.

Potential Energy Savings: 3000 kWh / year  
Potential Cost Savings: £5000 / year

ISERVcmb Ranking: 10<sup>th</sup> most efficient

McKenzie House: 3000 kWh/year, 3000 £/year

Below Average Peer: 3000 kWh/year, 3000 £/year

Most Efficient Peer: 3000 kWh/year, 3000 £/year

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## Performance Analysis

Inspection of HVAC Systems through continuous monitoring and benchmarking

### Rolling Annual Consumption - Electricity

HVAC Component Performance - Total kWh per m<sup>2</sup> per annum

Component	Total kWh per m <sup>2</sup> per annum	Average W per m <sup>2</sup>	NFLE	Performance
Packaged chiller 1	200	22.83	46.0%	Good
Packaged chiller 2	250	28.54	57.0%	Good
Boiler Room Supply Fans	4	0.46	23.0%	Good
Hot Water Primary Circulators	6	0.68	34.0%	Good
VAV AHU 1	150	17.12	57.0%	Good
VAV AHU 2	200	22.83	76.0%	Average
Chiller 1 - Heat Rejection Fans	90	10.27	86.0%	Needs inspection
Chiller 2 - Heat Rejection Fans	85	9.7	81.0%	Needs inspection

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## Energy Conservation Opportunities

Inspection of HVAC Systems through continuous monitoring and benchmarking

### BEVs and controls / Miscellaneous

Reduce power consumption of auxiliary equipment: Description To reduce energy consumption of pumps and fans the algorithm checks the following: It's happening that HVAC components like fans and pumps work outside the schedule of building. This ECO algorithm checks if pumps and fans work according to the building schedule, thereby preventing energy over-consumption.

Annual GBP Savings: £560,00  
Annual kWh Savings: 3500 kWh  
Annual Energy Savings: 5.2%  
Annual CO<sub>2</sub> Savings: 800 tons

### Cooling equipment / Free cooling

Consider cold storage applications (chilled water, water ice and other phase changing material): Description To reduce energy consumption of pumps and fans the algorithm checks the following: It's happening that HVAC components like fans and pumps work outside the schedule of building. This ECO algorithm checks if pumps and fans work according to the building schedule.

Annual GBP Savings: £560,00  
Annual kWh Savings: 3500 kWh  
Annual Energy Savings: 5.2%  
Annual CO<sub>2</sub> Savings: 800 tons

### Air handling / Heat recovery / Air distribution

Apply variable flow rate fan control: Description To reduce energy consumption of pumps and fans the algorithm checks the following: It's happening that HVAC component. Consider conversion to VAV: Description To reduce energy consumption of pumps and fans the algorithm checks the following: It's happening that HVAC components like fans and pumps work outside the schedule of building.

Annual GBP Savings: £560,00  
Annual kWh Savings: 3500 kWh  
Annual Energy Savings: 5.2%  
Annual CO<sub>2</sub> Savings: 800 tons

### General HVAC system

Shut off A/C equipment when not needed: Description To reduce energy consumption of pumps and fans the algorithm checks the following: It's happening that HVAC components like fans and pumps work outside the schedule of building. This ECO algorithm checks if pumps and fans work according to the building schedule, thereby preventing energy over-consumption.

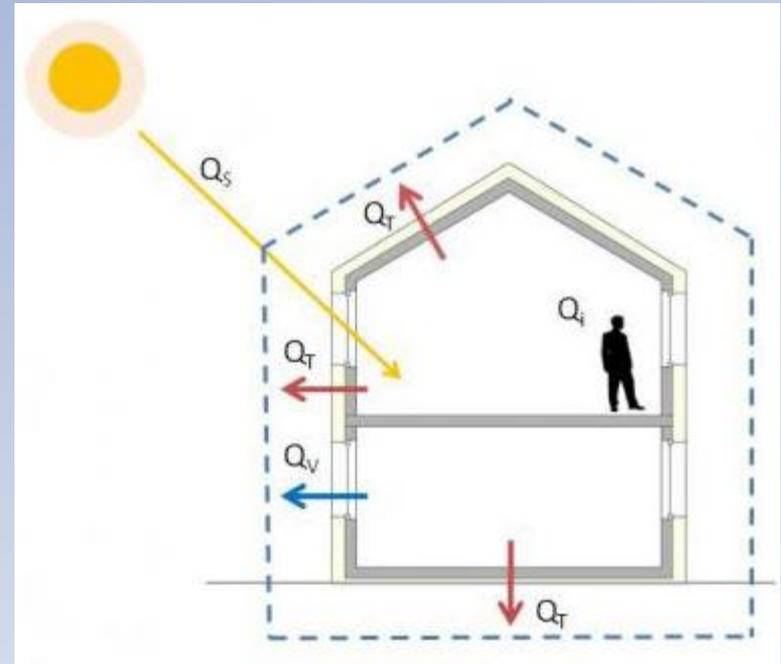
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# The near future

- Near zero energy buildings will require us to **BALANCE** the energy loads in a building with minimum **NET** use of energy
- With highly insulated structures this balance is mainly about how Solar Gains, Internal Gains and Ventilation energy needs interact with each other

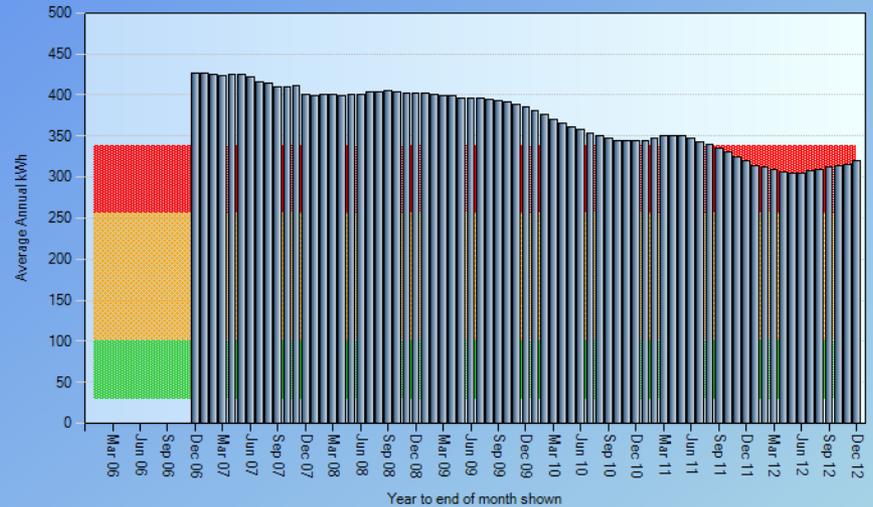


- The most controllable parameter is Ventilation
- In both hot and cold climates energy efficiency can be achieved by **MINIMISING** ventilation rates, with the attendant potential for IAQ problems and Health

# Savings in real buildings

Two buildings showing their electrical savings achieved since first participating in HARMONAC

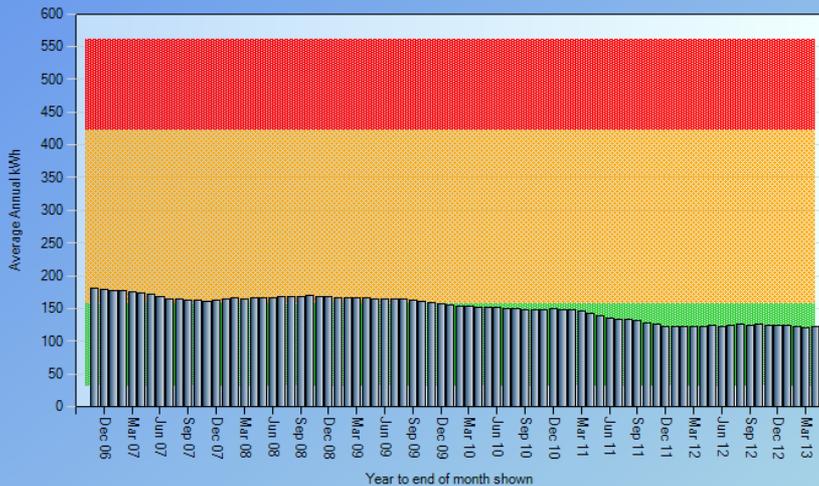
Whitefriars South Average Rolling Annual Electricity Consumption per m2 - Total Benchmark Ranges for Configured Systems



Benchmarks are for: HVAC, Lighting, Small Power  
 Needs Checking Average Good



McKenzie House Average Rolling Annual Electricity Consumption per m2 - Total Benchmark Ranges for Configured Systems



Benchmarks are for: Fire Control Panel, HVAC, Lifts, Lighting, Small Power  
 Needs Checking Average Good



# Monitoring savings: Case Studies

- Building electrical savings of between 19% to 33% p.a.
- Building electrical savings/m<sup>2</sup> between 61 to 100 kWh/m<sup>2</sup>/a
- In economic terms:
  - Measured recurrent savings of 9 to 14 EUR/m<sup>2</sup>/a
  - Recorded 'one-off' setup costs between 0.1 to 2 EUR/m<sup>2</sup>
  - Estimated 0.1 – 3 EUR/m<sup>2</sup>/a to maintain.
  - Net returns between 7 – 13 EUR/m<sup>2</sup>/a
- The savings actually achieved in these buildings indicate more significant ACTUAL savings could be achieved in the wider building stock.
- Success in reducing HVAC energy use is providing the confidence and finance (from savings) to tackle other electrical use as well

# Cost comparison of acceptable recast EPBD approaches

Topic	Inspection	Monitoring	Advice
Cost	<b>100 – 250 EUR</b> (Compliance) <b>0.5 – 2.5 EUR/m<sup>2</sup></b> (EPBD)	<b>0.1 to 2.0 EUR/m<sup>2</sup></b> setup <b>0.1 to 3.0 EUR/m<sup>2</sup></b> ongoing	Not known
Savings	Estimate (HARMONAC) : <b>2.0 to 3.2 EUR/m<sup>2</sup></b> at best	Measured (small sample): <b>9.0 – 14.0 EUR/m<sup>2</sup>/a</b> (electrical) Up to 33% building elec use	Not known
<b>Net savings</b>	<b>-100 to -250 EUR</b> or <b>-0.5 to 2.7 EUR/m<sup>2</sup></b>	<b>1.0 to 13.0 EUR/m<sup>2</sup>/a</b>	<b>Not known</b>
Impact assessment	No feedback route	Data allows precise 'before' and 'after' impact studies	No feedback route
Comments	Savings not likely to be sustainable where intervention is needed. Savings difficult to maintain.	Initial setup can be costly. Requires more attention than inspection or advice. Provides detailed understanding of energy use. Reduces investment risk. Proven real energy savings. Helps maintain savings Provides data for design decisions	Difficult to show impact. No mechanism for drawing attention to energy use. Not clear how it will help maintain energy savings.

# Proposal on implementing monitoring as a complement to Inspection

- iSERV proposes Monitoring and Inspection are complementary processes as DETAILED Inspections are the obvious route to improving buildings with poor benchmarks.
- **Monitoring requires the iSERV spreadsheet be completed first. (Whether or not a Monitoring scheme exists this step should be required by legislation as it informs both Inspection and Advice).**
- Second step is the accreditation of monitoring schemes. These schemes required to report key data to MS legislators.
- Set regular benchmarks from the data to ensure benchmarks continue to reflect best practice being achieved.

# Monitoring - Conclusions

- Monitoring brings:
  - Clarity and Certainty;
  - Proven energy and cost savings to the end user and MS;
  - End user engagement and ability to contribute to 2020 targets;
  - Proof of impact achieved;
  - Increased use of energy efficient products;
  - Reduced Risk;
  - Ability to use Smart Metering data which is coming
- As a commercial prospect monitoring makes sense already.

# Questions?

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