Deliverable 3.5

Implementation Guideline for Integrated Energy Systems

Revision :	**final**
Due date :	**2015-05-31**
Actual submission date :	**2015-06-06**
Lead Coordinator :	**BAM Techniek, NL**

Deliverable Administration & Summary			
No & name	D3.5 Implementation Guideline for Integrated Energy Systems		
Status	Final version	**Due Date**	2015-04-31 (month 45)
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Editor	Gaby Abdalla – BAM Techniek (NL)		
DoW	**Task 3.5: Implementation Guideline for Integrated Energy Systems** BAM leads the development of the Installations Guidelines for Integrated Energy Management Systems. Other industry partners contribute to the document development. Research partners contribute their documentation developed in WP4 to WP6. (result: D3.5; TL: BAM). **D3.5 Guidelines for implementation** **Report**: Guidelines for implementation: Guidelines for implementation		
Comments			

Document history			
V	**Date**	**Author**	**Description**
0.0	17-2-2015	BAM	Initial draft circulated including work approach, schedule and allocation of duties.
0.1	12-3-2015	BAM	Definitive ToC, work approach, schedule and allocation of duties finalized.
0.2	30-4-2015	HSG Zander, NEC, UCC-4C	Input from task partners
1.0	7-6-2015	BAM	Final version

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1. EXECUTIVE SUMMARY

1.1 Publishable summary

Deliverable D3.5 presents the final findings of the implementation of the integrated systems and reports on lessons learnt during the project CAMPUS-21. This document also outlines the most important issues that should be considered in the agreement between the facility management company and the campus owner.

This is a public document and will be, after has been approved, fully published on the website of the project.

2. INTRODUCTION

2.1 Task description and Objectives

Task 3.5: Implementation Guideline for Integrated Energy Systems.

BAM leads the development of the Installations Guidelines for Integrated Energy Management Systems. Other industry partners contribute to the document development. Research partners contribute their documentation developed in WP4 to WP6.

2.2 Contributions of partners

BAM, as task leader, coordinated the whole work including: introduction of the ToC, work approach, analysing of partners input and finishing the report.

NEC contributed to lessons learnt from WP4

UCC-4C contributed to lessons learnt from WP6

HSG Zander contributed to lessons learnt from WP3.

3. OVERVIEW USED INSTALLATION PLANS FOR INTEGRATED ENERGY SYSTEMS

3.1 Monitoring and Metering Concepts

The detailed monitoring and metering concepts have been developed as part of work package 2. Deliverable 2.1 identified gaps in the existing building performance monitoring and analysis. Installation plans were developed with respect to the final use case specifications described in D3.2.

3.1.1 UCC Demo Site, Cork

The UCC demonstration site involves the ERI and the CEE buildings, as described in d3.2, and the following is a summary of the gap analysis and recommended improvements to the monitoring and metering concepts for each.

Use Case 1 – ERI Building

The ERI building has already been installed with a comprehensive network of sensors and actuators as part of the BMS system. Additionally it has its own weather station module and there are a number of experimental research projects where wireless sensors are heavily deployed in certain test locations to model energy consumption behaviour relating to solar gain and natural ventilation cooling. These data are already being exported and have been populating the data warehouse consistently for the past number of years.

Therefore it was not envisaged that any additional installations have to be required. However as part of the QA process and continual building maintenance a number of sensors and actuators have been replaced and the accuracy of the sensors, installed since 2008, has been verified through testing.

Use Case 2 – CEE Building

The BMS in the Civil Engineering Building is a Siemens system and it is connected to a total of 62 wireless sensors located around the building. These sensors include space temperature sensors, carbon dioxide sensors, outside air temperature sensors, supply and return water temperature sensors and PIR sensors. SIRUS is carrying out a reconditioning of the sensor network which has been installed for some time, to remove some faults and validate the quality of the data.

G09 is the most automated of all rooms in the building with two temperature sensors and a CO2 sensor in the room. The position of the radiator valves and the dampers to the vents in the external wall of the room are controlled & recorded by the BMS. Also the automated windows allow for natural room ventilation and cooling adjusting the set point for the acceptable levels of CO2 in the room.

For the CAMPUS 21, the computer labs 108 and 109 were of main interest. These rooms have a heat exchanger ventilation system that maintains C02 and room temperatures with the latent heat sent to the drawing office nearby which has a high heat demand resulting due to large room height, volume and quantity of windows. To monitor occupancy these rooms have been equipped with a swipe card access system which can detect room entry events only due to safety requirements. In order to determine the occupancy levels an RFID gateway, which is used currently by UCC IRUSE in other research, has been deployed to calibrate the prediction of room occupancy which also uses college timetables and associated class sizes.

3.1.2 Commerzbank Arena Demo Site, Frankfurt

The building control system is centrally located internally at the arena which uses a DDC (direct digital control) system made by Sauter. As another layer on top of this, is a building management system which brings all data from each substation together and allows a visualized control of the project. The system consists of 37 data collection points (a.k.a. information focus points), each one is usually represented by one or more switch cabinets. All in all, the whole building consists of more than 9,300 data points. The used bus system on the field bus layer is the Sauter made "Nova-Net" bus. This BMS system has three layers:

1. A central management layer with a control unit as a graphical user interface for accessing the building facilities.
2. Automation layer for the various systems.
3. Field layer for actuators and sensors with downstream switch cabinets.

For the Campus 21 project a BAC net gateway has been installed by Sauter which allows the building data points to be exported to the project data warehouse for analysis and optimization. Other arena information points for occupancy, event schedules and facility operations (e.g. maintenance schedules) which are required for the use case ICT development have been exported to the database separately.

BMS Gateway Installation

The arena has a BMS system from Sauter and it is accessed locally. Sauter, the company who installed the BMS, have been installed a BACnet gateway at the arena which will allow external access by the CAMPUS21 middleware. The specifications for the system have been finalised by Sauter in consultation with NEC who are developed the middleware platform in CAMPUS 21.

Use Profiling & Demand Prediction

An important characteristic of the arena in terms of the optimisation of energy use is the varied and extreme differences in usage. To understand use patterns and predict demands access to the arena event schedules and the ticketing systems are needed (for this purpose a non-disclosure agreement (NDA) was required). The arena management are supplying event schedules via emailed spreadsheets only. The possibility of a more automated system is to be investigated in consultation with arena management. The facility uses the Navision management tool for maintenance activities.

Monitoring and Metering Installation

An additional deployment of 7 heating and cooling supply meters plus 5 water flow meters were required. Additionally there are 5 electricity meters and one gas meter that of interest to the project use cases were connected to a system (either the BMS or an additionally installed M-Bus) so that the data can be retrieved by the middleware and data warehouse. The finalised plans were verified during a site survey which is due to take place during the project.

3.2 Integrated ICT Systems Deployment

In D3.2 the deployment of the integrated ICT systems developed in CAMPUS 21 has been discussed to achieve the project goal of integrated automation and control for building and campus energy systems. The deployment plans are concerned with the functional operation of the middleware (mw) designed and developed in WP4 at each of the demonstration sites as well as a summary of the future deployment possibilities to facilities outside of CAMPUS 21. The mw has multiple interfaces which include the collection and distribution of the monitoring and metering data as well as external data sources as well as the implementation of the optimised commands back to the demo site BMS and scheduler. On overview of the integrated energy systems developed for CAMPUS 21 is shown in Figure 3-1.

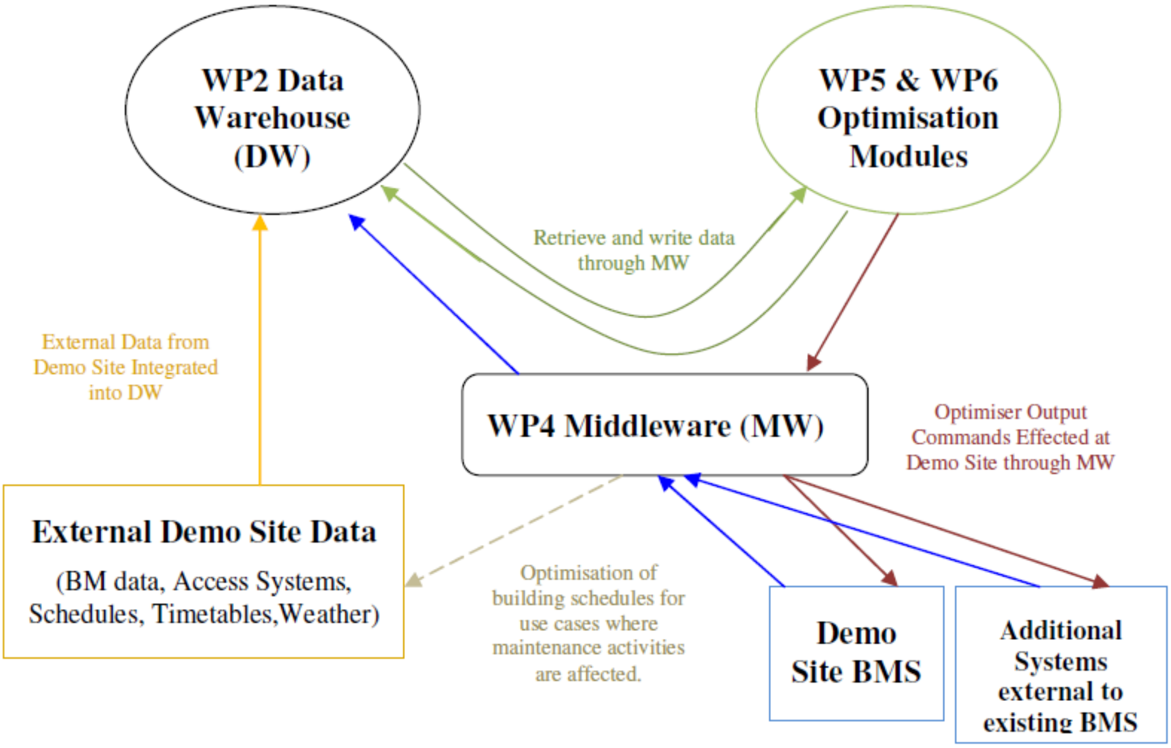

Figure 3-1 Overview of the CAMPUS-21 developed Integrated Energy Systems

The monitoring and metering concepts are described in detail in Deliverable 2.2 along with the additional installations required for the advanced use cases and the schedule for completion at the demo sites by the local contractors.

3.3 Overview of Middleware Design for Integrated Energy Systems Installation

The middleware system has been design such that it is interoperable with various use cases. This is significant in that it can then be easily applied not only to the CAMPUS 21 demonstrators but also other buildings and campus systems outside of the project. for the middleware specification, functions and operations design is contained D4.2.

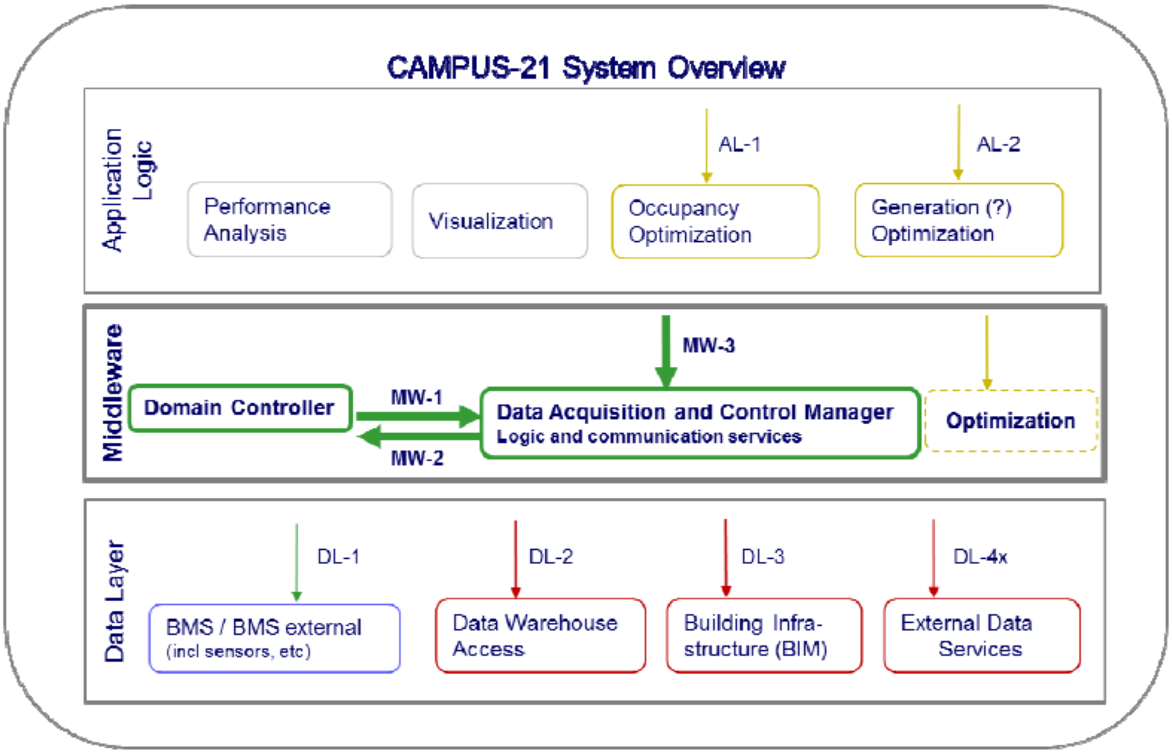

Figure 3-2 General overview of the CAMPUS-21 framework

From Figure 3.1 it can be seen that the Middleware system is the core of the integration of the energy systems. Figure 3.2 shows that the MW comprises of a Domain Controller (DC) and Data Acquisition and Control Manager (DACM) layer units. The interfaces are WM- 1 – interface offered by DACM to DC. MW-2 – interface offered by DC to DACM. MW-3- interface offered by the middleware in general to the Application Logic layer.

The integrated functions can be summarised as:

- Taking the BMS data relating to the performance of the building systems and send to the DW where it is stored as raw data.
- Handling the external data sources by sourcing and writing them to the DW.
- Optimisation module queries the DW through the MW for the data it requires to execute a particular optimisation process.
- Optimisation results, including predictions of future events such as weather, occupation, tariff pricing etc are then written back into the DW for analysis later.

When the result of the optimisation requires changes to the building systems operation then the commends are sent back through the MW to the BMS where they are implemented. The DC and the DACM are the components that integrate the optimisation with the BMS. They are also made up of additional components that perform specific functions. These are listed in the D3.2.

3.4 Installation Plans for Demonstration of Deployment systems

3.4.1 UCC Demo Site, Cork

ERI Building

The middleware DC and DACM components communicate with the ERI BMS through the access gateway with the local Cylon Communication Controller over a TCP/IP connection. The DC translates the optimiser commands into a format compatible with the Cylon system. These commands are sent either directly to low voltage actuators or through a relay pack for larger actuators requiring mains voltage power.

For installing the middleware, programmers determined the operation language required by the Cylon Communication Controller. The Cylon UC32.netk/Web controller is equipped with optional BACnet/IP/Modbus support. As BACnet is installed in other CAMPUS 21 demonstration sites it is logical that the middleware DC will use this language to translate commands to the ERI Cylon controllers. Further details on the Cylon UC32.netk/Web controller are listed in D3.2.

Additional Systems

In the ERI building there are numerous installations of monitoring and metering equipment projects experiments. These installations are openly available to other UCC research projects and have been integrated in the Cylon BMS control. There are also wireless installations but there are for additional sensing equipment such are PIR, temperature, CO2 and humidity. The data are sent to the DW and handled by the MW however they are nog required for control or automation functions and therefore are not a concern for this particular section.

CEE Building

The Civil and Environmental Building systems have already been described earlier in this document. The use cases in this building are concerned with reducing the demand for room heating and cooling from the campus CHP plant and AHU respectively. For the purposes of demonstration, the use cases experiments focused on the hydrology lab, drawing office and computer labs 108 and 109 which are the most complex zones and therefore best suited to develop control and automation strategies for integrated systems at a building and also campus level. The optimization, therefore, is concerned with the control and actuation of AHU, heat recovery, and controlled ventilation.

The CEE has a Siemens DESIGO BMS system installed with a Wireless sensor system installed. The communication protocol is compatible with the BACnet standard over an Ethernet IP connection. Therefore the MW system is deployed using the configurations and communication systems programmed for the ERI BACnet based system.

3.4.2 Commerzbank Arena Demo Site, Frankfurt

The Commerzbank Arena operates a Sauter designed BMS that is based on Nova Net protocol which is directly compatible with BACnet protocol. A BAC net gateway will be installed as part of the installation plans in the Commerzbank Arena for the CAMPUS 21 use cases.

The use cases were developed with the knowledge that the building owners have not permitted any experimentation on the arena in terms of changing set-points or control and actuation. However, it can be concluded that the middleware design for deployment of actuation and control commands could be configured for BACnet protocol similarly to all other demonstrators and use cases.

The middleware compiles data from a number of varied sources relating to the performance of the arena. Energy performance data from the Arena BMS will sent via a BACnet gateway installed by Sauter. Other data relating to the building operations were available through the Navision management tool (maintenance schedules and activities, event schedules, occupancy data e.g. records of no of visitors etc). The use cases developed for the arena were so designed as there is not an opportunity to implement optimised control and actuation. This is a requirement of the building owners. Therefore although the BACnet system would be capable to handle optimised control commands it is not used at that time.

4. LESSONS LEARNT

4.1 Lessons learnt regarding the installation of the integrated energy systems

4.1.1 Lessons learnt from defined Use Cases & Installation Plans

Building stock in the EU predates 1990 by at least 80% and 75% of buildings existing today will still exist in 2050. Energy related refurbishment cycles are typically 60-80 years approximately 1.5% of stock per year. In that period the typical procedure, which is evident from the demonstrators examined, is that building systems tend to experience ad hoc installations and upgrades depending on the latest requirements and functions of the facility and also the management strategy for the building operations, maintenance contracting and service agreements. Therefore it is vitally important that each facility ensures that accurate records of maintenance works, installation works and system upgrades are properly maintained so that the precise operation and relationship between the systems can be determined as part of any energy reduction or integration strategy.

We saw an example of the issues this can create during the Huerta del Rey installations where a flow meter was incorrectly installed and had to be removed and placed correctly and the piping repaired. In the case of UCC and Commerzbank demosites it was not an easy or straightforward task to access up to date schematics nor were control strategies documented properly. Instead we relied on numerous site visits and verbal discussions with the facility engineers and operators who deal with the facilities on a day to day basis. We also discovered that this could potentially lead to erroneous installations, renovation plans and extra expense when the staff with the retained knowledge move on to other companies and/or sites and the knowledge is lost.

Targeted building energy renovation offers considerable opportunity to realise the necessary energy reduction targets set by the EU for achieving more sustainable energy markets and reducing CO_2 emissions and climate change effects. What is needed is the promotion and support of holistic integration strategies for these renovation projects utilising ICT technologies. It is clear that significant cost savings can be achieved through integration of building systems to for energy management and optimal operation of renewable systems.

It is clear also there needs to be better support for businesses to engage in energy renovation projects particularly the instances where the building by nature has short term tenancies and therefore less attractive to investment. Financing will play a critical role in delivering energy renovation projects and there are a number of issues here that need to be resolved.

One aspect affecting these projects is the assessment and guarantee of the potential benefits in operational and maintenance savings. Currently ESCO’s set low savings thresholds to ensure returns cover investment costs. Indeed accurate assessment and monitoring of performance should be facilitated by ICT and used to generate support for funding such projects. Benchmarking should play a more prominent role in the determination of value propositions and business models for energy renovation projects in general but in particular ICT integration projects. Indeed it may be more difficult to analyse, determine and monitor performance benchmarks correctly and precisely if the building ICT systems are not adequately integrated through energy renovation projects.

Hardware installation requirements will typically vary between demonstration sites, and are not necessarily related to building or component age or current function. The decision on the BMS installations and the extent of metering and monitoring installed seems to be independent of standardisation and based on ad hoc decisions and viewpoint of the owners and operators at the time. Perhaps guidelines for minimum installations should be developed and supported by the EU for building retrofit which would encourage integrated ICT energy savings.

In general the required metering and monitoring systems have some commonality for basic operation and maintenance functions such as consumption tracking, set point programming and system operation and actuation control. The installation plan does not just refer to new installations and in many cases the installation works also included the repair or recommissioning of existing devices and components or upgrading with additional components to allow for BMS connectivity.

Summary of Difficulties and Challenges for Integrated Energy Systems Deployment

We have discussed a number of points and lessons learned in relation to the deployment of integrated energy systems in the context of reducing energy consumption in buildings and other operational and environmental benefits. For clarity we now summarise the main findings resulting from this task in the table below. Most important however is the need for a paradigm shift for facility managers from ad hoc installations and short term solutions to targeted, considered and holistic building energy renovation projects.

Table 1: Summary of deployment lessons learned from installation tasks.

Item No.	Description	Primary Impact
1	Up to date records of installations carried out since commissioning and updated schematics.	Planning installation tasks & costs, planning & accounting of maintenance costs.
2	Up to date control strategy documentation. (had to be created for each site as did not pre-exist)	Facility management & operational efficiency determination.
3	Detailed methodology to assess most cost effective and long term beneficial integration projects and upgrade works.	Bringing integration projects from concept to execution and realising energy, CO2 and operational cost savings.
4	Standardisation for BMS installations required to prevent the varied degrees of control, metering & monitoring found between sites. Also data point types and collection & storage of data,	Integrating and deploying energy management systems and platforms
5	Need for a paradigm shift from deployment of BMS systems based on the minimum level of actuation and control to operate the building system to deployments that are designed for a holistic understanding of building energy management.	Increased operational and maintenance efficiencies as well as reduced on site labour costs (e.g. automated optimised running of equipment reduces the need for a technician to carry pout daily programming.

4.1.2 Lessons learnt from deployment and evaluation of Integrated Energy Systems

In this chapter we conclude on the deployment outcomes of the field testing methodology presented in D3.4. There are no industry standards in place for field testing building systems or integration projects however as the integration relies on quality of data flows it was decided to use Brugge's methodology for software testing using the following categories for phase deployment of the integrated platform:

- Integration Testing: based on the integration strategy and testing the operation of the components as an integrated unit. This verifies that the installations were carried out correctly and the components calibrated correctly.
- Structure Testing: based on the implementation of system components the system architecture is tested. After integration testing is completed successfully the structure testing checks the system as a whole in a "white box" type scenario. Test data is entered into the system and the expected outputs are checked.
- Functional Testing: the integrated platform is verified against the specified demonstrator use cases and their experimental scenarios. This is analogous to "black box" testing where the system is made operational and the live data analysed and checked and confirmed as operating correctly.

In this document reporting of functional testing outcomes are limited to the events leading to adaptations or upgrades to the integrated system. Full details of the experimental outcomes are contained in the relevant deliverables D5.4 and D6.4

Integration Testing

Integration Testing was executed by the responsible partners in the period January 2013 to August 2013, i.e. all components, both installed under the project and pre-existing the project, were functional and data was being collected.

Validation checks were carried out on the collected data to ensure that the newly installed devices were configured and calibrated correctly.

Structural Testing

Structural Testing of the CAMPUS21 system was executed in the period between September 2013 and April 2014. Here the components of the integrated platform which are to be used in the execution of the use cases are tested. IN particular the load balancing components (D6.2 & D6.3) and the advanced control algorithms (D5.2 & D5.3) are tested and preliminary outcomes for the use case experiments are examined.

The implementation of setpoint and actuation control was successfully installed and tested from remote applications via the middleware which was a core objective of the integration concept.

Functional Testing

For this stage of the field testing the complete integrated system was tested in the execution of experiments. After the first iteration of testing a number of faults and errors were highlighted in some of the newly installed integration components. In summary the faults related to the propagation of data from the field device to the data warehouse via relays, gateways and BMS systems. A clear outcome was that when new components were installed the commissioning process did test that data was being collected but the quality of the data in terms of packet losses and deviations over time was not tested. Therefore functional testing is a critical aspect of the integration process. Similar errors were reported with existing components which were attributed to poor programming and maintenance of the BMS and building services systems.

Some devices were out of calibration, legacy upgrades and changes were not accurately recorded and commissioning data such as control logic, programming logic, schematics and component mappings were mostly wrong or not available. This outcome represents the main challenge for the implementation of an integration concept in existing buildings.

4.2 Lessons learnt from integration of middle ware

4.2.1 Performance requirements

For modern ICT, the performance requirements collected from WPs 2, 5 and 6 for aggregating data and communicating actuation commands posed no significant difficulties. Also the amounts of collected data amounts posed no significant difficulty for modern ICT systems' capacities and capabilities.

4.2.2 Reliability and Reconfigurability

Reliability for uninterrupted data collection and reconfigurability (e.g. in case new meters are deployed) are of high importance to the application layer. Also usability, i.e. the Application Layer interface functionality and its ease of use (e.g. by supporting standard HTTP/XML through HTTP GET), are of high importance.

4.2.3 Device identification

The choice of using application level identifiers (IFC) allows browsing and querying the BIM to find meter infrastructure and possibly (in future) also device capabilities (allowed ranges, units, sensitivity) which may be of importance for some applications. However, if application level identifiers stem from BIM, then external information sources need to be mapped/represented in the BIM for querying purposes, or a separate identification mechanism is needed for these sources.

4.2.4 Multi-tenancy

The hierarchical concept developed around the VDCs for addressing multiple tenants inside a single building/complex was not needed within the course of the project and further investigation is required for assessing this concept thoroughly.

4.2.5 Connectivity and Security

Relying on VPN for interconnecting application layer and middleware components not only helped address data security concerns. It also facilitated NAPT handling when interconnecting new DCs and increased the willingness of local IT departments to support the deployment as all other than the VPN traffic could be blocked from their network.

4.3 Lessons learnt from WP6

4.3.1 Data Quality

Data quality turned out to be, not surprisingly, one of the main issues of running our tools. In most locations a large set of data points is available. Typically these were not documented adequately, requiring a lot of work to identify which BMS ids correspond to which conceptual data point. As there is no consistent naming scheme, this relied heavily on experts recalling design details from the past.

Another issue was uncertainty about units for some of the sensors, where we discovered discrepancies between different systems. This in particular applies to counter based units, where the unit per count was often not documented.

Failure modes of sensors are not always obvious. In the easiest case, the data source indicates a missing data item. Slightly more complex are scenarios where data values returned can be identified as outliers, being outside the range of allowed values. But we also encountered problems where the connection to the sensor is lost, and the controller returns the last measured value over long time periods. This requires more complex error detection and correction, for which generic solutions are difficult to find.

Manpower to maintain data feed quality

The manpower required to maintain data quality and understand missing/wrong data is a major cost factor in implementing advanced solutions on an on-going basis. As the tools use many data sources that are currently unused, the quality is not monitored by the current operators of the building. There is a significant effort needed when using these new data feeds for the first time. But there is an ongoing effort to check daily for accuracy and availability of data feeds.

System tested only on boundary limits

Another issue we found during the testing of our tools was that the existing BMS, while in principle designed to work over a wide range of parameter values, in practice only is tested on relatively few boundary cases. For example, the heating lops in individual rooms are never used to limit the energy flow into rooms, to avoid overheating, since the overall building heating loop only provides enough energy to heat rooms to minimal comfort levels. Only if the building heating loop provides more energy, problems in the room control become evident.

System availability

The Campus21 architecture was designed as a distributed system, with data collection, data storage, and decision making located at possibly widely separated locations. Each of these components is needed for proper operations, but none of the platforms used has high availability. Downtimes can be due to network problems, required software updates on computers, or required work on the physical infrastructure. The building must operate adequately even if the high-level control has stopped working. This requires watchdog checks, or a heartbeat system as currently used in our system. This in turn not only requires additional functionality in the BMS controllers, but also needs extensive testing.

Network availability

Overall system availability depends on the availability of the network connections used. In the project, most problems came from “last-mile” connections of the BMS to the university or company network. As the network management typically is a centralized function, this creates issues of responsibilities and problem resolution times with an entity outside the project structure.

API changes for auxiliary data feeds

One of the objectives of the Campus21 project was to integrate non-BMS data sources into the building operations. Many of these additional systems are pre-existing, with their primary function not related to the building operation. As a consequence, the API used for these auxiliary systems may change at any moment following the requirements of their main users. We encountered such changes in the ResourceKraft system on the UCC campus, where unit ids and units of measurements changed during the project. As our use was only a secondary concern, we were not aware of upcoming changes until they occurred in real-life, breaking the data feed for several days. Data feeds linked to national data sources (weather, grid electricity) also undergo changes that require ongoing maintenance and development. This cost can be shared between all installations in a given region, but requires a certain number of installations to be economically feasible.

Cost of infrastructure

The cost of providing the infrastructure for an advanced system is not limited to the initial line-item cost of hardware and software. Total cost of ownership over the lifetime of the building (or management contract) needs to be understood to make a successful business case.

Security concerns

Any system that opens a previously standalone system to interaction with other devices creates a potential security problem. By using encrypted VPNs with good key management, the risk of compromised communications can be limited. Fighting potential attacks on servers and databases requires manpower and expertise, which contribute to the cost of running an advanced system. As the value of good system administration only becomes visible in case of its failure, it can be hard to convince customers of the necessity of these cost factors.

Standard (European) API for energy price data required

At the moment, there seems to be a lack of a European standard to query about prices, demand and CO2 cost of the national grid electricity. For the Irish market, the data is publically available, but accessing the data requires bespoke solutions for each data feed. A European standard for electricity data portals would reduce development cost and make a rollout to installations in multiple countries much easier.

5. LINK TO BUSINESS MODELS

In addition to the energy related issues, the implementation of the integrated ICT platform has strong effect on business related issues. Issues related to accessibility to owners assets, changes in HVAC systems during contract, taking control over about the technical systems, energy pricing, Key Performance Indicators and achieved efficiency levels are very essential to be beforehand studies and agreed between both the campus owner and the operator. The most of these issues have been discussed in D1.3. However, D3.5 will also deal with these issues from the perspective of system implementation.

Key Performance Indicators

Using Key Performance Indicators in energy saving contracts and business facilitates and supports building owners in the evaluation of the performance achieved by a facility management or an ESCo company in relation to achieving levels of efficiency. Especially in the cases that payments by the owner are based on the achieved performances.

KPI’s may refer to objective performances such as total energy consumption of a building, but also to subjective performances such as level of satisfaction of building owners in terms of thermal comfort. It is, therefore, very essential to agree on clear definitions of KPI's in energy saving contracts, how to measure those KPI's?, which internal/external factors may affect correctly and reliably measuring KPI's? and what margins should be considered in these measurements?

Current situation

Perhaps the one of the most important issues in relation to the use of KPI's in energy saving contracts. Prior to be engaged in an energy saving contract and to agree on KPI's it is very essential to understand the current performances of the campus assets in the current situation. The determination of the current situation will be very useful to measure and evaluate efficiency levels achieved by the facility management company.

Campus assets

In order to determine the current situation and performances of the campus assets, it is very essential to have full access to those assets. In some cases and due to some security and confidentiality issues, campus owner may decide to limit asset accessibility (agenda’s, BMS data, agreed energy prices and relevant HVAC data). In other cases, campus owner may ask to sign a NDA (Non-Disclosure Agreement) to provide access to assets. However, from the campus-21 project we learnt that this kind of agreements may limit the accessibility to and dealing with assets which may affect levels of improvements.

Also the accessibility and ownership of new generated data by the integrated ICT platform should be agreed among the project partners.

Changes in HVAC systems

As discussed above, efficiency and energy saving levels are very essential to determine on performance agreements in energy saving contracts and ESCo’s. Those levels are based on current situation of HVAC systems and energy contracts. Any change, thus, in those HVAC systems will directly have strong influence on the performance of the whole system. It is therefore very essential that any maintenance, replacement or modification in the HVAC systems will only be done through and in consultation of the facility/ESCo company. In case such a modification can affect system performance, new KPI's and performance levels should be agreed.

Control on mechanical systems

The ICT platform will act as a strong tool for collecting relevant data, analysing energy saving scenarios and controlling the HVAC systems to achieve higher levels of energy efficiency. To properly manage this process, facility/ESCo company has to have full control on the HVAC systems. Also this kind of agreements should be taken into consideration in contract arrangements.

6. IMPLEMENTATION GUIDANCE

In this chapter, an implementation approach for the integrated ICT platform will be introduced. The approach is based on discussions with project partners, discussions with professionals involved in the CAMPUS-21 demonstration sites and our experience during the development of the integrated ICT platform. Although the approach is designed for the implementation of the platform, additional steps and related recommendations have been mentioned to ensure the most optimized energy saving levels.

6.1 Implementation approach

The first step of the implementation approach reports on the current situation of the campus, its building, HVAC and BMS systems, energy flows and data flows.

6.1.1 Data collection of current situation

The first step in the feasibility study is to create a whole overview of the campus, buildings and energy infrastructure. This step will help the facility company to understand how the campus and its mechanical systems work. The following issues are very essential:

- Overview of all mechanical and architectural features of the buildings;
- Overview of all available relevant data for the campus:
    - BMS data
    - Energy monitoring data
    - Historical data
    - Weather data
    - Agenda and occupancy data
- Overview of all mechanical features of the BMS and HVAC systems including all installed meters, sensors and actuators and their technical condition;
- Overview of all energy harvesting systems in the campus;
- Overview of the energy infrastructure in the campus;
- Overview of internal energy exchange among the buildings;
- Overview of energy exchange with the national grid and related energy prices;

Other essential elements in the this step is to understand the building use. This study will support designing optimization scenario's that can match building use and users' needs. The following issues are very important:

- Overview of the most important functions in the buildings;
- Overview of the campus/buildings users and their needs and expectations;

Other important data are related to the current contractual and business agreements on the campus level. These data will enable the facility company to decide on the feasibility of some improvements on the campus levels due to contractual limitations. These information include:

- Current tenancy contracts of the campus, buildings and individual rooms;
- Current maintenance contracts of the buildings and mechanical systems;
- Current energy supply contracts to and from the campus;

6.1.2 Data analysis

In this step, all collected data will be intensively studied to understand all potentials and limitations of the campus in subject. This study will also facilitate the involved company to prepare realistic performance suggestions to the campus owner. Technical or contractual limitations should then be considered in performance agreements. In the feasibility phase, the following issues are essential:

Contractual:

- Who is paying for what in the campus; especially energy related issues?
- What are the most important elements of the current contracts:
    - Agreed KPI's and their priorities according to the campus user/owner
    - Agreed bonus/malus and their relationship towards performances
- Are there any specific agreements that can impede the implementation of the platform?
- Are there any other confidentiality issues that should be taken into consideration?
- Are the campus users interested to be engaged in new arrangements related to energy saving?

Mechanical and ICT:

- Properly understand how systems work, including:
    - Which factors influence individual and whole systems performance?
    - Which (sub-)systems mutually affect each other?
- What are potential improvements that can be achieved without implementing the platform?
    - Low hanging fruit first!
    - How can energy demand be reduced?
    - How can energy supply be met with sustainable energy sources?
    - Which mechanical systems can perform better?
    - How can energy demand and supply be optimized?
- What are the reliability levels of current sensors, meters and actuators?
    - Which of those can affect the quality levels of generated data?
    - Which of those should be replaced?
    - Which if those should be calibrated?
- When should the current mechanical systems be replaced or maintained?
- What budgets are needed to execute the abovementioned issues?
- Are any relevant interoperability concerns related to the abovementioned issues?

Financial and schedule

- Is there a need for additional staff to support the implementation of the platform?
- What is the planning needed to solve problems that impede the implementation?
- What is the budget needed to solve problems related to the implementation?

6.1.3 Preparation of an agreement

In this phase, after having all questions answered, the facility company can properly design and suggest a draft of a service level agreement. In this draft agreement the following issues should be taken into considerations:

- The improvement of the energy efficiency at the campus level should go through four steps approach which is based on the ‘Trias Energetica’ approach.
    1. Reduce the demand for energy by avoiding waste and implementing energy saving measures.
    2. Reduce the residual demand for energy by matching energy demand and supply through integration of building systems and optimal operation of renewable energy. This will avoid unnecessary energy generation, distribution, exchange and storage.
    3. Use sustainable sources of energy demand instead of fossils fuels.
    4. Use fossils energy as efficiently as possible.

- The abovementioned steps can be repeated to generate different scenarios:
    - Reducing of whole energy consumption
    - Increasing of thermal comfort
    - Reducing of whole energy costs
    - Minimization of energy exchange with the grid
    - Minimization of CO2 emissions
- For each of the abovementioned steps, a rough calculation should be prepared including:
    - Minimum energy saving with respect to the current situation
    - Maximum costs concerned with improvement in subject
    - Time needed to achieve that improvement (schedule)
    - Margins within the work can be achieved (depends on data and system reliability and accuracy)

6.1.4 Agreement

The different scenarios developed in the previous step should be discussed with the building owner in order to agree on a final optimization scenario for the campus. In some cases, scenarios can be combined to e.g. decrease energy consumption and increase thermal comfort. The following issues are essential in this phase:

- Which optimization scenario(s) should be considered?
- Which margins could be considered in the optimization scenario?
- What much time (in hours/year) may the systems underperform?
- Which bonus/malus arrangements can be agreed between the facility company and the building owner?
- How often should the facility company report to the owner about the achieved performances?

All these issues should be then discussed and agreed between the facility company and the campus owner. The final agreements should be written and signed in a final contrat.