KNOWLEDGE MANAGEMENT FOR INTEGRATED ENERGY DEMAND, SUPPLY IN BUILDINGS, CAMPUS AND DISTRICT.

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ABSTRACT

The aim of this research is to produce, from an energy management perspective, a detailed description of the University College Cork, (UCC), campus district heating network. Based on the detailed description of the Campus Network and gathered data, multiple simulations will be carried out to test behavior of three selected buildings with regard to the network's and buildings' performance. This paper introduce to the exercise of data collection of existing network. It also defines how to use simulation where some data is missing. Finally it proposes a general idea for knowledge management system that could compile all the information that is necessary to determine campus performance.

Keywords: District energy management, performance analysis, building stock, Building Information Modeling.

1. INTRODUCTION

The current economy in the EU dictates a closer look at energy usage in buildings. Since the majority of buildings in Europe are older than 10 years (2002/91/EC), the focus should be on increasing the energy performance of existing buildings. It is beneficial to look at buildings' energy management from a broader perspective. Today, where prices of fuels are increasing, governments are interested, in how to achieve lower energy usage (EDEA 2011).The majority of society knows that main energy consumers are buildings. Some research claims that typical Combined Heating and Power Plants are the cheapest methods of lowering a building's carbon footprint. District heating plants can provide higher efficiency than typical single building solutions. Therefore, it can be beneficial to extend research into the area of energy management solutions for District and CHP networks.
European politicians, businessmen and average consumers are facing major challenges to integrate new and efficient technologies into everyday use. In Western Europe most existing buildings, either commercial or residential, are using separate integrated building heating systems. These systems are not necessarily efficient enough for upcoming EU challenges. EU-32 countries primarily due to inefficiencies are wasting at least 38% of energy (COWI, 2007)
However there are many fields for new challenges to be applied, energy used for heating is one of the major ones.

Furthermore, by doubling the use of district heating, energy reductions can reach 9.3% (Ecoheatcool, 2005). In practice, any decisions made needs to have clear reasons and facts that are concluded from available information and knowledge. Therefore it is important to have standard and comprehensive way of managing energy related information.

2. KNOWLEDGE MANAGEMENT AND BUILDING INFORMATION MODEL

Engineering data and relative information can be gathered in two ways; manually or automatically. Before the IT industry evolved, any information about buildings and internal systems were stored manually, in the form of drawings, sheets etc. New technologies can be used to store any relevant information in a manual or automated way. One perfect example is a Building Information Model (BIM) which is a complete picture of information about the object or building. The design phase of any object or building produces multiple plans and drawings. Drawings are usually made using CAD packages and can be stored in electronic versions and easily disseminated if necessary. Together with drawings, there are multiple data sets that complete engineering designs: architectural, mechanical, electrical and other relevant information. With developing technology, most software packages are offering new 3D information models where all disciplines and relevant information are included. BIM is being widely incorporated into engineering areas where not only technical information is included but also different dimensions of the model like time, cost, resources etc.

On top of the information generated in the design phase, during the operation phase there is more crucial data to be stored. In order to determine performance, multiple meters and sensors have to be in operation. This data is usually collected automatically and stored in a database.

Large amounts of data in processes, like data mining, can provide analysis results and information about a building or a building cluster's behavior under external weather conditions. Fortunately, this is the case when newer buildings are being analyzed. However analysis of older buildings may be more work intensive, where the lack of data would lead to additional processes.

In this paper three potential buildings are considered. The oldest building was built in 1910. Information about this building was collected through archives but mainly through a surveying process. In 2009 the building did not have any measuring devices that could illustrate its performance. Therefore multi dimensional models were created for each of the buildings showing their main parametric data.

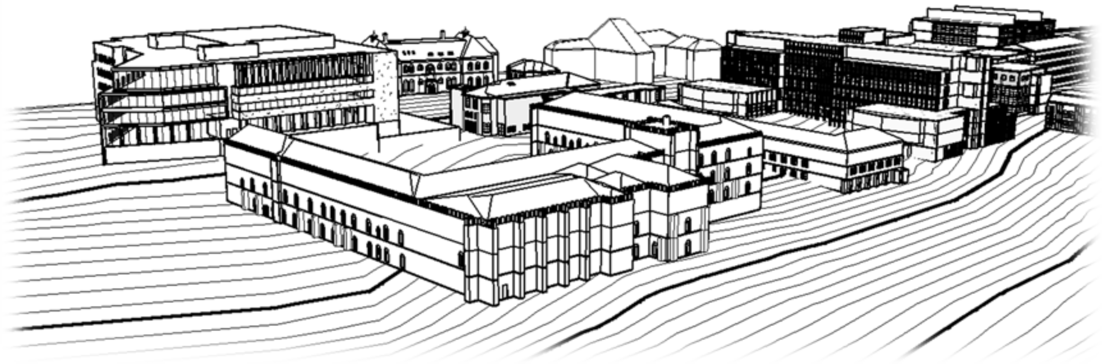

Figure 1: University College Cork campus model.

With the use of these models, simulations were carried out and some understanding of their performance was concluded.

Analysis of the heating network system had a similar level of required processing where only minimal information was provided. In the field of analysis, there are software packages that can simulate/calculate conditions of heating network behavior and also the performance of single buildings that are connected to the network.

In any industrial sector, knowledge management is widely used to provide information to employees on multiple security levels. In most cases knowledge management (KM) appears in the form of a system that, in an electronic way, can store data. When focusing on knowledge management for buildings or clusters of buildings this performance KM can be more complicated especially with older buildings where most of the required information is missing or provided in paper form. New approaches towards design and maintenance are offering digital approaches allowing better more efficient solutions and easier storage of building data.

A perfect KM system would be a server based storage system that compiles all relevant information about buildings, systems, and their performance.

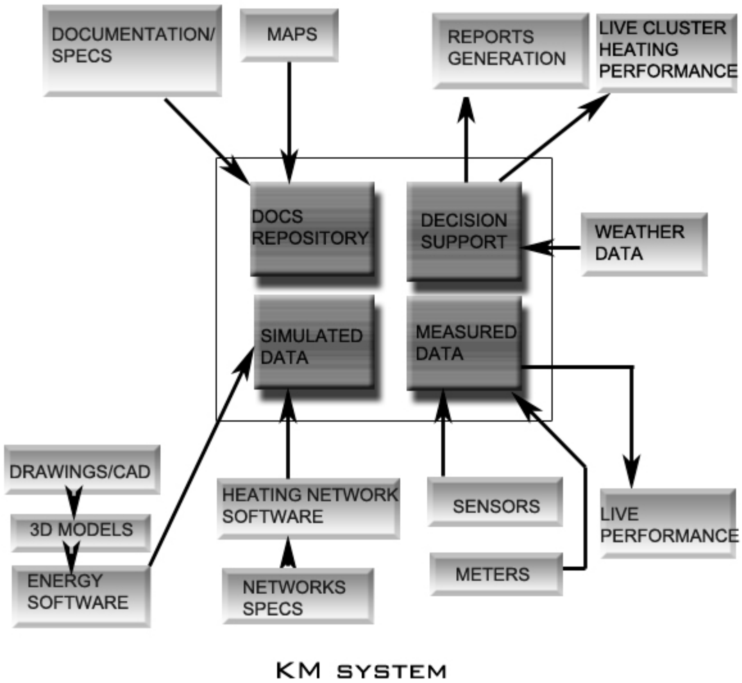

Figure 2: Knowledge Management system for campus heating system management.

Figure 2 presents a general architecture of a KMS for campus heating system. The graph describes how information can be fed into and stored in a server based location. It also contains a decision generation system that based on weather conditions can predict building's and network's behavior suggesting building's energy demand and supply conditions. Knowledge Management System (KMS) comprises of four main parts.

3. UCC CASE STUDY

The UCC Campus is located near to Cork City adjacent to College Road and Western Road. The property portfolio of UCC consists of over 120 buildings. These buildings range considerably in condition, size, construction type and vintage. Included in the university's portfolio are the newly constructed I.T. building, the Western Gateway Building which was constructed in 2009 and the Main Quadrangle, constructed between 1847 and 1849,which is a protected structure and a part of the original college campus. To meet the growing demand placed on the building stock by increasing academic needs and expanding student numbers, the college also rent a number of properties close to the college.

For the purposes of this project, this area will be used when referring to the campus and district of UCC. This area can be described as a district for a number of reasons. In terms of energy supply this district and its buildings are closely interconnected. This can be seen in the distribution of heat and electrical energy on campus. Heat energy is supplied to many of the buildings on Main Campus by the campus combined heat and power (CHP) plant. The plant produces steam which is distributed throughout the campus by means of an underground steam network. Many of the buildings on Main

Campus are connected to this network. The CHP plant runs based on the demand for electrical energy on campus. The plant will attempt to meet the electrical demand and this will affect the quantity of steam produced by the plant. The CHP plant is backed up by two additional steam boilers which are also located in the Main Boiler House, to meet the demand for heating energy on campus. Buildings not attached to the steam distribution network are heated by individual gas boilers located in their own buildings'. Figure 3 below shows the location of the Main Boiler House, the approximate arrangement of the steam and condensate mains (denoted by the red line) extending from the Boiler House which are in use, and the buildings connected to the Main Boiler house for heating purposes. A portion of the distribution network is not in operation and is not shown in the figure below. In addition to supplying steam for heating on campus the CHP plant also provides steam for domestic hot water to the Kane Building. Figure 3 shows three selected buildings that the research and the simulation model will be focused on, considering the different structure and construction types of the buildings.

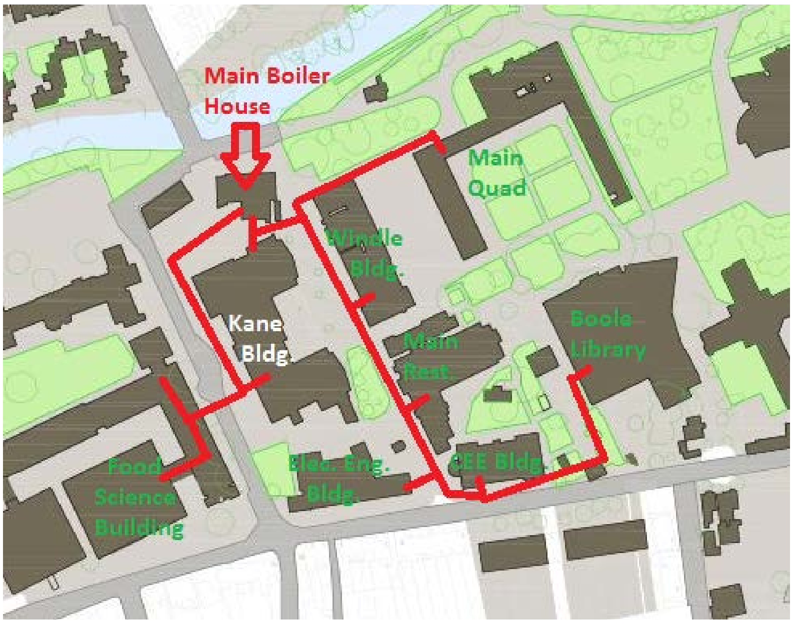

Figure 3: Campus Heating Energy Connections to Main Boiler House

3.1 Kane Building

On a campus level the Kane Building is the only building on campus to use hot water directly from the CHP plant to heat the building. This is an ideal building to demonstrate this type of connection to a CHP plant and in the context of this campus, this building represents a unique opportunity to select a representative building heated by CHP hot water.

It has been suggested that this infrastructure could potentially support additional pipe work carrying steam or hot water to other buildings. Analysis of building energy performance with regard to the potential for future energy expansion, the energy consumption of this building and the potential for extending supplies from this building will be crucial to any future decisions to expand the network. The building also serves a range of purposes from providing teaching and research facilities, to facilitating a computer centre and computer training centre and also accommodating a large canteen area. This building could be used to demonstrate the energy consumption of a large multi-functional building. As with the CEE Building and Boole Library this building is also controlled by a BMS and metered data for the building is available from the Buildings and Estates Office.

3.2 Civil Engineering

Taken in the context of the wider campus the CEE Building is quite an old building, it was constructed in 1910 making it one of the oldest remaining campus buildings. However taking this into

consideration it is also representative of many older buildings built in the same era. At the time many institutional buildings constructed in Ireland were of very similar construction.
The building retains many of its original features e.g. single glazed timber frame windows and cast iron radiators. This is also representative of many older buildings.
The building has undergone a retrofit to improve its energy efficiency. In this case, the building could be seen as an exemplar building as to how energy performance can be improved and monitored within buildings that traditionally perform poorly in terms of energy efficiency.
In the context of the wider campus, the CEE Building was the first building to have a heat meter installed and operational. Although heat meters are scheduled to be installed shortly on other campus buildings, the CEE Building represents the building with the longest record of heat consumption available for any campus building connected to the steam distribution network.
This building is also fitted with a Siemens BMS system which is connected to a wireless sensor network. The building has an individual electrical meter which meters electrical consumption attributable to the building.

3.3 Boole Library

The Boole Library is similar to several other buildings on campus in terms of heating energy. Steam is supplied to a heat exchanger where the heat is transferred to the hot water which is circulated through the building's heating system. This is one of the most automated buildings the campus has to offer. An extensive wired sensor network throughout the building is also be utilized for the monitoring of temperature, humidity and CO_2 levels. The building is fitted with a modern Trend BMS and can be controlled from the Buildings and Estates Office or viewed from a remote location.

The roof is a large flat open space which could be used to accommodate any equipment needed e.g. weather recording equipment needed to provide additional data for building performance analysis.

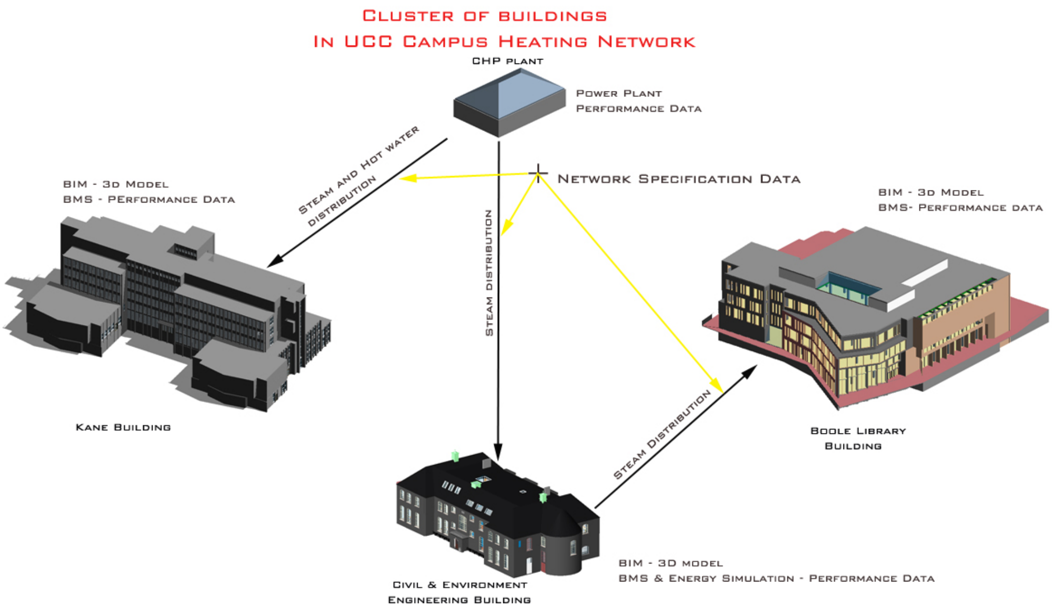

Figure 4 Three selected building and heating network situation plan.

4. MODELLING BUILDING AND NETWORK PERFORMANCE

The selected buildings have integrated BMS systems that provide a range of data used as performance measurements. During the last few months, several groups in UCC including PHD researchers and masters students have created multiple models and simulations. Where 3D models were created and performance simulations carried out. The results were calibrated with comparison to BMS sensed and metered data. There are three areas for which information was required for the BIM; building performance, Network Model, and network performance.

The process of creating the BIM will be further developed. The BIM was primarily created using the Autodesk Revit package. All parameters included, were exported to IFC and Autodesk 3DSMAX. The primary idea is to create virtual campus environment. The model created in Revit is exported to 3DSMAX which provides a raw background to integrate static and dynamic information. As a final output there will be a virtual 3D environment connected to repositories where all the data will be stored and available for users.

Table 1 represents general types of information required to gain complete knowledge about the campus and its performance. Some of the relevant data would be automatically stored in a database through the BMS systems with regard to buildings information. Unfortunately there is no data determining how the network performs.

Therefore to gain a full spectrum of building cluster's performance it is required to determine missing information through multiple simulation activities. Retscreen Int. (Retscreen) an Excel spread sheet based fast software package, can provide (in cases where measured data does not exist) information about single building performance's and also the performance of a cluster of buildings existing on district/campus network. In order to obtain more in-depth simulation results it is required to opt for more advanced energy simulation software like EnergyPlus, IES VE etc. These exercises may even require advanced knowledge about energy in buildings and a mechanical engineering background to provide missing information.

	BIM	**Building performance**	**District Heating Network Model**	**Network Performance**
Type of information	Architecture Structure HVAC Control	Metering Sensing Simulation Results	Heating plant metering Piping system detailed info. Maps/Plans	Simulation Results Sensing data Metering data
Software used	CAD packages Revit Bentley Documents/ specification	Matlab Excel Oracle database IES VE Ecotect EnergyPlus	Revit Bentley	Bentley sisHYD Retscreen INT.
Output	Detailed Model	Performance	Detailed Model	Performance Pressure Temperature

Table 1: Information collection process and selected outputs highlighted

5. CAMPUS HEATING NETWORK – REQUIRED INFORMATION

To create the campus model, data and information regarding the steam and hot water distribution network, the CHP plant and buildings connected to the network were required.

To model the pipe network CAD drawings of the campus were referenced. A CAD drawing of the campus showing the locations of all pipes, manholes, junctions in pipes and connections to buildings was imported to sisHYD (Bentley) and was the basis for the development of the model. This drawing also gave details of the pipe dimensions. Another CAD drawing showing elevations throughout the campus was used to calculate the cover levels for the steam pipes. Interviews with the plant operatives and correspondence with the CHP plant contractors provided additional information required within the model e.g. pressure levels with the pipe network, the material and characteristics of the pipe network.

Information regarding the buildings was gathered from a number of sources. Building drawings in both hard and soft copy were available from the Buildings and Estates Office. Detailed, comprehensive and up-to-date drawings were available in soft copy for buildings which had undergone recent construction works. While in the case of older buildings hard copies of building drawings or scans of the buildings original drawings were available in some cases these drawings were not accurate and did not document all changes that the building had undergone following initial construction. A walk through of the buildings was carried out to confirm the drawing details. The Buildings and Estates Office provided access to the building's BMS interfaces and metered data for the buildings. This provided details of the building's HVAC systems and gave an indication of the heating loads in the buildings where heat meter data was available. Buildings and Estates department also was able to confirm details of the buildings construction and operation where these were not fully documented.

5.1 Inputs to the Model

The network was named 'UCC Campus Network' and defined by the maximum pressure in the network, the maximum supply and return temperatures in the network system, the type of pipe system (supply and return), the medium (steam), the relative elevation and the type of pressure values used (gauge or absolute pressure).

The geometry of the pipe network was defined using an imported scaled CAD drawing of the pipe layout as a template for the input. The pipe network was defined as a series of pipes and nodes placed on the imported drawing. Nodes were created at pipe junctions or building locations and the pipes were connected at nodes.

Several types of pipe were used throughout the network and each was given a pipe type name and characterized by the following features; inner diameter size (mm), thermal coefficient (W/mK), wall roughness (mm), pressure level (bar), maximum pressure loss (Pa/m) and maximum velocity (m/s). A pipe type was then assigned to each pipe in the network. Valves and pumps in the network were defined in a similar way.

'UCC Main Campus' was defined as a 'consumer group' and all the buildings connected to the steam network were defined as 'consumers' of this consumer group. Each consumer within the group was defined by the common group attributes of required supply and return temperature and by the maximum and minimum limits of pressure difference, supply pressure and return pressure. Each consumer was then defined by its location (i.e. their start node and end node) and connected load (kW).

The 'supply' for this network is defined using the characteristics of the CHP plant; defining the supply location by its start and end node and using the pressure drop coefficient (bars^2/kg^2) and constant pressure drop (bar) associated with the CHP plant. According to figure 2 all the inputs above would be under "Network Specs" type of data. This would be fed to the software where the specific type of data would be stored into "Simulated Data" part of the database.

5.2 Software Results

SisHYD runs two types of calculations – steady state and dynamic. The results return a summary of the input data which the calculation is based on as and detailed results for nodes, pipes, consumers, suppliers, consumer groups, organization groups, model adaption, load factors and control. The calculations will be based on the inputs mentioned above (unless they are changed when defining the conditions for the calculation), a load factor (%) and an ambient temperature. In the case of dynamic calculations a timeframe will also be added.

When the calculation has been performed the results are available in the Report Centre. They are categorized by result type and displayed in a tabular format. Results can become quite detailed for example in the case of pipes the results return values of mass flow (t/h), volume (m^3), pressure loss (bar), velocity (m/s), diameter (mm), inlet and outlet pressure (bar), inlet and outlet temperature (°C), specific pressure loss (Pa/m), specific heat loss (W/m) for each branch or section of the pipe network under the conditions defined for the calculation. Where costs have been included in the inputs the investment required to lay each section of pipe is also included. At connections to buildings results of pressure (bar), temperature (°C), height (m) and heating load (kW) are returned. For the supplier values for mass flow (t/h), heating power (kW), supply and return temperatures (°C) and inlet and outlet pressures (bar) are returned.

These results describe the thermodynamic conditions throughout the pipe network under the conditions defined by the calculation input parameters to the model.

6. CONCLUSIONS

The data collection process is long and difficult. Especially when considering already existing older buildings where major parts of information are missing and surveying and engineering input are required. One of the major difficulties was the decentralization of data required to obtain model and performance information.

Some information was stored in the Archives Department or in the Building and Estates Offices, while other was non-existent or missing and finally some of the data was electronically stored in DB of separate BMS systems.

When focusing on KMS and its large amount of data that needs to be collected storage should be centralized. All the information should be placed into one server and agreed on specified type of files for specified type of information (CAD drawings - *dwg, 3D model – IFC etc.)

Considering constant IT industry development, future information/performance models should integrate in an interactive way all the information using a 3D interactive, fast and user friendly environment.

The final output of that created platform will help to organize in a visual way data, relevant to static information (building related) and also live measurements – dynamic information. Furthermore the dynamic information in conjunction with additional mathematical formulas or with accessible software packages can be used to estimate energy consumptions where energy meters are not available, this could be applied to heating networks or building services.

The figure below represents a mock-up of an interface that could be used for storing building information and building performance data using a graphical engine connected to several databases where obtaining information would be an easy process. The same solution could be implemented for the whole network system.

Figure 5 An interface mock-up of interactive information model – integrating its live performance.

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