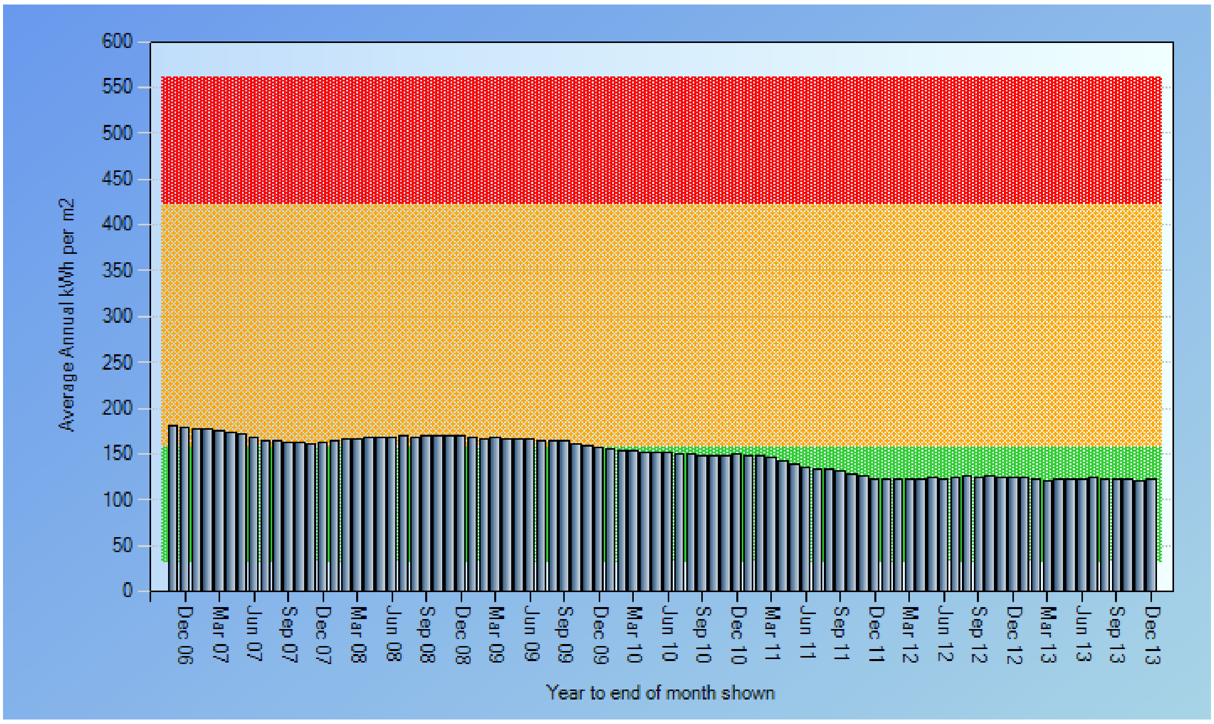
ISERVCMB FINAL REPORT – JULY 2014



THE INSPECTION OF BUILDING SERVICES THROUGH CONTINUOUS MONITORING AND BENCHMARKING –THE ISERVCMB PROJECT

Edited by Ian Knight

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2 Preamble

The iSERVcmb project arose out of HARMONAC, a previous IEE project, which demonstrated that the detailed energy monitoring of Heating, Ventilation and Air Conditioning (HVAC) components in operational buildings led to system owners improving their operation.

The ability to empower the owner/operators of HVAC systems to implement cost-effective energy efficiency improvements is one of the key problems facing legislators around the EU Member States as they attempt to meet their 2020 energy efficiency reduction targets. Current legislative approaches struggle to involve the end user in wanting to improve the energy efficiency of their buildings despite there often being a straightforward financial case to do so, as iSERVcmb will show.

The Co-ordinator of iSERVcmb considers that it is now practically feasible to understand and benchmark the energy use in our buildings to a level of detail that informs all aspects of building design, operation and maintenance. This depth of understanding is the key to a better understanding of the holistic energy use of buildings, and therefore to designing buildings which are ‘low energy’ in practice. This then ensures a more mature debate can be had about how much energy it is reasonable for a building to consume based on the activities it houses and the intensity of their operation.

An important driver for the need for a new approach is that the insulation levels of new buildings have reduced the relative importance of the fabric heat transfer component in the overall heat balance of a building. This means that the internal gains due to occupancy and activity are now a much more influential part of the demand on the building services for heating and cooling, yet we still categorise buildings mainly by sector e.g. Office, Hospital, etc. It is clear to all building professionals that there are legitimate reasons for wide variations in energy use/m^2 in these building types, yet we do not have a common means to discriminate between them. This has led to building energy labelling not having the impact it should have, as some buildings can never achieve a good performance for the activities they contain, leading to disengagement with the labelling process by the operators of those buildings. This is particularly true for older buildings and building services. The danger is that we risk condemning many older buildings as poor performers when it is the activities they contain that are the cause of their poor performance, not the inherent performance of the fabric or services.

The final obstacle to overcome is allowing for the difference between buildings requiring services such a filtration, mechanical ventilation, etc., because of their location and activities, and those buildings which do not require such intensive servicing. The iSERVcmb project therefore aims to:

- Produce a procedure for describing and benchmarking buildings based on the activities they contain, the areas they occupy and the way in which they are serviced.
- Produce a process for allowing operational energy data for HVAC components to be collected, benchmarked, reported and improved.
- Trial this process across 1600 operational HVAC systems in Europe
- Establish the scale of the electrical energy and cost savings possible from this approach
- Establish where these energy savings were most likely to occur
- Produce data on the measured energy consumption and power demands found in HVAC systems in operational buildings to help improve professional guidance in this area
- Establish if such an approach was feasible to be used across the EU Member States

This report establishes the outcomes and impacts of this project. I hope you find it useful.

Professor Ian Knight
iSERVcmb coordinator, Cardiff University
June 30, 2014

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3 Executive Summary

3.1 THE ISERVCMB PROJECT

Building on the results of its predecessor projects, AUDITAC (2005-2007) and HARMONAC (2007-2010), the iSERVcmb project provides a detailed insight into how energy is used in HVAC systems and buildings through analysis of operational energy use data from HVAC systems around Europe.

The project demonstrates significant electrical savings ranging up to 33%, and 9% on average, have been achieved by understanding the details of energy usage and power demands at the level of individual components within buildings.

The iSERVcmb project proposes and trials a practical, structured process which can be used across all buildings and HVAC systems in the EU Member States. Part of this approach is the use of benchmarks of energy use and power demands at HVAC component level, partially derived from sub-hourly automatic monitoring data collected from over 2800 HVAC systems across the EU.

The iSERVcmb approach uses existing metering and sensors, along with information on buildings assets and activities, such that benchmarks, powerful in diagnostic work, can be derived from that data - and produced for individual building configurations and activities supported.

Key features of the approach are:

- Benchmarks for operational buildings are unique to each building's specific mix of spaces, activities and services
- Benchmarks are derived from data on energy consumption and power demands being achieved in operational buildings, and therefore come with the major benefit to the end user of knowing that they are achievable in practice
- iSERVcmb end user reports are specific to physical assets within a building, enabling corrective actions to be applied directly where needed

3.2 PROJECT OUTCOMES

iSERVcmb has produced a unique set of insights and findings into the power demands and energy consumption of HVAC systems and components in operational buildings in EU Member States, along with insights into how to reduce this energy consumption. The major headlines are:

- A free, standalone spreadsheet which provides the basic elements of iSERVcmb, from collection and collation of data on a building and its services, through to providing estimated benchmarks for the building and each system within it. This spreadsheet is available in English, French, German, Dutch, Portuguese, Italian, Slovenian, Hungarian, Greek, Spanish and Danish at present and is designed for easy translation into further languages if needed. More detail can be found in section 8.4.
- The project recruited 330 buildings, comprising 2,831 HVAC systems, 7,685 HVAC components, 2,230 Meters, 11,173 Spaces, 72 Activity types and 1,551,638 m^2 of floor area, from 20 EU Member States during the 2011 to 2014 project period. The majority of the systems already had metering installed, and this figure was achieved despite the recession and the state of metering in some EU MS making recruitment difficult.
- Applying the iSERVcmb process to these operational buildings helped achieve **savings of up to 33% in a building's total electrical energy use** – often for little capital outlay. More detail can be found in the Case Studies referred to in section 11.
- Across all the buildings on the iSERVcmb database, the actual or projected **annual energy savings were around 9% on average**. Greater average savings are anticipated if the project were to run

longer, as shown by the savings generally being larger in those buildings which have been on the database for longer. More detail can be found in section 11.

- An **average annual saving of 18% of the electricity use in systems with more than a year's data**, where reductions were achieved, was a very encouraging figure - particularly as the project was late in providing reports back to end users - meaning that the full impact would not be seen over the life of the project. Evidence from those systems that were also in HARMONAC is that full savings can take easily 2+ years to achieve, due to time taken to implement the measures needed to produce all the savings available and for the full savings to appear in annual reporting.
- **Measured ranges of energy consumption and power demands by HVAC component and end use activity have been published** by iSERVcmb to provide a first insight into how EU HVAC components consume energy in operational buildings throughout Europe. More detail can be found in section 9.2.
- The process showed that **Power Demand benchmarks are needed** for immediate diagnostic work in operational systems, to overcome the need for annual figures to be obtained in the early stages of benchmarking specific systems.
- The **iSERVcmb process and procedures can be applied across all EU Member States** without any regional amendments, though the Benchmarks used will need some regional amendments depending on the utility type, service and component.
- To check the iSERVcmb benchmarks reflect reality, and are not achieved at the expense of Indoor Air Quality, the project **concurrently measured IAQ in a sample of 62 systems across Europe and Physically Inspected 64 iSERVcmb HVAC systems**. These showed that **individual system findings from the iSERVcmb process generally reflected the observations from the Inspections, and the IAQ measurements did not reveal major problems based on currently accepted IAQ standards**. More detail can be found in sections 12 and 13.
- Extrapolating the findings of the project across the EU as a whole, the projected likely annual electrical energy savings from the required use of iSERVcmb across the EU Member States are between 9,500 – 142,000 GWh per annum (2 – 32 MTOE/annum). This is between 0.3 to 5% of the total annual primary energy use (2,836,000 GWh or 188.7 MTOE) of the EU-27 in 2010.
- The projected **likely annual electrical cost savings** (@0.15 €/kWh) from the required use of iSERVcmb across the EU Member States are between **1,400M – 7,100 Million Euros per annum**, for an estimated annual cost of around 1,250 Million Euros. A **maximum potential saving of 60,000 Million Euros per annum is identified as possible, but not probable, based on achieved savings in operational buildings**.
- The projected **likely annual electrical carbon emission savings** from the required use of iSERVcmb across the EU Member States are between **2 – 32 Million tonnes of CO_2 per annum**, out of an EU total electrical carbon emissions figure of 642 Million tonnes of CO_2 per annum. This represents **a cost of €0.04 - €0.625 per kg of CO2 saved** based on the above assumed implementation costs for iSERVcmb across the EU.

3.3 LOOKING AHEAD: SETTING STANDARDS

iSERVcmb has shown that understanding what it is reasonable for HVAC system components to consume when designing new buildings or servicing existing ones, will lead to investment in more efficient operation and should allow realistic targets to be set for improvement. Part of the success of the project is down to helping building operators understand how their buildings truly operate – and the importance of having a clear and logical metering strategy to aid this understanding.

The iSERVcmb approach can also reward proactive behaviour by stakeholders in reducing their HVAC systems energy use. This could be through easing the regulatory burden where good practice can be demonstrated or through other suitable rewards. The approach can therefore act as a means of improving the overall energy efficiency of operational HVAC systems in Europe, as well as allowing the best practice approaches of individual organizations to become visible and celebrated.

The findings and data from HARMONAC and iSERVcmb are already helping European Standards and Directives understand how to use the explosion in building and services information to improve the operational aspects of building energy use.

4 Introduction

The societal, economic and strategic need to reduce the energy consumed in buildings continues to increase in importance year on year. Since the late 1990's, the European Union has introduced a series of Directives aimed at increasing building energy efficiency for its Member States to implement. Of all the approaches for reducing energy use which are addressed by these Directives, it appears that the least effective at present are those aimed at reducing energy consumption via improved operation of existing building services.

The reasons for this are many, but one of the most important reasons emerging from iSERVcmb and its predecessor, HARMONAC, is a general lack of knowledge on what services are actually installed in any building, which meters feed those services and which areas the services themselves supply in a building. This leads to a lack of confidence in any recommendations on improving the situation in existing buildings and therefore hampers the achievement of sustainable energy efficiency improvements.

iSERVcmb demonstrates how a more detailed understanding of a buildings services, activities, areas and metering can provide this missing confidence and lead to significant electrical energy savings in operational buildings and systems from across the EU. The legislation needed to adopt such an approach already exists within Articles 14 to 16 of the Energy Performance of Buildings Directive – what is needed is to now implement it within the individual EU Member States. This raises different issues – some of which are addressed in this report.

The report presents summaries of the results, findings and observations from the various aspects of the iSERVcmb project and provides links to the more comprehensive underpinning information from the project where available.

There are also some personal opinions expressed which are not able to be substantiated by the data collected at the time of publishing the report but which the Coordinator believes to be correct based on experiences and observations from the last 9 years of examining this issue through the IEE AUDITAC, HARMONAC and iSERVcmb projects. Where these occur they are clearly marked as such.

The structure of the report examines the following aspects of building performance, maintenance and operation that have been explored in buildings and systems across Europe:

- The establishment and testing of a procedure for describing and collating buildings in terms of their spaces, activities, building services components and meters
- The electrical energy consumption and power demands measured in HVAC components across Europe
- The energy conservation opportunities (ECOs) identified in HVAC components across Europe and the predicted overall savings from these ECOs
- The actual electrical energy savings achieved in buildings using the iSERVcmb system
- The Indoor Air Quality of a sample of the buildings and systems tested
- The findings from EPBD Inspections undertaken on a sample of Systems across Europe
- The impact on Professional Bodies, HVAC Manufacturers and Maintenance Companies
- The implications of the results of iSERVcmb for future legislation and operation of buildings
- How the process might be transposed into a working system within EU MS

5 Specific objectives and outputs for iSERVcmb

The specific objectives of the European Commission's Executive Agency for Competitiveness and Innovation (EACI) at the start of the project are shown in the IEE funding call aims below. During the course of the iSERVcmb project EACI changed its name to EASME (the Executive Agency for Small and Medium Sized Enterprises).

5.1 INTELLIGENT ENERGY EUROPE 2010 AIMS

- The specific aims of the IEE 2010 call were:
- Reduce energy consumption across the EU MS over the life of the project in line with the EU 2020 targets.
- To build strong foundations for further reductions after the project officially finishes.
- Projects to have a significant impact in terms of energy efficiency.
- Strong replicability across the EU MS.
- To create the right market conditions for their use.

5.2 ISERVCMB PROJECT AIMS AND OUTCOMES

In addition to the EASME aims, the iSERVcmb project had the following specific aims:

- **Produce a procedure for describing and benchmarking buildings based on the activities they contain, the areas they occupy and the way in which they are serviced.**
    - Outcome: A unique multi-lingual spreadsheet-based methodology for collecting and collating information on the physical spaces, activities, HVAC components and meters within a building so that the end users can understand their building properly. This spreadsheet also provides benchmark ranges based on this description.
- **Produce a process for allowing operational energy data for HVAC components to be collected, benchmarked, reported and improved.**
    - Outcome: An online database into which the iSERVcmb spreadsheet data can be input, along with on-going consumption data, to produce targeted energy benchmark reports for buildings, HVAC systems and HVAC components.
- **Trial this process across 1600 operational HVAC systems in Europe, along with supporting IAQ and Physical Inspections**
    - Outcomes: Over 2800 HVAC systems were described in the project
    - Detailed Inspection and Indoor Air Quality studies of selected systems to understand current maintenance and IAQ standards better – as well as the opportunities arising from these aspects.
- **Establish the scale of the energy and cost savings possible from this approach**
    - Outcome: The project has been able to estimate the practically achievable energy and cost savings as being up to 142 TWh/a and €21.2Bn/a
- **Establish where these energy savings were most likely to occur**
    - Outcome: Bespoke Energy Conservation Opportunity identification based on measured and modelled data for Buildings, HVAC Systems and HVAC Components
- **Produce data on the measured energy consumption and power demands found in HVAC systems in operational buildings to help improve professional guidance in this area**
    - Outcomes: An understanding of the correlation between installed HVAC component loads, activities, HVAC system type and floor area across the EU Member States

    - Unique energy consumption and power demand ranges published, based on achieved performance in-use
- **Establish if such an approach was feasible to be used across the EU Member States**
    - Outcomes: Involvement of the HVAC Industry and Professional Bodies in the standards being proposed by iSERVcmb
    - Presentation of the project findings to EU Member State legislators on multiple occasions.
    - Overall, 2.7 million people were informed about the project through print, audio visual and electronic media (78,000 per month)

5.2.1 Aims and Outcomes in detail

In more detail, the iSERVcmb project aimed to:

- Demonstrate the approach leads to significant cost-effective, quantifiable energy savings reductions in HVAC system consumption around Europe. This is an important support to the wider scale use of Energy Management approaches to reducing energy demand such as those advocated by EN 16000 – Energy Management Systems. Expectations were for reductions of up to 50% in individual HVAC systems, and an **overall HVAC system electrical energy reduction of between 3 - 15%** across all the systems on the application compared to Business As Usual projections derived from the monitoring of the plant.
- Outcome: The expectations for the savings achieved were exceeded significantly in some buildings with **sustained total building (not just HVAC) electrical savings of over 33% being achieved** in some of the longer-term buildings. The additional savings appear to derive from lighting and small power aspects also being addressed once the Services components of the buildings were better understood. These savings are in line with the EU's 2020 energy reduction objectives and the IEE's requirements to have a significant impact in terms of operational energy efficiency.

- Obtain over a year's worth of energy consumption data (automatically or manually read at a maximum time interval of one month) for the energy consuming components of 1600 EU Member State HVAC systems. This data to be linked to the end use activities served, as well as building and geographical information. To obtain a good representative sample, the project aimed to gather data from different and relevant types of systems.
- Outcome: This goal was met with over 2,800 HVAC systems eventually supplying data to the iSERVcmb project.

- Show through physical Inspection that the approach can correctly identify the level of energy efficiency at which the HVAC systems are performing.
- Outcome: Comparing the Inspections undertaken with the predicted benchmark ranges for iSERVcmb showed that both approaches generally agreed on the performance being achieved by most systems, though iSERVcmb also showed many systems had much greater potential savings than the Inspections suggested.

- Show through Indoor Air Quality tests and on-going monitoring that benchmark boundaries are not set inappropriately for good IAQ.
- Outcome: The IAQ measurements undertaken demonstrated this requirement was clearly met for the 64 sample buildings tested.

- Analyse the HVAC system data collected to provide publicly available information on HVAC system performance, including data on measured HVAC system component consumption by end use activity and geographical/climate location. This information is important for producing meaningful Physical Inspection recommendations for HVAC systems that are likely to be acted upon.

- Outcome: A unique set of **measured consumptions and power demands for HVAC components in operational buildings have been generated** and are available from the iSERVcmb website. The only element missing is the geographical/climate variation analysis which was not complete for the final report. However, unique power demand measurements are presented which were not originally envisaged.

- Disseminate the findings to all the key actors; and demonstrate that this approach achieves at least the same impact on energy use as physical Inspection thus allowing the approach to be used as an acceptable alternative to Inspection.
- Outcome: HVAC Manufacturers, Professional Bodies, Legislators and End Users have all been kept informed of the project progress during the project period. The project findings show that the monitoring approach appears more effective than Inspection at identifying potential energy savings within specific buildings, systems and components where the appropriate metering is in place.

- To recover around 50% of the cost of the project through energy savings achieved by the HVAC systems users adopting this approach. This was verifiable directly from the data collected as part of the iSERVcmb methodology.
- Outcome: The project Partners reported a combined saving of €1M in the iSERVcmb systems during the project period – equivalent to **an average 9% energy reduction**.

- Establish which HVAC energy consumptions and installed loads are location-independent along with their ‘good’ and ‘poor’ practice benchmarks, and which loads are driven by the geographical situation in which they are used.
- Outcome: At the time of this report this had not been done.

- To build strong foundations for further reductions after the project completes, iSERVcmb aimed to establish at least one commercial product into the EU Marketplace which offered the iSERVcmb procedure as an option for interested potential end users to adopt this approach.
- Outcome: The iSERVcmb project Partner, K2n Ltd, who were responsible for developing and operating the HERO database and spreadsheet, have launched a product to the marketplace. More details can be found at www.k2nenergy.com.

- To create the right market conditions for the introduction of the iSERVcmb process, the project worked with legislators, professional bodies, end users and HVAC components manufacturers to try and overcome the hurdles to its adoption.
- Outcome: At the time of writing this report (July 2014) it was clear that all the actors to which the project had been presented understood the benefits and value of such an approach. However, the fine detail of how to move the process into mainstream benchmarking to which the legislators could refer was still to be determined. This work continues beyond the iSERVcmb project period.

Overall, the project has produced information which supports the effective implementation of the use of metering and feedback as now allowed in the recast EPBD in EU Member States.

One of the main lessons learnt from HARMONAC is that showing users how much energy they are using against bespoke targets is a powerful means of achieving energy reductions and energy efficiency investment. This project used this approach as part of achieving its aims.

5.3 WHAT ABOUT GAS, OIL AND WATER SAVINGS?

The iSERVcmb approach should also achieve significant heating and cooling energy reductions at the building level, with around 10% anticipated from other research undertaken. These savings are not included here as metering of these fuels was not

sufficiently extensive to draw major conclusions. Any cost and energy savings are in addition to those shown here. They reinforce the ability of iSERVcmb to help EU Member States reach their energy conservation goals in a cost-effective manner.

5.4 OTHER OUTCOMES

5.4.1 How do the three approaches for estimating savings compare?

Whilst not a specific initial aim of the project, iSERVcmb also intended to compare the ECOs suggested by the three different approaches of Physical Inspection, Analysis of Measured Data and Modelling of Measured Data to provide some indication of the variation in estimated savings from each method.

The predicted savings potential across all the systems, based on the iSERVcmb database benchmarks, and the predicted savings from the measured and modelled ECO's approaches broadly agree with each other. This suggests that using the iSERVcmb approach can identify energy savings potentials properly, and that the ECOs can help more accurately pinpoint where to make some of these savings.

5.4.2 How much does it cost to follow the iSERVcmb procedure?

From the project, it was found that initial annual costs per m^2 to participate in iSERVcmb can vary between €0.1 - 3 m^2/a, including setup costs to describe the building and systems, with larger buildings costing less per m^2.

5.4.3 How much could be saved by following the iSERVcmb procedure?

Net savings of €1 - 13 m^2/a were found in practice at the level of whole buildings after the setup costs were considered.

Were the whole EU tertiary sector to participate then, if the 50 kWh/m^2 average consumption figure and the 3 - 15% saving range in electrical energy use achieved was found representative of the whole population, the potential annual cost savings across the EU would be between €1,400M - 7,100M.

It is the coordinators opinion that the average 50.4 kWh/m^2/annum consumption measured is a reasonable average figure for just the HVAC component of a building's electrical load across all the building types tested, based on existing knowledge of energy consumption figures in buildings. An average total electrical consumption for a building of 100 - 150 kWh/m^2/annum is a more usual figure found in the buildings for which we have the main incomer data, and these buildings also show savings of 10%+ are practically achievable for the whole load – indicating that a further €7,000M - 14,000 M of electrical energy savings should be available on top of those already shown.

In terms of the total EU electrical energy use in 2010 of 2,836 TWh (Source: JRC) the project could save 0.33% of this total energy use based on a 100% uptake and 3% saving scenario, assuming an average figure of 50 kWh/m^2. This would increase to 5% of the total EU electrical energy use if there were a 100% uptake and the 15% savings figure were achieved, based on a 150 kWh/m^2 average annual demand.

This latter figure appears practically achievable when considering the total electrical energy use/m^2 in operational buildings, and the total electrical energy savings of up to 33% occurring in the longer-term iSERVcmb buildings. Indeed, it appears savings of over 13% of the total EU electrical energy use are potentially available if the iSERVcmb approach were required throughout the EU tertiary sector. This would be a significant step towards achieving the 20-20-20 energy efficiency target and, more importantly, it appears these savings could be quickly accessed.

Table 1 shows the project outcomes presented as a series of performance indicators.

Table 1 - Project Performance indicators for iSERVcmb

Indicator	Description	Additional information
Energy saved in kWh (toe)	Total energy reduction measured over all participating systems.	7,154 MWh/a shown to be saved, equivalent to 1,619 toe. Average savings of ~9% achieved from a shorter impact period than intended.
Energy saved in €	Total cost reduction measured over all participating systems.	Just over €1M per annum saved based on measured energy reductions and an average unit cost of €0.15 per kWh.
Emissions saved in tCO$_2$	Energy saved in kWh is converted into tCO$_2$ based on an average electricity emission factor for Europe of 0.5246 kgCO$_2$/kWh$_e$ taken from UK DECC figures for EU Member States as a whole	Measured annual savings of around 3,750 tCO$_2$
Cumulative investment made by participants (€)	Recorded end user investments in systems, time, etc., converted into monetary equivalent	Not established during project
Establish which HVAC energy use is location independent, and which isn't	To establish which data can be applied across all Member States and which have to be qualified by geographical location	Not completed during project.
HVAC systems tested in project	The project aimed for 1600 systems.	2,831 HVAC systems and 7,685 HVAC Components were assessed
HVAC systems tested in each Member State	The project aimed for between 50 to 100 systems in each MS targeted. It can be seen this even level of coverage was not achieved.	Country Systems Austria 98 Belgium 32 Cyprus 2 Czech Republic 32 Germany 3 Greece 76 Hungary 94 India 6 Italy 60 Luxembourg 8 Poland 34 Portugal 1492 Slovenia 97 Spain 6 Sweden 58 United Kingdom 733

Indicator	Description	Additional information
Responses from HVAC system owners to usability of system and improvements needed	Important to understand how the users found the approach	Generally happy with the reports and the usefulness of the information, but identified the initial description of the building and systems as a hurdle.
Physical Inspections and IAQ tests to substantiate ECOs identified by the monitoring	The acceptability of the benchmarks depends on achieving confidence that the savings identified by the iSERVcmb system are found in reality, and that IAQ is not detrimentally affected by the achievement of high energy efficiency in systems	64 Inspections and 62 IAQ tests were completed which substantiated the iSERVcmb approach and showed the IAQ in a sample of the systems was acceptable within current standards.
Number of HVAC Manufacturers who participated	To ensure the Industry view is represented in the approach	Direct involvement from SWEGON and Camfil Farr provided this input.
Ability of HVAC Manufacturers to support the benchmark approach	A check that HVAC system component manufacturers can comply with iSERVcmb data requirements in their components	Swegon amended their software to enable iSERVcmb requirements to be met by their AHU components. Eurovent Certification participated late in the project and are evaluating the requirements as part of future certification plans
MS adapting legislation to allow iSERVcmb approach	The project aimed to support EU Member State legislation allowing this approach to be used as a complement to Inspection.	The project was presented to EU Member State legislators on 4 occasions. There is interest in the approach but no formal commitment to adopt this approach in any EU Member State at the time of this report.
Number of benchmarks proposed by iSERVcmb	Number of different benchmarks and datasets produced and proposed by the project	Datasets were produced for energy consumption and power demands by HVAC component serving a given activity by unit floor area.
Number of benchmarks adopted by professional bodies	Of the benchmarks and datasets produced, how many are to be adopted by REHVA and CIBSE as guidance to their members	CIBSE intend to publish the datasets as part of their professional guidance for their members and REHVA are writing a Guidebook on the iSERVcmb approach for use across the EU HVAC Professional Bodies
Professional body publications produced	Official guidance documents produced by the professional bodies of CIBSE and REHVA	2 publications at least expected which reference the iSERVcmb findings and approach. These will occur in the coming year or two after publication of the project findings

Indicator	Description	Additional information
Number of publications by project team	Papers, Professional Journal Articles, Newsletters, etc. These can be found in the project Appendices	Overall: 228+
Number of presentations by project team	Conferences, Workshops, Invited talks, etc	Overall: 105
Estimate of savings and investments from above indicators beyond the life of the project and up to 2020	Extrapolation of the anticipated impact of iSERVcmb beyond the project end. Particularly leading up to 2020.	Time investment rather than financial investment appears to be the key to initial savings. The potential impact of iSERVcmb is discussed in detail in the following section

5.5 STRATEGIC (LONG-TERM) OBJECTIVES OF ISERVCMB

As a result of the savings achieved by the project it is anticipated that the EU MS will accept the approach as being acceptable as an alternative to Inspection as allowed for in the recast EPBD.

This will help stimulate the use of this approach in MS, which in turn will stimulate a market for better monitoring of HVAC systems, and will reward good energy management and HVAC design by achieving real energy savings and potentially avoiding Inspection costs.

It will also encourage more efficient HVAC products and services as owner/operators will be able to specify an expected HVAC consumption range for their end use activities. The strategic long-term objectives are therefore:

- Provide significant real, measureable reductions in energy use in EU HVAC systems and to show energy savings of 20%+ being achieved in operational buildings on average.
- Introduce the principle of rewarding the owner/operator of HVAC systems for good operation
- Have the approach accredited as an alternative to physical Inspection where acceptable energy efficiency performance is demonstrated.
- To establish a market for this approach to Inspection. This in turn would help establish a market for skilled HVAC Inspectors rather than the existing compliance Inspection market that has been created.
- Establish a robust market for HVAC systems that have demonstrably low operational energy consumption.
- To explore the wider use of benchmarking as a means of identifying and quantifying many aspects of building performance, not just energy.
- To make this approach available to the market and EU MS in the coming years.

6 Report Structure

This section explains how the information for the project is structured and presented. This report is the key report for the project and all other reports are derived and linked to this one.

iSERVcmb builds on the IEE AUDITAC (http://www.cardiff.ac.uk/archi/research/auditac/) and IEE HARMONAC (www.harmonac.info) projects, as it demonstrates how using sub-hourly data at the level of individual HVAC components can provide a more effective route to understanding and managing operational energy use and power demands in building HVAC systems.

6.1 PROJECT REPORT LAYOUT

The iSERVcmb project has provided a unique approach and accumulated a unique set of operational data for building services components during its 3 year period. This data is presented in the following sections using this structure:

- How the iSERVcmb process works and is structured
- The energy and power demand data collected using this process, for each HVAC component and sub-component type when servicing a given end use activity type
- The energy conservation opportunities (ECOs) identified in HVAC components through the process
- The measured energy savings achieved in buildings and systems on the iSERVcmb project
- The results obtained from Indoor Air Quality measurements and Inspections to ensure the iSERVcmb process findings are supported by physical measurements.
- The views of the stakeholders and actors affected by this approach
- iSERVcmb and legislation

The underlying data for each section is available from the iSERVcmb website at the referenced links in each section.

7 Discussion of the project results, findings and observations

iSERVcmb has gathered a large amount of information during the project period, further details of which are accessible through the project publications referred to in this report and available on the iSERVcmb project website. This section considers the potential impact of iSERVcmb in terms of the most common questions arising during the project:

1. **Why is monitoring so important to achieving lasting energy savings in buildings, and what difference can be achieved compared to Inspections and existing approaches?**

From the Case Studies undertaken in both HARMONAC and iSERVcmb over a period exceeding 8 years, it has been observed and measured that data at this level of detail not only enables building operators to know where to focus efforts to save energy, but also helps them prove that the energy has been saved in specific energy consuming equipment. The long-term benefit of employing iSERVcmb approach's basic principles can be seen in the McKenzie House Case Study under the "iSERVcmb Case Studies" folder, where it has led to significant long-term savings in the overall energy use with little 'rebound effect'.

iSERVcmb shows that electrical energy savings of up to 33% can be achieved AND maintained in operational buildings from using its processes and procedures. It is the Coordinators opinion that such an approach will achieve sustainable electrical energy savings of 10 to 30% in practice in most buildings. Heating and Cooling energy savings were not explored in detail in this project due to a lack of enough appropriate metering, but savings of 5 – 10% in these aspects would appear very achievable from the project observations, and probably more would be achievable in practice.

In comparison, the Inspection approach required by legislation is shown by both the HARMONAC and iSERVcmb projects to be capable of identifying some of the energy conservation opportunities available. However, because it has no impact assessment route, anecdotal evidence collected from building owners across Europe regarding Inspection reports is that they are seen as a legislative necessity but the report contents are rarely acted on. There is also evidence that many owners of systems requiring Inspection are simply not having them done as there are little or no consequences to not undertaking them.

Other approaches that might be employed include advice campaigns, along with more traditional energy reduction campaigns. There are a number of studies showing that initial savings from traditional approaches may achieve good initial savings. However, it is the Coordinators experience that these savings are difficult to maintain over time without continuous feedback being provided to keep the impetus going.

In conclusion, iSERVcmb has shown that continuous monitoring and targeting has the ability to achieve and sustain significant energy reductions in operational buildings. The alternative approaches have yet to demonstrate that they have either the same depth or timescale of impact, and there appears to be reasonable evidence to show that they do not achieve the same level of impact as iSERVcmb has attained.

2. **Why do I need to understand my buildings, services and metering to the level of detail required by iSERVcmb?**

iSERVcmb has found that very few building owners or operators in Europe understand their Building Services fully. Part of providing the confidence needed to produce the long-term energy savings possible is to ensure the monitoring relates to physical assets that can be acted on. This requires connecting and collating all the HVAC components, meters and space in the building so that clarity is achieved. Monitoring is then able to play its part, as it is what drives change of operation, maintenance and procurement procedures. The monitoring also makes the easy, and free to obtain, out-of-hours savings visible.

Also, and often overlooked, all buildings are in a continual state of change. This means operational setpoints can change frequently. The use of operational benchmarks to help ensure nothing untoward is happening for the new activities or hours being serviced is vital to achieving the culture change needed in understanding the value of the information obtained from monitoring systems.

Finally, and equally as important iSERVcmb has found, is that without understanding how the meters, systems and building spaces are interconnected, it is often difficult for building operators to know how to control the building services properly. This information is as important to business continuity as it is to energy management.

3. What savings can regular maintenance and EPBD inspections achieve. Will Advice campaigns be any better?

One of the key questions for iSERVcmb, partially addressed in the first question above, is why is this approach better than the existing legislative approaches that have already taken time and effort to implement.

iSERVcmb does not have the quantitative evidence to show what is achieved by existing Inspection reports as the Inspection method inherently does not record ‘before’ and ‘after’ performance of these systems. However, if we were to take the full effects of a good Inspection of a cooling and heating system’s components, combined with a thorough maintenance of these components at the time of the Inspection, then the iSERVcmb Inspection reports indicate that these would identify and remedy physical defects, such as dirty filters, at the time of the Inspection leading to potential energy savings in those items of equipment of up to 15% at that moment in time. The Inspections are unlikely to identify poor operation or control of the systems as there is rarely data available to identify this is occurring.

As noted later in this report, comparison of Case Studies where Inspection and Monitoring are both occurring suggests Inspection will only identify 25 to 66% of the savings projected for those systems by the iSERVcmb process.

As a rule of thumb the Coordinator suggests that, given the practical implementation of the Inspection approach that appears to be occurring across Europe and the lack of a feedback mechanism to maintain savings, then Inspection should be considered as only achieving **20% on average** of the savings possible through continuous monitoring and benchmarking.

What could not be answered from the Inspection and Monitoring approaches studied is whether Advice schemes, as now allowed in the EPBD, would have achieved better or worse savings or investment than Monitoring and/or Inspection. The Coordinator’s **opinion** drawn from looking at the impact on the end users of the Monitoring and Inspection approaches studied, is that Advice will have very limited impact in the practical reduction of operational energy use. This conclusion is reached as there is no trigger for investment in a specific area, as well as no mechanism for assessing the benefits of any change made. Therefore there is no reason to disrupt existing design, operation and maintenance practices in either new or existing buildings and systems. Other mechanisms such as improving the general efficiency of available plant in the market will occur with or without an Advice scheme. Advice therefore does not seem to be the correct route to achieving the savings possible from improving operational energy use.

4. Why are benchmarks important if monitoring already shows where the energy is going?

Benchmarks are the key to putting monitored energy use into context. It is one thing to know how much is being used, but another to know whether the amounts are reasonable or not. The iSERVcmb benchmarks are produced from operational buildings for each HVAC component type servicing a given end use activity. This again provides confidence that the benchmarks are achievable in practice, while providing the ranges of energy use or power demands being achieved allows the calculation of potential achievable savings as well. Knowing these potential energy, and therefore cost, savings helps to unlock investment in more efficient components and practices.

5. How much energy is wasted by not managing our existing stock properly?

iSERVcmb suggests that acceptable electrical energy performance can be achieved in most buildings once they are well understood and monitored. Savings of 19 to 33% have been achieved in the total electrical energy use in three of the longer-term monitored buildings using the iSERVcmb process. This suggests that these savings are readily accessible as one of these buildings achieved a good energy rating from simply controlling their existing, obsolete plant more accurately.

Heating and cooling energy requirements are however determined by design and location as well as services and not enough information was obtained from iSERVcmb to ascertain the variation in these loads, though it was clear that poor operation of services can ruin a good design. The other issue which it is important to include in any analysis is the creation of a productive indoor environment along with energy efficiency, and this debate still has to be resolved.

6. Is the EPBD still appropriate for reducing energy use in operational buildings?

The original EPBD was designed to focus attention on reducing the overall energy use of buildings. Proposed and written in an era when operational energy use and descriptions of buildings, systems and services were hard to collect and collate. This has led to poorly focussed metrics such as having complex mixed use buildings described loosely by terms such as ‘Office’, ‘Retail’, etc. It has also led to ‘single issue’ approaches to deciding actions to be taken, e.g. increasingly stringent insulation requirements; need for inspecting AC and heating equipment in isolation; etc.

This world increasingly no longer exists, and the EPBD as currently enacted could be argued to be hindering the design of genuinely low energy use buildings. These approaches understand that operational low energy use is only achieved when the occupants and activities to be housed are an integral part of the design process. In highly insulated buildings, the energy balance of a building – which ends up as a demand for heating and cooling on the services – is increasingly dependent on the internal loads produced by the activities and occupants. The two other crucial factors are ventilation heat losses/gains and solar gains.

In a world where Building Information Modelling (BIM) is rapidly becoming a design requirement for many new buildings and refurbishments, the EPBD as currently enacted with prescriptive requirements, rather than performance based requirements, is hampering the ability of designers, manufacturers, developers, etc., to work together to produce the next generation of buildings needed to meet Europe’s low environmental impact aspirations – where energy use is just one variable amongst many other equally important ones.

The iSERVcmb project and results show that it is possible to implement an alternative approach to reducing the energy use of buildings where the determinant of compliance is achieved energy use, as measured by utility consumption at the main billing meter, benchmarked by the activities being serviced, and the plant used for that servicing. This is a simple concept to understand and does not require complex calculations to achieve. It also supports the end aim of every European Directive aimed at reducing energy use in practice.

The iSERVcmb approach also has the significant incentive of allowing all building designers, procurers and operators to make their actual benchmarked energy consumption achievements visible to the whole of Europe if they wish – helping them in their Corporate Social Responsibility aims too. This allows all building professionals to participate in helping move the achievement of low energy buildings forward in a manner which will rapidly improve our understanding of what makes a building **operationally** energy efficient, once you include all the confounding factors such as humans, unpredictable occupancy and weather, control approaches, etc.

It is the Co-ordinators opinion therefore that the EPBD needs a major revision to promote performance based operation and design of buildings, if Europe is serious about reducing its operational energy demands by 2020. This change is also essential if we are not to produce a new generation of buildings that are low or zero energy in label only.

7. What incentives should there be for building owners and operators to invest in the monitoring route instead of regular inspections?

Inspections as currently implemented appear to be a minor tax in all but name, as their cost is rarely recovered in any form of savings achieved as a direct result of the Inspection. However, the low cost of these Inspections means that simply reducing or removing the requirement for Inspection is unlikely to provide a sufficient incentive to encourage a change to monitoring instead. While the iSERVcmb approach appears to return more than 500% of its annual cost in buildings on average this still does not always mean adoption will happen as these savings may not be significant in the overall operation of a company. Removing the potential need to comply with compulsory implementation of recommendations in Inspection reports would help, but as many systems have still not been inspected this may have less impact than expected. Legislation could also make the alternatives a sufficient headache to make them worth changing from in terms of manpower requirements.

Possibly the most promising approach would be to run a European-wide reward and acknowledge system that used the data from such an approach to highlight good performance being achieved. The Corporate Social Responsibility aspects of such acknowledgements appears to be more important for many organisations than the cost savings to be achieved.

However, clearly the most effective way would be to make the adoption of such an approach compulsory for all new buildings and to have a gradual requirement to adopt the approach over time imposed on existing buildings.

8. Are there particular building categories for which iSERVcmb is relevant? (e.g. offices, hospitals, buildings with complex heating and cooling systems, with poor EPC's, etc.)

All buildings can benefit from the iSERVcmb approach. It is important to note that iSERVcmb does not work with building types, but with space types defined by area and primary activity. iSERVcmb has shown that there are significant savings to be made in the operation of all HVAC component types in all situations. Clearly buildings with larger energy intensities would benefit more from this data but findings suggest that the cost of monitoring should normally be more than repaid by the Management Information returned to the end user on where the energy is going and what it is costing to run various activities and components.

9. What other benefits are available from having a detailed database containing measured energy use correlated to the building services components and the end use activities serviced?

The information obtainable from such a database would be of immense value to all actors involved in trying to provide more energy efficient services into buildings. HVAC manufacturers benefit from being able to sell the energy efficiency aspects of their kit for a premium; Building and Services Designers benefit from a greater emphasis on their skills in producing lower energy buildings; Professional Bodies benefit from being able to provide more focussed guidance to their Members; Building

Procurers and Operators benefit from being able to reduce their energy risk and use in operation; Legislators benefit from a better understanding of the issues and problems to be overcome in achieving more operationally efficient buildings and therefore where to target increasingly scarce subsidies to achieve this aim.

Ultimately the whole sector would also benefit from the ability to reduce unnecessary legislation and therefore to reduce the regulatory burdens on all actors.

8 The iSERVcmb procedure

Major points for this section:

- It is possible to set up a system to underpin the iSERVcmb procedure in operational buildings
- An important source of potential errors will be minimised if a common data format can be agreed for sub-hourly data
- Data needs to be sent from systems to a database. It is very difficult to try and collect data via external requests due to security issues
- The iSERVcmb spreadsheet enables the initial description of a building and its systems to be standardised and undertaken offline.
- The main implementation barrier is the initial completion of the spreadsheet. This would be overcome by legislation recognising the procedure as an acceptable means of meeting EPBD requirements.
- The approach has been shown to be scalable to enable whole countries to be covered
- A robust metering methodology is needed for the EU, to resolve not only data collection problems but also where to install meters and how to use data from components.
- Continuously updated benchmarks for HVAC component energy use by activity and area served can be generated directly from the data.

8.1 OVERVIEW OF THE ISERVCMB APPROACH

The iSERVcmb approach is founded on an understanding of the interaction of the physical attributes of a building, including its meters, services and the activities undertaken in the building.

Benchmarks, ECOs and other guidance are derived wholly from data obtained from the operation of buildings, as HARMONAC showed that this was a major factor in persuading end users to act on their energy data.

8.2 UNDERSTANDING THE BUILDING AND SYSTEMS

To provide its benchmarks, iSERVcmb requires details on the physical composition of buildings in terms of Utility Meters, Floor Areas, Activities undertaken and the Building Services components installed.

In iSERVcmb, an HVAC system is a virtual entity comprised of a series of physically described HVAC sub-components. This virtual entity is then attached to the spaces and activities it services within the building. An HVAC sub-component, for example a cold generator, can serve one or more such HVAC systems within a building depending on the arrangement of the services in that building. iSERVcmb handles all interactions between meters, component, activities and spaces once described in the iSERVcmb spreadsheet.

8.3 METERING AND DISTRIBUTION SYSTEMS

The physical layout of the utility distribution systems in a building can have a significant effect on the viability of metering systems using traditional metering approaches. It is therefore important that, where possible, the design of these systems makes it as simple as possible to separate the utility consumption by various end uses such as pumps, cold generators, air handling units, lighting, small power, etc..

8.4 THE ISERVCMB SPREADSHEET

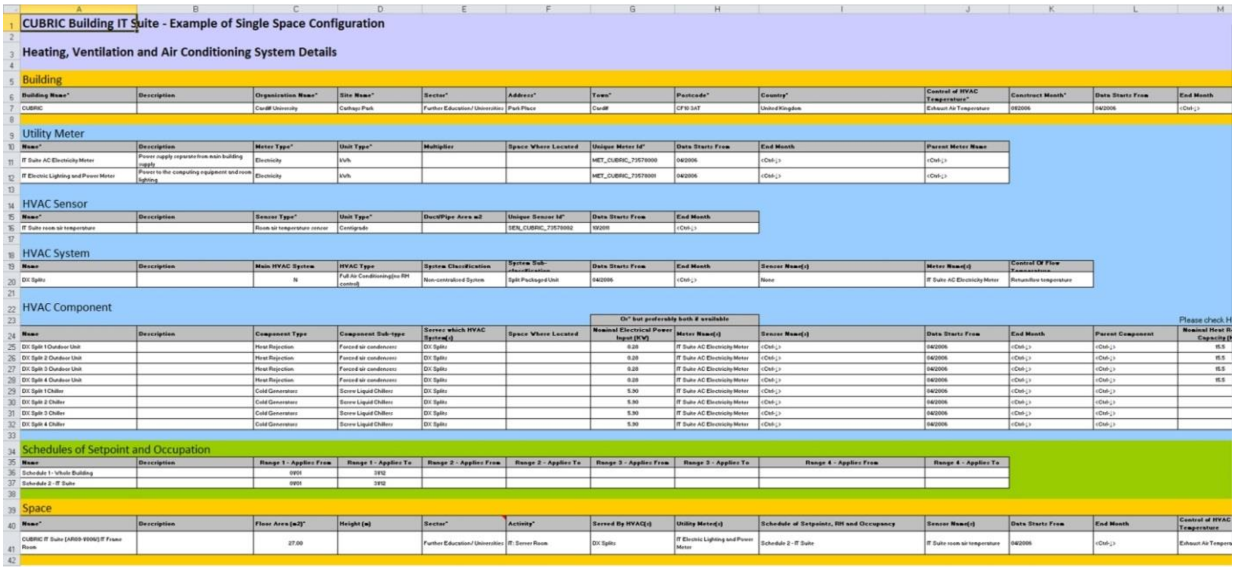
Initial experience within iSERVcmb of collecting the data required for the process from the participating buildings, meters and sub-components quickly established that a standardised format was required to ensure comparability between systems across the EU. The project has therefore established an active Excel spreadsheet for both collecting AND collating information about HVAC systems, activities and areas served in buildings. This can be downloaded from the iSERVcmb website and enables anyone wishing to collate and benchmark information on their HVAC systems to do so.

Initially envisaged as an online interface, it became apparent that the asset data collation process should take the form of a standalone spreadsheet to allow for a simpler and faster use. In this respect, the spreadsheet acts as a front end to the database as well as providing a data resource for storing data on building services, systems, floor areas, activities and meters within a building.

Once completed, and its data verified as being consistent via a built-in validation check, a spreadsheet can be sent to the database for uploading, and to allow bespoke benchmark energy consumption ranges for the building, systems and components to be produced. The spreadsheet can also automatically generate a more limited set of benchmarks by going to the ‘benchmarks’ tab in the spreadsheet.

The logic of the iSERVcmb process requires the following information to be provided:

- Floor area and activities, on a room-by-room basis
- HVAC system components, sensors and utility meters installed in the building
- Hours of use of areas by activities (schedules)
- How these all connect together, to provide the relationship between activities, HVAC components and utility use.



CUBRIC Building IT Suite - Example of Single Space Configuration

Heating, Ventilation and Air Conditioning System Details

Building

Building Name*	Description	Organisation Name*	Site Name*	Sector*	Address*	Town*	Postcode*	Country*	Control of HVAC Temperature*	Construct Month*	Data Starts From	End Month
CUBRIC		Cardiff University	Cathays Park	Further Education / Universities	Park Place	Cardiff	CF10 3AT	United Kingdom	Exhaust Air Temperature	01/2006	04/2006	<Ctrl-;>

Utility Meter

Name*	Description	Meter Type*	Unit Type*	Multiplier	Space Where Located	Unique Meter Id*	Data Starts From	End Month	Parent Meter Name
IT Suite AC Electricity Meter	Power supply separate from main building supply	Electricity	kWh			MET_CUBRIC_73578000	04/2006	<Ctrl-;>	<Ctrl-;>
IT Electric Lighting and Power Meter	Power to the computing equipment and room lighting	Electricity	kWh			MET_CUBRIC_73578001	04/2006	<Ctrl-;>	<Ctrl-;>

HVAC Sensor

Name*	Description	Sensor Type*	Unit Type*	Duct/Pipe Area m2	Unique Sensor Id*	Data Starts From	End Month
IT Suite room air temperature		Room air temperature sensor	Centigrade		SEN_CUBRIC_73578002	10/2011	<Ctrl-;>

HVAC System

Name	Description	Main HVAC System	HVAC Type	System Classification	System Sub-classification	Data Starts From	End Month	Sensor Name(s)	Meter Name(s)	Control Of Flow Temperature
DX Splits		N	Full Air Conditioning(no RH control)	Non-centralised System	Split Packaged Unit	04/2006	<Ctrl-;>	None	IT Suite AC Electricity Meter	Return flow temperature

HVAC Component

Please check H

						Or* but preferably both if available						
Name	Description	Component Type	Component Sub-type	Serves which HVAC System(s)	Space Where Located	Nominal Electrical Power Input (KW)	Meter Name(s)	Sensor Name(s)	Data Starts From	End Month	Parent Component	Nominal Heat R Capacity (
DX Split 1 Outdoor Unit		Heat Rejection	Forced air condensers	DX Splits		0.28	IT Suite AC Electricity Meter	<Ctrl-;>	04/2006	<Ctrl-;>	<Ctrl-;>	15.5
DX Split 2 Outdoor Unit		Heat Rejection	Forced air condensers	DX Splits		0.28	IT Suite AC Electricity Meter	<Ctrl-;>	04/2006	<Ctrl-;>	<Ctrl-;>	15.5
DX Split 3 Outdoor Unit		Heat Rejection	Forced air condensers	DX Splits		0.28	IT Suite AC Electricity Meter	<Ctrl-;>	04/2006	<Ctrl-;>	<Ctrl-;>	15.5
DX Split 4 Outdoor Unit		Heat Rejection	Forced air condensers	DX Splits		0.28	IT Suite AC Electricity Meter	<Ctrl-;>	04/2006	<Ctrl-;>	<Ctrl-;>	15.5
DX Split 1 Chiller		Cold Generators	Screw Liquid Chillers	DX Splits		5.30	IT Suite AC Electricity Meter	<Ctrl-;>	04/2006	<Ctrl-;>	<Ctrl-;>	
DX Split 2 Chiller		Cold Generators	Screw Liquid Chillers	DX Splits		5.30	IT Suite AC Electricity Meter	<Ctrl-;>	04/2006	<Ctrl-;>	<Ctrl-;>	
DX Split 3 Chiller		Cold Generators	Screw Liquid Chillers	DX Splits		5.30	IT Suite AC Electricity Meter	<Ctrl-;>	04/2006	<Ctrl-;>	<Ctrl-;>	
DX Split 4 Chiller		Cold Generators	Screw Liquid Chillers	DX Splits		5.30	IT Suite AC Electricity Meter	<Ctrl-;>	04/2006	<Ctrl-;>	<Ctrl-;>	

Schedules of Setpoint and Occupation

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		01/01	31/12						
Schedule 2 - IT Suite		01/01	31/12						

Space

Name*	Description	Floor Area (m2)*	Height (m)	Sector*	Activity*	Served By HVAC(s)	Utility Meter(s)	Schedule of Setpoints, RH and Occupancy	Sensor Name(s)	Data Starts From	End Month	Control of HVAC Temperature
CUBRIC IT Suite (AR03-Y006) IT Frame Room		27.00		Further Education / Universities	IT: Server Room	DX Splits	IT Electric Lighting and Power Meter	Schedule 2 - IT Suite	IT Suite room air temperature	04/2006	<Ctrl-;>	Exhaust Air Temper

Figure 1 - iSERVcmb spreadsheet showing part of the data sought

Co-funded by the Intelligent Energy Europe Programme of the European Union

An example of part of the iSERVcmb spreadsheet is shown in Figure 1, while the process of describing and setting up a building's assets using the iSERVcmb spreadsheet is presented in Figure 2.

The iSERVcmb spreadsheet can therefore take the role of an asset register in which all building and system assets are described and linked to each other. During the iSERVcmb project, the spreadsheet was translated into 11 EU Member States languages and spreadsheets were completed in 16 EU Member States.

Completing the spreadsheet was found to need a time and cost investment at a conservative cost of approximately €1/m^2 based on the iSERVcmb experience.

The uncertainties that were observed during the use of the iSERVcmb spreadsheet include a likely error of -1 to +4% of the recorded floor area value, the need to initially verify data in order to identify wrongly installed or described meters quickly. An error of ±2% is assumed for verified data. The largest likely error observed was the uncertainty over exactly what energy end uses and spaces each meter served as electrical circuit diagrams were often missing or not up-to-date.

It is also important to note that the initial use of the benchmark process across Europe revealed the anticipated need for further information on occupancy and temperatures to help reduce the spread of some of the benchmark ranges.

The final version of the spreadsheet available for free on the iSERVcmb website link (shown in the box alongside) will also provide a first estimate of the benchmark ranges for a building and its systems entered into the spreadsheet, without having to upload the spreadsheet to the HERO database.

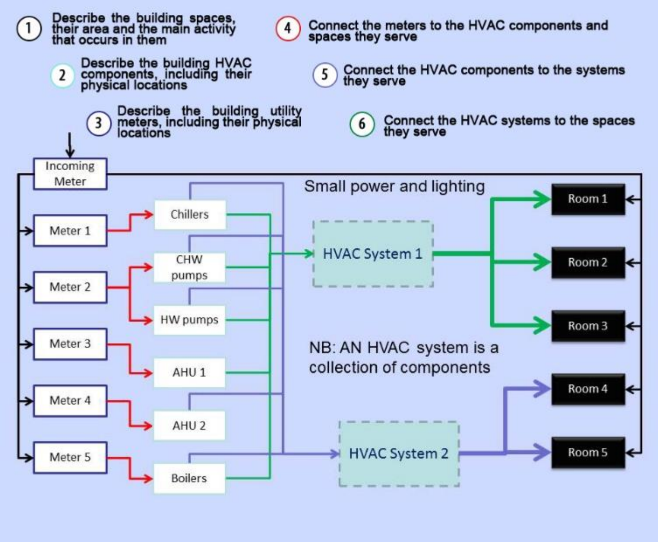


Figure 2 - iSERVcmb spreadsheet completion procedure

iSERVcmb spreadsheet key points:

- The iSERVcmb process revolves around physical items.
- The information concerning the meters, HVAC components, spaces, etc within the buildings resides with a number of people within the organization. Commonly much information does not exist.
- Permissions to obtain the information needed can be difficult to obtain depending on organization operation
- Collating this information in the spreadsheet unlocks the ability to provide better control of the systems and investment
- The electrical distribution and metering strategies are key to eventual information provision
- Information on existing plant can be difficult to obtain

Further information can be found in the "iSERVcmb Spreadsheet" and "Database information" folders under the following hyperlinks:

- Process overview
- Latest version of spreadsheet
- Spreadsheet Quick Start Guide
- Spreadsheet FAQ document

However, uploading the completed spreadsheet to HERO will provide additional insights into the building, systems and component performance. This upload can be done by following the instructions in the spreadsheet. An example of the benchmark ranges report from the spreadsheet is shown alongside in Figure 3 for a building in the iSERVcmb project.

The iSERVcmb spreadsheet has been endorsed by both REHVA and CIBSE as a means of collating the data needed to better understand HVAC systems in buildings as well as being beneficial for mandatory Inspections. It is also now part of the UK's Education Funding Agency's process for new schools.

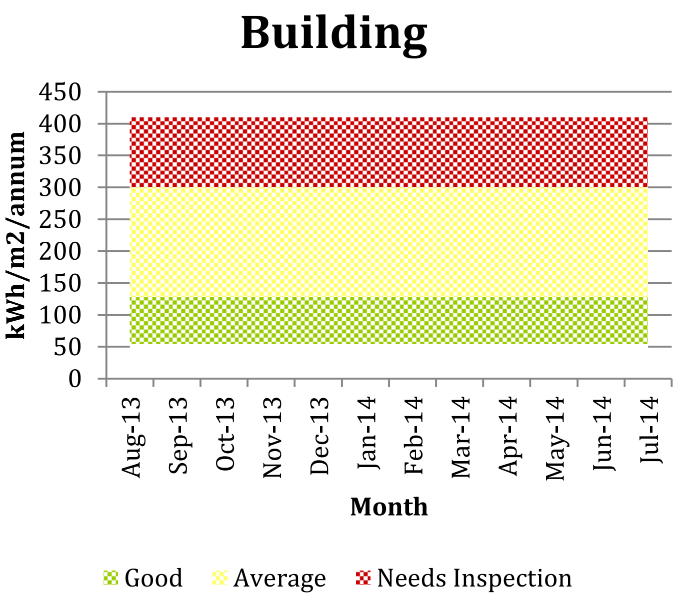


Figure 3 - Example building benchmark ranges produced from the iSERVcmb spreadsheet

8.5 HERO - THE ISERVCMB DATABASE

Once the physical assets in the building are described and entered into the spreadsheet, it can be sent to an email address where it is then automatically loaded and configured in the HERO database. Once loaded, a set of blank benchmark ranges can be produced which are tailored to the building, systems and activities described.

As the process receives data continually for many buildings, meters and sensors it can produce regularly up-dated benchmark ranges by HVAC component type servicing specified end-use activities by unit area. The benchmarks derived from this real consumption data can be presented by system, component, space and activity.

For a particular building, plotting the actual metered consumption over the tailored benchmark ranges immediately shows how well the building, system or component is performing. A major strength of this approach is that, as the benchmark ranges are derived from operational data from other users servicing the same end use activities, this is persuasive in getting end users to act on the information provided.

End users also receive analysed data showing potential ECOs (Energy Conservation Opportunities) in automated monthly reports, or on demand between monthly intervals. More than 20 ECOs have been integrated to HERO, which scan the data provided to detect and report on potential energy saving opportunities. The provision of HVAC component technical specifications is required to allow some ECOs to be triggered and included in the HERO reports end users receive.

The diagram in Figure 4 shows the major inputs and outputs of the HERO database. These inputs and outputs are further described below.

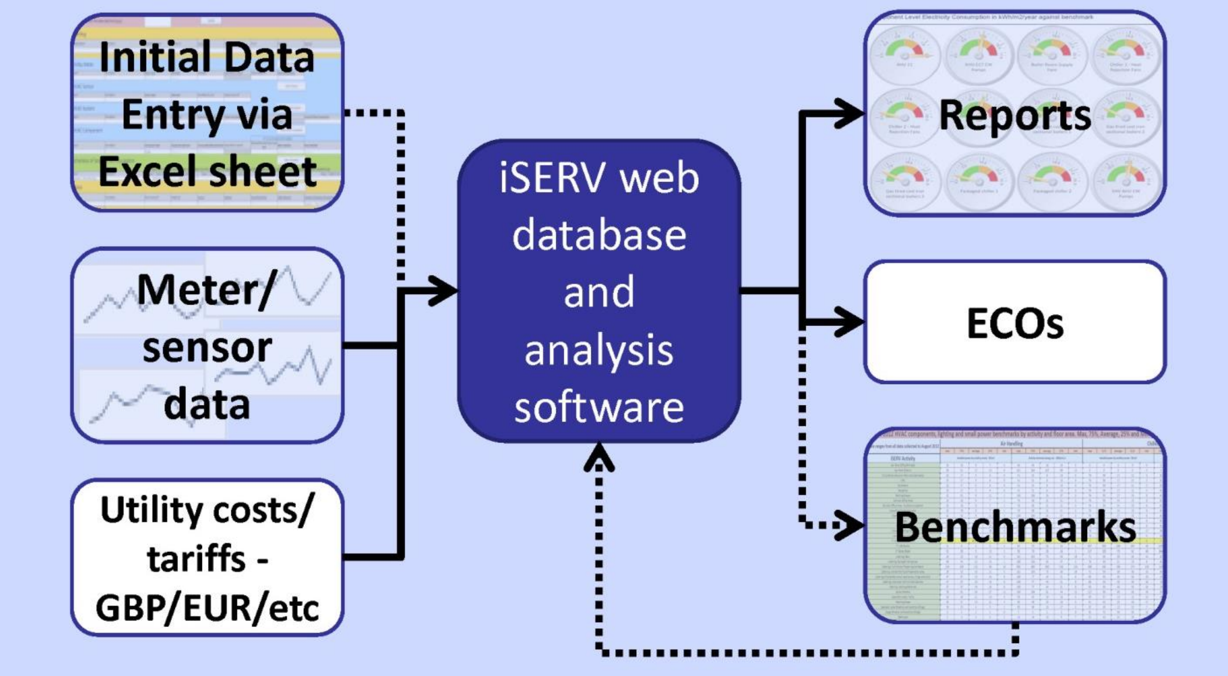


Figure 4 - Schematic of iSERVcmb process

8.6 HERO AUTOMATED DATA LOADER

HERO's automated data loader is an essential part of the system and provides the following data input functionality:

- Data import:
  - Automated loading of email attachments via the iSERVcmb data domain
  - manual entry via the online user interface
- File Types:.txt and .csv files
- Data Formats: The HERO configuration tool allows users to load the majority of Member States data formats.
- Meter Types. Able to load all common utility types as well as sensors such as external and internal temperature.
- Sub-hourly, daily, monthly and annual interval data
- Consumption and Reading Meters

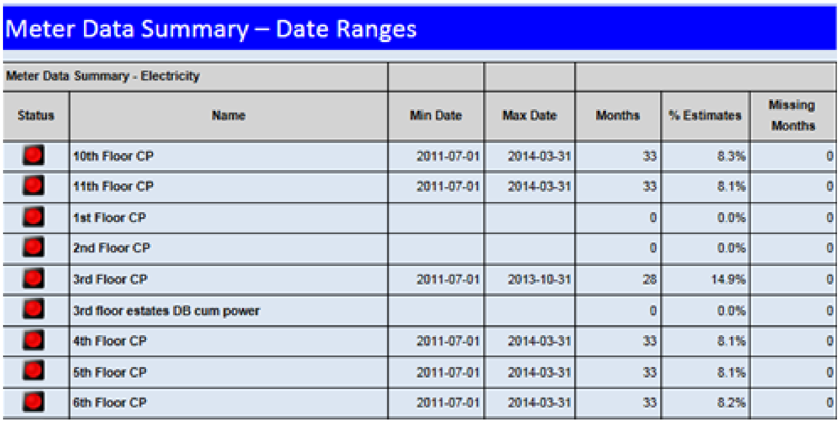
The data loader’s data cleansing function proved central to the provision of high quality data for the project as the data supplied from meters from around Europe was of a variable quality. Over 50% of the data eventually loaded for iSERVcmb either had missing data, corrupted data or both. The HERO system has handled 100+ different data formats as well as differing numeric and date formats. To improve the quality of the data being supplied, HERO’s data cleansing module provides the following functions:

- Identification and quarantine of corrupted readings
- Intelligent algorithms to clean data where there have been spikes, negative readings, changes in units and meter flips.
- Estimated readings for missing meter reading and consumption meters. Estimated readings are automatically profiled if historical data exists. If no historical data exists, the loader produces a flat consumption profile.
- Production of a set of meter exception reports sent to the data provider that show:
  - The number of readings loaded

  - The range of data available
  - The percentage of estimated data in the meter
  - The meters that were not loaded

8.7 HERO REPORTING

Figure 5 shows an example meter data quality report for a building. For each meter it presents the date range of the data loaded, the percentage of this data that has been estimated and the number of missing months for a building's meters. The traffic light colours are green when the data has no missing months and less than 2% is estimated, amber with no missing months and 2 to 5% of the data is estimated, and red when more than 5% of the data is estimated or there are missing months.



Meter Data Summary – Date Ranges

Meter Data Summary - Electricity						
Status	Name	Min Date	Max Date	Months	% Estimates	Missing Months
🔴	10th Floor CP	2011-07-01	2014-03-31	33	8.3%	0
🔴	11th Floor CP	2011-07-01	2014-03-31	33	8.1%	0
🔴	1st Floor CP			0	0.0%	0
🔴	2nd Floor CP			0	0.0%	0
🔴	3rd Floor CP	2011-07-01	2013-10-31	28	14.9%	0
🔴	3rd floor estates DB cum power			0	0.0%	0
🔴	4th Floor CP	2011-07-01	2014-03-31	33	8.1%	0
🔴	5th Floor CP	2011-07-01	2014-03-31	33	8.1%	0
🔴	6th Floor CP	2011-07-01	2014-03-31	33	8.2%	0

Figure 5 - Example report showing meter data quality

The HERO Reporting Module allows users to log into the HERO website and configure sets of standard reports which can be automatically emailed out to end users in a series of formats such as Excel, Word, PDF and HTML. Users are able to produce individual reports on demand from the HERO library of reports. . The HERO Reporting Module automatically generates 2 standard reports per building. The first is a high level report that shows a summary of the building, its consumption and any potential savings that can be made. The second report is very detailed and shows a breakdown at the services level for the building along with heat maps at the meter level where sub-hourly data is available.

From simple building consumption reports to detailed reports, HERO is able to aggregate sub-hourly data up to a standard monthly consumption interval to produce a variety of graphs and reports to suit end user needs.

The report in Figure 6 is central to the iSERVcmb project. It shows the tailored benchmark ranges for the iSERVcmb McKenzie House Case Study in red, orange and green bands, with the measured Rolling Annual Consumption per m^2 for the building overlaid in blue columns. Rolling Annual Consumption is one year's data summed up to the end of the month shown. The Dec 2006 consumption would therefore be the aggregation of the 12 months Jan 06 – Dec 06.

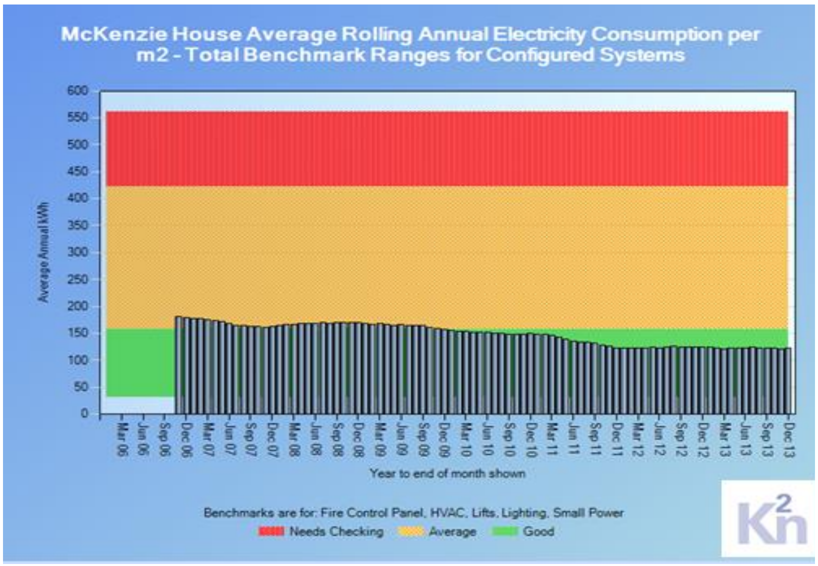
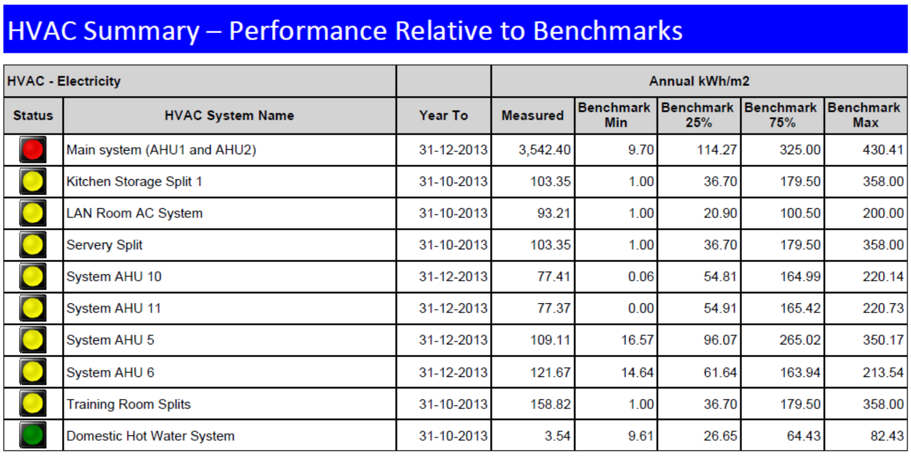


Figure 6 - Example iSERVcmb benchmark report - whole building level

If the consumption is in the red band, iSERVcmb proposes that the building “Needs Checking”, the amber band is “Average” utility usage and the green band is “Good”.



HVAC Summary – Performance Relative to Benchmarks

HVAC - Electricity			Annual kWh/m2				
Status	HVAC System Name	Year To	Measured	Benchmark Min	Benchmark 25%	Benchmark 75%	Benchmark Max
🔴	Main system (AHU1 and AHU2)	31-12-2013	3,542.40	9.70	114.27	325.00	430.41
🟡	Kitchen Storage Split 1	31-10-2013	103.35	1.00	36.70	179.50	358.00
🟡	LAN Room AC System	31-10-2013	93.21	1.00	20.90	100.50	200.00
🟡	Servery Split	31-10-2013	103.35	1.00	36.70	179.50	358.00
🟡	System AHU 10	31-12-2013	77.41	0.06	54.81	164.99	220.14
🟡	System AHU 11	31-12-2013	77.37	0.00	54.91	165.42	220.73
🟡	System AHU 5	31-12-2013	109.11	16.57	96.07	265.02	350.17
🟡	System AHU 6	31-12-2013	121.67	14.64	61.64	163.94	213.54
🟡	Training Room Splits	31-10-2013	158.82	1.00	36.70	179.50	358.00
🟢	Domestic Hot Water System	31-10-2013	3.54	9.61	26.65	64.43	82.43

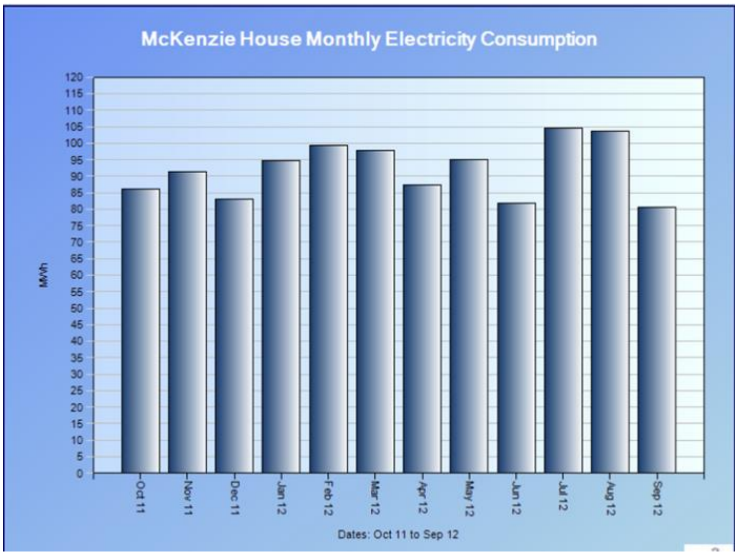
8.8 HERO REPORTS

8.8.1 Individual HVAC system performance summary

The report alongside provides a summary of the performance of a Building’s HVAC systems relative to their benchmarks using the Red, Amber, Green methodology as shown in the previous report.

8.8.2 Standard Monthly Consumption

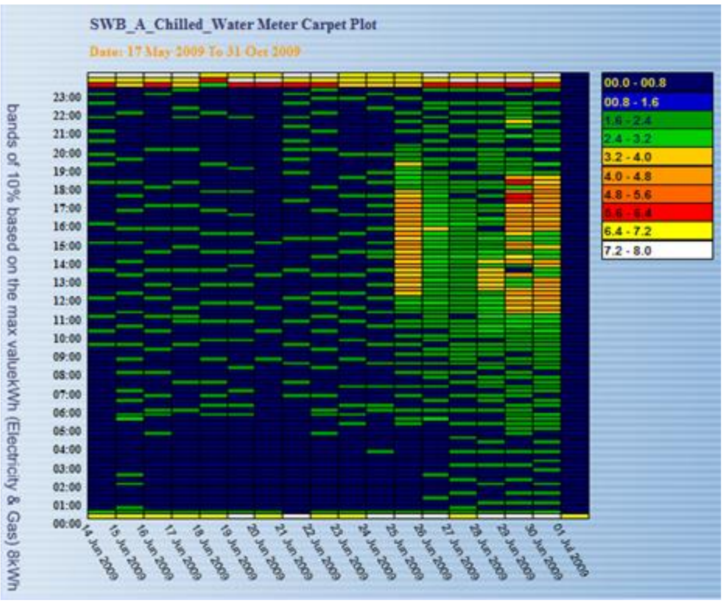
This is a simple building consumption report. The HERO system aggregates sub-hourly data up to a standard monthly consumption interval which gives a simple to read report.



8.8.3 Sub-hourly meter report

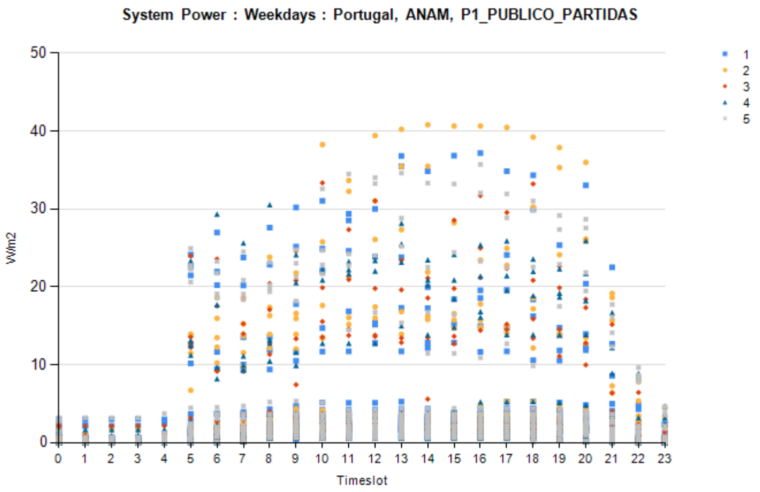
The ability to load sub-hourly data allows iSERVcmb to produce reports at the resolution of the supplied data. The two reports presented next show examples of these.

The first report is a Carpet Plot. It finds the highest consumption value for the period chosen and splits it into 10% steps with purple being 0-10% and white being 90-100%. It is a very quick and visual way to identify operational anomalies. In this case the chiller pump comes on at 11:15 every night due to a commissioning oversight. 3 – 4% saving in AC system annual energy use resulted from rectifying this problem.



Co-funded by the Intelligent Energy Europe Programme of the European Union

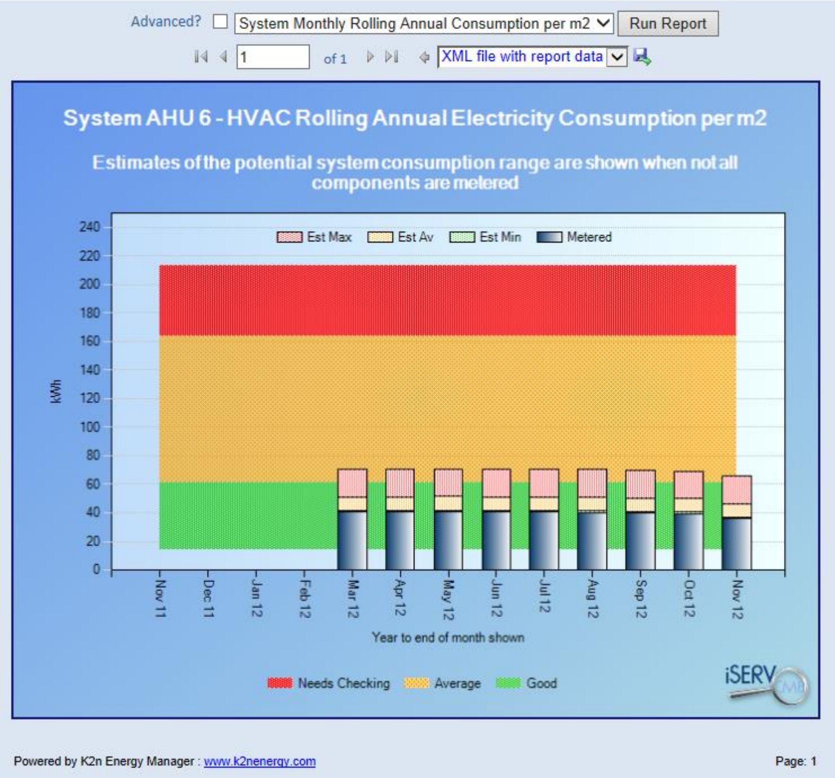
The next report is a power demand scatter graph. It enables high and low energy use to be quickly identified by day and time. This information is also used for producing benchmarks. The 1-5 numbers in the legend refer to Monday through to Friday.



8.8.4 Using Benchmarks for estimating consumption

The database uses K2n's proprietary benchmarks to cover those combinations of spaces, activities and components which are not available from the data collected by the iSERVcmb project.

The benchmark information allows us to estimate energy consumption at the system, component, space and activity level with only the building main incomer data available. This allows ISERVcmb to provide a top-down methodology for energy efficiency. This estimated consumption will provide building owners with an indication of where the utility consumption is most likely taking place in the building. The accuracy of these estimates can then be improved by sub-metering if desired.



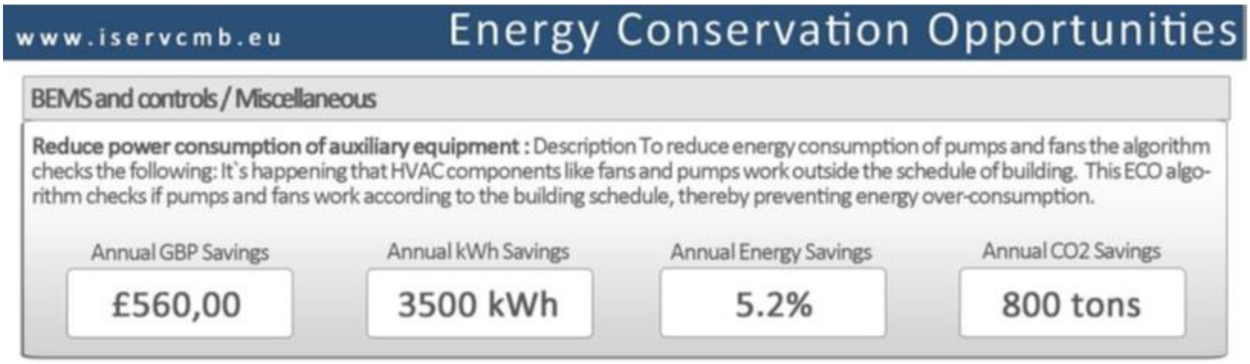
The report alongside shows a HVAC system with only partial metering of the HVAC components. The consumption data columns are broken into three parts. The blue section denotes the metered components. The yellow and pink sections denote estimates of the range of consumption for the non-metered components. The yellow section shows estimated average consumption whilst pink shows the estimated maximum consumption.

This report type can also be produced for HVAC System Components.

8.8.5 Energy Consumption Opportunities (ECOs)

There have been two specific work strands in the project looking at identifying ECOs from the building description and the metered data respectively. The algorithms and models for these ECOs are incorporated into the HERO reporting system to enable estimates of savings to be obtained and reported. The more meter and sensor data for a building being held in the iSERVcmb database the more ECOs will be activated.

The ECO reports are grouped together in a configured report which is produced automatically and emailed out to the end users. A single ECO report within a building is shown below.



www.iservcmb.eu

Energy Conservation Opportunities

BEMS 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	Annual kWh Savings	Annual Energy Savings	Annual CO2 Savings
£560,00	3500 kWh	5.2%	800 tons

8.9 PRODUCING BENCHMARKS FOR THE OPERATIONAL ENERGY USE OF HVAC COMPONENTS

The HERO database uses the metered data from the buildings and components in the system, in conjunction with the spaces and activities served, to generate updated benchmark figures on demand. This shows that the continual updating of benchmarks can be quickly and easily achieved by this process. This is an important part of achieving confidence in the end user of the ongoing relevance and reliability of the benchmarks they are using to make decisions on whether to invest or not.

Examples of the latest version of these benchmarks are presented later in this report.

8.10 FURTHER DETAILS

More detail of the HERO Database, underlying algorithms and iSERVcmb spreadsheet can be found at: www.iservcmb.info/results

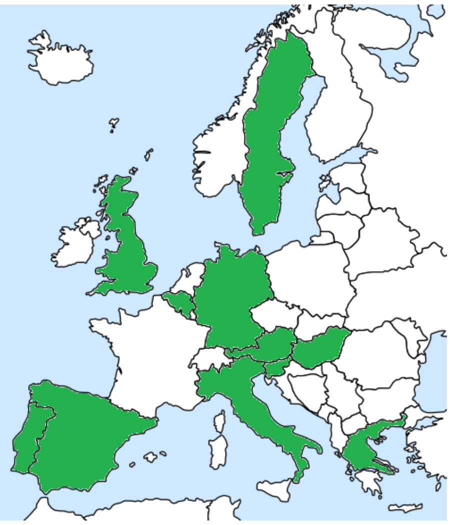
9 Measured energy consumption and power demands in European HVAC components

- Unique tables of measured power demands and energy consumptions in HVAC sub-components serving specified activity types across Europe are provided.
- Approach is possible to implement in any building across Europe with the appropriate metering

9.1 SOURCES OF DATA FOR THE ISERVCMB PROJECT

The project acquired data from 16 countries around Europe as shown in Figure 7. This section presents the insights gained during the project into the sources of data currently available. The information presented should be read with consideration of the fact that at the time the project began in May 2011, many European Member States were in the economic crisis that persists to this day. This had a major impact on the ability of many building owners to participate – particularly in those EU Member States with less developed metering infrastructures.

Despite this major hurdle, the project succeeded in reaching its initial goal of obtaining data from over 1600 HVAC systems throughout Europe. During this process the project reached a wide range of building owners, managers, associations and other actors across Europe. In total, more than 1750 entities from across the European MS were presented with the project objectives, from which approximately 15% delivered systems and data to the project.



Country	Systems
Austria	98
Belgium	32
Cyprus	2
Czech Republic	32
Germany	3
Greece	76
Hungary	94
Italy	60
Luxembourg	8
Poland	34
Portugal	1492
Slovenia	97
Spain	6
Sweden	58
United Kingdom	733

Figure 7 - EU distribution of iSERVcmb data sources

What was clear during the project is that there is great interest in the use of a tailored benchmark approach to understanding building and system energy use, with the main hurdle to participation being a lack of resources at that time for building operators, along with uncertainty about the longer term availability of the approach to make the effort of participating worthwhile.

The total number of buildings that attempted to participate was double the number that actually succeeded. This reveals there is a strong potential for more buildings to adopt the iSERVcmb methodologies for energy monitoring. The Partners collected the reasons provided for not entering the project. The most frequent ones are reported in Figure 8.

Not surprisingly, it appears that across Europe as a whole many buildings are not yet currently equipped for detailed monitoring. This can be seen in the combined share of 40% that covers the reasons linked to metering capabilities. From this, 19% of the cases were not monitored at the required level, probably having only the main incomer metered, and 21% didn't have recording capabilities for their meters.

The 29% of cases without time or resources might be able to adopt the iSERVcmb approach under better economic scenarios. If funding is available it is expected that all these cases could install the necessary metering devices to adopt the iSERVcmb methodology.

There was a small share, about 4%, of buildings which were well monitored but did not consider the iSERVcmb activities interesting for their needs.

From the data collected it seems reasonable to conclude that the existing building stock would require some investment in energy monitoring to be able to participate in an iSERVcmb type process. The costs of this investment would however be small in relation to the cost savings to be obtained and should be avoided completely in the near-future as manufacturers start to embed the required monitoring within their HVAC components.

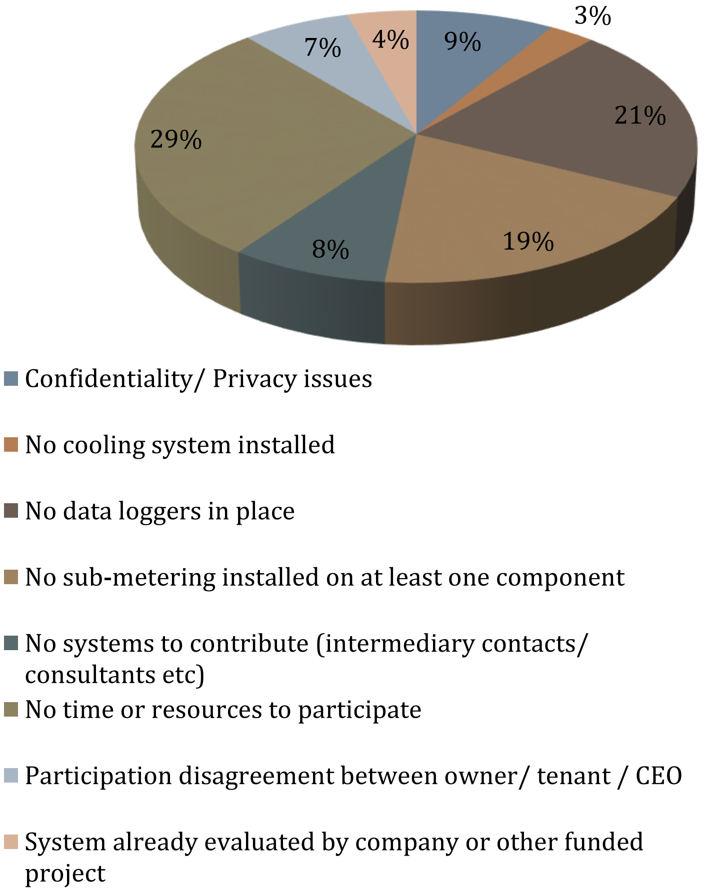


Figure 8 – Main reasons why people didn't participate in iSERVcmb

At the end of the project the iSERVcmb HERO database contained the following data:

Buildings	330
HVAC Systems	2,831
HVAC Components	7,685
Meters	2,230
Spaces	11,173
Activities	72
Total floor area m^2	1,551,638

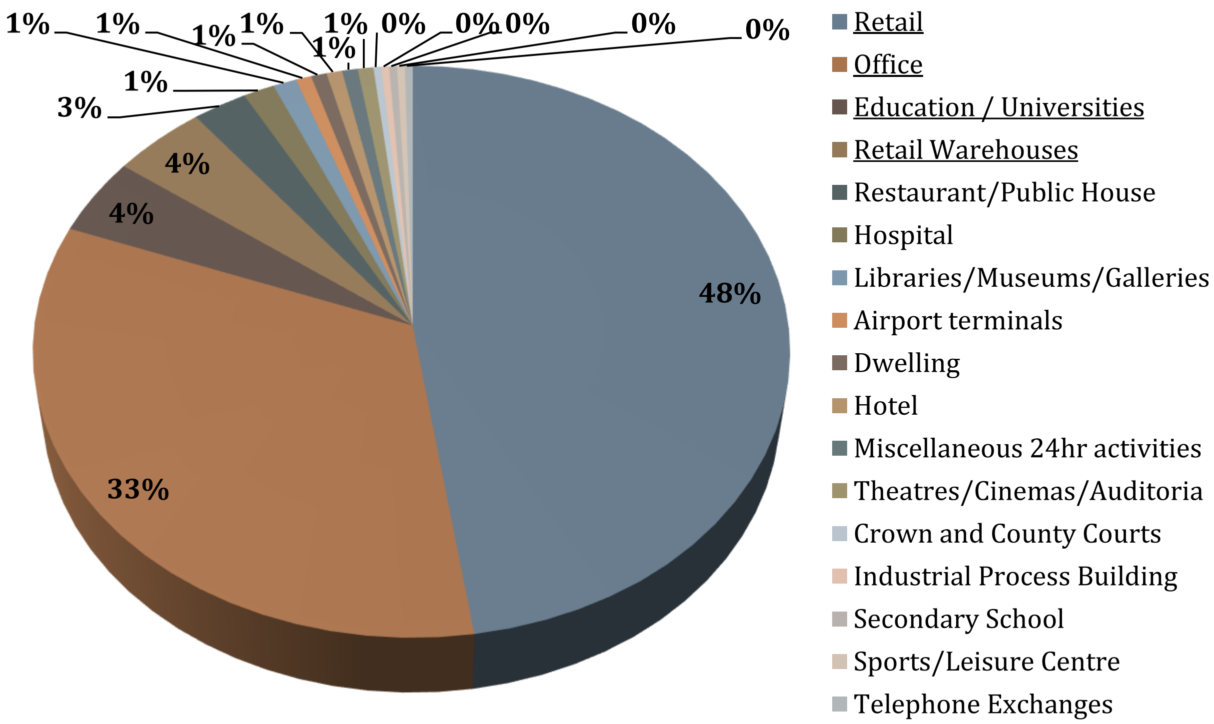


Figure 9 - Distribution of the database by primary sector of buildings monitored

Finally, Figure 9 shows that the data in the HERO database is dominated by Retail and Office Accommodation (81%).

9.2 BENCHMARKING ENERGY AND POWER DEMANDS IN BUILDINGS

9.2.1 Basis

As has already been shown in Figure 2, the basis of the iSERVcmb benchmarking methodology is that buildings are composed of spaces and activities, and that these are serviced by individual HVAC components assembled into HVAC systems. The approach therefore requires knowledge of the activities in a building, the floor area they occupy in m^2 by each individual space, and the HVAC components that service these spaces. Once these are known, then the energy used by each component is given by individual submeters or by apportioning the consumption recorded by each main utility incomer into a building based on the above parameters.

A significant advantage of such a system is that it can be used to produce tailored benchmarks for any combination of spaces, activities and HVAC systems i.e. it is independent of current building sector considerations. For example, an office space is considered to be the comparable with all other office spaces regardless of what building type or sector they exist within.

The benchmarking of HVAC component energy use also means that the HVAC energy use of serviced offices is automatically compared with similarly serviced offices, providing further confidence to the owner/operator that the tailored benchmarks are applicable to their specific situation.

9.2.2 Deriving a benchmark for an HVAC component serving a specific end use activity

A **practical** benchmarking system for the energy consumption of buildings, systems and components should be as simple as possible to enable clarity in what should be altered to improve a system's performance. The balance sought is to produce a system that is practical to implement for a wide range of end users whilst giving sufficient detail to enable opportunities to reduce energy use to be seen clearly. iSERVcmb already achieves this, and the absolute accuracy with which iSERVcmb can benchmark buildings and systems will gradually increase as more operational data is collected.

A guiding principle for iSERVcmb is that it must not discriminate against any approach to reducing operational energy use, so ALL energy consuming items must be recorded and included in HVAC systems e.g. the fans in terminal units in a building, which individually may not consume much energy but when aggregated together can be a significant and continuous load.

To demonstrate how such a system might work across the EU, iSERVcmb has adopted the approach of calculating the expected **ranges** of consumption or power demands by HVAC component when serving the end use activities and areas detailed in each iSERVcmb spreadsheet for a building.

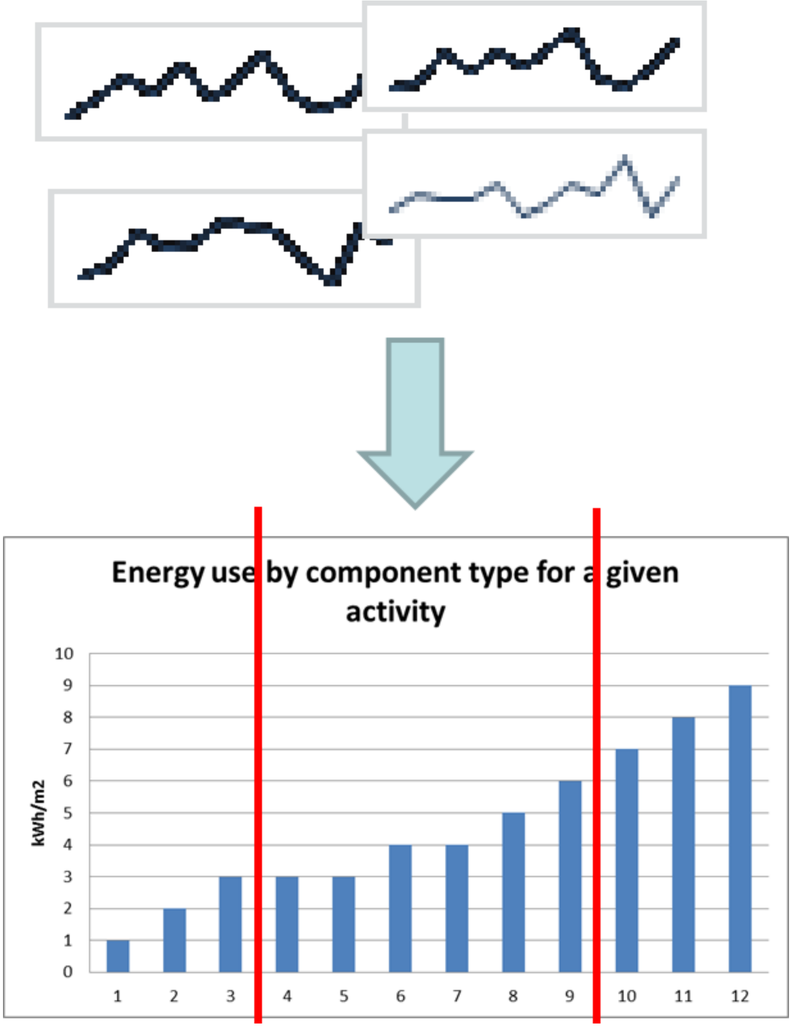


Figure 10 - Recorded meter data by activity and floor area produces ranges of measured consumption for each component type

Figure 10 shows how measured data at the level of individual components serving an activity in a specific space can be built up to produce a range of measured operational consumptions for the component related to an activity and area. This is the basis of the benchmarks used in iSERVcmb.

iSERVcmb has used the above approach to produce ranges of measured energy consumption and power demands from across Europe for many HVAC components servicing given end use activities.

The current nature of most buildings is that their sub-metering rarely serves only one component connected to one activity type. While this situation is gradually changing as more embedded intelligence is entering the market in various HVAC components, the project also used existing K2n benchmarks to help apportion the metered energy use of HVAC components between the activities they serve. This enabled the project to derive a first set of measured power demand and energy consumption ranges for HVAC components by activity.

Table 2 shows an example of this data for the measured electrical energy power demands for various HVAC components when serving the activity of a High Density IT Suite. This particular data covers the whole dataset produced from around Europe. There are tables showing the variation of these ranges by country in the wider data tables produced by the project. These can be found at www.iservcmb.info/results under the “Power and Energy Benchmarks” folder.

Table 2 – Example measured electricity power demand ranges by HVAC component for a specified end use activity

Electricity : IT: High Density IT Suite - Average, Max and Min Power Demand in W/m² by Component Type and Activity																		
	Air Handling Units	SD	All in One Systems	SD	Cold Generators	SD	Heat Generators	SD	Heat Pump	SD	Heat Recovery	SD	Heat Rejection	SD	Pumps	SD	Terminal Units	SD
Average	5.8	3.7	17.6		16.7	13.4	0.1	0.2	4.2	-	0.2		0.1	0.1	8.1	12.1	1.6	
Maximum	16.1	10.2	62.4		119.4	89.8	0.2	0.5	15.1	-	0.6		1.1	1.8	19.7	28.8	7.5	
Minimum	0.5	0.6	2.3		1.4	3.3	0.0	0.0	0.0	-	0.0		0.0	0.0	0.4	0.6	0.1	
Sample Size	22		1		16		19		4		1		6		40		1	

9.2.3 Measured Operational Electrical Power Demands/m² by HVAC component and activity

This section considers the analysed measured data in terms of power demands per unit area serviced. As with the energy consumption figures later, data is received directly from the end users and is reliant on them describing their buildings, metering and systems correctly.

However, as this is using metered data from operational buildings, there are also built-in safeguards to ensure that major errors do not enter the final analysis. These safeguards exist in being able to look at the statistical sample for each component and the database as a whole to identify clearly unusual behavioural patterns for each data stream. This has been used to identify and amend errors in meter connections, data units, floor areas, HVAC system descriptions, etc. The data is therefore believed to be reasonably robust. However, this data is currently provided for information purposes only and no guarantee is made or implied as to its accuracy. In particular, many benchmarks will evolve and change over time as more data becomes available and operational practices for buildings change.

It is important to note that this work is trying to establish a fully evidence-based underpinning to benchmarks so is not allowing 'expectations' of performance to affect the publishing of what has been measured using this approach.

Table 3 shows the measured Average and Standard Deviation Electrical power demands in W/m² found by HVAC component type, serving the Activity types shown, across the entire iSERVcmb dataset for Europe. The presence of 2 decimal places in the figures is not intended to convey accuracy but to allow comparison across all component types, some of which have the second decimal place as a significant figure.

The data shows that measuring power demands in operational buildings at this level of detail is possible and reveals interesting variations in these figures which should help building owner and operators better understand their HVAC systems and their interaction with their activities. The data also helps start an evidence-based debate on how much power it is reasonable for an HVAC component and an activity to consume once the use of the building spaces is known. It can be seen that there are still gaps in the data where specific instances of HVAC component and activity did not exist in the iSERVcmb data. The sample sizes are also provided.

It is important to note that Table 3 is a summary table of all the sub-components for each HVAC component type. Therefore there will appear to be some unusual average figures. The underlying data for these figures can be found, by EU Member State, in the "Power and Energy Benchmarks" folder at www.iservcmb.info/results. From these tables it is possible to start exploring power demand benchmarks for specific HVAC system configurations serving specific end use activity mixes.

Table 3 - iSERVcmb Measured Average Electricity Power Demands/m^2 by HVAC Component and Activity Type for the EU as a whole

Electricity - Average Power Demand and Standard Deviation in W/m^2 by Component Type and Activity

Activity Name	Meter Type	Sample Size	Air Handling Units		All in One Systems		Cold Generators		Dehumidification		Heat Generators		Heat Pump		Heat Recovery		Heat Rejection		Pumps		Terminal Units	
			AVG W/m2	SD	AVG W/m2	SD	AVG W/m2	SD	AVG W/m2	SD	AVG W/m2	SD	AVG W/m2	SD	AVG W/m2	SD	AVG W/m2	SD	AVG W/m2	SD	AVG W/m2	SD
Assembly areas / halls	Electricity	23	2.37	3.55			0.43	0.46			0.00	0.00	3.23		0.04	0.00	0.01	0.00	1.92	3.74		
Bathroom	Electricity	6	0.55	0.38			3.92															
Bedroom	Electricity	24	6.79	0.83			7.53	6.31														
Catering: Bars	Electricity	11	3.75	1.03			9.63				1.71	0.33							3.66	1.69		
Catering: Eating/drinking area	Electricity	102	4.21	6.42	0.02		5.45	7.80			0.11	0.42	3.36	0.91	0.16		3.03	7.39	0.53	0.78	0.71	1.87
Catering: Full Kitchen Preparing Hot Meals	Electricity	139	13.54	22.14	9.10	1.19	19.97	40.76			0.33	0.78			0.04	0.00	0.05	0.00	0.68	1.04		
Catering: Kitchenette (small appliances, fridge and sink)	Electricity	38	18.47	47.76			1.07	2.72			0.25	0.51	0.77	-	0.16		0.01	-	0.44	0.55		
Catering: Limited Hot Food Preparation Area	Electricity	99	7.81	7.72	10.62	2.79	5.64	5.13			2.93	10.91	3.23				0.01	0.00	0.79	0.87	0.06	0.10
Catering: Snack Bar with Chilled Cabinets	Electricity	39	6.13	5.88	10.62	2.78	1.48	1.00			0.20	0.27	3.75	1.58			0.02	0.00	0.45	0.34	0.23	0.81
Catering: Vending Machines	Electricity	15	2.36	2.79			1.23	1.49			0.00	-					0.02	0.00	0.75	0.51	0.14	-
Cellular Office Area	Electricity	237	1.55	3.27			4.64	4.78	0.01		0.29	0.61	8.58	33.96	0.16	0.00	0.02	0.04	0.28	0.53	29.53	105.79
Cellular Office Area - multiple occupation	Electricity	119	5.79	8.07	9.10	1.19	2.40	2.34			0.20	0.27	1.07	0.53			5.61	7.04	0.26	0.40	0.31	0.02
Circulation area (corridors and stairways)	Electricity	453	1.60	4.01	0.76	-	3.45	5.51	0.01		0.06	0.15	2.81	1.23	0.16	0.00	1.00	2.60	0.51	0.75	0.29	1.21
Consulting/treatment room	Electricity	90	2.06	1.57			4.97	4.69			0.03	0.03	0.95	-			1.41	2.80	0.56	0.66	1.82	5.03
Dept Store Sales area - chilled	Electricity	43	6.58	5.56			13.59	9.51														
Dept Store Sales area - general	Electricity	199	4.34	4.76	9.16	6.18	4.36	3.32					1.40	1.72			0.83	0.98	1.44	0.99	0.52	0.81
Diagnostic Imaging	Electricity	21	13.06	14.55			4.92	3.06			0.06	-	5.65	-					3.44	1.55	2.37	
Exhibition rooms, museum	Electricity	20	8.59	2.34			1.44	1.26			0.50	-					0.05		0.19	0.16		
Generic Checkin areas	Electricity	37	0.32	0.66			6.56	8.01			1.91		1.17	0.91			0.03		0.07	0.07		
Generic Ward	Electricity	8	16.10	26.23			8.85	9.28			6.90	1.74										
Heavy Plant Room	Electricity	5	0.17	0.13			0.02	0.00														
Industrial process area	Electricity	17	0.51																			
IT: High Density IT Suite	Electricity	39	5.78	3.65	17.55		16.74	13.38			0.07	0.16	4.21	-	0.16		0.05	0.09	8.13	12.09	1.65	
IT: LAN Rooms	Electricity	41	3.28	6.19	4.65		100.84	196.37			0.06	0.15			0.16		0.56	0.48	7.57	11.64	2.37	1.15
IT: Server Room	Electricity	112	5.44	9.37	53.66	49.38	175.82	221.49			0.07	0.13	0.50	0.20			4.11	12.10	23.94	41.39	6.01	11.36
Laboratory	Electricity	87	33.50	33.20			21.54	34.04			0.13	0.21	6.78	10.76			0.11		1.16	1.71	29.39	103.39
Laboratory - Sterile	Electricity	2	5.83																1.48	-		
Laboratory with fume cupboards	Electricity	16	37.05	27.92			7.66	1.32					1.15	-			0.13	0.03	0.71	0.62		
Laundry	Electricity	22	16.76	15.85							0.01	-										
Lecture theatre	Electricity	56	17.58	19.99			2.88	5.17			0.25	0.38					0.08	0.13	12.18	30.69	3.80	-
Library - open stacks	Electricity	19	0.97	0.58			0.20	0.24			0.12	0.22	6.64	4.75	0.16	-	0.02	0.00	0.42	0.91		
Library - reading room	Electricity	20	5.06	3.63			3.81	7.15			0.17	0.26	6.13	5.47	0.16				0.27	0.25		
Library - stacks and storeroom	Electricity	12	6.74	14.08			0.24	0.44	0.01	0.00	0.00	0.00			0.16		0.06	0.07	0.12	0.30		
Lifts	Electricity	46	0.79	0.50			0.42	0.31			0.10	0.20			0.16		0.00	0.00	0.81	0.93		
Light Plant Room	Electricity	128	1.61	4.61			0.06	0.13							0.16	0.00	0.00	0.00	0.18	0.07		
Lounges	Electricity	52	4.67	6.61			8.11	13.52			0.00	0.00	3.23				0.01	-	0.69	0.80	1.54	0.62
Meeting Room	Electricity	95	5.74	7.40	18.98	12.92	6.76	13.04			0.27	0.54	3.19	2.90	0.16		0.89	2.23	0.79	1.34	7.64	14.09
Multi-storey car parks (office and private use)	Electricity	17	0.01	0.00																		
Nursery	Electricity	25	1.67	1.88			12.67												1.05	0.30	3.14	0.05
Open Plan Office Area	Electricity	298	4.90	12.41	7.95	1.58	5.81	7.72			0.03	0.08	6.02	5.67	0.04	0.00	2.79	3.91	0.71	0.95	0.95	5.75
Operating Theatre	Electricity	29	20.48	9.69			7.57	0.10														
Physiotherapy Studio	Electricity	4	2.99				13.73	0.17														
Post Mortem Facility	Electricity	3					7.57	0.10														
Reception	Electricity	95	0.80	1.49	0.53	-	1.87	2.13			0.11	0.21	1.86	1.70			0.51	1.29	0.44	0.78	1.66	4.31
Recreational : Changing facilities with showers	Electricity	69	11.61	18.93							0.02	0.02	13.08	-					0.37	0.33	0.64	-
Recreational : Fitness Studio	Electricity	3	2.48	1.43	28.06		2.30	1.39			0.00	-					0.01	-	0.09	0.08		
Recreational : Fitness Suite/Gym	Electricity	7	8.24	13.69	28.06		1.73	1.59			0.00	0.00			0.04	0.00	0.01	0.00	0.21	0.32		
Recreational : Recreational Pool	Electricity	1									39.28											
Recreational : Sports ground changing rooms	Electricity	10	11.85	12.35	39.32						0.01	0.02							0.49	0.62	1.88	5.27
Retail Warehouse Sales area - chilled	Electricity	21	4.30	11.32			3.35	0.44											2.17	2.24	0.76	0.10
Retail Warehouse Sales area - electrical	Electricity	9	1.49	2.03																		
Retail Warehouse Sales area - general	Electricity	82	1.37	2.49	11.40	15.55	2.10	2.29			0.04	0.05	0.54	-			0.31	0.13	3.50	4.29	0.76	0.82
Small Shop Unit Sales area - chilled	Electricity	14	0.81	0.63			0.89	0.89									0.13		0.51	0.52	2.17	
Small Shop Unit Sales area - electrical	Electricity	2	4.40	-			6.52															
Small Shop Unit Sales area - general	Electricity	84	1.95	1.37	9.95	2.21	8.38	8.55					6.65	10.04			0.92	-	0.91	1.41	9.67	5.79
Spectator area (theatres and event buildings)	Electricity	3	5.84				2.74	1.19											1.20	0.89	6.74	
Stage (theatres and event buildings)	Electricity	14	2.23	0.91			9.16	12.70									0.02		0.71	0.46		
Storage Area/Cupboard	Electricity	236	2.99	6.38			0.87	1.21			0.11	0.28	2.11	1.79	0.16	0.00	0.18	0.44	1.41	4.82	3.16	10.55
Teaching Areas	Electricity	85	3.58	4.24			0.97	0.95			0.09	0.18			0.16				0.52	0.63		
Toilet	Electricity	340	2.19	5.87	7.61	1.93	0.79	1.11			0.10	0.22	1.51	0.96	0.16	0.00	0.02	0.03	0.38	0.60	10.39	
Unoccupied space	Electricity	24	0.40	0.54			0.68	0.33			0.01	-							0.39	0.40		
Waiting Rooms	Electricity	14	2.39	1.93			2.81	6.23			0.01	0.00					0.01	-	0.31	0.43		
Warehouse storage	Electricity	94	1.06	1.05			1.21	1.23									1.57	2.17			0.31	0.02
Workshop	Electricity	40	44.09	39.92			5.07				0.13	0.21	1.35	-					0.02		1.18	

9.2.4 Measured Operational Annual Electrical Energy Consumption/m^2 by HVAC component and activity

This section considers the analysed measured electrical data in terms of annual energy consumption. As with the power demand figures shown in section 9.2.3, data is received directly from the end users and is reliant on them describing their buildings, metering and systems correctly. The same discussion for the power demands accuracy applies to the energy consumption benchmarks.

Table 4 shows the measured Average and Standard Deviation in Annual Electrical Energy Consumption in kWh/m^2 found by HVAC component type, serving the Activity types shown, across the entire iSERVcmb dataset for Europe. Again, the presence of 2 decimal places is not intended to convey accuracy but to allow comparison across all component types.

The data shows that measuring energy consumption in operational buildings at this level of detail is possible. It can also be seen that there are fewer annual energy consumption figures by activity than there are power demands figures in the previous table. This is because power demand figures can be quickly obtained from very little consumption data, allowing incomplete data sets to still provide useful information on the operational performance of buildings.

This is an important point to note when we consider how we should benchmark the operational energy consumption of buildings and systems, as power demands are a more immediate indicator of the efficiency of some installed components, such as pumps, and could contribute to improving the value of spot checks of these components, e.g. such as those undertaken during an Inspection.

The figures presented in this table are NOT the benchmarks used during iSERVcmb, as they are still to be fully studied and any anomalies either explained or corrected.

It is also important to note that Table 4 is a summary table of all the sub-components for each HVAC component type. Therefore there will appear to be some unusual average figures. The underlying data for these figures can be found, by EU Member State, in in the "Power and Energy Benchmarks" folder at www.iservcmb.info/results. It is usually simple to understand from these more detailed figures where the data is statistically robust and how large variations can appear in energy use between sub-components of the same HVAC component type. For example, the 'heat generator' HVAC component type encompasses direct electric heating as well as just the electricity use for the forced draught fan in a gas-fired boiler. This is why the exact HVAC sub-component type is important to understand when producing benchmarks of expected performance for a system and component.

Table 4 - iSERVcmb Measured Average Annual Energy Consumption/m^2 by HVAC Component and Activity Type for the EU as a whole

Electricity - Average Annual Energy Consumption and Standard Deviation in kWh/m2/Year by Component Type and Activity

		Air Handling Units		All in One Systems		Cold Generators		Heat Generators		Heat Pump		Heat Recovery		Heat Rejection		Pumps		Terminal Units	
Activity Name	**Meter Type**	**AVG kWh/m2/Year**	**SD**	**AVG kWh/m2/Year**	**SD**	**AVG kWh/m2/Year**	**SD**	**AVG kWh/m2/Year**	**SD**	**AVG kWh/m2/Year**	**SD**	**AVG kWh/m2/Year**	**SD**	**AVG kWh/m2/Year**	**SD**	**AVG kWh/m2/Year**	**SD**	**AVG kWh/m2/Year**	**SD**
Assembly areas / halls	Electricity	56.16	92.81			0.16	0.21	2.36	3.21	21.44		0.33	0.00	0.03	0.02	41.66	124.11		
Bathroom	Electricity	4.91	4.35																
Bedroom	Electricity	17.07	16.40																
Catering: Bars	Electricity	34.69	1.38			66.06		150.13	236.48							28.62	12.78		
Catering: Eating/drinking area	Electricity	17.86	19.65			45.08	48.78	1.70	4.52	26.32	4.02	1.32		0.07	0.04	5.59	17.61	4.65	4.42
Catering: Full Kitchen Preparing Hot Meals	Electricity	176.08	278.18			265.39	528.40	6.36	10.76			0.33	0.00			9.78	13.78		
Catering: Kitchenette (small appliances, fridge and sink)	Electricity	18.88	19.08			3.43	5.27	1.58	2.54	6.45	0.00	1.31				1.78	3.62		
Catering: Limited Hot Food Preparation Area	Electricity	68.90	48.67	63.93	28.17	1.17	0.74	0.84	2.04	21.43				0.06	0.04	16.20	40.19		
Catering: Snack Bar with Chilled Cabinets	Electricity	39.83	27.84	63.93	28.17	0.43	0.27	0.82	1.08	28.64	6.00			0.06	0.04	8.04	28.80	14.11	14.00
Catering: Vending Machines	Electricity	26.03	26.09			8.40	13.80	0.03	0.00					0.06	0.04	15.96	34.00		
Cellular Office Area	Electricity	10.87	30.61			32.95	34.49	2.23	4.61	48.18	139.95	1.31	0.00	0.35	0.54	5.33	16.70	24.00	25.68
Cellular Office Area - multiple occupation	Electricity	25.83	47.37			3.95	4.69	2.26	2.63	18.26	22.33			0.13	0.15	5.61	14.48	5.08	1.51
Circulation area (corridors and stairways)	Electricity	11.62	24.32			15.98	39.46	23.18	96.86	21.71	6.78	1.31	0.00	0.05	0.08	3.02	10.46	6.03	4.71
Consulting/treatment room	Electricity	6.13	2.41			26.83	36.68	0.56	0.00	7.94	0.00					14.81	0.00	18.55	23.27
Dept Store Sales area - chilled	Electricity	55.97	31.00			29.83													
Dept Store Sales area - general	Electricity	35.39	32.35	44.79	22.49	73.25				12.80	35.84			17.45	0.00			3.97	7.02
Diagnostic Imaging	Electricity	102.76	139.06			19.88	0.00	0.56	0.00	46.94	0.00					41.34	0.00	4.19	
Escalators	Electricity	2.53	1.26			1.11													
Exhibition rooms, museum	Electricity	5.36	0.58			1.75	0.00	2.00	0.00					0.31		0.22	0.14		
Generic Checkin areas	Electricity	14.45				37.14	35.93	18.78						0.20		0.70	0.54		
Generic Ward	Electricity	18.69	7.23					36.21											
Hotel room	Electricity					19.11	0.00												
IT: High Density IT Suite	Electricity	58.41	111.67	149.73		98.83	138.23	0.98	1.90	35.01	0.00	1.32		0.92	1.43	138.41	341.20	8.42	0.00
IT: LAN Rooms	Electricity	19.64	57.44			40.75	33.78	0.87	1.87	41.20		1.31		6.64	4.90	181.26	378.84	22.04	9.11
IT: Server Room	Electricity	10.20	15.22	775.45	349.79	791.85	1041.47	1.99	3.01					6.66	6.94	210.31	515.64	28.93	18.57
Laboratory	Electricity	56.94	131.33			22.52	24.68	0.60	0.82	41.51	56.15			0.40		8.59	15.37	30.46	11.35
Laboratory - Sterile	Electricity	19.14																	
Laboratory with fume cupboards	Electricity	167.77	271.91			16.20	0.00			9.54	0.00			0.40	0.00	1.83	1.28	6.83	
Laundry	Electricity	87.50	74.54					0.06	0.00										
Lecture theatre	Electricity	159.14	191.47			21.74	26.86	2.42	3.94					2.89		144.57	345.78	13.01	9.67
Library - open stacks	Electricity	4.66	4.25			0.41	0.21	0.48	0.87	22.66		1.32	0.00	0.08	0.05	10.52	34.10	4.21	
Library - reading room	Electricity	48.59	37.68			0.41		0.69	1.02			1.32				2.06	1.91		
Library - stacks and storeroom	Electricity	5.77	3.35			0.72	0.98	0.02	0.01			1.31		0.25	0.29	2.60	10.61	6.83	
Lifts	Electricity	2.71	1.38			0.28		0.65	0.86			1.31				8.81	9.31		
Light Plant Room	Electricity	11.03	17.76			0.73	1.53					1.31	0.00	0.01	0.01				
Lounges	Electricity	39.54	58.64			127.55	135.65			21.44						6.70	5.65	15.68	0.00
Meeting Room	Electricity	20.59	27.66	64.21	26.45	18.95	28.23	1.71	2.75	23.44	16.88	1.32		0.24	0.24	10.09	22.59	8.71	5.51
Multi-storey car parks (office and private use)	Electricity	0.20	0.16																
Nursery	Electricity	2.39	2.02			86.92										8.21	2.26		
Open Plan Office Area	Electricity	20.66	30.42	47.10	14.11	37.01	69.87	0.04	0.02	47.79	34.91	0.33	0.00	2.91	4.37	4.24	14.36	5.26	8.78
Operating Theatre	Electricity	7.78	11.25																
Physiotherapy Studio	Electricity	4.86																	
Reception	Electricity	2.64	3.00			4.33	6.08	44.00	133.23	16.64	11.61			0.03	0.02	8.74	23.72	8.26	10.07
Recreational : Changing facilities with showers	Electricity	38.51	12.45					0.20	0.24	108.84	0.00					5.14	2.89		
Recreational : Fitness Studio	Electricity	20.48	1.47													0.39	0.38		
Recreational : Fitness Suite/Gym	Electricity	83.23	128.79			0.02	0.00					0.33	0.00			2.72	3.57		
Recreational : Recreational Pool	Electricity							386.37											
Recreational : Sports ground changing rooms	Electricity	41.93	46.35					0.15	0.21							11.00	23.14	35.01	
Retail Warehouse Sales area - chilled	Electricity	282.20																	
Retail Warehouse Sales area - general	Electricity	12.03	33.44	38.84	2.04			0.49	0.84					1.91		52.53	69.60	4.73	2.50
Small Shop Unit Sales area - chilled	Electricity	6.46	5.69			4.90	2.72							0.55		3.33	3.10	9.08	
Small Shop Unit Sales area - general	Electricity	16.36	11.67	54.71	11.54	39.79	58.15	5.88	0.00	81.70	102.76					6.08	9.19	26.42	
Spectator area (theatres and event buildings)	Electricity	73.02														22.28	0.00		
Stage (theatres and event buildings)	Electricity	17.29	7.06			62.02	87.81							0.14		5.47	3.60		
Storage Area/Cupboard	Electricity	17.74	19.79			1.46	2.01	22.53	94.33	16.48	11.89	1.31	0.00	0.01	0.01	26.97	64.29	15.02	21.49
Teaching Areas	Electricity	12.22	21.88			5.24	4.80	0.43	0.73			1.31				4.56	5.83	84.25	0.00
Toilet	Electricity	14.89	21.25	45.04	16.59	3.33	8.57	20.42	89.98	11.49	5.56	1.31	0.00	0.12	0.15	2.70	10.12	47.57	57.61
Unoccupied space	Electricity	3.86	4.38					0.06	0.00							2.48	2.36		
Waiting Rooms	Electricity	9.61	1.75			1.14		0.06	0.00							6.11	4.60	84.25	0.00
Warehouse storage	Electricity	5.61	5.15			12.03	15.13												
Workshop	Electricity	278.63	310.89			17.61	24.26	0.60	0.82	11.24	0.00					0.12		3.15	1.50

9.3 THE ENERGY AND POWER BENCHMARKING OF HVAC COMPONENTS AND SYSTEMS

From the previous sections it can be seen that iSERVcmb has produced data on the operational HVAC component energy use when servicing end use activities at the level of:

- Annual kWh/m^2
- Power W/m^2

Whilst not possible during the project, it also appears that monthly energy consumption benchmarks are possible. These will be explored post-iSERVcmb for both practicality and value within an energy management context.

9.3.1 Assembling a benchmark for a building or system

Once we have the benchmark consumption ranges for an HVAC component servicing a given end use activity we can then use this information to assemble benchmark **ranges** for buildings and their HVAC systems.

As an initial method, iSERVcmb adds together the individual energy consumption or power demand **ranges** expected for **each** HVAC sub-component type in a system, when serving the stated mixture of end use activities.

The expected consumption or power demand **ranges** of an HVAC system comprised of a number of sub-components are the arithmetic sum of the benchmark consumption **ranges** for each of these sub-components when serving the specified end use activities.

Note that SYSTEM benchmark **ranges** are assembled from the benchmarks for the SUB-COMPONENTS used in the system, this prevents apparent ‘good’ performance being achieved by just moving energy use to other sub-components e.g. reduction in Chiller energy use might be achieved by increased energy use in CHW pumps using ‘free’ cooling.

The example shows the calculation of a value at just the average point in a range. iSERVcmb calculates these values at points across the ranges for each combination of system sub-components, activities and spaces to arrive at the final ranges of expected performance for each given combination.

Example average benchmark calculation

A heating system serving radiators is comprised of a gas fired heat generator and secondary hot water pump. If the system serves 20 m^2 of corridor space and 80 m^2 of cellular office space then its **average** benchmark ELECTRICAL annual energy use, taken from the sub-component data in the “Power and Energy Benchmarks” folder on the project website, is:

Heat generator (corridor) – 0.96 kWh/m^2

Pumps (corridor) – 5.1 kWh/m^2

Heat generator (offices) – 0.96 kWh/m^2

Pumps (offices) – 14.1 kWh/m^2

Therefore the corridors would be expected to have an average annual energy consumption in total of 6.1 kWh/m^2 and the offices to have an average annual energy consumption in total of 15.1 kWh/m^2.

Given the 80:20 floor area ratio we would therefore expect the average overall electrical annual energy use for this type of HVAC system servicing these activities in Europe to be:

= (0.8 x 15.1) + (0.2 x 6.1) = **13.3 kWh/m^2**

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10 Energy conservation opportunities in European HVAC components

For the ECO's from measured data:

- Most frequent ECO's identified from analysing the measured data are night time ventilation; change filters; switch off pumps when not required
- ECO's can be used to automatically interpret measured data and identify savings
- Savings from ECO's identified from the data in HERO range from 2 – 40% in nearly all systems on HERO, with a mean predicted saving of 15%

For the modelled ECO's:

- Replacing lighting equipment by low consumption type has the largest predicted impact on electricity savings at the building level
- Reducing solar gains (e.g. window film or tinted glass) has the highest predicted potential for electricity savings at HVAC system level
- Lack of available data, especially nominal power rating of components, limits the occurrence of some ECOs calculations

Conclusions:

- For various reasons noted earlier in this report, the ECOs were produced too late in the project to be able to quantify their impact on operational energy use. However, it has been seen from other interventions in HARMONAC and iSERVcmb that where savings are quantified then almost invariably the end user will attempt to realise them. We therefore anticipate that most of the savings shown will at least be explored for financial feasibility.
- The predicted savings potential across all the systems, based on the iSERVcmb database benchmarks, and the predicted savings from the measured and modelled ECO's approaches broadly agree with each other. This suggests that using the iSERVcmb approach can identify energy savings potentials properly, and that the ECOs can help more accurately pinpoint where to make some of these savings.

10.1 ENERGY CONSERVATION OPPORTUNITIES (ECOS) FROM MEASURED DATA

As identified in AUDITAC and HARMONAC, an ECO is an Energy Conservation Opportunity that exists for a Heating, Ventilation or Air Conditioning (HVAC) system – specifically AC systems in HARMONAC. HARMONAC found that current AC Inspection procedures would identify less than 40% of the potential savings available in many AC systems.

The iSERVcmb project has taken the ECOs identified in HARMONAC and, where possible, looked at their automatic identification along with analysis of the possibility for implementation and evaluation of system specific potential savings from the data collected, via HERO. The benefits of implementing the ECO algorithms into HERO are as follows:

- Many significant Energy Conservation Opportunities (ECOs) are possible to identify automatically using long-term monitored data for specific HVAC components.

- Easy route to informing the end-user via an automatically generated online report showing which ECO`s were identified and the potential savings to be obtained by rectifying them.
- Significant energy savings are shown to be possible from providing the end user with these details.
- ECO's are predicted for nearly all of the 2800 systems in the HERO database

From the work on ECO's within iSERVcmb, Table 5 shows the predicted average saving to be achieved; the frequency of occurrence of the opportunity within the iSERVcmb dataset; and the product of these two parameters as an indication of the most promising routes for reducing energy use in practice.

It can be seen that the most rewarding ECO would be to perform night time ventilation to aid pre-cooling of a building before the following day. This ECO is obviously dependent on a number of practical factors but does start to offer additional options to end users based on their geographic location.

Six out of the top eight ECO's based on frequency of occurrence and predicted savings are operational ECO's – showing the importance of control and understanding of the HVAC systems in achieving energy reductions. The savings are not additive as improving the control of existing equipment reduces the opportunity for energy savings from improving system efficiency.

Figure 11 shows that that the predicted potential ranges of total energy savings available lie between 2 to 40%, with a mean of 15% predicted - which corresponds to the size of savings being found in practice before we consider lighting and small power energy reductions too.

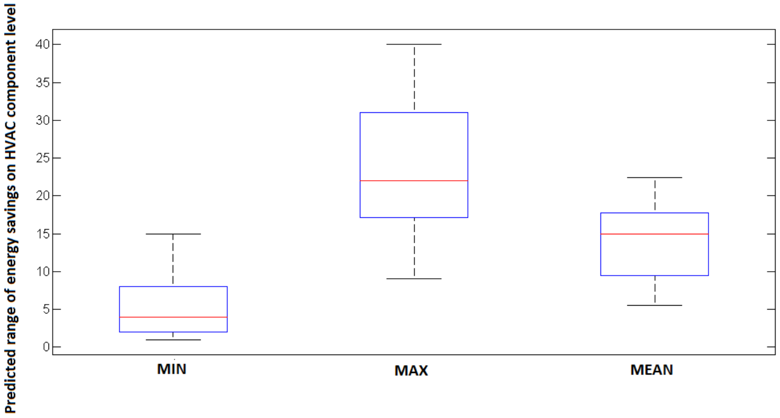

Figure 11 - Predicted range of energy savings from HERO operational data

Table 5 - List of ECO`s implemented in HERO with predicted savings and frequency of occurrence from HERO data:

ECO		Predicted average % saving at system level	Occurrence Frequency %	Saving x Occurrence = Average saving (%)
O4.2	Perform night time ventilation	15	62	9.3
O4.14	Clean or replace filters regularly	8	74	5.9
O4.19	Switch off circulation pumps when not required	7	79	5.5
P3.1	Reduce motor size (fan power) when oversized	12	41	4.9
O2.3	Shut off auxiliaries when not required	8	48	3.8
O2.7	Sequence heating and cooling	15	25	3.8
P1.7	Reduce power consumption of auxiliary equipment	5	72	3.6
O3.1	Shut chiller plant off when not required	6	55	3.3

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ECO		Predicted average % saving at system level	Occurrence Frequency %	Saving x Occurrence = Average saving (%)
P2.13	Consider cool storage applications (chilled water, water:ice, other phase change)	8	37	3.0
P1.3	Modify controls in order to sequence heating and cooling	4	68	2.7
P2.6	Replace or upgrade cooling equipment and heat pump	4	67	2.7
O2.2	Shut off A/C equipment when not needed	12	22	2.6
O3.14	Check (reversible) chiller stand-by losses	6	40	2.4
P2.2	Reduce compressor power or fit a smaller compressor	8	28	2.2
P1.1	Install BEMS system	7	27	1.9
P2.5	Improve central chiller / refrigeration control	5	35	1.8
O3.3	Operate chillers or compressors in series or parallel	4	18	0.7
P2.3	Split the load among various chillers	3	16	0.5
P2.4	Repipe chillers or compressors in series or parallel to optimize circuiting	2	1	0

10.1.1 Integration of ECO algorithms With the HERO Database

- Each ECO shown in the table above has a detailed description and flowchart available in the “Energy Conservation Opportunities” folder under the following link – www.iservcmb.info/results - along with information on a number of other ECO’s that have yet to be integrated with the database.
- The basic schematic showing how an ECO report is generated from HERO is shown in Figure 12. These reports can be generated automatically on entry of the data to the system or on request by the user. The database also allows the generation of a cost estimate based on a simple estimation of the cost of a unit of electricity.

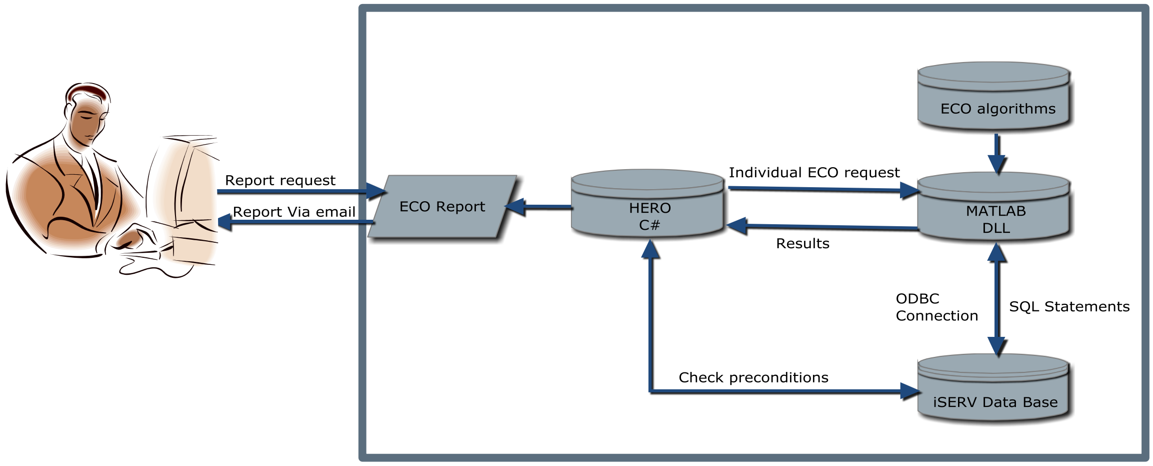

Figure 12 - Schematic of ECO generation process within HERO

10.2 ENERGY CONSERVATION OPPORTUNITIES FROM MODELLING

- These model generated ECO's supplement those derived from the metered data profile analysis in the previous section. Detailed modelling of Energy Conservation Opportunities (ECOs) in operational buildings would normally need precise data for accurate modelling. The models developed within the iSERVcmb project take an opposite approach by aiming to identify and quantify relevant savings opportunities based on minimum data availability – the situation most likely to exist in practice.
- The objective is to be able to identify opportunities for optimization of HVAC system or building operation, while avoiding major expense which do not deliver the required paybacks (e.g. fabric change or major HVAC system change). iSERVcmb ECOs are a logical evolution from benchmarking and energy metering visualization, as they use this data within models to propose measures to reduce energy use.
- The final list of the modelled ECOs implemented in HERO is shown in Table 6. The ECO numbers correspond to the HARMONAC ECO numbering and the full list of ECOs studies available under the "Energy Conservation Opportunities" folder at www.iservcmb.info/results.

Table 6 - Final list of 13 modelled ECOs implemented in HERO

ECO O2.2 - Shut off AC equipment when not needed
ECO O2.3 - Shut off auxiliaries when not required
ECO E1.1 - Install window film or tinted glass
ECO O3.1 - Shut off chiller plant when not required
ECO E4.6 - Replace lighting equipment with low consumption type
ECO E4.5 - Replace electrical equipment with energy star or low consumption types
ECO P2.6 - Replace or upgrade cooling equipment and heat pump
ECO O4.19 - Switch off circulation pumps when not required
ECO O2.7 - Sequence central heating and cooling
ECO E2.4 - Correct excessive envelope air leakage
ECO O4.1 - Consider modifying the supply air temperature
ECO E1.3 - Optimize control of blinds
ECO P3.9 - Introduce exhaust air heat recovery

To enable the implemented model to work with very little data, the core of the model, based on ISO standard 13790, calculates a reference building using data from the building's iSERVcmb spreadsheet to provide:

- ➔ Geographic location: for meteorological zone determination
- ➔ Activity: for capacity, internal gains assumptions of reference building
- ➔ Year of construction: for estimation of building envelope thermal transmission
- ➔ Nominal power of components: for assumptions concerning electric energy use based on heating and cooling needs
- ➔ Schedules with heating & cooling setpoints

Then three options per ECO noted above are evaluated, considering a minimum, an average and a maximum case (ECO O4.1 excepted where three different setpoints are suggested). These ECOs are based on ECO’s defined within the HARMONAC project and are modelled independently of HERO through Matlab to complete the core model. Finally, the results of the ECO calculations are expressed as a percentage of potential electric energy savings relatively to both the HVAC system concerned and the whole building. All assumptions for the core model as well as each ECO are detailed in the “Energy Conservation Opportunities” folder at www.iservcmb.info/results.

The data provided by the end-user in defining his building defines which parts of the HERO building sample are available to be evaluated for each ECO.

Figure 13 presents the number of buildings evaluated for each ECO as a pie chart in order to show the sample size for each ECO that Figure 14 and Figure 15 were derived from.

Figure 14 and Figure 15 summarize the results of the 13 ECOs respectively in relation, firstly, to the HVAC system alone, and then for the building as a whole.

What is clear from Figure 14 is that, for HVAC systems, the major energy savings available appear to be from ECO’s E1.1 (install window film or tinted glass), E1.3 (optimise control of blinds) and P2.6 (Replace or upgrade cooling system and heat pump), with average savings of 5 – 15% predicted as being available from these measures.

When the whole building is considered in Figure 15, ECO’s E1.1 and E1.3 are still important but the largest average saving is predicted to be from E4.6 (replace lighting equipment with low consumption type).

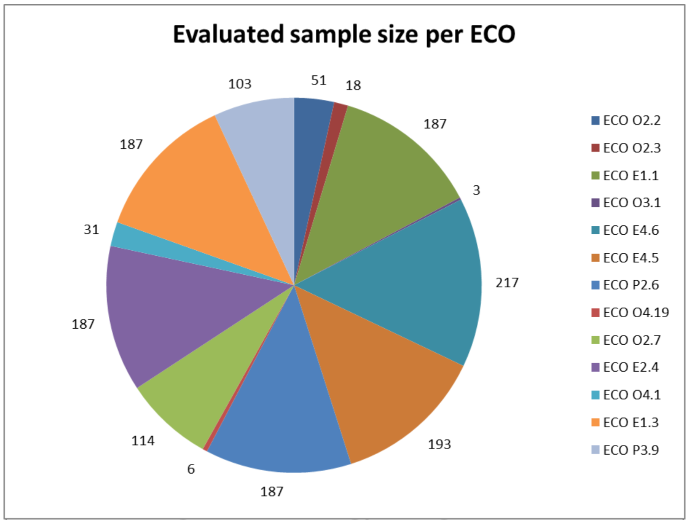

Figure 13 - Evaluated sample size per ECO

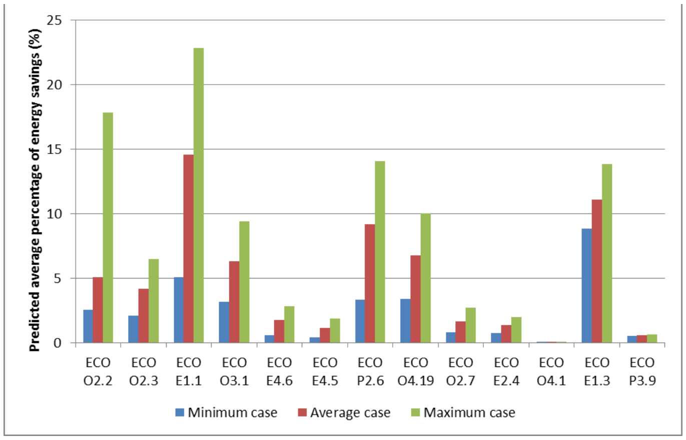

Figure 14 - Average potential of savings over HVAC system

Envelope ECO’s are not possible to evaluate from the physical monitoring in the time available for the project, but it is interesting to note that the size of the savings being achieved in practice from better control of existing services (ECO’s O2.2, O2.3 and O3.1) are up to 60% in some cases, and these are not fully reflected in the modelling results. It is possible therefore that the modelled savings predicted may be underestimated for some of the ECO’s.

More detailed results from the ECO’s modelling are available in the “Energy Conservation Opportunities” folder at www.iservcmb.info/results.

Unfortunately, the ECO models were implemented too late in the project to evaluate what happens to the operational building and systems energy use when they are reported back to the end users in large numbers. The older systems on iSERVcmb, which also participated in HARMONAC, suggest these savings will be substantial and will achieve indirect savings in the lighting and small power loads as well.

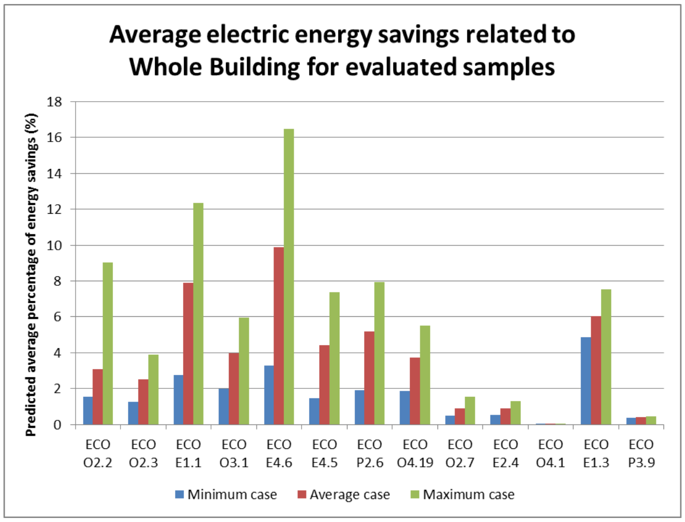

Figure 15 - Average potential of savings over the whole building

10.3 COMPARISON OF ECOS FROM MEASUREMENTS, MEASURED ECOS AND MODELLED ECOS

When the iSERVcmb benchmarks are applied to all the systems and buildings in the HERO database, the predicted overall average electrical savings are around 9% - with a range between 3 – 15% being expected across buildings as a whole, as seen in the next section.

Comparing this to the predictions from the two ECO modelling approaches (5 – 22% with an average of 15% for measured data based ECOs; and savings of 3 – 8% for whole buildings plus 5 – 15% for systems using the modelled ECOs approach) shows there is broad agreement between the various approaches as to the size of the average savings available.

This supports the proposal that the iSERVcmb approach is capable of providing a reasonable estimate of the potential savings to be achieved as well as being able to identify where those savings are to be found.

The maximum savings predicted from the modelling and measured control ECOs are over 30%+ for HVAC systems and 25%+ for whole buildings. This is supported by the actual data from iSERVcmb and HARMONAC showing that operational buildings have achieved electrical energy savings of up to 33%, and that average possible savings are around 9%+.

The next section explores the actual savings achieved in operational buildings in more detail.

11 Energy savings achieved in operational buildings

- The achieved electrical energy savings during iSERVcmb range up to 33% for entire buildings.
- Average achieved electrical savings across the whole dataset are between 9 – 15% with even further potential it seems once buildings have used the approach for some time.
- Predicted energy savings potentials for systems based on them achieving Best Practice (top 10% performance) and Good Practice (top 25% performance) range from over 1000 kWh/m^2 for IT server rooms, through to more typical savings of 10’s – 100’s of kWh/m^2 for the majority of the systems.
- 58% of systems on iSERVcmb already meet the standard for Good Practice.

Conclusions:

- In conjunction with the predicted savings potential across all the systems from the ECO’s section, these figures suggest that the predicted and actual savings possible in operational buildings are broadly in agreement.
- Sustainable energy savings of up to 33% of the total electrical energy use of operational buildings have been both predicted and achieved.
- A conservative figure of sustainable average electrical energy savings of 9 – 15% is supported by the modelling and achieved performance. This means that this approach can play a significant role in improving the efficiency of electrical energy use in operational EU buildings.

This section presents the actual savings achieved across the systems on the database.

The delay in getting the HERO database and data reporting fully functional has led to an inevitable reduction in the hoped for impact of the process on the operational energy use of individual buildings and systems. This means that many of the best performing systems are ones which were initially exposed to the iSERVcmb process during HARMONAC, as they have already been implementing many of the lessons learnt during that project. Despite this problem the overall average savings at building level from the project exceed the 1 – 5% anticipated from HARMONAC.

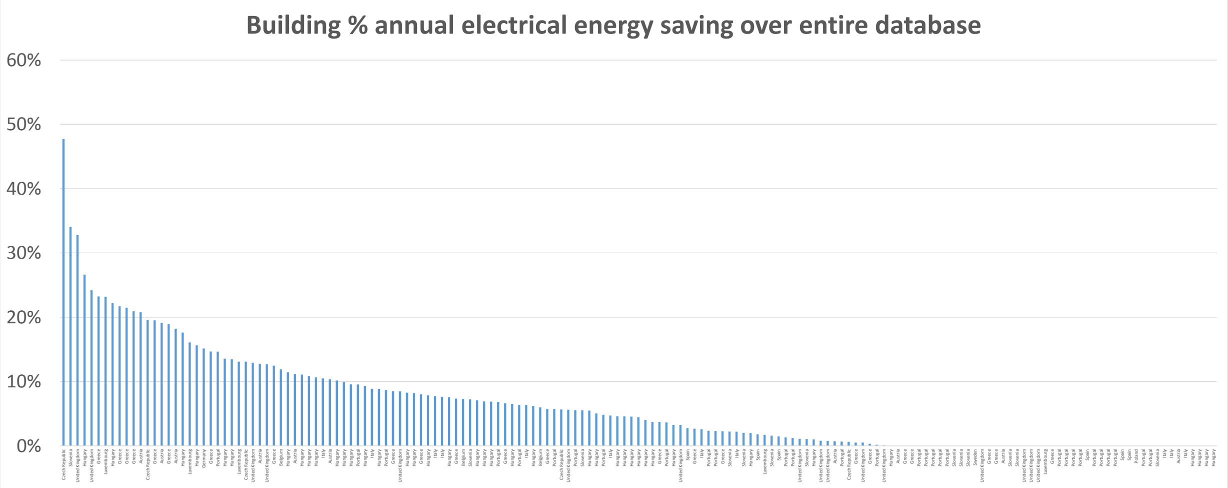

Figure 16 - Annual electrical energy savings at building level across entire iSERVcmb database

Average annual building electrical energy savings, at the latest date for each system compared to their peak annual consumption, were found to be 9% over the entire iSERVcmb sample – rising to an average 15% saving in the 18% of systems with more than a year between their peak annual consumption and the latest data available for them. The savings over the entire dataset are shown in Figure 16.

Approximately 30% of the buildings showed no improvement during iSERVcmb, but these were generally the buildings that had been on the system for the shortest period and had no time to act on any feedback provided.

Figure 17 below shows predictions of the % savings to be achieved in individual HVAC systems in those same buildings, should they be able to improve to meet their predicted 'Good' and 'Best Practice' benchmarks from their current level of measured performance.

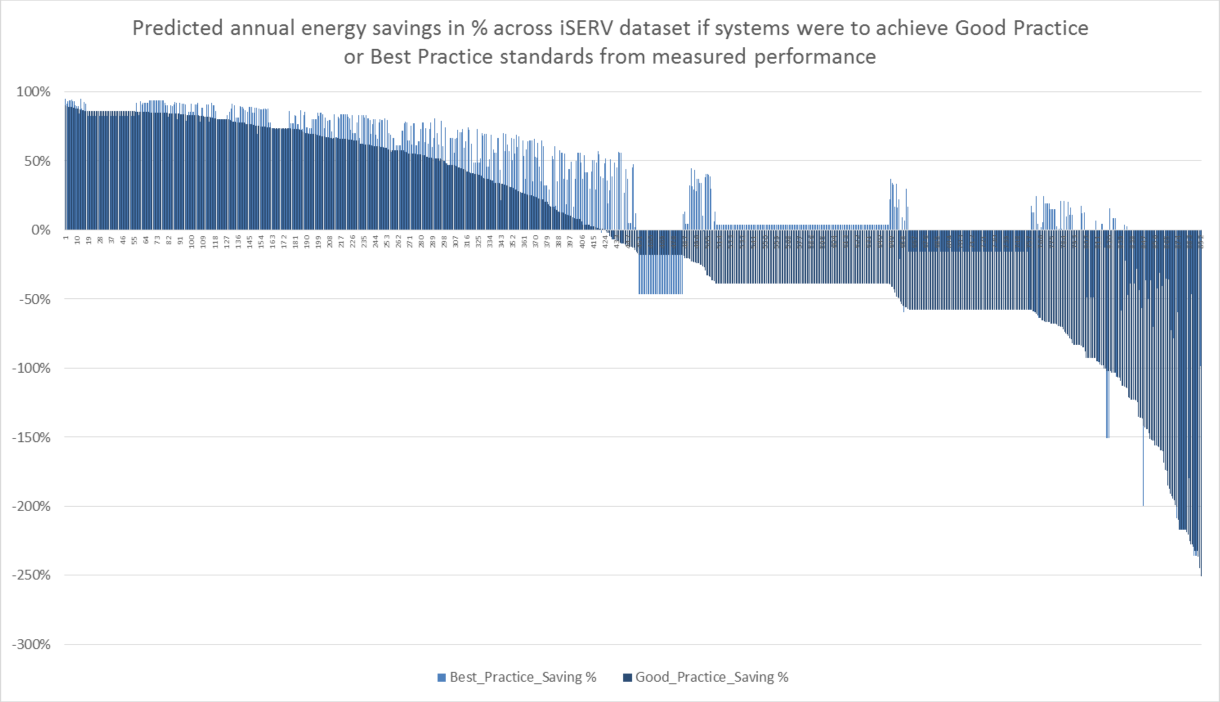

Figure 17 - Predicted annual energy savings in % across iSERVcmb dataset if systems were to achieve Good Practice or Best Practice standards from their current measured performance

It can be seen from the figure that % savings in individual systems can be significant, with 41% being able to achieve savings if they were to reach the iSERVcmb 'Good practice' standard. This also means 59% of systems are already at a Good Practice level of performance based on the current iSERVcmb benchmarks. These are the systems showing negative savings relative to the benchmarks.

Some of the predicted energy savings are significantly above 90% of the current usage of the systems.

The overall findings from looking at the impact of iSERVcmb on energy use in operational buildings show that it will usually take some time for the full energy savings available in a system to be realised, but that significant savings can still be achieved quite quickly. This is logical and in line with expectations for improving the operational energy efficiency of buildings. It seems that buildings with 2+ years on the system are more likely to show electrical energy savings of 15 to 18% on average.

iSERVcmb has produced written Case Studies for 40+ HVAC systems/buildings across the EU Member States. These Case Studies can all be found in the “iSERVcmb Case Studies” folder at www.iservcmb.info/results. The Case Studies illustrate different facets of the impact of the iSERVcmb project, ranging from significant energy savings in single buildings through to changes in the specification, operation or maintenance of individual building services components. These Case Studies help illustrate how the iSERVcmb process might work in many different situations.

12 Indoor Air Quality (IAQ) in the buildings and systems tested

- The indoor air quality of the majority of buildings tested was satisfactory.
- CO2 concentrations were at low values in the majority of buildings tested, indicating a good air quality and adequate ventilation with minor exceptions.
- Overall, VOC concentrations showed no major problems, also indicating that ventilation is adequate.
- Indoor Air Quality shows some correlation with the age and the maintenance of the HVAC system.
- There is no obvious correlation between IAQ and energy consumption
- A portable standalone IAQ system can measure IAQ successfully.
- Turning HVAC systems off at night does not lead to a decreased IAQ except in specific circumstances where Volatile Organic Compounds remain at higher levels during the non - operation of the buildings due to emission of materials in super market stores or due to the presence of people e.g. cleaners, after normal operational hours.
- One portable IAQ system can successfully represent a building which has similar activities throughout. For example, in Super Market stores the IAQ does not appear to vary significantly across a store, except for

During iSERVcmb, a compact Indoor Air Quality system was developed and placed in buildings across Europe with HVAC systems larger than 12kW, in order to investigate whether a relationship exists between IAQ and energy consumption. The study was also to provide confidence that the measured lower energy consumptions were not being obtained at the expense of IAQ.

To check comparability within buildings, cities and Member States, a large number of initial measurements were taken firstly from one Greek building (which served as a pilot building) and then from a number of Greek Offices and Supermarket stores. Finally the IAQ kits were sent to several European Cities to explore the variation of IAQ across Europe in Offices and Supermarkets.

The sensors employed were able to continuously monitor temperature, relative humidity, CO_2 as well as VOC (Volatile Organic Compounds) levels, while existing energy monitoring systems were used to provide information regarding the building and HVAC system energy profiles.

The buildings were classified as Offices, Supermarket or Electronics Stores. Greek Offices are shown separately to facilitate comparison with the findings in Offices in the rest of Europe. Air quality levels were distinguished into 3 categories corresponding to 'Good', 'Acceptable' and 'Poor' for CO_2. 'Comfort', 'Decreasing comfort' and 'Discomfort' were the descriptions used for VOCs, due to exposure to multiple factors. The summary of this study is shown by building type in Figure 18.

24 IAQ kits were installed In Offices, which were in operation for periods ranging from 3 to 16 months. 23 IAQ kits were installed In Super Market stores, with monitoring periods from 3 to 15 months. The results showed that the majority of Office systems recorded low values of CO_2, indicating that these buildings have a generally good indoor air quality. However, a few Offices had more than 25% of the recorded values exceeding 1000 ppm and this was found to be due to smoking. Other European offices showed a general tendency towards higher CO_2 and VOC levels than the Greek Offices but still the majority of them recorded values below 600 ppm.

In Super Markets, indoor air quality is again generally good, apart from 4 Super markets that recorded the majority of their values between 600 and 1000 ppm, indicating an acceptable indoor air quality.

6 IAQ systems were installed in electronic stores, monitoring from 5 to 12 months and the results also showed that indoor air quality was generally good.

The recorded Volatile Organic Compound (VOCs) levels in all offices and electronic stores indicated that the air quality of the majority of them was very good. In contrast, in Super Markets the Indoor Air Quality could lead to possible irritation or discomfort depending on the interaction with other factors, probably due to high quantities of emitting products in some of the aisles. A summary of all the systems is shown in Table 7, which also shows the findings from the Inspections undertaken as well when these occurred in the same buildings. There appears to be no obvious correlation between Inspection findings and the IAQ in the spaces in the Non-Greek systems

Overall the measurements show that IAQ in general around Europe is good or acceptable in this small sample of buildings, indicating that the ventilation systems work well and the ventilation standards are appropriate.

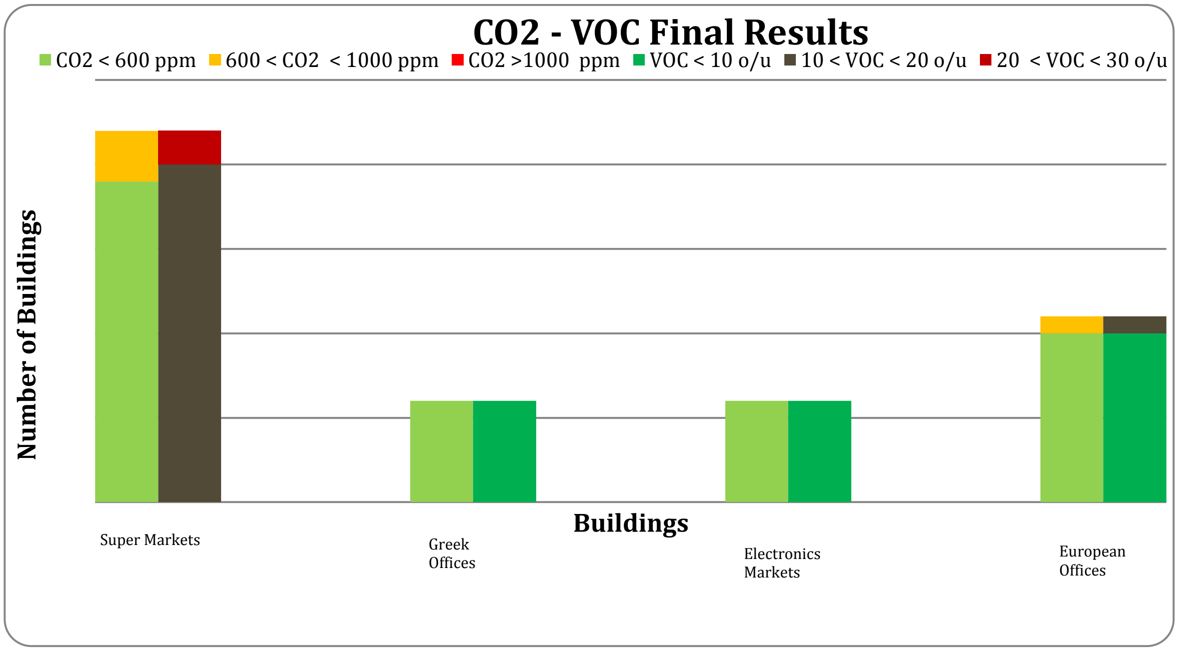

Figure 18 - Summary of CO2 and VOC's by building sector type

Table 7 - CO2 and VOCs percentages for each IAQ test plus MacWhirter's comments from their Inspections

CO_2 (%)					VOCS (%)				Inspections Comments
Electronics Market	< 600 ppm	600 - 1000 ppm	>1000 ppm	Category	< 10 o/u	10 - 20 o/u	20 - 30 o/u	Category	
IAQ 04	88.7	11.2	0.0	**GOOD**	95.8	4.0	0.1	**No irritation or discomfort**	Not inspected
IAQ 11	72.1	27.2	0.7	**GOOD**	59.0	39.6	1.4	**No irritation or discomfort**	Not inspected
IAQ 14	72.6	27.1	0.3	**GOOD**	72.4	25.8	1.8	**No irritation or discomfort**	Not inspected
IAQ 15	92.4	7.1	0.6	**GOOD**	85.8	13.3	0.9	**No irritation or discomfort**	**Overall well maintained system. Over the suggested minimum forced fresh air level.**

IAQ 28	71.7	27.6	0.7	GOOD	84.5	14.7	0.7	No irritation or discomfort	Not inspected
IAQ 44	75.0	25.0	0.0	GOOD	96.5	3.0	0.5	No irritation or discomfort	Not inspected
Summary	**71.7 - 92.4**	**7.1 - 27.6**	**0 – 0.7**		**59.0 - 96.5**	**3.0 - 39.6**	**0.1 - 1.8**		
Offices	**< 600 ppm**	**600 - 1000 ppm**	**>1000 ppm**	**Category**	**< 10 o/u**	**10 - 20 o/u**	**20 - 30 o/u**	**Category**	
IAQ 03	50.6	32.6	16.8	GOOD	37.5	62.4	0.0	Possible irritation or discomfort depending on the interaction with the other factors	Not inspected
IAQ 04	66.0	23.0	11.0	GOOD	50.1	49.8	0.0	No irritation or discomfort	Not inspected
IAQ 07	53.4	23.7	22.9	GOOD	90.3	9.7	0.0	No irritation or discomfort	Not inspected
IAQ 08	50.0	25.7	24.3	GOOD	63.4	36.5	0.1	No irritation or discomfort	Not inspected
IAQ 09	46.4	29.8	23.8	GOOD	20.9	78.5	0.5	Possible irritation or discomfort depending on the interaction with the other factors	Not inspected
IAQ 10	66.6	26.8	6.6	GOOD	1.9	91.1	7.0	Possible irritation or discomfort depending on the interaction with the other factors	Not inspected
IAQ 11	72.8	25.8	1.4	GOOD	72.5	27.0	0.4	No irritation or discomfort	Not inspected
IAQ 12	58.9	27.6	13.5	GOOD	75.4	22.0	2.5	No irritation or discomfort	**Units are in a reasonable condition. Over the suggested minimum forced fresh air level.**
IAQ 13	52.6	24.3	23.1	GOOD	44.0	55.9	0.1	Possible irritation or discomfort depending on the interaction with the other factors	Not inspected
IAQ 14	76.0	21.1	2.9	GOOD	54.7	45.2	0.0	No irritation or discomfort	Not inspected
IAQ 18	0.0	54.2	45.8	ACCEPTABLE	73.1	26.7	0.2	No irritation or discomfort	Not inspected
IAQ 20 (1)	69.4	25.4	5.1	GOOD	80.1	19.9	0.0	No irritation or discomfort	Not inspected
IAQ 20 (5)	92.9	7.1	0.0	GOOD	29.2	70.4	0.4	Possible irritation or discomfort depending on the interaction with the other factors	Not inspected
IAQ 25	96.4	3.6	0.0	GOOD	99.5	0.5	0.0	No irritation or discomfort	Not inspected
IAQ 27	45.7	31.7	22.6	GOOD	60.0	40.0	0.0	No irritation or discomfort	Not inspected
IAQ 28	77.6	18.8	3.6	GOOD	93.4	6.6	0.0	No irritation or discomfort	Not inspected
IAQ 31	53.3	19.9	26.8	GOOD	66.0	34.0	0.0	No irritation or discomfort	Not inspected
IAQ 35,49	82.2	17.4	0.4	GOOD	44.7	50.9	4.4	Possible irritation or discomfort depending on the interaction with the other factors	Not inspected
IAQ 36	75.0	22.4	2.5	GOOD	71.5	28.4	0.0	No irritation or discomfort	Not inspected

IAQ 38	75.7	9.0	15.3	**GOOD**	21.1	63.2	15.7	**Possible irritation or discomfort depending on the interaction with the other factors**	**Overall well maintained system. No forced fresh air supplied.**
IAQ 41	94.2	5.8	0.0	**GOOD**	92.3	7.7	0.0	**No irritation or discomfort**	Not inspected
IAQ 42	45.2	25.4	29.4	**GOOD**	98.1	1.9	0.0	**No irritation or discomfort**	Not inspected
IAQ 44	72.5	19.9	7.6	**GOOD**	79.1	20.8	0.0	**No irritation or discomfort**	Not inspected
IAQ 47	42.5	22.1	35.3	**GOOD**	95.8	4.2	0.0	**No irritation or discomfort**	Not inspected
IAQ 50	54.7	28.8	16.6	**GOOD**	5.7	68.8	25.5	**Possible irritation or discomfort depending on the interaction with the other factors**	**Overall well maintained system. No forced fresh air supplied.**
Summary	**0 - 96.4**	**3.6 - 32.6**	**0 - 45.8**		**1.9 - 99.5**	**0.5 - 91.1**	**0 - 25.5**		
Super Market Stores	**< 600 ppm**	**600 - 1000 ppm**	**>1000 ppm**	**Category**	**< 10 o/u**	**10 - 20 o/u**	**20 - 30 o/u**	**Category**	
IAQ 01,37	71.7	28.0	0.3	**GOOD**	17.0	75.0	8.0	**Possible irritation or discomfort depending on the interaction with the other factors**	Not inspected
IAQ 03	38.2	44.8	17.0	**ACCEPTABLE**	0.0	1.2	98.7	**Symptoms - Possible headaches depending on other factors**	Not inspected
IAQ 05,12,21,26	62.8	35.9	1.2	**GOOD**	12.9	62.9	24.2	**Possible irritation or discomfort depending on the interaction with the other factors**	Not inspected
IAQ 06,43	53.0	37.0	10.0	**GOOD**	0.6	67.1	32.3	**Possible irritation or discomfort depending on the interaction with the other factors**	Not inspected
IAQ 07	36.3	53.5	10.1	**ACCEPTABLE**	2.2	65.4	32.3	**Possible irritation or discomfort depending on the interaction with the other factors**	**Overall well maintained system. No forced fresh air supplied.**
IAQ 08	54.3	43.6	2.1	**GOOD**	0.0	86.5	13.5	**Possible irritation or discomfort depending on the interaction with the other factors**	Not inspected
IAQ 10	83.6	15.2	1.2	**GOOD**	0.2	42.3	57.5	**Symptoms - Possible headaches depending on other factors**	Not inspected
IAQ 13	76.2	23.1	0.7	**GOOD**	3.9	65.0	31.1	**Possible irritation or discomfort depending on the interaction with the other factors**	Not inspected
IAQ 16	63.9	35.9	0.2	**GOOD**	14.9	83.0	2.1	**Possible irritation or discomfort depending on the interaction with the other factors**	Not inspected

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IAQ 19	62.2	36.9	0.9	**GOOD**	9.4	62.7	27.9	**Possible irritation or discomfort depending on the interaction with the other factors**	Not inspected
IAQ 22	51.6	36.9	11.5	**GOOD**	11.1	67.7	21.2	**Possible irritation or discomfort depending on the interaction with the other factors**	Not inspected
IAQ 24	53.1	36.9	10.0	**GOOD**	20.6	72.2	7.2	**Possible irritation or discomfort depending on the interaction with the other factors**	Not inspected
IAQ 29	77.1	22.6	0.3	**GOOD**	1.9	63.4	34.7	**Possible irritation or discomfort depending on the interaction with the other factors**	Not inspected
IAQ 30	19.0	52.7	28.2	**ACCEPTABLE**	0.0	52.6	47.4	**Possible irritation or discomfort depending on the interaction with the other factors**	Not inspected
IAQ 31	68.6	31.2	0.1	**GOOD**	21.3	69.4	9.3	**Possible irritation or discomfort depending on the interaction with the other factors**	Not inspected
IAQ 33	37.3	35.4	27.3	**ACCEPTABLE**	4.1	74.4	21.6	**Possible irritation or discomfort depending on the interaction with the other factors**	Not inspected
IAQ 34	45.2	47.1	7.6	**ACCEPTABLE**	2.4	64.0	33.6	**Possible irritation or discomfort depending on the interaction with the other factors**	Not inspected
IAQ 40	40.6	21.5	37.9	**GOOD**	9.9	55.7	34.4	**Possible irritation or discomfort depending on the interaction with the other factors**	Not inspected
Summary	**19.0 - 83.6**	**15.2 - 53.5**	**0.1 - 37.9**		**0 - 21.3**	**1.2 - 86.5**	**7.2 – 98.7**		
Offices Abroad	**< 600 ppm**	**600 - 1000 ppm**	**>1000 ppm**	**Category**	**< 10 o/u**	**10 - 20 o/u**	**20 - 30 o/u**	**Category**	
Portugal 1 (IAQ 02)	-	-	-		92.2	7.8	0	**No irritation or discomfort**	**Two of the three AHUs are not operational due to faults resulting in some zones not being supplied with forced fresh air.**
Portugal 2 (IAQ 09)	0	95.4	4.6	**ACCEPTABLE**	99.2	0.8	0.1	**No irritation or discomfort**	**Overall well maintained system although a filter was missing from one AHU.** **Over the suggested minimum forced fresh air level.**
Belgium 1 (IAQ 23)	96.8	3.2	0	**GOOD**	97.8	2.1	0.1	**No irritation or discomfort**	**Well maintained system. Humidistat wrongly**

									positioned may cause poor RH control. **Over the suggested minimum forced fresh air level.**
Belgium 2 (IAQ 27)					81.4	18.4	0.2	**No irritation or discomfort**	**Overall well maintained system.** **Over the suggested minimum forced fresh air level but only if the terminal unit is manually enabled.**
Slovenia 1 (IAQ32)	81.2	17.2	1.6	**GOOD**	22.2	77.1	0.7	**Possible irritation or discomfort depending on the interaction with the other factors**	Not inspected
Slovenia 2 (IAQ 36)	83	15.7	1.3	**GOOD**	69.2	30.7	0.1	**No irritation or discomfort**	Not inspected
Hungary 1 (IAQ 39)	58.6	40.9	0.4	**GOOD**	100	0	0	**No irritation or discomfort**	**Overall well maintained system.** **Over the suggested minimum forced fresh air level.**
Hungary 2 (IAQ 42)	76.4	22.6	1	**GOOD**	94.5	5.5	0	**No irritation or discomfort**	**Overall well maintained system.** **Over the suggested minimum forced fresh air level.**
UK 1 (IAQ 45)	84.2	15.6	0.2	**GOOD**	97.7	2.1	0.2	**No irritation or discomfort**	**Units are in a reasonable condition. Lower than the suggested minimum forced fresh air level.**
Austria 1 (IAQ 47)	82	16.2	1.8	**GOOD**	99	1	0	**No irritation or discomfort**	**Units are in a reasonable condition. No forced fresh air supplied.**
Austria 2 (IAQ48)	67.4	21.8	10.8	**GOOD**	97.2	2.8	0	**No irritation or discomfort**	**No maintenance carried out. No forced fresh air supplied.**
Summary	**0 - 96.8**	**3.2 - 95.4**	**0 - 10.8**		**22.2 - 100**	**0 - 77.1**	**0 – 0.7**		

In addition to MacWhirter's Inspections, whose comments are shown in Table 7, the NKUA team also undertook an overall physical inspection of the HVAC systems in the Greek buildings. The results are presented in Table 8 and show that there is a correlation between IAQ and HVAC systems. The Indoor Air Quality appears to depend on the age and the maintenance of the HVAC system, and it was also found that poor maintenance or an older system could lead to high energy consumption. However no direct correlation could be found between Indoor Air Quality and HVAC system energy consumption.

Further details can be found in the "Indoor Air Quality" folder in www.iservcmb.info/results

Table 8 - Correlation between IAQ and HVAC system age and maintenance in Greek Systems

No of IAQ	Category CO_2	Category VOCS	HVAC Systems		
			Age of equipment	Energy consumption kwh/m^2/a	Maintenance
		ELECTRONICS STORES			
IAQ 04	Good	No irritation or discomfort	New	133.93	Good
IAQ 11	Good	No irritation or discomfort	New	99.69	Good
IAQ 14	Good	No irritation or discomfort	New	96.13	Good
IAQ 15	Good	No irritation or discomfort	N/a	87.53	Good
IAQ 28	Good	No irritation or discomfort	New	87.38	Good
IAQ 44	Good	No irritation or discomfort	New	78.13	Good
		OFFICES			
IAQ 03	Good	No irritation or discomfort	New	71.35	Good
IAQ 04	Good	No irritation or discomfort	New	71.35	Good
IAQ 07	Good	No irritation or discomfort	New	71.35	Good
IAQ 08	Good	No irritation or discomfort	New	71.35	Good
IAQ 09	Good	Possible irritation or discomfort depending on the interaction with other factors	New	71.35	Good
IAQ 10	Good	Possible irritation or discomfort depending on the interaction with other factors	New	71.35	Good
IAQ 11	Good	No irritation or discomfort	New	71.35	Good
IAQ 12	Good	No irritation or discomfort	New	N/a	Not satisfactory
IAQ 13	Good	Possible irritation or discomfort depending on the interaction with other factors	New	71.35	Good
IAQ 14	Good	No irritation or discomfort	New	71.35	Good
IAQ 18	Acceptable	No irritation or discomfort	New	71.35	Good
IAQ 20 (1)	Good	No irritation or discomfort	New	71.35	Good
IAQ 20 (5)	Good	Possible irritation or discomfort depending on the interaction with other factors	Old + new	66.47	Good
IAQ 25	Good	No irritation or discomfort	Very old + new	100.2	Good
IAQ 27	Good	No irritation or discomfort	New	71.35	Good
IAQ 28	Good	No irritation or discomfort	New	71.35	Good
IAQ 31	Good	No irritation or discomfort	New	71.35	Good
IAQ 35, 49	Good	Possible irritation or discomfort depending on the interaction with other factors	Old	30	Good
IAQ 36	Good	No irritation or discomfort	New	71.35	Good

IAQ 38	Good	Possible irritation or discomfort depending on the interaction with other factors	New	71.35	Good
IAQ 41	Good	No irritation or discomfort	-	N/a	Not satisfactory
IAQ 42	Good	No irritation or discomfort	New	71.35	Good
IAQ 44	Good	No irritation or discomfort	New	71.35	Good
IAQ 47	Acceptable	No irritation or discomfort	New	71.35	Good
IAQ 50	Good	Possible irritation or discomfort depending on the interaction with other factors	New	71.35	Good
SUPER MARKET STORES					
IAQ 01,37	Good	Possible irritation or discomfort depending on the interaction with other factors	Old	N/a	Good
IAQ 03	Acceptable	Syptoms – possible headache depending on the interaction with other factors	Old	40,75	Good
IAQ 05,12,21, 26	Good	Possible irritation or discomfort depending on the interaction with other factors	Old	64,56	Good
IAQ 06,43	Good	Possible irritation or discomfort depending on the interaction with other factors	Old	N/a	Good
IAQ 07	Good	Possible irritation or discomfort depending on the interaction with other factors	Old	64,78	Good
IAQ 08	Acceptable	Possible irritation or discomfort depending on the interaction with other factors	Old	51,28	Good
IAQ 10	Good	Syptoms – possible headache depending on the interaction with other factors	New	N/a	Good
IAQ 13	Good	Possible irritation or discomfort depending on the interaction with other factors	Old	35,34	Good
IAQ 16	Good	Possible irritation or discomfort depending on the interaction with other factors	Old	68,51	Good
IAQ 19	Good	Possible irritation or discomfort depending on the interaction with other factors	Old	85,47	Good
IAQ 22	Good	Possible irritation or discomfort depending on the interaction with other factors	Old	41,07	Good
IAQ 24	Good	Possible irritation or discomfort depending on the interaction with other factors	Old + new	36,61	Good
IAQ 29	Good	Possible irritation or discomfort depending on the interaction with other factors	New	49,66	Good
IAQ 30	Acceptable	Possible irritation or discomfort depending on the interaction with other factors	Old	N/a	Good
IAQ 31	Good	Possible irritation or discomfort depending on the interaction with other factors	Old	30,57	Good
IAQ 33	Acceptable	Possible irritation or discomfort depending on the interaction with other factors	Old	38,23	Good
IAQ 34	Acceptable	Possible irritation or discomfort depending on the interaction with other factors	Old	45,56	Good

13 Findings from HVAC Inspections on Systems across Europe

- Very few building operators have many details of their HVAC components
- Very few building operators have maintenance records
- Southern European States tend to have better maintenance regimes and sizing of components
- Energy saving initiatives are rarely followed up to verify savings
- Free cooling/heat recovery was rarely used, even if available as an option
- Energy Conservation Opportunities noted during inspection are listed for each Inspection undertaken but calculations of specific savings to be made were rarely possible for anything other than the main cooling plant
- The frequency of occurrence of various ECOs is presented

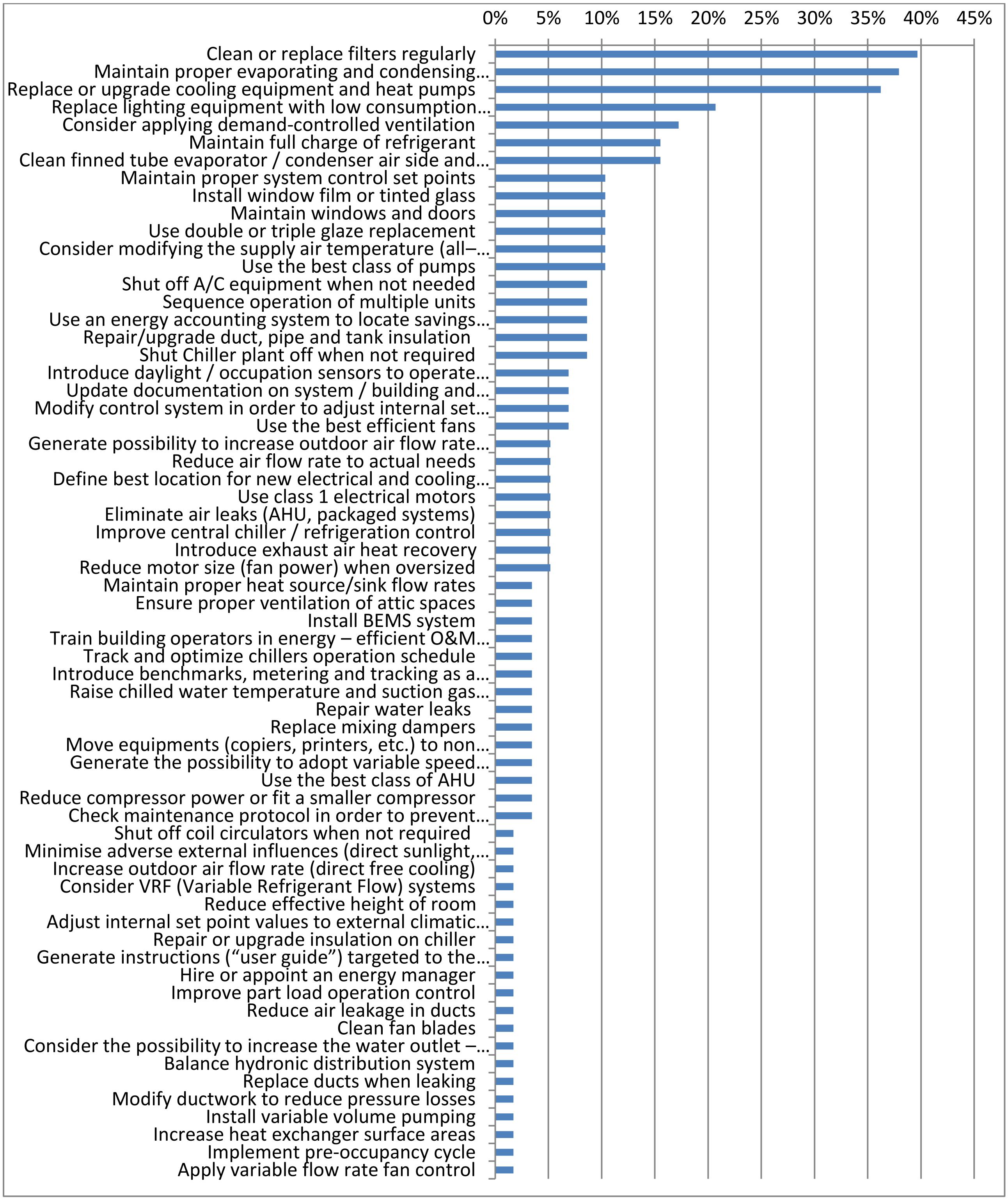
The IEE project HARMONAC (www.harmonac.info) found that continuous monitoring identified more ECOs than Physical Inspection. iSERVcmb used EPBD inspections, enhanced for iSERVcmb purposes with more detail than normal, to enable this comparison to be made directly. The iSERVcmb inspections also clearly established the additional benefits to be had from combining Inspections and Monitoring.

The following are the main observations and findings of these Inspections:

- iSERVcmb inspected 64 of the systems participating in iSERVcmb. The buildings inspected included offices, education facilities, retail and leisure facilities and were located in the United Kingdom, Greece, Austria, Slovenia, Italy, Portugal, Belgium, Luxembourg and Hungary
- The inspections were carried out using CIBSE's TM44: 2012 UK, the official EPBD guidance for the energy efficiency inspections of air conditioning systems over 12kW cooling capacity. These requirements were supplemented with more intrusive measures to collect data, in particular from the Cold Generator, to determine its actual performance and assessment of efficiency at the time of the Inspection. This was undertaken with the use of a refrigeration circuit performance analyser and data logger; as well as carrying out airside checks in addition.
- Obtaining basic information about the installed equipment from the end user proved to be almost impossible. This meant spending significant time trying to obtain system performance information from the manufacturers' literature, where we were able to confirm the advice from CIBSEs Guide 'F' that nameplate information should not be relied upon. Typically, the highest cooling capacity and the maximum compressor input power values stated were outside recognised design conditions.
- Some of the main observations from the inspections show a distinct contrast between Northern and Southern Europe, and are as follows:
- **Installed capacity:** In Northern Europe both Chilled Water and DX systems alike often suffer from over-sizing – other than in perhaps the retail sector, by reason of not appreciating or ignoring the need for basic room load calculations. In one case where a 'one size fits all' approach was used, it might not have been an issue if inverter compressor models had been available at the time. In Southern Europe, where there might have been overcapacity it was usually needed for flexibility of building/zone use. Often multiple, split DX systems were installed which enabled load shedding, in contrast to using one large AHU to deliver the cooling, whereby the fan input power might be excessive under certain conditions.

- **Maintenance records:** Whilst it is considered desirable for an inspector undertaking a UK EPBD Air conditioning inspection to view the user's maintenance records, during iSERVcmb these were just enquired about. It was commonly observed that, where a specialist contractor was employed to carry out inspections, the end user rarely knew what was being done with the systems. Only on the few occasions when the contractor was on site was it possible to find out if, for instance, leak checking under the F-gas and ODS (Ozone Depleting Substances) Regulations was being carried out.
- **Maintenance frequency:** In Southern Europe maintenance visits appear to be more frequent, albeit they are more likely to be minor inspections – monthly in respect of the retail sector and quarterly elsewhere. Whilst in Northern Europe, other than in the retail sector where monthly visits are the norm, the frequency of visits ranges from zero to twice annually. Our observations of issues with refrigeration systems show that frequency of maintenance in Northern Europe should be re-assessed and EU operating regimes would be enhanced by embracing the ethos of the F-gas and ODS Regulations.
- **Verifying savings:** Throughout the whole of Europe, it appears, where various energy saving measures/schemes/designs have been admirably employed, albeit in the interest of saving money, the users generally are not following them up by verifying the savings, nor are they likely to introduce good energy saving maintenance procedures, other than the obvious ones such as cleaning condensers and filters, in the first instance.
- **Free Cooling/Heat Recovery:** Where 'free' cooling or heat recovery options were available, whether water or air, they were rarely found to be used effectively, or at all, by reason of:
  - ✓ Poor changeover control on critical systems.
  - ✓ User insisting that "it just doesn't work".
  - ✓ Cooling water pumps silting up with contaminants from river water.
  - ✓ Lack of understanding by the user/maintenance of the installed equipment. A prime example was where, because of a control anomaly, a proportion of warmer return air was being mixed with cooler fresh air on multiple supermarket AHUs, instead of discharging 100% to exhaust.. This was corrected by the user by re-assessing the BMS damper control.
  - ✓ Heat/coolth recovery - by passed, poor damper control and/or dirty recuperation unit filters/elements.
- **Energy Conservation Opportunities (ECOs):** The aim was to discern from the Inspection whether a systems energy performance appeared to be good, average or bad, and what energy conservation opportunities would be expected to be found from the operational diagnosis. The detailed Inspection reports (available in the "Physical Inspections" folder at www.iservcmb.info/results) note all ECOs found, as per a normal EPBD inspection, but without a site specific energy saving value attached to them. The ECOs are presented as listed by the HARMONAC Project and the average HARMONAC savings are used to estimate potential energy savings for each ECO found. Most of the Energy Conservation Opportunities were found in Northern European systems.
- **The frequency of occurrence of various ECOs** identified during the Inspection process are shown in Figure 19. This shows that the most frequent ECO, the need to clean or replace filters regularly, occurred in nearly 40% of the systems inspected. The majority of the ECOs found occurred in Northern European HVAC systems.

Figure 19 - Frequency of occurrence of ECOs identified during Inspections



A fundamental question for the project was whether the energy savings possibilities identified by a detailed measurement system are comparable, in quality and in costs identified, to a properly undertaken Physical Inspection.

To encapsulate the points to be made, the findings for EPBD inspections and detailed energy monitoring are compared in three Austrian Case Studies – two of which also had IAQ measurement findings. One of the approaches shows where iSERVcmb can't be used at present with only annual energy consumption benchmarks to base findings on. However, the iSERVcmb approach also allows for Power Demand and **monthly** energy consumption benchmarks to be used if required, and when sufficient data becomes available. If this were already the case, then iSERVcmb would have been able to estimate savings based on in-use power demands and monthly energy use figures.

The findings of the Physical Inspection and iSERVcmb approaches are shown by building in Table 9.

Table 9 - Comparison of the findings of the physical inspection and iSERVcmb processes

Building	Findings from Physical Inspection	Findings from iSERVcmb System
Building 3	2 of 9 systems inspected are oversized. Cooling systems generally in bad shape. Average energy savings potential estimated between 14 to 40%. Besides the air temperature being slightly too high and the relative humidity being slightly too low, the air quality is acceptable.	Electrical energy consumption of 9 of the 12 identified cooling systems lie in the poorest section of their benchmark ranges. The systems have year-round operation. Most consumption intensive days are Monday through Thursday between 09:00 and 15:00 o'clock. Energy savings potential of around 61% identified if they were all to reach borderline Good Practice standards.
Building 5	4 of 6 systems are oversized. Parts of the Cooling system are in a poor state. Energy savings are on average > 20 %. Besides the air temperature being slightly too high and the relative humidity being slightly too low, the air quality is acceptable.	Insufficient data to analyse savings potential. Most consumption intensive days are Monday through Sunday between 13:00 to 15:00 o'clock.
Building 12	Ventilation system is sized correctly and in a very good state. Same remarks can be made about cooling system. Energy savings potential low. No air quality test made.	Electrical energy consumption lies in the good region (4.2 kWh/m²a). System in year-round operation. Most consumption intensive days are Wednesday through Thursday. Already exceeds Best Practice performance.

The main finding from a comparison of the two approaches is that both agree with each other about the general state of the systems being evaluated, though iSERVcmb was unable to assess one building due to a lack of data. This general agreement continues across the larger EU dataset as well.

For the system for which poor performance was identified and for which we had enough data for iSERVcmb to predict savings, then iSERVcmb predicted 1.5 to 4 times greater savings potential for the systems than the Physical Inspection. This is not unexpected due to the differences in the amount and depth of data available to the online system. This is also despite MacWhirter undertaking more detailed Inspections for iSERVcmb which are unlikely to be performed in the typical Inspection market currently existing in the EU Member States. It appears that the inability of the Inspection process to quantify the full potential savings available is still a problem when it comes to achieving the energy savings possible from a system.

To evaluate the cost differences of the two evaluation methods, the following calculation was undertaken:

Physical Inspection: Two employees took two days for the Physical Inspection. One of them then summarized the results in an inspection report. In total, this took an average expenditure of 40 man hours plus travel and other costs.

Continual Monitoring: The Austrian experience is that it took 16 hours to prepare the initial required data and examine the iSERVcmb reports for plausibility. This meant the man hours needed to undertake a Physical Inspection was around 2.5x those needed for the continuous monitoring system.

From a financial viewpoint, the iSERVcmb approach appears to have a definite advantage since the energy savings potentials are more quickly recognizable, are presentable via diagrams to be used during discussions with decision makers and the inspection itself is more cost-effective and continuous.

On the other hand, the responsibility for the implementation of iSERVcmb recommendations often lies in the hands of the operator of the system (facility manager, energy manager within the business) instead of in the hands of the service technician who might normally maintain and inspect the system. Also some opportunities are often only discernable from a Physical Inspection.

Overall, the Austrian example is a good summary of the benefits and deficiencies of both approaches as currently applied. Physical Inspections can be undertaken on any qualifying system and will be able to identify the general state of an HVAC system but will probably struggle to identify the full energy saving potential as well as only providing a snapshot in time. The iSERVcmb approach is much better at identifying the full potential for energy reductions in a building but requires more setting up and cannot address systems with no historic data.

13.1 INSPECTION CONCLUSIONS

What iSERVcmb has shown is that regardless of how their impact is perceived, Inspections can still have a role to play in EU legislation if they are valued and undertaken properly – this means properly funded and allowing time for a full report to be written. iSERVcmb considers that, as a minimum, this role could be to act as a statutory consequential requirement when poor performance is identified by systems opting for the iSERVcmb continuous measurement type approach to compliance. The other important role is as the option for those systems which do not adopt the metering approach.

What could not be answered from the Inspections and Monitoring approaches studied is whether simple Advice marketing schemes alone, as now allowed in the EPBD, would have achieved savings or investment better or worse than Monitoring or Inspection.

The conclusion the Coordinator draws from looking at the actual impact of the Monitoring and Inspection approaches studied, is that Advice will have very limited impact in the practical reduction of operational energy use as there is no trigger for investment in a specific area, as well as no mechanism for assessing the benefits of any change made. Thus there would be no compelling reason to disrupt existing design, operation and maintenance practices in either new or existing buildings and systems.

Further details of all the Inspections undertaken, including each detailed Inspection report, are available in the “Physical Inspections” folder at www.iservcmb.info/results.

14 The potential for implementation of iSERVcmb

- REHVA, CIBSE, EUROVENT Certification, Camfil Farr, SWEGON and SKANSKA supported and helped steer the project.
- The necessary infrastructure is already in place or readily implementable with existing technology
- The necessary European Legislation already exists to enable such an approach. It just needs to be implemented at Member State level now.
- The large majority of people responding to the project through surveys or workshops understood and were happy with such an approach if it were to be implemented.
- More than 313 dissemination activities were undertaken, more than 2,000 people were directly involved in the project and more than 2.6 million people were informed about the project

This chapter presents qualitative information from the Actors and End Users that participated in the project. It covers their views on the project feasibility, and their potential to participate in such an approach.

Part of the project's aims was also to inform relevant stakeholders about the scope, progress and results of the project, and to establish a network of actors. The following groups were identified as stakeholders:

- End users, building owners and consultants
- EU Member States legislators
- Building service professional bodies (building designers, HVAC system designers, HVAC inspection bodies and facility managers)
- HVAC manufacturers
- Other actors not falling into the above categories, including maintenance companies

As shown in Figure 20 the established network of actors consists of 53% end users, 5% EU member States legislators, 22% building service professional bodies and 7% HVAC manufacturers.

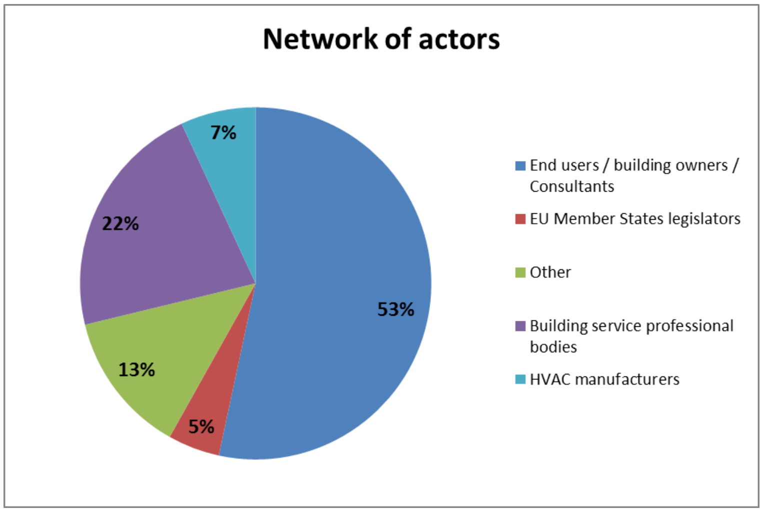


Figure 20 - Network of actors

14.1 READINESS OF EUROPE TO PARTICIPATE

During the project, **reaction from end users** was captured by conducting interviews with possible participants on a local level, and by conducting a survey amongst CIBSE EPG (Energy Performance Group) members. The main interests of end users included the benefits from participation in the project, the possible outputs of the project and the size of expenditure needed to participate. The main findings from the survey were:

- Sub metering is more prevalent in office buildings, educational facilities and hotels.
- Fully metered buildings are more likely to record and store sub hourly data equally at 15’ or 30’ intervals, while partly metered buildings (sub metering on at least one HVAC component) are more likely to use 30’ interval data.
- Metered buildings appear to usually record sub-hourly data for the main electrical or gas supply, with main water supply metered from a smaller percentage of the population.
- In rank order, sub metering recording sub-hourly data is statistically more likely to be installed on either lighting, chillers, HVAC system as a whole, or small power. A smaller amount of buildings appear to record sub hourly data for fans, boilers, pumps or IT systems. IT systems and pumps are mostly recorded in educational facilities and offices, while metering catering is popular amongst participants in retail and education.
- It appears that in offices and educational facilities there is a greater variety with respect to what is metered.
- No obstacles were observed in metered buildings being in a position to directly send their data for analysis. Sending data manually to an email address is preferred over an automatic option.
- It appears that the majority of metered buildings have energy consumption data in electronic form.
- Professionals based in NW Europe who are in charge of operating, managing and maintaining HVAC systems in their buildings, appear to have a wider variety of responsibilities compared to professionals based in SE Europe, that touch upon duties regarding the enforcement of sustainability to building management and legislation compliance matters. Moreover, they tend to be managing larger floor areas compared to SE Europe.

To summarize, we can conclude that current capabilities in buildings means that there is great potential for an iSERVcmb type approach to be implemented across Europe. It appears there is a significant population of buildings equipped with sub metering recording at sub hourly intervals, one which adheres to the prerequisites iSERVcmb sets. Currently, such an approach appears easier to implement in offices, retail, educational facilities and hotels, as there is strong evidence these sectors already have sub metering recording at sub hourly intervals, in a variety of areas and components inside their buildings, and are in a position to send energy consumption data electronically for analysis, if asked.

14.2 REASONS FOR PARTICIPATION

The main reactions collected from interviews with end users about why they might be interested in using such an approach can be summarized as follows:

- By participating in the project, end users were most interested in benchmarking their HVAC systems, getting more information about their HVAC system(s), saving money and improving their company’s corporate image.
- The majority of end users were satisfied with the HERO reports and stated that iSERVcmb helped them better understand their HVAC system(s).
- The majority of companies believed they already had suitable metering arrangements or could achieve them relatively easily.

- The HERO reports encouraged most end users to change the times for which some or all of their HVAC systems are working, with a few of them making or planning changes to their HVAC systems operation or equipment.
- Many end users stated that cost intensive measures are not implemented because of internal hurdles, e.g. lack of manpower resources, organizations only doing what is required by legislation.
- The majority of end users surveyed stated they would check the performance of their system on a monthly basis, if this could be visualized by a central database such HERO.

Building Services Professional Bodies appeared more interested in how HERO operates, and in the energy performance of real buildings. REHVA and CIBSE adapted existing information and aligned their dissemination activities to include iSERVcmb results that were subsequently distributed through their own international networks consisting of more than 100.000 engineers around the world.

In order to involve and inform other relevant stakeholders, namely HVAC manufacturers and the HVAC industry, the project established a Steering group comprised of Camfil Farr, SWEGON and EUROVENT representatives.

The **reaction from manufacturers** was captured through a survey that was distributed to Eurovent Association members. The main findings were:

- ✓ Continuous monitoring of HVAC components is clearly considered to be helpful in reducing overall energy consumption in buildings.
- ✓ Current HVAC products can provide energy and other performance data over the internet for use by their customers with energy Use (kWh), Air Temperatures (°C), Flow rates (l/s or m3/s), Fluid Temperatures (°C) and Pressure drops (Pa) readily available in most products. Data for Power Demand (W), Relative Humidity (RH) and Flow velocity (m/s) appear not to be as available compared to the aforementioned metrics.
- ✓ HVAC Manufacturers appear to be divided regarding the prospect of providing HVAC energy and performance data, with those willing to share data being able to provide data primarily for Air Handling Units for use by their customers.
- ✓ From the HVAC manufacturers' point of view, the main barriers preventing them from integrating online monitoring within their products are related to the technical know-how/technology behind the use of online monitored data, followed by cost (cost to manufacturer, investment and maintenance cost for customer) and the lack of coherent standards for these systems.
- ✓ According to HVAC manufacturers, it appears that the main advantages for integrating online monitoring systems within their products would be the additional value for the customer and the ability to comply with forthcoming legislation aimed at nearly Zero Energy Buildings.
- ✓ Amongst those manufacturers that knew about iSERVcmb, there is unanimous agreement that similar projects can be helpful for their companies, indicating that the immediate benefit from iSERVcmb is to "Obtain information, comparison and analysis of the in-use energy consumption of my systems and components". The vast majority also agreed they would be interested in participating in a follow-up project to iSERVcmb.
- ✓ It would appear that HVAC manufacturers are sceptical about the prospect of complying with a standard covering data requirements from HVAC components to allow their products to

participate in an iSERVcmb-type process. There is a widespread belief that a possible agreement on this issue would depend on the final data standard agreed, on the numbers of competitors participating, and on ensuring that all extra costs would be imposed fairly across competing technologies.

- ✓ In the case of the creation of an iSERVcmb-type of standard, manufacturers would be interesting in seeing HVAC component energy consumption and Outdoor climate conditions recorded, with Whole building energy consumption and Comfort related parameters following. To meet such a standard, most manufacturers indicated that they can currently provide non sub-hourly data. It is presumed that a move to sub-hourly would be possible if required by the standard.

To conclude, it appears there is great potential for an iSERVcmb-type process to be implemented across Europe given the current state of technology available. HVAC Manufacturers consider that continuous monitoring of HVAC components is clearly helpful in reducing overall energy consumption in buildings, and most can provide energy and other performance data over the internet for use by their customers. Further cooperation with the HVAC manufacturing industry is required to address:

- The HVAC industry's current reluctance to provide HVAC energy and performance data for use by their customers.
- The main barriers HVAC manufacturers believe to be preventing them from integrating online monitoring within their products.
- The HVAC industry's scepticism on complying with a standard covering data requirements from HVAC components to allow their products to participate in an iSERV-type process.

14.3 PROJECT FEEDBACK

A parallel process of holding local workshops at the end of each project meeting, contributed in recovering valuable feedback from the targeted stakeholders. Across Europe, the 9 iSERVcmb project workshops allowed stakeholders the opportunity to ask more details about the project in person, and their main foci were usually the participation specifics and the project's results. During the workshops, building services professionals supported the project by sharing their experiences which allowed the project to develop the iSERVcmb process further.

During the later stages of the project, the professional bodies participating to the project, CIBSE and REHVA, and the iSERVcmb Steering Group members were asked to provide feedback about the project. Overall, continuous monitoring at a sub-hourly level was recognized to provide unique information on the energy consumption of HVAC system and components. Benchmarks that derive from this real world 'big data' were considered to be invaluable in the evaluation of HVAC market products.

The lessons learned through the iSERVcmb project were noted to have the potential of allowing the creation of new standards and guidelines for on-site monitoring and benchmarking of HVAC system products. REHVA has already planned to produce a REHVA Guidebook about inspections of air conditioning systems, and the REHVA Technical and Research Committee has decided to include chapters about monitoring of air conditioning systems based on iSERVcmb results. EUROVENT is also considering producing guidelines for on-site monitoring of HVAC products and systems in the near future. CIBSE is interested in providing up to date guidance on the monitoring and management of HVAC systems, recognizing that the iSERVcmb project has produced invaluable information on this topic. At the time of this report CIBSE are in discussions with the Coordinator about how best to incorporate the project findings into professional guidance for their members.

14.4 OTHER FEEDBACK AND QUOTES

14.4.1 Presentation to EU Member State legislators

iSERVcmb has been presented to the EU Member States legislators via the Concerted Action 3 Project meetings on 4 occasions. The general principle was well received with the main hurdles to implementation being the lack of such a scheme to which the MS could refer, along with uncertainty over costs of implementing and operating such a scheme as there were no existing precedents.

14.4.2 Feedback from EUROVENT

As the main objectives of the iSERVcmb project are to provide indicative benchmarks and energy conservation opportunities to end users based on on-site monitoring of HVAC components, products and systems, this project is complementary to the EUROVENT activities as it aims to provide to the end users more information about the efficiency of their HVAC systems. Therefore, it was a very good opportunity for EUROVENT to follow and support the iSERVcmb project and to disseminate the project concept and its results to European HVAC manufacturers. Real performances of HVAC products and systems are not only affected by standard performances of the products leaving the factory. Other parameters like design, installation, control strategy, maintenance and usage are to be taken into account by energy managers in order to have a good understanding of their final energy bills. Therefore the iSERVcmb onsite monitoring approach is complementary to the EUROVENT approach. It is anticipated that the results of this project will impact the future work of EUROVENT regarding their certification schemes. As one of the main barriers to the widespread iSERVcmb approach are the availability of onsite monitoring systems, and also the quality and reliability of the gathered data, therefore EUROVENT may work in the future on the guidelines of on-site monitoring of HVAC products and systems.

“The reports produced within the iSERVcmb will be a useful information regarding real energy use of HVAC&R products.” Sylvain Courtey, Eurovent Certita Certification

14.4.3 Feedback from Camfil Farr

The iSERVcmb project provides the opportunity to address two important issues: improving building HVAC energy efficiency, while maintaining or improving clean indoor air quality. The building HVAC energy data, when compared to other building real energy performance profiles will give owners and building operators the opportunity to make informed decisions on implementing ECO’s. The information from the iSERVcmb project forms a basis for comparison with other similar buildings and over time, if further developed, will give improving accuracy for analyzing building energy use profiles. Any benchmarks produced would need to be regularly checked and updated in the light of new data.

“The iSERVcmb database provides a good first step on the road to help ensure healthy sustainable buildings for the next generations of people working in our city based economies.” Peter Dyment, Camfil Farr Ltd.

14.4.4 Feedback from SWEGON

SWEGON joined the iSERVcmb project as a member of the Steering Group, because the planned goals of the project were attractive for a European manufacturer of ventilation systems. During the project SWEGON could gather information about the situation of metering and the type of HVAC systems in the different European countries. It is a conclusion from SWEGON that the product needs to be matured and fitted into a commercially viable frame.

"The idea of climbing Mt Everest is simple to understand, but the doing it requires raw motivation and a will to succeed. This is like the task before us; lowering the energy in European building stock, easy to understand, difficult to implement without motivation and the will to succeed." John Woollett, Swegon Ltd.

14.4.5 Feedback from REHVA

REHVA was previously involved in promoting HARMONAC and became a partner of iSERVcmb because its topic is within its key interest areas. Increasing the efficiency of HVAC systems through remote and continuous monitoring, and the development of a monitoring tool and methodology, which can have big advantages compared to inspection, is very interesting for the REHVA HVAC community. They found it useful to gain reliable, evidence-based information on system efficiency as well as EU-wide benchmarks about HVAC system energy use and efficiency. REHVA's main interest is to inform its network about the verified and final results from the HERO application and database. They have learnt that professional maintenance, and making metering systems compatible for monitoring are key in order to operate the database and benchmarking tool. REHVA will inform its members and supporters – representing more than 100,000 HVAC professionals and industry representatives – about the iSERVcmb results via publications in the REHVA European HVAC Journal and REHVA online media.

"iSERVcmb will change the guidelines on achieving energy efficiency in HVAC systems" Olli Seppänen, REHVA

14.4.6 Feedback from CIBSE

The work that the iSERVcmb team undertook is at the heart of CIBSE's knowledge areas. Increasing the energy efficiency of HVAC systems by monitoring and improving their operation is of high importance to CIBSE members and the wider CIBSE community. Providing up to date guidance on monitoring and management of heating, ventilation and air conditioning systems is a key task for CIBSE.

CIBSE found the energy use and system efficiency benchmarks based on up to date and real building case studies to be very useful. Although the iSERVcmb outputs could not be incorporated into CIBSE knowledge within the life of the project, due to the need for peer review, the information generated by the project will form a significant contribution to future CIBSE guidance.

Following a questionnaire answered by CIBSE members, the initial complexity of the iSERVcmb application seemed to be the main barrier to implementation. Recommendations provided to the iSERVcmb team aimed to help in reducing this complexity and in making the process more user friendly.

CIBSE is exploring different ways of disseminating the iSERVcmb knowledge to its members, in particular how to use the iSERVcmb data to contribute to the updating of CIBSE energy benchmarks.

"The iSERVcmb project has demonstrated the very considerable scope to save energy in our existing building stock and the potential benefits to UK and EU energy and climate change policies." Anastasia Mylona, CIBSE

14.4.7 Feedback from End Users (CIBSE iSERVcmb seminar)

“iSERVcmb has great potential to become a tool to help designers, building users and the whole construction industry in our search to improve the energy efficient use of building.” Dr Jose Hernandez, Associate at Pick Everard

14.4.8 Feedback from the European Commission

“iSERV will produce advances in continuous monitoring & benchmarking that will help shape the future of EU legislation on Energy Efficiency and, in particular, system inspections.” Pau Audi-Garcia, EC-EASME

14.5 PUBLICATIONS AND PAPERS

The project was disseminated in over 313 separate events, publications, papers, etc. Full details of all these can be found under the folder “Publications and other dissemination” at www.iservcmb.info/results.

15 Transposing iSERVcmb into a working system within the EU

This section considers the following issues to be overcome to implement iSERVcmb across the EU:

- Collecting sub-hourly utility data
- Collecting sub-hourly sensor data
- Describing the floor area in a building
- Describing an activity in a space
- Describing an HVAC component
- Describing a lighting system
- Describing small power systems
- Who should operate such a system?
- Who should have access to the data on the system?
- How often should the building description be updated?
- Can owners of buildings 'cheat' to obtain better apparent performance?

iSERVcmb has identified that an approach based on physical assets and utility monitoring in buildings can be implemented throughout the EU and can return significant savings to end users in many forms, including improved choice of energy efficient plant, understanding of operational needs, reduced energy costs, reducing business continuity risks, improved clarity of building energy use, etc..

However, as with the introduction of any new process or system, a successful implementation depends on agreement on definitions of terms along with operational parameters such as frequency of reporting, who should administer such a scheme, etc..

This section outlines the main elements of iSERVcmb, and discusses what is needed to enable it to be referred to by EU Member State legislators as part of their transposition of the EPBD into National Legislation.

This section proposes that this implementation may be undertaken in the following stages:

1. Require description of all non-domestic buildings in the EU in the iSERVcmb spreadsheet, so that all building owners can obtain the immediate efficiency benefits of simply understanding their buildings and systems more clearly. This can be implemented at a minimal cost to the EU in a time-frame of under a year.
2. In parallel, examine the practical issues surrounding the implementation of the proposed large-scale data collection needed. It is proposed these issues be determined within 6 months through a working group comprising representatives of all actors in this area i.e. iSERVcmb Coordinator, iSERVcmb database designers, European Commission, end users, building developers, financiers, building operators, EU MS legislators, HVAC equipment manufacturers, HVAC maintenance companies, building services professional bodies, building services consultants, HVAC Inspection bodies.
3. If stage 2 shows the approach is practically achievable then a series of actions will emerge which should then be addressed by the relevant actors e.g. HVAC manufacturers might need to provide additional functionality such as internet connectivity for the embedded intelligence in their building services components.

4. Once the actions in stage 3 have been completed then there should be a process to which legislators can refer to in their countries legislation.

In reality the following are the main issues that iSERVcmb raises, along with solutions where they already exist:

Issue	Solution
Collecting sub-hourly utility data	There are a number of existing market solutions for retrofitting utility meters to existing HVAC components or systems. For new HVAC equipment, many manufacturers already offer remote access data collection options which could be used to provide the data at component level for iSERVcmb purposes
Collecting sub-hourly sensor data	There are a number of existing market solutions for retrofitting sensors to existing HVAC components or systems. For new HVAC equipment, many manufacturers already offer remote access data collection options which could be used to provide the data for iSERVcmb
Describing the floor area in a building	The measurement of floor area is undertaken differently in different Member States for existing buildings. The modularity of the iSERVcmb approach means that currently acceptable means of describing floor areas could continue to be used in the interim. The rapidly increasing use of Building Information Modelling (BIM) in building design and operation means that in future detailed floor area information will be directly available from these models and will enable direct comparison between Member States, increasing the potential value of the data in the database for more accurate benchmarking across EU Members States.
Describing an activity in a space	iSERVcmb has based its activity types on existing methodologies which use activity descriptors. The project has revealed there are gaps and overlaps in some of these descriptions which should be addressed e.g. the activity type of a cold room (a refrigerated walk-in store) needs to be added. It is estimated these should be capable of being added within six months, to include suitable benchmarks derived from the iSERVcmb dataset.
Describing an HVAC component	Established descriptions of HVAC systems and their components already exist in Professional Body literature, and these are used by iSERVcmb. iSERVcmb has worked to use HVAC component performance information pertinent to the aims of iSERVcmb e.g. nominal installed power, but recognise that further fields may wish to be added by various actors. The involvement in iSERVcmb of HVAC accreditation body Eurovent Certification has meant there is a possibility of referencing their laboratory performance database in future

Describing a lighting system	iSERVcmb has not fully developed a description of all lighting system types or benchmarks but this should be simple to do based on the limited number of lighting system types available and the lighting system data already collected by iSERVcmb but not yet analysed. A lighting system section already exists in iSERVcmb but simply covers the complete range of lighting types currently used.
Describing small power systems	This area requires further discussion, but is covered to a large extent by the activity description for a space. What this information does is allow the small power electrical energy component of an activity to be extracted to assist in setting future benchmarks – thus allowing more accurate predictions of loads on the HVAC systems for modelling applications
Who should operate such a system?	There are a number of bodies, organisations and companies who would wish to operate such an approach should it be offered. The technical feasibility has been proven, the rest is politics. iSERVcmb suggests that whoever the operator is in each Member State they should have no conflicts of interest regarding the use of the data.
Who should have access to the data on the system?	For the full benefits of the system to be realised then all the actors noted above will have legitimate interests in various analyses of the data. If the principle of only the data provider having access to their specific building data is held as a central tenet, then there should be no issue with providing anonymised and aggregated analyses of the data for various interested groups. An example of useful use of the data would be in aiding the EU MS in targeting financial support or advice towards those areas that the data is showing would provide a substantial return in terms of reducing National Power demands and overall energy consumption.
How often should the building description be updated?	This is not yet known. It is possible through analysis of the sub-hourly data to know when a significant change has occurred in a building, such as a major change of use, addition of new space or change of building services. At this point a request to update the building description could be sent to the building owner with a trigger to check whether this happens or not. All building descriptions are held on the database and can be downloaded into the most recent iSERVcmb spreadsheet template for amendment by the relevant person in an organisation.
Can owners of buildings 'cheat' to obtain better apparent performance?	The nature of the system means that it is difficult to provide a false building description that is supported by the subsequent data sent to iSERVcmb. Should this prove to be a problem in practice there are a number of ways to make it more difficult e.g. a requirement that initial entry of a building to the system should be accompanied by floor plans; a signed declaration by the building owner that the description is factually accurate at that date; etc,.

The above are some of the main points raised in workshops and meetings during the iSERVcmb project. It is the opinion of the Coordinator that existing accepted descriptions of all the elements needed for the approach already exist, so these should not be a major hurdle for the project.

The main hurdles likely to need to be overcome are legislative and political ones which the Coordinator is not yet aware of.

On the legislative front, it would simply require legislation to refer to an acceptable implementation of the iSERVcmb system within a Member State to enable end users to start to use the approach. The details of the additional benefits of doing so for the end user, above and beyond the likely energy savings achieved, still need to be explored and agreed e.g. could it be used to replace requirements for universal EPBD Inspections with evidence based Inspections instead?

The above discussion shows there are a few issues still to be resolved before iSERVcmb can be implemented at a large scale, but the rewards of up to 30+% reductions in electrical energy use alone at building level means it is worth spending the time to try and resolve these issues. Savings of this magnitude could avoid the construction of unnecessary power stations, improve the overall resilience of our power networks and contribute significantly towards the 20% energy efficiency targets for 2020.

16 Conclusions

- Significant energy and cost savings up to 5% of the total EU electrical energy use can be made using the iSERVcmb approach
- The production of novel benchmarks for HVAC component power demand and energy use by activity served has been shown and the measured demands and consumptions across HVAC components in Europe by Activity type have been provided
- Technical challenges to implementation of the iSERVcmb methodology are shown to be solvable and describable with existing accepted terminology
- Main implementation barriers are the initial description of the buildings and their services, and the establishment of a reference service to which the EU Member States can refer in legislation
- A robust standard metering methodology for the EU would resolve data format issues and provide guidance on where to install meters.
- The iSERVcmb methodology addresses how to use the increasingly large amounts of data available directly from HVAC components.
- Maintenance issues for HVAC components seem neglected in Northern Europe and can add significant savings quite easily
- A portable method for collecting IAQ data was established and the data shows IAQ to be within existing guidelines in most systems tested.
- Physical Inspections have shown that the same systems/components are used across the EU. Maintenance standards and system sizing appear to divide by climate and activity, with Southern European Member States having better maintenance and less oversizing of systems. 'Filter maintenance' and 'refrigerant pressures in Cold Generators' are the most frequent issues requiring attention in the iSERVcmb inspected systems.
- The automatic detection of ECO's from data collected was demonstrated.
- The use of modelling to identify ECO's was demonstrated. The commonest ECO's predicted were replacement of lighting equipment with low consumption types; install window film or tinted glass; optimise control of blinds; and provide correct time control of HVAC components.
- Monitoring is shown to be generally 1.5 to 4 x more effective in identifying potential savings than Inspection

The iSERVcmb project has been trialled across Europe, and there are many findings and observations that have not fitted into this final report, which is meant to provide a basic overview of the project and its potential impacts.

Analysis of the project data will continue, with the aim of encouraging a move towards using the explosion in data and information available to building professionals to help produce more efficient, healthy buildings that are fit for the challenges of the 21st Century.

17 Websites and contact Information

iSERVcmb results: http://www.iservcmb.info/results

iSERVcmb website: http://www.iservcmb.info and http://www.eaci-projects.eu/iee/page/Page.jsp?op=project_detail&prid=2430

HARMONAC website: www.harmonac.info and http://www.eaci-projects.eu/iee/page/Page.jsp?op=project_detail&prid=1605

AUDITAC website: http://www.cardiff.ac.uk/archi/research/auditac/ and http://www.eaci-projects.eu/iee/page/Page.jsp?op=project_detail&prid=1439

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