KnoholEM

Knowledge-based energy management for public buildings through holistic information modeling and 3D visualization

FP7 – 285229 – Collaborative Project

Knowledge-based energy management for public buildings through holistic information modelling and 3D visualization

Deliverable 5.2

Evaluation Procedure for Energy Savings and Investment Amortisation

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Executive Summary

As described in the Description of Works, in this task the procedure for the evaluation of the energy savings realised by “both a single measure (reflected through an ontology rule) as well as through the entire building-specific ontology rule set will be developed. This procedure will be strongly linked to the data mining algorithm developed in WP2 (task 2.4)”. In this related task, data mining algorithms for knowledge extraction from the energy consumption and production data collected from the demonstration object buildings are developed (KIT and Isotrol). However this task has just been completed for WP task 2.4, this task’s on-going works becoming due for months 18-30 of the project. Once the development of data mining algorithms that are required for the extended data analysis based on the specifics of the input data (on energy demand and consumption) is completed it will be possible for some level of evaluation of the energy savings. Therefore until this point only a generic methodology for this procedure can be drawn up and so this document outlines which historic energy consumption data has been made available for analysis and where applicable any information that will be provided for future use (typically where additional metering has been applied or existing meters added to the BMS).

The Description of Works also states that in a second step, “this procedure will be enhanced to consider also investment costs and evaluate the amortisation duration”. Again, to date, the KnoHolEM solution has not been integrated into any demonstration object building, thus no investment in hardware or software in the buildings has been made or any savings created by the solution. Therefore, it is also not possible to provide more than a generic methodology for this procedure within this Deliverable Report.

Contents

1 Introduction

As described in the Description of Works, in this task the procedure for the evaluation of the energy savings realised by "both a single measure (reflected through an ontology rule) as well as through the entire building-specific ontology rule set will be developed. This procedure will be strongly linked to the data mining algorithm developed in WP2 (task 2.4)". However the initial stage of this task has just been completed and WP task 2.4 is only due between months 18-24 of the project, therefore it is only feasible at this stage of the project to create a methodology statement for the evaluation works and list the information available for analysis. Once the related task's data mining algorithms have been created (by KIT and Isotrol) for knowledge extraction from the energy consumption data collected analysis work can begin on the demonstration object buildings. Further, one of the Demonstration Object buildings, the PICA building (Seville) was brought into the project as a replacement one year into the project and thus analysis of this building will be delayed in comparison to the remaining original buildings as data collection, including energy consumption, started one year later.

From current information received it is clear that the validation process in the study may be hindered by a lack of suitable sub-metering on many items of plant across a number of Demonstration Objects. This will necessitate approximations to be made and rather than the monitoring of sample of areas of the building studied, the results gained from a whole building or floor level then applied to the Knoholem sample areas on a pro rata basis. For example, it was not possible to gain accurate information on the breakdown of air conditioning electricity consumption – i.e. fan, pump and heating/cooling use – even in the buildings where the level of electricity consumption data can be applied to the set Knoholem study area. Without additional sub-metering placed on many of these missing items and/or a greater disaggregation of energy use by floor, any comparisons between the "before" and "after" optimisation of control proposed and then used by Facilities Managers will be difficult to detect with any level of certainty.

The project assumed that such sub-meter networks could be monitored and records logged for all major items of plant automatically via the BMS for the Demonstration Objects. In reality, there has proved a wide degree of granularity of the data submitted between buildings, making comparisons between the buildings during the evaluation procedure very difficult, though clearly some buildings provide a clearer picture of their energy use than others. There may also be issues for the "post Knoholem" solution when comparing the energy use against the current levels. Across the very different HVAC and electricity distribution layouts found within the Demonstration Objects there may be a great variance between which items of the tenant power distribution boards and their specific heating/cooling zones that the project will be able to control and thus optimise. Furthermore, the Demonstration Objects have been chosen as they are new builds with low energy consumption and innovative building services techniques, for example the HHS building. Comparisons against these already low energy demands will be even harder to determine and the disaggregation of energy consumption against demand harder to discern for the novel systems (e.g. HHS' aquifer and ventilation system working in combination). Therefore, any future comparisons being made against already estimated/aggregated data in this study will face a further difficulty in the evaluation procedure.

Though all Demonstration Objects collect sensor data for internal environmental parameters, such as air temperature and CO_2 for control within the building, some also collect external parameters that would aid build a picture of the local micro-climate, however they have not as yet been provided. For the evaluation procedure such localised data would be useful to create site specific information, such as Heating & Cooling Degree Days, for the later normalisation of the heating and cooling energy consumption during the validation procedure.

2 Evaluation Procedure Methodology

2.1 Existing Data Granularity from Demonstration Objects

As summarised by the initial data gathering within Deliverable 5.1 the granularity of data regarding energy consumption for the Demonstration Objects within the Knoholem project ranges greatly from very good, hourly automated meter readings that disaggregate sub-areas and plant items in the buildings to much poorer granularity with data that is collected only via manual meter readings and finally to data that will not be available at all as there is no facility to measure that particular metric or power usage.

Therefore, whilst in some buildings it appears achievable to evaluate the “pre and post Knoholem” energy consumptions for the sampled areas, in others this may only be possible with a number of approximations and pro-rata assumptions about the energy use – naturally, such approximations and assumptions could induce a positive or negative skewing of the comparison in energy use terms. Whilst in some instances, the data that can be categorically attributed to an end use makes up the majority of energy demand, in no building can all energy use be attributed. However, where sub-metering allows for the collection of a combination of data, for example small power on a ring main plus lighting or HVAC data also containing pump and fan use, it may be possible to determine each individual part by analysis of the run hours and power rating of individual plant items and subtracting them from the total. Furthermore, the innovative nature of some building services technologies in the case study buildings ensures that some level of assumption is necessary to determine actual power consumption rather than heating or cooling demand as consumption is not specifically metered. For example, the cooling and heating systems within HHS allow, with some effort, the BMS to identify the heating and cooling demands down to individual room level (via supply and return temperatures) from the ground water sourced heat pump supplying the radiant system and air supply, yet on a similar room basis it is not possible to determine energy consumption - instead the heat pump coefficient of performance calculated on a building total basis must be used to create the “real” power consumption.

As detailed in the Introduction to this document, this lack of detail/granularity in the energy consumption data will greatly affect the veracity of the evaluation procedure i.e. if the energy use drop (or gain) cannot be directly attributed to equipment now optimised via Knoholem (or energy use disaggregated to the extent where such inferences can be detected) it will be difficult to conclude that these project works have been the reason for a change in energy consumption. Whilst any assumptions or approximations are made to discern localised energy use are reasonable workaround solutions in themselves, e.g. assessing cooling energy consumption within the studied area of a building by pro rata of the entire building/floor’s usage, these add an error margin to the certainty with which the energy consumption change can be attributed to Knoholem. For this reason, and given the large variance of the metering and sub-metering between the Demonstration Object buildings, it is only reasonable to evaluate and analyse their energy use on a building by building level rather than using a common and thus more ideal methodology for all buildings. More importantly, as Knoholem proposes no active control of building services rather the information to Facilities Managers (FM) or other users to actively optimise control, some measure of gauging the FM’s interactions will also be needed to gauge the level of actual optimisation performed.

2.2 Proposed Analyses and Current Energy Consumption Profiles

Below, broken down by Demonstration Object building, is the current Energy consumption information available as previously reported in the precis tables of Deliverable 5.1 and gathered through the Data Collection table common to all buildings (also included within D5.1 Section 1.1.1). The information is current to 28/2/13 with any additional information received from the Demonstration Object’s owners/Facilities managers or any added metering applied since D5.1 included. The comments section of the table gives the proposed analysis procedure given the scope of information received and any further information expected from that building.

2.3 Energy Consumption Data for Analysis per Demonstration Object

2.3.1 Forum Building, Eersel

FORUM	Availability*	Source of Information	Analysis Procedure
A.1 OVERALL ENERGY USE AND CO2 – **WHOLE BUILDING**			
♦ 1)Imported electricity consumption (i.e. excluding renewables): total and per m^2 floor area (by calculation)	Available	Manual meter reading with update of electricity meter to BMS on-going. Metering by sub areas of building e.g. Lunetzorg, Fisio	The Facilities management manual meter readings can act as a seasonal or annual check against future use. The frequency of past readings is too low to allow any improved analysis. Further data is expected once the incoming gas and electricity main incomer readings are automatically placed on the BMS.
♦ 2)Gas Consumption (where relevant): total and per m^2 floor area (by calculation)	Available	Manual meter reading with update of gas meter to BMS on-going. Gas metered also by sub areas of the building.	As above, the frequency of past meter reading data is low enabling little seasonal comparison for low heating demand.
♦ 3) Resulting CO2 emissions per m^2 floor area	N/A	calculation	To be used with relevant CO2 conversion factor for each country applicable for the demonstration building.

A.2 CONSUMPTION OF DELIVERED ENERGY – **END USE & SAMPLE AREA OF DEMONSTRATION OBJECT**			
♦ 1) Electricity use for lighting: total and per m^2	Available for selected rooms used within project	Automated hourly collection from Plugwise meter. Also full details of lighting load known for each room (lamp and rating count)	The lighting load has effectively been sub-metered, per room in several sample areas. Where this is not achieved it can be attributed by assuming run hours against total load. The Plugwise enabled zones are sufficient for detailed analysis of the Knoholem optimisation on lighting loads.
♦ 2) Electricity use for ventilation: total and per m^2	Not appropriate to all areas within the building. Mixture of natural ventilation, AHUs and direct (DX) air conditioning in building.	No Automated collection of energy consumption from individual AHUs	The sample area is served by a variety of systems, though no individual AHU supplies are sub-metered and logged. No opportunity to compare energy consumption via meter readings.
3) Total run-hours for fans	Can be gained from Facilities Team.	Fan ratings and hours run can be gained by FM and a ventilation energy use derived by calculation	This will give a daily use estimate for ventilation for comparison provided run hours/operating times remain constant, calculation possible only if fans run to set operating schedule, set flow rates.
♦ 4) Cooling energy use by Main Chillers or other AC unit: total and per m^2	Dependant on AC system	For the areas within the study, it is not possible to attribute cooling use or it is not relevant (natural ventilation areas)	Data gathering would need to be for the multiple different AC systems in use in Forum. However, there is no Chiller plant supplies sub-metered and logged that can be attributed to solely Knoholem project areas, analysis does not appear possible.
♦ 5)Electricity use for pumps: total	Not available	Automated meter reading is not available.	Pump power cannot be accounted for in sample areas or for building. A calculation of hours run given flow rate and duty to give an energy consumption would be needed(w).
6) Total run-hours for pumps	Unknown at present	calculation	As per fans can only be calculated if pumps run to set times

♦ 7) Electricity use for other purposes (e.g. lifts, catering): total	Unknown	Lifts and catering areas are not regarded as part of sample study area	Though vertical transport and catering are on site, these areas are not within the circuit of the sampled areas within the project , rendering their analyses irrelevant even for subtraction from total power consumption purposes.
♦ 8)Electricity use for small power (which includes local water heating and task lighting): total and per m^2	Available for selected rooms used within the project.	As per the lighting load, Plugwise dataloggers are installed to measure selected rooms additional electricity consumption. Elsewhere in the sample zone a full list of electrical devices and rating has been collected.	The level of sub-metering of small power is very good where the Plugwise loggers are installed i.e. collected data down to discrete rooms of the building. Only a total possible load is known for other sample rooms, although it is possible to swap the Plugwise units to these rooms as the energy use is season independent. Small Power should therefore be metered in enough detail for adequate analysis..
♦ 9)Heating energy use for ventilation air: total	Not Applicable	Gas heating system for radiators in sample areas only	Not applicable here, see point 10.
♦ 10)Total gas use for heating and per m^2	Not available for the sample area of the building, only partial building meter.	As in A2, gas is metered by sub area of the building, however manual readings to date with upgrade to add gas meter to BMS	Whilst the main incoming gas meter data is not metered separately for the purely “Knoholem areas”, as with electricity meters the building is divided into metered sub areas. The pro rata of gas consumption for .the sampled area will therefore be more accurate, however only manual meter readings exist at present providing little granularity of data to analyse.
♦ A.3 OTHER INFORMATION			
♦ 1) weather data: air temperature, windspeed, solar radiation, humidity or moisture content	Available	Automated collection started in January 2013	This data can be used to normal the heating and cooling energy consumption for site specific weather data.

♦ 2) operation of automatic blinds	Not applicable	-	-
♦ 3) operating times of plants	Available via Facilities team	The various parts of the building have different operating hours. Knoholem nonly within Ground floor areas	For use with approximating HVAC energy use where there is no sub metering available
♦ 4) known changes to total occupation levels. Also representative patterns of occupancy	Available	Collected for other Work Packages	To normalise consumption data for occupied and unoccupied periods. Sensors within Knoholem system should provide occupancy data "post optimisation" analysis.

2.3.2 Bluenet Building, Seville

Bluenet Building	**Availability***	**Source of Information**	**Analysis Procedure**
A.1 OVERALL ENERGY USE AND CO2 – **WHOLE BUILDING**			
♦ 1)Imported electricity consumption (i.e. excluding renewables): total and per m^2 floor area (by calculation)	Available	Automated meter readings are available but the data is already provided for the 5^{th} floor only. This is adequate as the Knoholem surveyed areas are within this floor.	The frequency of past readings is very good with hourly readings for a year. This will allow analysis of electricity use for the 5^{th} floor's main incomer readings by season also.
♦ 2)Gas Consumption (where relevant): total and per m^2 floor area (by calculation)	Not Applicable	No gas usage within building.	Building has a very low heating demand, supplied by electricity – this can be analysed in the sub-meter catering

			for the HVAC within the 5th floor and its smaller sections..
♦ 3) Resulting CO2 emissions per m^2 floor area	N/A	calculation	To be used with relevant CO2 conversion factor for each country applicable for the demonstration building. Spanish electricity carbon emissions factor will be used – this analysis will be simple but may need to highlight CO2 emissions factor changing between sampled years.
A.2 CONSUMPTION OF DELIVERED ENERGY – **END USE & SAMPLE AREA OF DEMONSTRATION OBJECT**			
♦ 1) Electricity use for lighting: total and per m^2	Available for all selected sub sections used within project	Automated hourly collection from BMS. As with all hourly sensor readings this is provided by individual sections of the floor, equating to one corner of approx. 300m^2 each..	The lighting load has been sub-metered, per corporate area across the project's sample areas. This hourly rate data for each zone is sufficient for detailed analysis of the Knoholem optimisation on lighting loads.
♦ 2) Electricity use for ventilation: total and per m^2	Available within a totalised HVAC meter.	Hourly energy consumption fpr HVAC is provided by the BMS rather than meters on individual AHUs	Whilst the building is metered so that discrete individual areas can discern the HVAC use, the sub-metered and logged does not distinguish between end use (e.g. fan power). Disaggregation of fan power may need to be approximated from run times for the mechanical ventilation..
3) Total run-hours for fans	Can be gained from M&E drawings and design notes and Facilities Teams.	Fan ratings and hours run can be gained by FM and a ventilation energy use derived by calculation	This will give a daily use estimate for ventilation for comparison provided run hours/operating times remain constant, calculation possible only if fans run to set operating schedule, set flow rates. Used to disaggregate A2.2 above.

♦ 4) Cooling energy use by Main Chillers or other AC unit: total and per m^2	See A2.2 above. HVAC totalised reading only.	HVAC total would need to have fan power subtracted by calculation to provide a heating/cooling consumption.	As A2.2 above states, analysis of heating and cooling could be assessed if fan power for the mechanical ventilation element can be disaggregated as stated in A2.3 above.
♦ 5)Electricity use for pumps: total	See A2.2 above. HVAC totalised reading only	Hourly energy consumption fpr HVAC is provided by the BMS rather than meters on individual AHUs.	Pump power cannot be accounted alone. HVAC totalising meter only. Without a gas supply and t would therefore be assumed that all domestic hot water runs on point of use water heaters and there will be no pump power attributable to this.
6) Total run-hours for pumps	Unknown at present	calculation	As per fans can only be calculated if pumps run to set times
♦ 7) Electricity use for other purposes (e.g. lifts, catering): total	Available for UPS element of energy use (known as "clean" energy)	Hourly data per sub section of the 5^{th} floor is provided for electricity provided by the UPS.	The UPS system consumes 11% of electricity demand and is used for financial as well as security of supply purposes rather than simply to protect from voltage changed from the grid incoming supply. Its level of use is so substantial that the same hourly data collection is important when analysing energy consumption, post Knoholem – however, all things being equal it would be expected to make up a similar annual electricity consumption..
♦ 8)Electricity use for small power (which includes local water heating and task lighting): total and per m^2	Available for the selected floor and sub areas/rooms used within the project.	As per the lighting load, HVAC and UPS, the additional electricity consumption going to the sockets is metered hourly. A full year's electricity consumption is available for the sockets as per the other items.	The level of sub-metering of small power is very good and is. collected down to the discrete $300m^2$ sections of the sampled floor.. Small Power should therefore be metered in enough detail for adequate analysis. However, any significant changes in per person equipment load or occupancy rates will need to be catered for in the analysis (see A3.4)

♦ 9)Heating energy use for ventilation air: total	See A2.2 above. HVAC totalised reading only	HVAC total would need to have fan power subtracted by calculation to provide a heating/cooling consumption	As A2.2 above states, analysis of heating and cooling could be assessed if fan power for the mechanical ventilation element can be disaggregated as stated in A2.3 above..
♦ 10)Total gas use for heating and per m^2	Not Applicable	Gas heating system not in use.	Not applicable here.
♦ A.3 OTHER INFORMATION			
♦ 1) weather data: air temperature, windspeed, solar radiation, humidity or moisture content	Not Available	-	Local weather station data will therefore be used to normal the heating and cooling energy consumption for site specific weather data.
♦ 2) operation of automatic blinds	Not applicable	-	-
♦ 3) operating times of plants	Available via Facilities team	Detailed operating hours can be collected for building, however only Isotrol office floor is part of. Knoholem project.	For use with approximating HVAC energy use where there is no disaggregation of mechanical ventilation to assess ventilation operating hours thus fan power consumption.
♦ 4) known changes to total occupation levels. Also representative patterns of occupancy	Available	Collected for other Work Packages	To normalise consumption data for occupied and unoccupied periods. Occupancy detail should be readily available as the building area studied is occupied by project partner. Sensors within Knoholem system should provide occupancy data "post optimisation" analysis.

2.3.3 MediaTIC Building, Barcelona

MediaTic Building	Availability*	Source of Information	Analysis Procedure
A.1 OVERALL ENERGY USE AND CO2 – **WHOLE BUILDING**			
♦ 1)Imported electricity consumption (i.e. excluding renewables): total and per m^2 floor area (by calculation)	Available	Automated meter readings are available for the main electrical incoming meter, There is also a separated meter reading for the UPS consumption.	The frequency of past readings is very good with 10 minute interval readings – these have been received for 7 months data do far and need updating to cover a full year (2012). This level of detail will allow analysis of electricity use for the main incoming meter by season also and disaggregate the UPS use..
♦ 2)Gas Consumption (where relevant): total and per m^2 floor area (by calculation)	Not Applicable	No gas usage within building.	Building has a very low heating demand, supplied by electricity.
♦ 3) Resulting CO2 emissions per m^2 floor area	N/A	calculation	To be used with relevant CO2 conversion factor for each country applicable for the demonstration building. Spanish electricity carbon emissions factor will be used – this analysis will be simple but may need to highlight CO2 emissions factor changing between sampled years. The emission factor for the district heating system will also need to be calculated and applied for the heating/ccoling demand element of total consumption.

A.2 CONSUMPTION OF DELIVERED ENERGY – **END USE & SAMPLE AREA OF DEMONSTRATION OBJECT**			
♦ 1) Electricity use for lighting: total and per m^2	Available for selected floor sections used within project	Automated hourly collection from BMS. As with all hourly sensor readings this is provided by individual sections of the floor, equating to one corner of approx. $300m^2$ each..	The lighting load has been sub-metered and is recorded for the BDigital office area across the project's sample areas. This 10 minute interval rate data is sufficient for detailed analysis of the Knoholem optimisation on lighting loads.
♦ 2) Electricity use for ventilation: total and per m^2	Not Available	meter readings of AC system flow and return only	No ventilation energy use data has been provided for analysis.
3) Total run-hours for fans	Not Available.	Fan ratings and hours run can be sought from FM and a ventilation rate only energy use derived by calculation	This will give a daily use estimate for ventilation for comparison – MediaTic ventilation runs 24 hour a day according to operating schedule, set flow rates must be found.
♦ 4) Cooling energy use by Main Chillers or other AC unit: total and per m^2	District heating system's cooling requirement is metered and it's electrical consumption on a building level.	AC total would need to be pro rata for Bdigital offices – this is heating/cooling consumption from District system only	No data for the mechanical ventilation element can be disaggregated and information is only available at present for the District energy system..
♦ 5)Electricity use for pumps: total	See A2.4 above.	Hourly energy consumption fpr HVAC is provided by the BMS rather than meters on individual AHUs.	Pump power cannot be accounted alone. Pump power supplying the District system may be available from scheme operator and attributed to the building pro rata.
6) Total run-hours for pumps	Unknown at present	calculation	See A2.5

♦ 7) Electricity use for other purposes (e.g. lifts, catering): total	Available for UPS element of energy use (known as "clean" energy)	10 minute interval data within BDigital sections of the 5th floor is provided for electricity provided by the UPS.	The UPS system consumes a large element of electricity demand and is used for financial as well as security of supply purposes. For this reason the 10 minute interval data collection is separated between "clean" and "dirty" electricity consumption, i.e. UPS and grid supply– this electricity consumption is available for analysis disaggregated for the BDigital offices of the project area..
♦ 8)Electricity use for small power (which includes local water heating and task lighting): total and per m^2	Available for the selected BDigital floor used within the project by subtraction of lighting usage.	Whilst there is no metering of the additional electricity consumption going to the sockets, the 10 minute interval building total use can subtract the lighting load for all other unregulated energy use on the sample floor.	By subtraction of the lighting load the level of sub-metering of small power is very good and the unregulated electricity use will be known on the same 10 minute interval. Small Power should therefore be disaggregated in enough detail for adequate analysis.
♦ 9)Heating energy use for ventilation air: total	See A2.4 above. District heating system meter reading only	Meter readings available but manual only and for district system on a building level.	As A2.4 above states, analysis of heating and cooling cannot be assessed for anything under than building level and via the meter readings on the district heating/cooling system making detailed analysis difficult.
♦ 10)Total gas use for heating and per m^2	Not Applicable	Gas heating system not in use.	Not applicable here.
♦ A.3 OTHER INFORMATION			
♦ 1) weather data: air temperature, windspeed, solar radiation, humidity or moisture content	External weather station reads these values but as yet no historic data gathered.	Permission needs to be bought to gather external weather sensor data from BMS from building owner. No historic data is available.	Local weather station data will therefore be used to normal the heating and cooling energy consumption for site specific weather data until/if the weather sensor data on the BMS can be collected.

♦ 2) operation of automatic blinds	ETFE system in place	This has a manual operation and cannot be recorded.	ETFE glazing system operation (i.e. its changing opacity) cannot be gauged.
♦ 3) operating times of plants	Available via Facilities team	Detailed operating hours can be collected for building.	Overview of building operation within general mechanical services description for WP1.
♦ 4) known changes to total occupation levels. Also representative patterns of occupancy	Available	Collected for other Work Packages	To normalise consumption data for occupied and unoccupied periods. Occupancy details provided for the building area studied – i.e. Bdigital offices (project partner).

2.3.4 HHS Building, The Hague

HHS	**Availability***	**Source of Information**	**Analysis Procedure**
A.1 OVERALL ENERGY USE AND CO2 – **WHOLE BUILDING**			
♦ 1)Imported electricity consumption (i.e. excluding renewables): total and per m^2 floor area (by calculation)	Available	Automated meter readings are available but the data is already provided for period to August 2012..	The frequency of past readings is very good with hourly readings however it needs updating for a full year. This will allow analysis of electricity use for the sampled area of 340m^2 by season also but on a pro rata basis.
♦ 2)Gas Consumption (where relevant): total and per m^2 floor area (by calculation)	Main gas incomer unmetered, though heat demand from it is metered	Calculation of gas usage within the building has been calculated assuming a 90% efficiency boiler.	Building has a very low heating and cooling demand, supplied by electricity to a heat pump – Additional heating by gas boiler is unmetered but HHS assumption of boiler efficiency will allow calculation of gas use and future analysis..
♦ 3) Resulting CO2 emissions per m^2 floor area	N/A	calculation	To be used with relevant CO2 conversion factor for each country applicable for the demonstration building. Dutch

			electricity carbon emissions factor will be used – this analysis will be simple but may need to highlight CO2 emissions factor changing between sampled years. Gas consumption conversion rate to carbon is also known.
A.2 CONSUMPTION OF DELIVERED ENERGY – **END USE & SAMPLE AREA OF DEMONSTRATION OBJECT**			
♦ 1) Electricity use for lighting: total and per m^2	Available for all selected rooms used within project via meter readings.	Automated hourly collection from BMS not only per room but per luminaire. Will require significant work to extract from database, however.	The lighting load has been recorded per lamp across the project's sample rooms. This hourly rate data for each zone is sufficient for detailed analysis of the Knoholem optimisation on lighting loads. However, this large quantity of data will require further work to automate the meter readings.
♦ 2) Electricity use for ventilation: total and per m^2	Ventilation fan consumption known for whole building only.	Hourly energy consumption for HVAC is provided for the whole building by the BMS. Individual room air supply rates are CO_2 controlled and thus changing.	Whilst the building is metered so that fan, pump and heat pump electricity use is known this can only be applied pro rata to discrete individual areas – the system supplying conditioned air to several zones of multiple rooms. Disaggregation of fan power cannot be approximated on a room basis from run times for the mechanical ventilation as this is demand controlled (CO_2) per room.
3) Total run-hours for fans	Not available.	Fan ratings can be found but hours run cannot be gained for the individual rooms or sampled area as mechanical ventilation is zero unless demanded (CO_2 control)	Sampled area (1st floor offices and lecture rooms)cannot be disaggregated therefore estimates for mechanical ventilation for future comparison will not be possible.
♦ 4) Cooling energy use by Main Chillers or other AC unit: total and per m^2	Available via calculation of consumption from metered	Individual room heating/cooling demand can be gained from meter	Whilst demand rather than consumption is metered via calculation it will be possible to determine energy consumption

	demand.	readings calculation. This demand can be used to calculate the hourly electricity consumption.	per room for heating and cooling. This will provide good granularity for future analysis of energy consumption for heating and cooling.
♦ 5)Electricity use for pumps: total	Pump total consumption for whole building recorded only.	The known pump use for the building can only be gained - pro rata application to the study 1st floor areas.	Pump power can only be attributed on a pro rata basis.
6) Total run-hours for pumps	Unknown at present	calculation	Unknown if pumps run to set times for manual calculation of energy consumption given their rating.
♦ 7) Electricity use for other purposes (e.g. lifts, catering): total	Not applicable to surveyed area	-	-..
♦ 8)Electricity use for small power (which includes local water heating and task lighting): total and per m^2	Available for the selected floor and sub areas/rooms used within the project.	As per the lighting load, the additional electricity consumption going to the sockets is metered within each room. The two meters break down each room to switched and un-switched readings..	The level of sub-metering of small power is very good and is. collected down to the discrete room of the sampled floor.. Small Power should therefore be metered in enough detail for adequate analysis. However, at present only a sample month (June 2012) has been provided. A better interrogation of the BMS database is needed to best glean the small power information from the relatively small portion of the building used within the project rather than the manual procedure currently used.
♦ 9)Heating energy use for ventilation air: total	See A2.4 above.	As A2.4 heating/cooling demand rather than consumption is metered.	As A2.4 above states, analysis of heating and cooling consumption per room can be assessed from metered demand.
♦ 10)Total gas use for heating and per m^2	Not Applicable	Gas heating system not in use.	Not applicable here.

♦ A.3 OTHER INFORMATION			
♦ 1) weather data: air temperature, windspeed, solar radiation, humidity or moisture content	Not Available	-	Local weather station data will therefore be used to normal the heating and cooling energy consumption for site specific weather data.
♦ 2) operation of automatic blinds	Not applicable	-	-
♦ 3) operating times of plants	Available via Facilities team	Detailed operating hours can be collected for building, however only a 340m^2 section of 1st floor is part of. Knoholem project.	The operating times of the 1st floor lecture rooms studied can be gauged from existing information and occupancy data.
♦ 4) known changes to total occupation levels. Also representative patterns of occupancy	Available via room sensor	Collected for other Work Packages (datamining)	To normalise consumption data for occupied and unoccupied periods. Occupancy detail should be known within the study area as each zone/room contains an occupancy sensor (PIR) as part of the monitoring system..

2.3.5 PICA Building, Seville

As detailed in the Introduction section, the PICA building was only introduced to the Knoholem project in October 2012 as a replacement for the initial (and still unoccupied) IDEAS building in Seville. No historic energy consumption data will be available for the periods before this date and at present only limited details of the extent of metering, sub-metering and automatic Monitoring and Targeting software used within the PICA building has been provided. However, it is envisaged that the details provided by the same project partner, Isotrol, will match the granularity of data found in the other Seville located Demonstration Object, the Bluenet building.

Total electricity consumption for the entire building has been provided (from October 2012) on a 10 minute logging basis, which indicates that some form of aM&T is present of which details have still not been provided. It is also unclear, as to the extent of the area within the PICA building which will be used within the Knoholem project or if it will include the entire 1,500m^2 building. Without incoming data or information regarding the level of detail that can be expected, it is therefore not possible at this time to table a breakdown of the analysis procedure as has been done for the other buildings.

3 Weather Normalisation Data

3.1 Existing Meteorological Sites and Demonstration Objects' Site Based Weather Data

As can be seen in the data gathering tables in Section 2.0 meteorological data has yet to be picked up from the on-site external sensors on the Mediatic building. The other Demonstration Object building that has an on-site weather station, the Forum building, has only begun to log this data since January 2013. It is hoped that sufficient information will be gained to allow these on-site weather stations data to be used in place of the national meteorological station data so that microclimate effects can better be allowed for. However, in both instances this on-site data is easily replaced with meteorological data from national weather stations as must be used for the other 3 buildings.

As described in Deliverable 5.1 Section 3.0, localised weather data will be sought from the USA's National Climatic Data Center's web-portal which allows the download of meteorological data from weather stations around the World i.e. real monitored environmental parameters rather than artificial or interpolated data is used. This data can then be re-calculated to create Heating and Cooling Degree Days for the future analysis of the heating or cooling energy consumption within the Demonstration Objects. This weather normalisation will be important to standardise the energy consumption for heating and cooling in the buildings for both the "pre" and "post" Knoholem solution periods.

The following weather stations will be used for weather normalisation of the heating and cooling energy consumptions for the Demonstration Objects:

- Barcelona Airport (Weather Station Ref: 81810) – for the MediaTic (BDigital) building
- Seville/San Pablo (Weather Station Ref: 83910) – for the BlueNet and PICA (Isotrol) buildings
- Eindhoven Airport (Weather Station Ref: 63700) – for the Forum (Smarthomes) building
- Rotterdam/The Hague (Weather Station Ref 63440) – For the HHS building, Delft/Den Haag

3.1.1 Heating and Cooling Degree Days

The methodology and application of both Heating and Cooling Degree Days has been covered under Deliverable 5.1 Section 4 i.e. the discussion of simple comparison data and linear regression samples (for each building in Sections 4.1 to 4.5). Below is the weekly output format of the Heating and Cooling Degree Days (15.5°C base) for each of the above 4 Weather Stations that will be used in the future analysis of energy consumption data:

Weekly Summary of Heating and Cooling Degree Days for 2012: Four National Meteorological Stations used in combination with Demonstration Objects

Station ID:	Barcelona	Sevilla	Eindhoven	Rotterdam	Barcelona	Sevilla	Eindhoven	Rotterdam
Week ending	HDD	HDD	HDD	HDD	CDD	CDD	CDD	CDD
07/01/2012	45	40	58	55	0	2	0	0
14/01/2012	43	46	90	87	0	0	0	0
21/01/2012	33	43	72	68	0	1	0	0
28/01/2012	62	53	132	126	0	0	0	0
04/02/2012	70	58	163	154	0	1	0	0
11/02/2012	56	60	100	93	0	0	0	0
18/02/2012	39	40	68	65	0	5	0	0
25/02/2012	24	28	55	57	1	7	0	0
03/03/2012	24	25	63	61	1	10	0	0
10/03/2012	22	19	50	53	2	15	0	0
17/03/2012	19	22	44	48	2	10	2	1
24/03/2012	10	5	41	44	8	18	3	1
31/03/2012	8	14	59	62	4	2	0	0
07/04/2012	10	13	58	56	4	13	0	0
14/04/2012	15	10	58	60	3	10	0	0
21/04/2012	4	6	40	40	8	18	0	0
28/04/2012	5	12	18	26	8	6	6	3
05/05/2012	2	3	24	23	20	46	8	3
12/05/2012	0	0	38	37	25	79	1	0
19/05/2012	1	3	4	7	24	42	29	22
26/05/2012	0	0	6	10	42	72	22	15
02/06/2012	0	0	23	22	47	64	4	3
09/06/2012	0	0	12	14	44	66	5	3
16/06/2012	0	0	4	6	56	72	13	10
23/06/2012	0	0	6	5	66	98	20	17
30/06/2012	0	0	3	2	53	75	30	25
07/07/2012	0	0	5	2	62	75	10	10
14/07/2012	0	0	5	5	66	100	8	5
21/07/2012	0	0	6	5	65	74	35	30
28/07/2012	0	0	4	2	74	85	21	16
04/08/2012	0	0	5	3	70	93	16	14
11/08/2012	0	0	2	2	78	84	36	33
18/08/2012	0	0	2	0	87	98	44	38

25/08/2012	0	0	6	4	75	73	16	14
01/09/2012	0	0	13	6	57	79	14	12
08/09/2012	0	0	12	6	62	72	14	14
15/09/2012	0	0	22	14	53	66	4	3
22/09/2012	0	0	22	20	48	34	2	1
29/09/2012	0	0	23	16	32	40	1	1
06/10/2012	0	0	43	39	44	52	0	0
13/10/2012	2	4	30	27	28	21	4	2
20/10/2012	0	3	23	22	26	18	3	2
27/10/2012	16	9	68	61	6	6	0	0
03/11/2012	12	4	56	50	6	13	0	0
10/11/2012	10	14	58	58	7	8	0	0
17/11/2012	11	8	63	59	4	6	0	0
24/11/2012	25	30	65	66	2	2	0	0
01/12/2012	41	45	95	88	0	0	0	0
08/12/2012	41	35	100	90	0	1	0	0
15/12/2012	15	11	65	65	3	3	0	0
22/12/2012	26	31	48	48	0	2	0	0
29/12/2012	41	43	50	46	0	0	0	0

4 Conclusions and Recommendations

The tabularised data indicates a wide breadth of granularity for the Demonstration Objects' energy consumption data. The inherent differences between the buildings makes a consistent analysis approach impractical, this is made more difficult by the fact that the case studies chosen are towards the very good and exemplar end of the low energy use building stock,. Thus, analysis procedures of the "pre and post" Knoholem energy consumption will need to be on a building by building basis. This building by building basis will also be needed as Knoholem produces no automatic control of building services, instead offering user in the loop advice on possible optimisation to Facilities Managers or other users that may be taken up or foregone – obviously, this level of take-up will vary between buildings.

There is also an added complication in the project is that only selected sample areas of each building will be used - for example just sample floors within the Seville and Barcelona case studies and smaller but discrete areas of some 400m^2 for the two buildings in the Netherlands. The existing building metering and sub-metering was not set-up to disaggregate such small sections from the whole building and such practices would seldom have been expected during commissioning. A reasonable expectation was that individual plant items and services would be separately metered and this has been borne out somewhat by the Demonstration Objects chosen. However, where the tabularised data has shown a lack of this latter sub-metering by building services item it may be possible to separate out some uses via calculation, for example air conditioning fan use or heating/DHW pumps (where information such as the run hours, rating of equipment or the specific fan power and air mechanical change rate is known). For the sample areas that cannot be disaggregated by such techniques only a pro rata approach of applying energy consumption use from a larger area that is known (e.g. floor or whole building) can be used. However, this pro rata approach will introduce a larger error band in the later cross comparison of energy consumption. Therefore, it would be recommended that, as with the addition of the Plugwise sensors in the Forum building, where suitable disaggregation of the energy consumption cannot be performed with the existing metering regime the remaining Demonstration Objects apply some additional metering to cater for this.

In some instances, such as the HHS building, little additional metering may be required, as the data is available from the existing sensor and meter information and via calculation. However, the data manipulated by the BMS to extract such information may require additional works, as in this instance the sensors are set to provide room based heating and cooling demands rather than energy consumptions. Due to the late substitution of the PICA building, it is still unclear at this stage, to what level of detail the energy consumption data can be provided by the existing BMS, however it is hoped to be analogous to that of the other Seville case study building (Bluenet) and therefore should contain more than enough granularity for later analysis.