The VERYSchool Project: Valuable EneRgY for a smart School - Intelligent ISO 50001 Energy Management Decision Making in School Buildings

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Abstract. This paper describes an innovative energy management methodology to support intelligent decision-making that ensures both energy efficiency and savings. At the core is the EC VERYSchool project, a result-oriented and industry led and market driven project co-funded by the European Commission under the Competitiveness and Innovation Programme (CIP-ICT-PSP 2011).
VERYSchool demonstrated how an effective energy action management based on the ISO 50001 standard and the successfully integration of cutting-edge ICTs, such as smart meters, smart control functions for HVAC and lighting, energy simulation modeling, with the Enerit ISO 50001 software suite has realized a complete Energy Action Navigator system (a web based platform called VSNavigator).
The result is a high degree of innovation with significant energy, environmental, socio and economic challenges and impacts, while contributing to the Near-Zero Energy Buildings concept. Along with school buildings, the high degree of repeatability of the VERYSchool methodology, extends to all building sectors and large energy infrastructures.

Keywords: Energy Management, Energy Management Systems, ISO 50001, EnMS, Energy Efficiency

1 Energy Management System (EnMS)

It is a common understanding, nowadays, that automated control system, even sophisticated ones, alone are not able to guarantee energy efficiency and optimal energy management. It is true that the market has 000s of technologies (ICTs), management systems, good practice, and approaches to do better. But every sector (domain) has specific energy infrastructures, energy uses and usage patterns and decision makers that have the authority to affect strategies, programs, and management actions, are often far removed from the problem.

Knowledge on what technologies to select, what energy conservation measures to pursue first, how to implement choices in a systematic way, are simple barriers that limits the effectiveness on the creation of an optimal energy management program. Moreover, many layers of hierarchy exist between someone that authorizes high-efficiency solutions and the person who will install it. As research and technologies progresses with increasing velocity, people that take decisions and act upon to meet energy reduction targets are often far removed from the problem or left behind.

The ISO 50001 international standard was introduced to specify the requirements for establishing, implementing, maintaining and improving an Energy Management System (EnMS) in the form of a more efficient and sustainable energy management program. To get efficiency in energy management Organizations need to apply a systematic approach to continuously improve their energy action plans.

A successful EnMS implementation depends on commitment from all levels of the organization covering technical, organisational and people aspects. The standard application of the EnMS key elements is depicted in Figure 1.

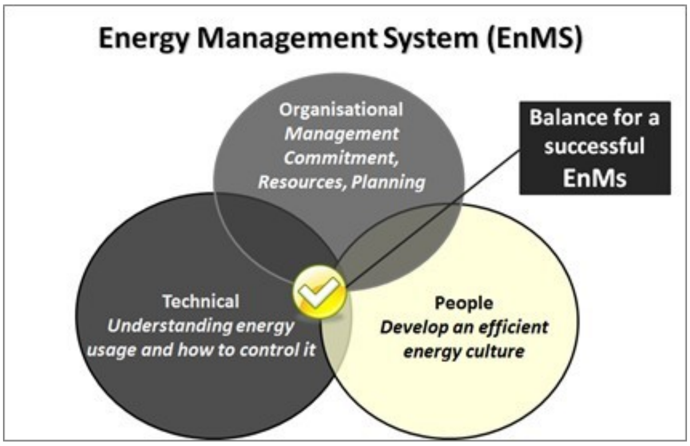

Fig. 1. Key elements for a standard EnMS application.

This means that the commitment of the Organization has to define a comprehensive action plan of the energy management system instead of specific levels of energy performance to be achieved.

Energy costs in most buildings are escalating year-on-year and owners/managers are keen to reduce these costs. However, energy consumption reduction efforts never seem to succeed in the medium and long term. Sometimes, the managers or owners of buildings will raise urgent concerns about energy costs and this can lead to reductions of energy in the short term. But, when management focus returns to other issues more directly related to the main mission of the business, energy consumption normally returns toward previous levels and costs tend to rise year on year. The overall scenarios for optimized versus not-optimized EnMS can be depicted as shown below, in Figures 2a and 2b.

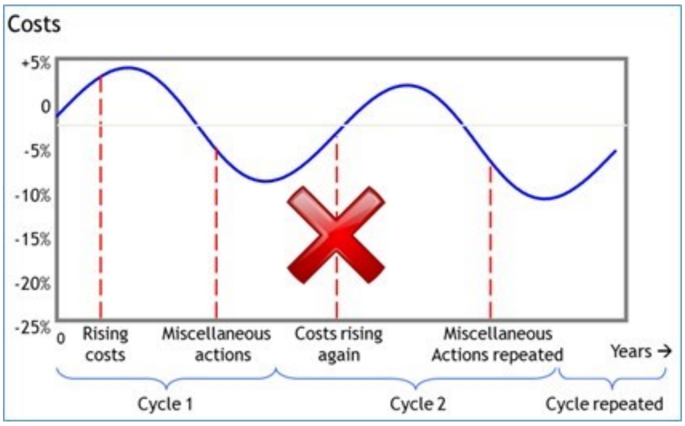

Fig. 2a. EnMS - not optimized scenario.

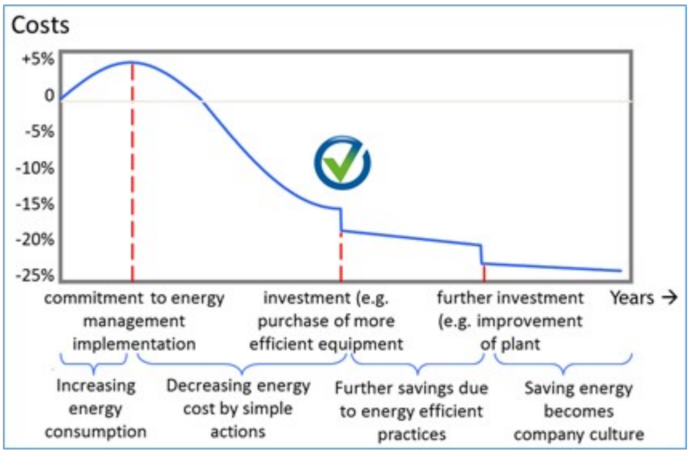

Fig. 2b. EnMS - optimized scenario

Thus, key questions and challenges for optimal EnMS become:

- How can energy expertise and support be provided at modest cost?
- How can energy savings be achieved quickly?
- How can people who are consumed with critical day-to-day business issues be helped to support efforts to reduce energy cost at the sites?
- How can the EnMS be prevented from losing direction over time?
- How can energy consumption and cost continue to be reduced year-on-year?
- How can staff enthusiasm be maintained about energy savings?

The main mission of the VERYSchool project development was to get the above challenges, while the overall concept linked all actors in the value chain under the common platform that provides “how to” information and energy management strategies devoted to the needs of the building (and of its Organization).

Core to the VERYSchool energy management programme was the way of working based on the ISO 50001 energy management system standard. ISO 50001 is applicable to all types and sizes of organizations. It provides a globally recognised framework to establish the systems and processes necessary to improve energy performance, including energy efficiency, use, and consumption.

ISO 50001 is based on the 'Plan-Do-Check-Act' (PDCA) method for control and continual improvement and incorporates energy management into everyday organizational practices (Figure. 3).

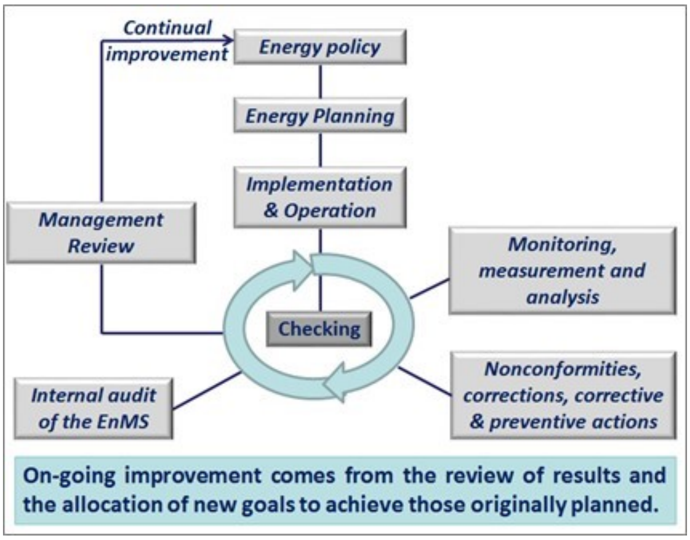

Fig. 3. ISO 50001 EnMS model and relations

The overall PDCA methodology, together with mature ICT solutions, such as smart lighting, smart meters, control systems, energy simulation modeling, has been successfully integrated in the VERYSchool project with the Enerit ISO 50001 software suite to deliver a complete Energy Navigational system customized for school energy management solutions. It is to underline that any reference to the school building, or school organization, automatically extends to the general concept of "building" or "organization".

2 VSNavigator

Schools and the associated stakeholders (decision-making, energy policy and building operational) were at the centre of the ICT-related energy efficiency development to provide the tools necessary to implement a systematic Energy Management Programme at organisational and building levels, in compliances with the practices of the ISO 50001 International Standard (Figure 4).

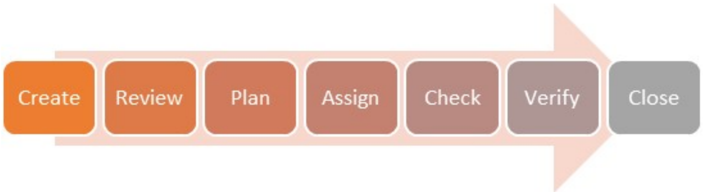

Fig. 4. Key steps of an effective Energy Action Plan

The Energy Action Navigator, called VSNavigator, was the core development to deploy innovation for energy efficiency in school buildings. The VSNavigator is a High-Level Management tool, usable as web-tool with a friendly and intuitive user interface. Built upon the specific Enerit ISO 50001 software for Energy Management, VSNavigator is integrated with other two technologies already mature market.

1. BEMS, which ensures monitoring and the automatic control of HVAC systems, LED lighting and indoor environments. The communication between VSNavigator and BEMS is unidirectional: that is, only for data acquisition of measured energy consumptions, status of devices and indoor comfort conditions.
2. Software for the building performance assessment, which allows users to estimate the achievable benefits coming from a change of management or implementation of an energy renovation action.

This means that VSNavigator is not a control system and it doesn't issue automatic control signals. VSNavigator suggests possible actions for optimization, and estimates the achievable benefits. The fundamental architecture of VSNavigator platform is depicted in Figure 5.

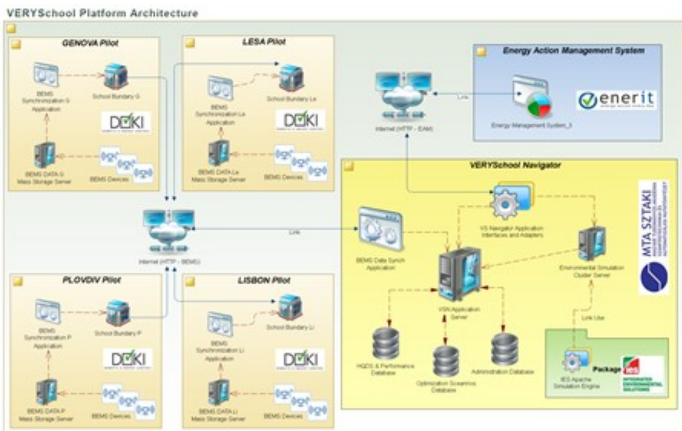

Fig. 5. VERYSchool over-all architecture

A user-friendly graphical interface provides seamless integration of the navigational elements (Figure 6).

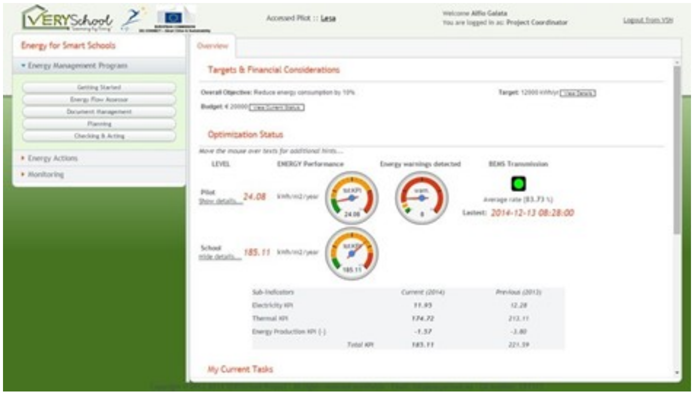

Fig. 6. VSNavigator start page

The VSNavigator integration process was performed through the development or the adoption of communication and interaction adapters, both at automation and management level.

For the data model and the communication stream between VSNavigator and the Enerit ISO 50001 software suite, three basic elements of synchronisation were defined and formalized through XML schemas: users, schools and actions. An FTP approach was adopted for data transfers: VSNavigator uploads XML files to the Enerit FTP server when a new user/school/action is created or an existing user/school/action is updated.

The Enerit ISO 50001 software suite regularly checks the XML files for new or updated requirements. Examples of contents of the ICT development and compliance to the implemented ISO 50001 Action Plan are depicted in Figure 7.

Fig. 7. Contents of the VSNavigator

3 VSNavigator as Decision-Support System

VSNavigator is mainly a decision support system, with superior performance to any commercial SCADA. The decision process is provided with the support of a Catalogue of Optimization Scenarios developed in the project. The Optimization Scenarios are a set of best practices aimed at improving energy usage within schools, and suggesting either technical or behavioural actions. These Optimization Scenarios account for school needs based on building structures, users' behaviour and usage of educational buildings (Galata et al. 2014).

The Catalogue comprises 76 Optimization Scenarios, of which 63 relate to technical issues and 13 to managerial and behavioural aspects. It includes recommendations for building envelope, lighting, heating, ventilation, and air-conditioning (HVAC) systems; system setting strategies related to thermal comfort; and integration of renewable energy sources. Typical examples of Optimization Scenarios (not exhaustive list for the Catalogue) applicable to the needs of improved energy efficiency and management are:

- building envelope/components and building energy infrastructures:
  What energy conservation measures are most appropriate? What is the cost benefit analysis?
- renewable technology:
  What options are most appropriate?
- HVAC, Lighting and Water schedules:
  What is happening when the facility is in use and not in use? what to do? What is installed? What should be installed? Are (each energy system) controlled manually, or by set points, or by localized sensors? Is each energy system running optimal and do they actively account for the weather and building occupancy?

The Catalogue of Optimization Scenarios is the kernel of the Energy Action Navigational System, to drive selection, implementation and management of energy efficiency measures in a standard way. Set Rules are the beating heart of the decision-making process defined as the mechanism, which proposes specific Optimization Scenarios in an intelligent and dynamic way (Figure 8).

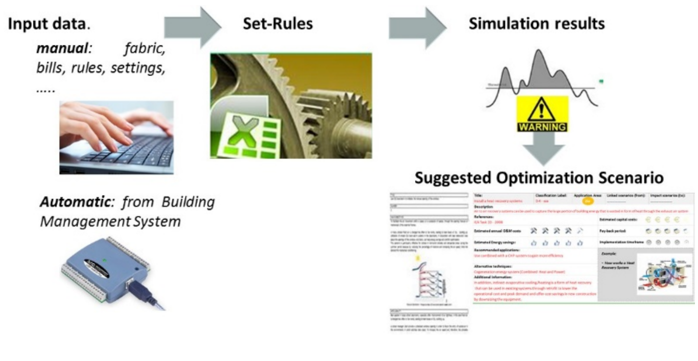

Fig. 8. The VERYSchool decision-making process

Adopting set-rules built around the measured data provided by the BEMS, as well as with input data gathered from the energy bills and specific building data, VSNavigator proposes a list of possible actions for energy efficiency and optimization (Figure 9), and provides operational guidance on how to:

- help managers committed to reducing energy costs in many buildings,
- get a company energy know-how at limited cost,
- reach an energy saving in the short term,
- reduce energy consumption, year after year.

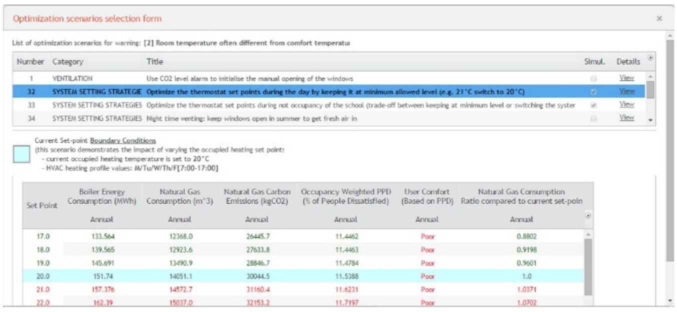

Fig. 9. List of possible Optimization Scenarios

The catalogue is published as an e-Book and it is downloadable from the project site, as well as from some Partner's websites.

4 Action Management and VSNavigator

The specific ISO 50001 requirements that the action management system meets are to identify, prioritize and record improvement opportunities (ISO 2011, clause 4.4.3) and to establish energy objectives, energy targets and energy management action plans (ISO 2011, clause 4.4.6).

With regard to action management, some of key features of VSNavigator, provided by the integration of the Enerit ISO 50001 software suite, ensure an "easy to" access area to review, manage and assign actions related to improvement opportunities from optimisation scenarios and suggestions. The following points summarise an energy action life cycle:

- Actions are triggered automatically or manually from the suggested Optimisation Scenarios.
- The User (e.g. Energy Manager) is notified by email with a link to the created action (new or already assigned). The action appears in VSNavigator in the "My Tasks" menu, and other views, when the User accesses the system online.

- The action contains the relevant details to review (User) and to implement (assignee) the action.
- The action is prioritised based on the expected savings, payback, complexity, maintenance and impacts.
- The User reviews the action and assigns it to suitable person (e.g. a technician).
- The action then progresses through the workflow (Assigned → For Validation → Awaiting Closure → Closed), to successfully satisfy the PDCA diagram.

A feedback loop function shows an indicator on the associated Optimisation Scenario in the repository when an action is going through the workflow until it is closed.

5 Energy and Environmental Challenge

The energy and environmental challenges that the VERYSchool project pursued along its three year of technical development, demonstration and validation, were established on several levels.

- Energy assessment using measured data;
- eeMeasure, which is a software tool provided by the EC to validate results of EC-CIP projects), and IPMVP customized for school environments;
- Energy Flow Assessor, which is a software tool provided by the Enerit ISO 50001 software suite;
- Building Energy Index, Climate Energy Index and Carbon Assessor, which are software tools provided by the IES <Virtual Environment> software suite.

The achieved savings on the annual energy consumptions, considering the specific Pilot's configuration and climates, ranged as:

Heating	19% - 48%
Lighting - LED versus traditional lamps:	49% - 90%
Lighting - Dimming versus ON/OFF control:	52% - 77%
Lighting - Automatic ON/OFF versus manual control	25%

According to the eeMeasure results, assuming the four schools as belonging to the same school district, the project demonstrated a potential 53% energy saving and a CO2 reduction of 6164 [kgCO2/year], with a financial saving capacity of 3001 [€/year].

As case studies, a Green Design has been performed for each pilot school, to demonstrate how through a systematic action management based on the ISO 50001 and new ICTs solution for energy efficiency other than those implemented in the project, the existing schools can be transformed into Near-Zero Energy Building. A number of suitable Optimization Scenarios were selected and simulated. Results were used to determine savings in relation to energy consumption (electrical and thermal), energy generation (renewables) and associated energy costs. On the average, considering each building technical provisions/configurations and climates, the results were:

annual energy saving in the range 64-113%, corresponding to annual cost savings of 26-57 K€, with requested investment costs in the range 327-743 K€, and payback periods varying from 9.6-18.4 years.

6 Socio-Economic Impact

Evaluating the impact and legacy of a project at the moment of completion is challenging because it involves assumptions about the future. There are however some clear indications that demonstrate very clearly that the work carried out in VERYSchool could have a positive legacy. With a new vision, innovative ICT solutions for energy efficiency, Organization's rules and user's behaviour have been merged to be a whole and sole process driving a systematic EnMS.

VERYSchool has demonstrated under real operational conditions that can contribute directly to reduce energy consumptions in European schools. Supporting this outcome, the project validation has demonstrated that a substantive energy saving and carbon emission reductions can be achieved in annual consumption.

Dealing with the public awareness campaign, an on-line survey was launched, throughout a questionnaire implemented in the project website and designed around three main blocks of questions:

- opinions about energy efficiency management,
- implementation of Energy Management System,
- management and economic aspects.

At the end of the project, 1669 responders from different Countries have participated. Responder's answers have been used for understanding barriers and opportunities and to gain an insight on how EU schools managers evaluate energy management systems and their intent for future actions. The main figures are:

- Energy Management: about 44% consider it a necessity; for about 23% it is a concern; for 21% an opportunity and for 12% core business.
- Main barriers for implementing Energy Efficiency measures: lack of funds are the main obstacle (33%); lack of interest/awareness for such measure (26%); lack of technical knowledge (18%), and technical difficulties (13%); bills not so high (67%); other (3%).
- Role of ICT applied to Energy Efficiency: about 49% consider it extremely important and 47% important; marginal for the 3% and not relevant for 1%.
- Awareness of standards for Energy Management in school Buildings: about 46% declares to know the European standards for Energy management in buildings, but only 19% of them have already implemented an EnMS in their school based on the above mentioned standards. About 57% knows the EBPD and the Energy Certificate requirements.
- Main drivers to implement an Energy Management Program: cost reduction (18%); followed by possibility to keep in the schools money saved through the EnMS (14%) and transition towards a low carbon environment (14%); prestige of the

school (13%); legal requirements (11%); National/European recommendations (9%); improve Performance assessment of the school and related staff (8%).

- Main expectations in terms of potential energy savings: about 36% believe that energy savings should be in the range 20-30%; 32% expect saving in the range 10-20%; 19% saving over 30% and 12% believing that saving should be below the 10%.
- Responsible for Energy Management: 47% have a person dealing with this role. In the large majority of cases (63%) an employee is appointed for that; 23% use outsourcing services and 14% ESCOs.
- Benchmarks to energy consumption: 47% of Schools apply a benchmark to energy consumption.
- Systems for monitoring/analysing energy consumption: 70% schools are not equipped; almost 24% is equipped with a BEMS.
- Temperature profiles systems: The majority of the schools (69%) is not equipped with such systems.
- Lighting monitoring systems: The majority of the schools (74%) is not equipped with such systems.
- IAQ monitoring systems: the large majority of the schools (79%) is not equipped with such systems.
- Use of Renewable Energy: almost 28% of them declare to make use of Renewable Energy Sources.
- Energy Audits: 55% schools have performed energy audits in the last 3 years.
- Energy efficiency certificates: only 35% obtained an energy efficiency certificate, among the respondents who declared of having already performed energy audits in the last three years.
- Energy Efficiency measures implemented: even if the majority of schools have not conducted energy audits in the last 3 years, the 55% of them declare of having implemented measures related to energy efficiency in the same period of time.

7 Lessons Learnt

The development of the VERYSchool project has been a challenging and rewarding activity. Interviews with school managers, public administrators and technology providers, the systematic management of the energy action plans in the four pilots, the experimental data analysis and the validation results, allowed them to learn a lot about the needs of the School environment. The following key learnings can be drawn from the experience of the VERYSchool project development.

- Energy Management in Buildings is considered important together with plans to adopt Energy Efficiency measures.
- Even if the awareness level on Energy Standards and certifications is high, about 70% of the school buildings are not equipped with systems to monitor energy consumption, temperature profiles, lighting levels, IAQ management. This could suggest a large untapped market potential for these solutions.

- The main barriers to be addressed seem to be the lack of awareness and of technical knowledge, as well as the difficulty in raising the needed capital.
- The accuracy on BEMS selection and related Optimization scenarios is strongly recommended.
- Energy audits and implementation of monitoring and targeting techniques should be evaluated in strict collaboration with the local users.

8 Conclusions

VSNavigator is a specific technology and a replicable model, while the VERYSchool project provided a multi-stakeholders approach to implement an effective EnMS centred on the ISO 50001 standard in schools. The stakeholders in the value chain were:

- Public Administrators, who can overview cost savings, reward efforts to best energy schools, broadcast best practices and energy management to under performing schools.
- Operational, Energy and Facility Managers, who take energy decisions to improve the energy management process to be more effective on the current operational energy scenario.
- Technicians who have the day-by-day responsibility to maintain and operate the buildings.
- ESCO and Financial Institutions, who can promote concepts of green economy where energy saving pays for investments.
- ICT and Scientific Professionals who present best practices and new technologies, while producing awareness on efficient scenarios and habits.
- Practitioners who can learn about best practices on energy efficiency.

Any reference to the school building, or school organization, automatically extends to the general concept of "building" or "organization".

9 Acknowledgements

The VERYSchool project (GA n° 297313 for CIP-Pilot actions) received funds from the EC under the ICT-PSP-CIP framework Program. The Consortium was made by 12 Partners, which collectively contribute to achieve the project results.

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WATERNOMICS

(ICT FOR WATER RESOURCE MANAGEMENT)

METHODOLOGY FOR DEPLOYMENT OF A WATER MANAGEMENT SYSTEM

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Abstract. WATERNOMICS is a three years EU funded research project and responded to the call FP7-ICT-2013-11. The partners variously specialize in ICT & Automation systems development, sensors development, business model development, water system design, open source based platform, energy and sustainable management, exploitation and dissemination activities. WATERNOMICS will provide actionable information on water consumption/availability to individual households, companies and cities in an intuitive & effective manner at relevant time-scales for decision-making. Key project objectives include: to introduce demand response and accountability principles in the water sector, to engage consumers in new interactive and personalized ways increasing their water efficiency and leads to changes in water behaviors; to provide decision makers with the actionable information they need to get started in the implementation of a water management program. WATERNOMICS will develop a standards based methodology to implement a Water Management System (WMS) as a personalized and customizable solution for stakeholders.

Keywords: ICT· water savings · water management system · water consumption · raising awareness

1 Introduction

A lack of information, management and decision support tools that present meaningful and personalized information about usage, price, and availability of water to end users can hinder efforts to manage water as a resource. WATERNOMICS aims to address these issues using innovative information, communication and technology (ICT) tools [3]. The project will develop and introduce ICT as an enabling technology to manage water as a resource, increase end-user conservation awareness and affect behavioral changes, and to avoid waste through leak detection and diagnosis. This report describes the first version of a standards-based methodology for the development and implementation of ICT-enabled water management programs. This methodology will, given constraints, standards, corporate preferences, and key performance indicators (KPIs), provide decision makers and designers with a systematic way to select technologies, measurement points, data collection methods, and data management techniques for ICT-based water management systems.

Currently the limited information available from the water services ecosystem is not interoperable or not presented effectively to stakeholders. Waternomics overcomes this problem by implementing a new level of smart meter and sensor technology and a standard based methodology. These decision support services are enabled by smart water technology [5], which (i) enables the detailed and real-time measurement of water flows and usage, (ii) informs analysis of water consumption patterns and (iii) provides key recommendations on how to increase water efficiency in a holistic context that includes governance, standards and local area policies and environmental conditions.

Waternomics project aims to raise awareness on water consumption and conservation issues in a range of different contexts and users [1]. The project is going to explore and test applications and results in four different contexts (pilot sites). The first is placed in Italy in the large corporate environment of an airport (Linate Airport). The second and the third are to be conducted in Ireland at a primary school building and the Engineering building of NUI Galway. Finally the fourth pilot is to be conducted in a set of households in the municipality of Thermi (Greece) engaging domestic environment users.

In the first year of the project a standard based methodology for the implementation of Water Management System has been developed and is going to be validated and demonstrated in the three high impact pilots:

1. Domestic: Households in the municipality of Thermi, Greece.
2. Corporate: Operator from Linate Airport in Italy.
3. Municipal: University in Galway, Ireland.
4. Municipal: Public school in Galway, Ireland.

2 Objectives

The goal of Waternomics is to explore how ICT can help households, businesses and municipalities with reducing their consumption and losses of water in the framework of a water management program [2]. A key component of the Waternomics project aims at collecting water consumption and contextual information from different sources to be used for effective data analytics to drive decision making that optimises water consumption: e.g., planning, adjustments and predictions and to raise user awareness of water consumption. In doing this, it is important to develop a common standards-based framework with which to plan, implement and assess Water Efficiency Measures (WEMs).

To this end, a key outcome of the work consists of designing the first version of Waternomics methodology and the tools, techniques and methods to put it into action. The methodology is standards-based and implements best practices and approved guidelines from the energy sector where efficiency efforts have received greater attention. Intended attributes of the methodology are that it is simple, able to be useful across the home, business and community levels, and can be integrated into existing resource management programs (typically energy) already in place at host organizations. Coupled with ICT in the form of sensors, meters and the project water information system, the methodology provides decision makers with the knowledge to enact and implement a water management program and to realize subsequent water efficiencies.

3 Outline of the work

One of the main outcomes of The Waternomics Project is the Standards based Methodology adopted to guide the project phases.

Waternomics Methodology is a standards-based methodology developed "ad hoc" for the development and implementation of ICT-enabled water management programs. This methodology will, given constraints, standards, corporate preferences, and key performance indicators (KPIs), provide decision makers and designers with a systematic way to select technologies, measurement points, data collection methods, and data management techniques for ICT-based water management systems.

The desired outcome of the Waternomics methodology is that decision makers and end users at the community, corporate or home levels have a framework, set of tools, and references that enable them to take action towards water efficiency measures and to enact water management programs. The methodology is customizable to the needs of different end users and as such the report packages phases and activities to carry out the methodology into a number of discreet, concise and accessible summary briefs.

4 Materials and methods

The developed methodology, which in itself is a new development for the water sector, has five phases: Assess, Plan, Do, Check, Act. These phases are intentionally similar (with the exception of Assess being added as a first step to engage users) to those of

ISO50001 (Energy Management Systems). In this way, environmental managers and the organizations, staff and service providers that work with them will immediately recognize the correlation between energy efficiency and the desired outcome of water efficiency.

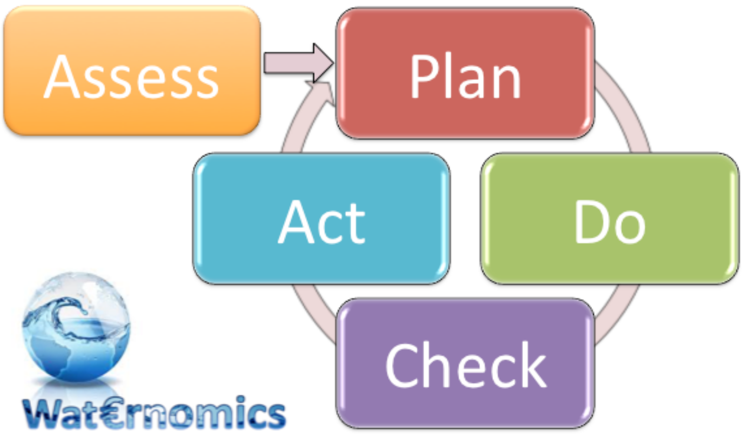

Fig. 1. Waternomics Methodology Overview

Other standards that many stakeholders will recognize include ISO50002 (Energy Audit), IPMVP (measurement and verification planning), and ISO14046 (Water Footprint). In this way, a comprehensive and holistic standards-based approach is established. For each of the phases, the steps to carry out and implement the methodology are provided. The methodology is customized to for the water sector in areas including Energy-Water relationships, water related KPIs, technology selection tools, rules to design physical measurement frameworks and assessment mechanisms.

5 Results and discussion

The development of a new methodology can be elusive. Teams working on methodology development may struggle to define an appropriate scope or lose focus as the process and way forward is beforehand unknown. The development of the Waternomics methodology benefitted from the knowledge and expertise of partners like R2M Solution and BMC (Business Model Change) who brought best practices and ideas from energy sector and from the business model generation community where ideation, roadmapping, and iterative process development are community strengths.

In general five elements, namely: discipline, description, key concepts, rationale and methods, cover the components of a methodology. These five elements are captured in the accompanying table

Table 1. Five main elements of a Methodology

A methodology:		
Is targeted at	A discipline	Which defines the scope of the methodology
Has a	Definition	Which explains the goal of the methodology
Is based on	Key concepts	Which describe the basic ideas behind the methodology
Contains	Methods[1]	Which describe how specific ends can be achieved
Describes	The Rationale	Behind the use of the these methods

Waternomics leads to the project methodology which creates a common standards-based methodology for the design and implementation of ICT enabled water management systems. It should be noted that such a methodology is sorely lacking in the water sector and thus this document is an important step in ensuring water efficiency measures can be implemented in a similar way that energy efficiency measures have been. The culmination of the methodology work is a 5 phase methodology (Assess, Plan, Do, Check, Act).

The methodology draws strong inferences from and integrates the principles of ISO50001 (Energy Management Programs), ISO 50002 (Energy Audits/Diagnosis), IPMVP (International Performance Measurement & Verification Protocol) and ISO14046 (Water footprint) into a holistic framework. This is coupled with project activities toward the development of a water information system, directed at the challenge of water resource management.

Several of the associated standards are recent (ISO50002 and ISO14046) and furthermore the focus of several is energy (ISO50001 and ISO50002). The application and adaptation of such standards in a holistic framework is innovative and new. It should be noted that the authors did not confine their research to just energy and water based standards but also looked across other disciplines.

However, the Energy-based standards were found to be most relevant and applicable to this sector. Added to the PDCA cycle is an initial "Assess" phase. Because end users may be less aware of water efficiency, water scarcity and how/why it affects them, the Assess Phase in the Waternomics methodology is a deliberate attempt to engage and educate the end user.

In assembling relevant standards and in constructing the Waternomics methodology, it is noted that many standards have overlapping aspects and as such a direct overlay of each of the steps from the standards would produce redunancies.

It is also true that terminology is not yet completely harmonized across the various standards and that some propose themselves as an umbrella to group other available standards [4]. Regardless of any sticking points, we instead found it most useful to look at

[1] An additional note on methods: The Waternomics methodology is made of five phases. Those phases are broken into a series of activities and these activities can be considered a method to conduct each phase.

what each standard was trying to do and then to assemble those intents in a logical way from initial consideration of the problem to its definitive conclusion and/or iterative loop.

The result is a logical process (the five phases) where it was not constrained to have a one-to-one mapping between a standard and phases (e.g. each phase does not correspond to only one standard). Figure 2 shows a more refined and full view of the Waternomics methodology. In specific, the activities, desired outcome, and related standards are shown for each phase.

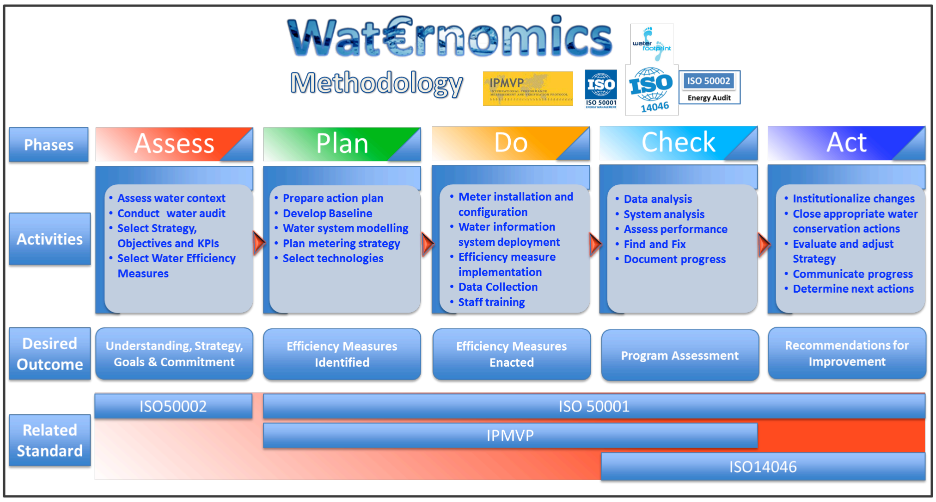

Fig. 2. The Waternomics Methodology (full view) which includes activities, outcomes and its relation to the assembled standards

Each of the five phases has approximately roughly five activities which are the steps and methods associated with each phase. The approach is general enough to applicable to the different targeted stakeholders (domestic, municipal, corporate) but also detailed enough to be useful and actionable.

Deliberately and by design, the methodology is based on standards so that the approach overall has a higher likelihood of adoption, uptake and replication. The use of ICT is the second cornerstone of the methodology and overall the methodology is branded as a "Standards based approach for the implementation of an ICT-enabled water management program".

In considering the methodology, special attention is drawn to the "Activities." These in fact become the core of the methodology and are the steps necessary to accomplish the phases. Within each activity, various methods are possible. For example, IPMVP offers four unique methods to calculate a baseline (an activity under the Plan phase). We propose three different levels (or types) of water audits (an activity within the Assess Phase).

In using the methodology, it is up to the end user to determine what method and level of detail from the methodology is appropriate for them. For example, a domestic user may most appropriately employ only the higher level concepts (phases and select activities).

Instead an environmental manager of a large and complex organization may utilize available phases, activities, methods and references with more rigor.

In a further detailing of Figure 2, Figure 3 - 4 – 5 – 6 – 7 provide an additional intuitive view of the method.

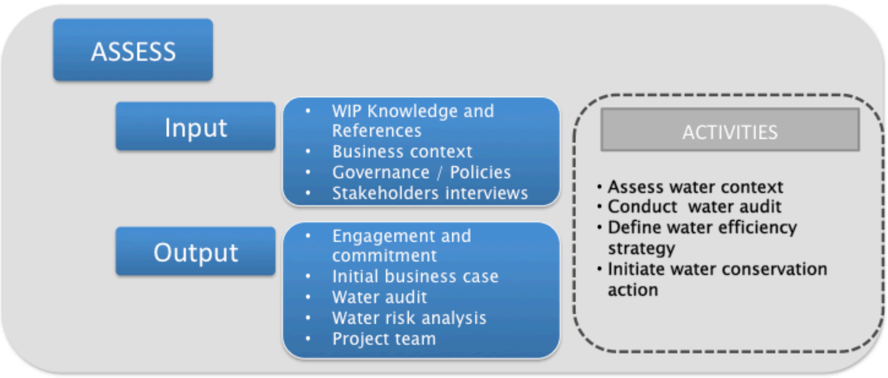

Fig. 3. The guidelines to follow to implement Waternomics Methodology – Phase 0

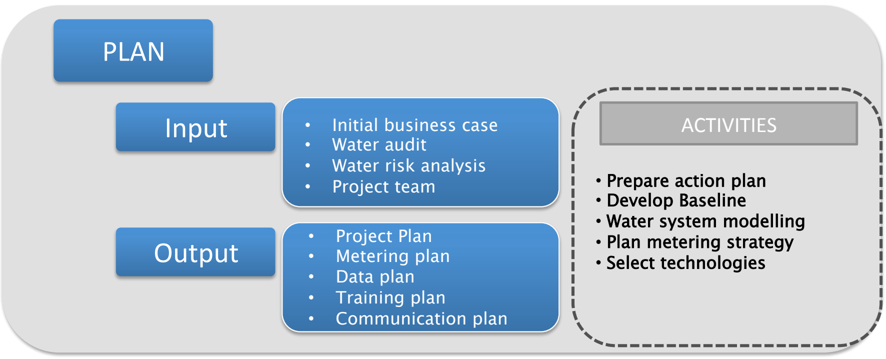

Fig. 4. The guidelines to follow to implement Waternomics Methodology – Phase 1

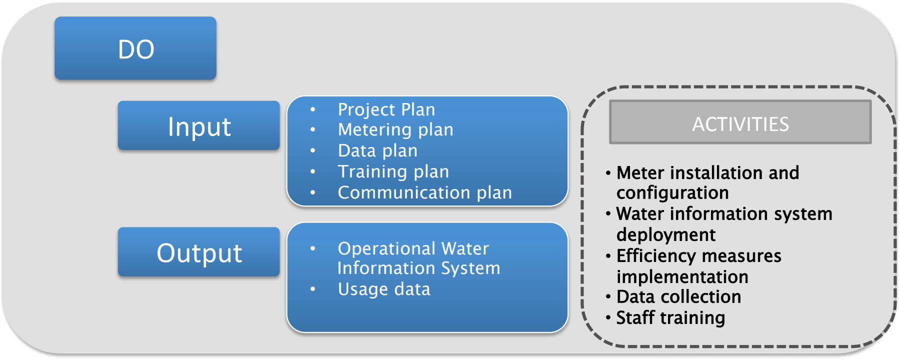

Fig. 5. The guidelines to follow to implement Waternomics Methodology – Phase 2

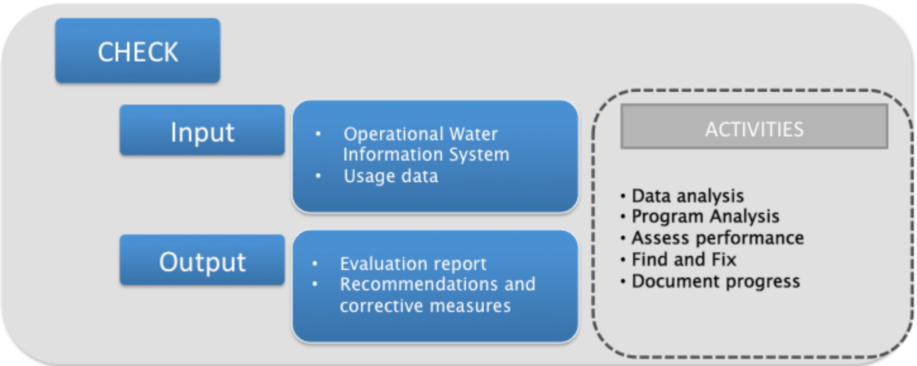

Fig. 6. The guidelines to follow to implement Waternomics Methodology – Phase 3

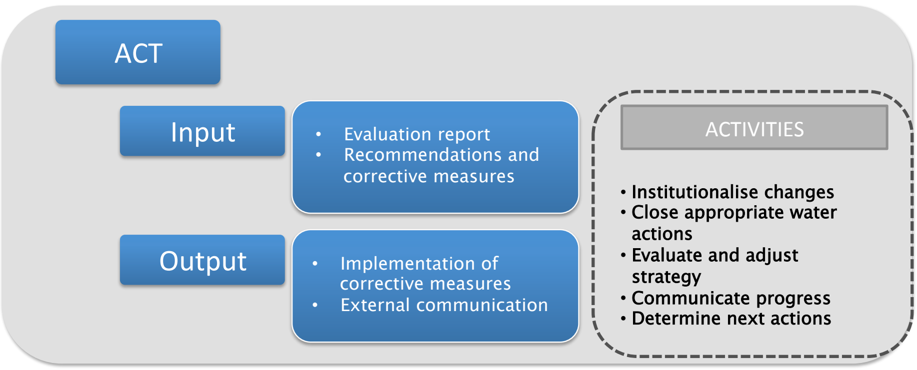

Fig. 7. The guidelines to follow to implement Waternomics Methodology – Phase 4

In the following each phase is described. Its goals and activities are described. More references are provided in "D2.1 – Waternomics Methodology" [7] available on line [8] as public report.

5.1 Phase 0 – ASSESS

The goal of the "Assess" phase is to determine whether or not an end user or decision maker should engage in the construct of a water management program, take water efficiency measures and/or implement a water information system. During this phase a decision making team will identify if a water management program can realistically be deployed and if so, what goals should be met and which strategy is the best to reach these goals. The activities that make up this phase are:

1. Assess water context
2. Conduct water audit
3. Select strategy, objectives and KPIs
4. Select Water Efficiency Measures

5.2 Phase 1 – PLAN

The goal of the "Plan" phase is to take all necessary actions to fully prepare water efficiency measures for implementation. The activities that make up this phase are:

1. Develop baseline
2. Conduct water system modelling (if applicable)
3. Plan metering strategy
4. Prepare action plan
5. Select technology

In this plan phase, the activities are highly interdependent and may occur in parallel or in a different order than presented herein.

5.3 Phase 2 – DO

This phase executes previous planning activities and begins the data collection for charting and analysis in the following "CHECK" and "ACT" steps. It consists of the following activities:

1. Meter installation and configuration
2. Efficiency measure implementation
3. Data collection
4. Water information system deployment
5. Staff training

5.4 Phase 3 – CHECK

According to ISO 50001, an important aspect of management is the process of continuous improvement. In order to ensure this, regular checks are required to ensure all water objectives and targets set in the Assess and Plan phases have been achieved. Checks should also ensure that the Water Efficiency Measures (WEMs) are functioning optimally. If necessary, corrective measures can be undertaken.

By frequently and regularly comparing the expected and actual water consumption, it is possible to quickly detect inefficient use of water or problems in the network. Indeed, fault detection and diagnosis rules and algorithm are a part of Waternomics research objectives. In the IPMVP this phase is named “Operational Verification” and its aim is to check that the WEMs are installed and operating properly and have the potential to generate savings. Operational verification may involve inspections, functional performance testing, and/or data trending with analysis. IPMVP includes both operational verification and an accounting of savings based on site water measurements before and after implementation of a project, and adjustments. The activities of the Check Phase are:

1. Data Analysis
2. Programanalysis
3. Assess performance
4. Find and fix
5. Document progress

5.5 Phase 4 – ACT

The Act Phase is a systematic leader level review of the program to determine if it is meeting its objectives, if all or some parts can be concluded, or if adjustments to existing objectives or new objectives are required. If it is the case that the objectives of the WEMs are not fulfilled, then one must put in place corrective actions.

The activities of this phase are:

1. Institutionalize changes
2. Close appropriate water efficiency measures
3. Evaluate and adjust strategy
4. Communicate progress
5. Determine next actions

6 Validation Approach

The effectiveness and efficiency of the Waternomics methodology is assessed both qualitatively and quantitatively in the project in the following way.

- Development: Throughout its development, meetings and interviews with end users and targeted stakeholder profiles have been used to both aid development and to validate the usefulness of the concepts coming into place.
- Coding into the Water Information System: An additional level of scrutiny is provided when one has to transform from paper (this report) into an interactive software environment. This is forcing the methodology team to think additionally of "how" to bring the methodology concepts to end-users in a term internally being called "methodologization."
- Use case and exploitation scenarios: D1.1 (Usage Case and Exploitation Scenarios) [6] is a public Waternomics deliverable that details a series of examples (use cases) that bring project core concepts to life for end users in an engaging way. These examples are being connected also to the methodology and two are provided immediately following paragraphs 6.1 and 6.2.
- Pilots Implementation: Waternomics has four pilots across three targeted stakeholder groups (domestic, corporate, municipal). These real-world pilots provide a unique and excellent opportunity to assess the methodology and impact of project results.
- Methodology Revision: Lessons learned from all project activities (and especially the pilots) will be reflected back into the methodology for a second updated version at project conclusion.
- Scientific Validation: A peer-reviewed publication is planned to introduce the final methodology to the scientific community and to receive independent expert feedback.
- PAB Validation: The project has a project advisory board (PAB) consisting of external experts and organizations that provide feedback on project results. The methodology will be shared with the PAB and their opinion solicited.
- Methodology Replication: The methodology will pass an initial validation if it is use is continued and expanded at the pilot activities. After the first cycle of the methodology (in the project), this would take the form of the decision makers at the pilots completing the act phase, adjusting strategy and selecting a new round of efficiency measures to be conducted after the project, thus continuing the PDCA cycle.

Two use case examples that link project use cases to the project methodology are provided in the following.

6.1 Example 1: Using WATERNOMICS methodology in a household situation

Situation: Mary and John are married and have two children. They own a house with a garden in a small village in southern Europe and both are concerned with the environment.

Phase 0 - Assess: Mary and John are discussing on how they could decrease their environmental footprint. They compare their energy and water usage with households that have similar characteristics. Because they installed solar panels last year, their energy consumption is below average but their water usage is still a bit high. Looking at their night-time water usage it is not likely that they suffer from leakages so they decide to purchase a rainwater harvesting system. Their goal is to reduce their drinking water consumption with 15%.

Phase 1 - Plan: Mary is creating an overview of available rainwater harvesting solutions. They can opt for an underground storage with large capacity or they can decide to connect a barrel to the drains from the roof. Since they plan to use rainwater for the garden and the toilets, they decide to go for a 5000 litre underground silo. Mary requests some proposals from construction companies and selects one that has a fair price and good service.

Phase 2 – Do: The construction workers place the reservoir and connect the pipes and pumps to the drains and the toilet. A smart meter is placed at the entry and the exit of the rainwater reservoir so Mary and John can still track their total water usage.

Phase 3 - Check: In the months after the reservoir has been installed, Mary and John check their water usage. Despite the fact that is summer time, and it did not rain very much, their drinking water consumption is reduced with 12%. The expectation is that annually they will save up to 20% of drinking water.

Phase 4 - Act: With the rainwater harvesting system in place, the house of Mary and John improves the rating of their house's sustainability label from rating B to rating A. Mary is already thinking about how they can improve their environmental footprint even more.

6.2 Example 2: Using WATERNOMICS methodology in a corporate environment

Situation: ABC Company is an established furniture company, producing wooden furniture for over 50 years and selling their products worldwide. They have one production plant with offices for the commercial departments located near a medium sized city in the northern part of Europe.

Phase 0 – Assess: During a regular strategy meeting, the managing director and the environmental manager decided that it was time to review their sustainability strategy. They both noticed an increased interest of their customers about the ecological footprint of their products and up until now they hadn't reported about their use of energy, water or carbon footprint. The results from an assessment showed them that there where gaps in their information on water consumption. Although the more recently build offices where all equipped with fine grained meters for water, the water distribution network in the older part of the factory was never recorded properly. Without this information it would be very difficult to identify areas for improvement, so they decided to start an action to install baseline metering throughout all facilities. Their goal was to have metering in place for water usage on department and production process level and to make the first step in reaching ISO14046 compliancy.

Phase 1 – Plan: The project manager who was assigned to lead this project, started with mapping the locations which lacked proper metering or descriptions of the water distribution network. Based on the baseline information a plan was made that included a metering strategy, technical architecture and cost overview. Third parties where invited to make a proposal for the installation of the sensors and meters and the configuration of the information systems.

Phase 2 – Do: Third parties installed the meters and a technology provider installed the information system and management dashboard. During the whole process, staff from the factory was closely involved in the implementation process.

Phase 3 – Check: During the 3 month pilot phase, the complete system was tested and the collected water usage data was checked against historic data. Results of the pilot where communicated back to the factory workers and already after 2 months a decrease of water consumption was measurable.

Phase 4 – Act: After the pilot phase, the project has reached it goals and was considered successful. The new information about water usage and performance was included in the regular reporting structure of the company and new KPI's on water management where set. An ISO14046 (water footprint) assessment showed that the company had not fully met its objectives but had made significant progress. Based on the results of the assessment and the analysis of water consumption, recommendations for a follow up actions and new efficiency measures were made.

7 Concluding remarks

This paper presents and discusses one important result in terms of outputs of the WATERNOMICS project: the standard based methodology.

With respect to the Waternomics methodology and developed content, the research and interaction with stakeholders have shown a clear need for this project development. Waternomics is developing tools, references and resources to assist in the construct and implementation of water management programs and the execution of water efficiency measures. Waternomics standards-based methodology offers an innovative way of merging together the main standards of the water and energy sectors and providing the end users a step-to step guide to follow in implementing their water saving programs.

All the Waternomics Team strongly believes in the potential of this project and is investing heavily in the development of this new ICT technology. In the following months we will develop the Waternomics Information System and the applications to provide the water information to the end users and to make them easily apply the methodology.

At the end of the Waternomics project a final version of the presented methodology will be presented to the scientific community.

Acknowledgements.

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Recent Developments in City Scale Modelling, Monitoring and Performance Information Delivery

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Abstract. This paper corresponds to a presentation delivered at the *SmarT-ABCD'15* workshop on *Smart Technologies and Applications in Buildings, Cities and Districts* organised within the framework of the 11th International Conference on Artificial Intelligence Applications and Innovations. It reports outcomes from recent research that established a means to deliver, rapidly and at low cost, energy-related apps corresponding to discrete issues such as inappropriate HVAC system regulation, occupant discomfort avoidance, energy use reporting, upgrade quality assurance and the like.

Keywords: pervasive sensing, data processing, energy services, building performance simulation, benchmarking

1 Introduction

Many technologies and systems are routinely mooted as potential solutions for low energy/carbon cities. Examples include innovative insulation products, advanced glazing, context-aware smart control, combined heat and power plant, heat pumps, solar thermal/electric systems, fuel cells, urban wind power, low energy lighting, smart grids and biomass/district heating. Given the complexity of the problem domain, it is unlikely that fiscal measures alone will bring about solutions comprising effective blends of such technologies. This notion gives rise to two aphorisms.

1. If a proposal is not simulated at the design stage then it is unlikely to deliver the required performance when built.
2. If post occupancy performance is not routinely monitored then the present gap between operational performance and design intent will persist.

These issues may best be addressed by a data-centric approach whereby estate simulation and monitoring is routinely applied; a means to blend the virtual and real outcome data established; and transformation techniques applied to this blend to yield information that may be acted upon by interested stakeholders, including designers, planners, property managers and citizens. Ensuring such a whole-systems approach to the design, commissioning and operation of single or groups of buildings is the intent of the recently launched *Hit2Gap* project [1] as funded under the European Commission's Horizon 2020 R&D programme.

2 Data-centric Approach

Figure 1 summarises the data-centric approach to performance assessment when applied at the city scale. Data is collected from a variety of estate monitoring devices – such as utility meters, weather stations and pervasively deployed environmental sensors – and used to quantify the multi-variate performance of the estate being addressed. These performance data are then delivered to a range of stakeholders in user-specific format, e.g. as spatial maps depicting low carbon technology deployment opportunity at the city level or as timely advisories to building operators. To support action planning, scenario simulations are undertaken to quantify the likely outcome of proposed interventions, such as existing building upgrades, the introduction of demand management/response, or the introduction of a disruptive technology such as electric vehicles.

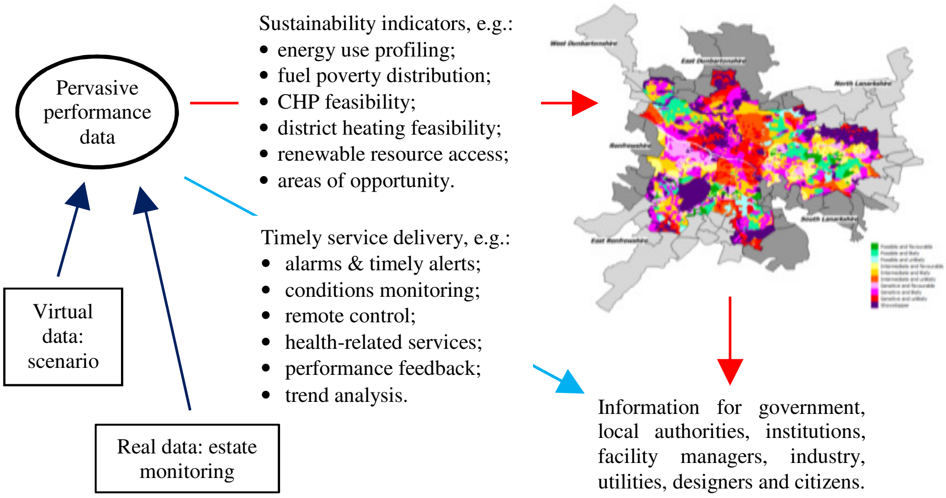

Fig. 1. A data-centred approach to future city management.

As depicted in Figure 2, a significant feature of the simulation approach [2] is its ability to generate disaggregated demand profiles at high resolution (per property, technical system or connected estate for example) for building stock models generated automatically on the basis of rules derived from stock survey [3].

The significant point is that the approach respects the underlying thermodynamic complexity, links energy use considerations to wider issues such as comfort, air quality, emissions *etc*., enables life cycle assessment, and accommodates uncertainty – all while providing an integrated view of the overall, multi-variate performance as depicted in Figure 3. Within the present work, the ESP-r system has been modified to these ends and made compatible with the EnTrak data management system [4].

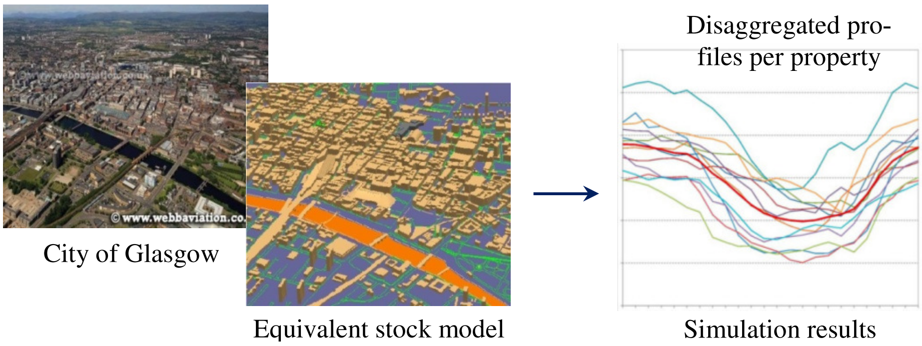

Fig. 2. Disaggregated load profiles generated from a building stock model.

This notion of a virtual reality approach to building performance assessment is encapsulated in the future vision statement as published by the International Building Performance Simulation Association [5] and portends a future wherein proposals may be pre-tested under conditions that emulate the likely future reality.

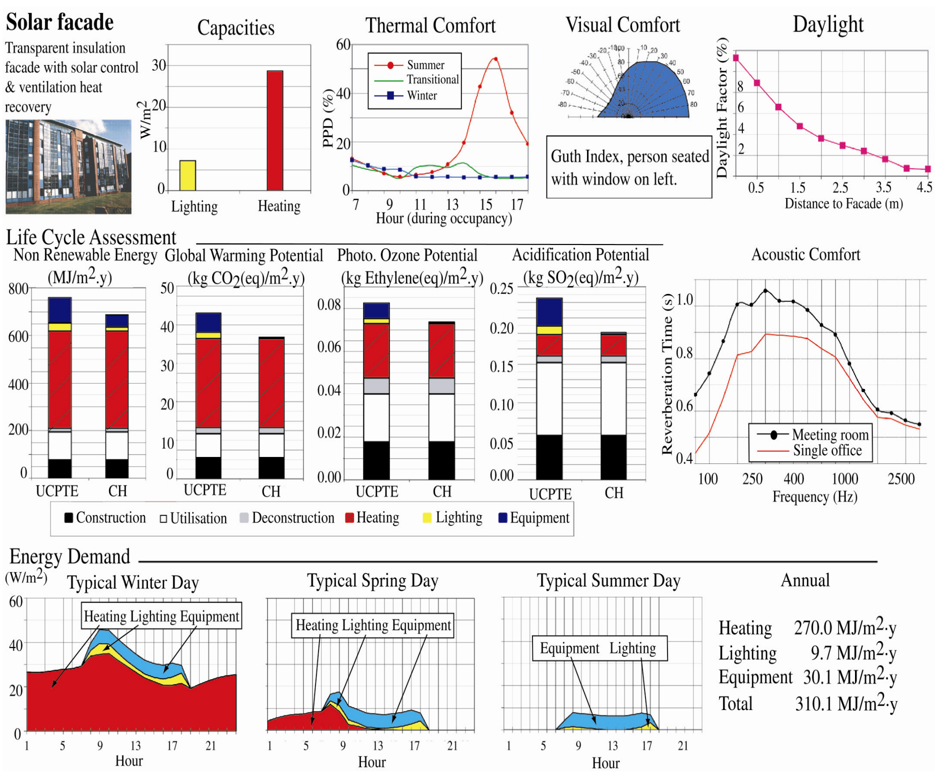

Fig. 3. An integrated view of performance resulting from multi-domain building performance simulation.

3 Estate Monitoring

While it may be expected that building energy management systems are able to provide a portion of the required estate performance information, it is unlikely that the required dataset will be complete in several important respects. Because the focus will be on HVAC system state measurement and control, issues such as occupancy presence and behaviour, the spatial distribution of indoor conditions, disaggregation of load profiles, and local weather will typically be omitted. It is for these reasons that the BuildAX monitoring system, as depicted in Figure 4, was developed within a project funded by the UK Science and Engineering Research Council (project EP/I000739/1) [6].

Fig. 4. A BuildAX logger/router/server (left) and multi-sensor environmental monitor.

The environmental monitor integrates sensors for temperature, relative humidity, movement, illuminance, contact (e.g. door/window opening), and battery state. These data are broadcast to the logger/router wirelessly at 2.4 GHz from whence they may be collected by remote agents as described below. The technology is open and has an established supplied chain. The logger/router encapsulates a Web server that enables immediate display of the monitored data as depicted in Figure 5 for the case of a deployment of 6 monitors at locations throughout an office as shown.

Fig. 5. BuildAX data superimposed on a plan view alongside a graph of the environment state data.

4 Energy Service Definition

Whether the collected data are real or virtual, they must be transformed to useful information. This requires the imposition of data processing rules that depend on the service being enacted. This transformation is performed by the EnTrak system [7] via a three stage process as follows.

As shown in Figure 6, the first stage involves the formal definition of the entities being monitored – here buildings on the Strathclyde University campus. In another application an entity might be a utility meter, a vehicle, a plant component *etc*., or any heterogeneous mix of such objects.

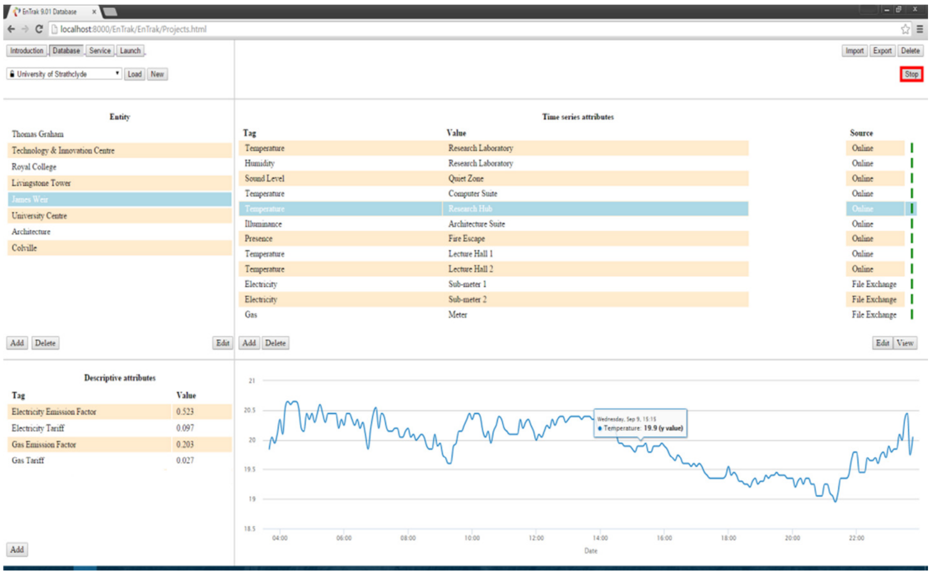

Fig. 6. Data schema definition in EnTrak.

Entities are defined in terms of descriptive and time series attributes, where each attribute is a tuple comprising a tag/value pair. Typically, attribution is restricted to only those data required to enact the targeted service, i.e. EnTrak should not be considered as a general building database system. Each time series attribute has an associate data location definition, such as collection by file exchange with a remote server or by the direct querying of monitoring devices deployed in the field, e.g. a BuildAX logger/router. The required fetch frequency is then specified per attribute and a test connection made; at some later time, usually after completion of stage 2, the overall data monitoring scheme is commenced with all data stored in a mySQL database.

In the second stage, services are established by associating actions with all or part of the data schema as required. For example, in the upper part of Figure 7 an operational Energy Performance Certificate (EPC) has been defined by applying a set of actions to electricity and gas meter readings, while in the lower portion a high temperature alert is defined by range checking all dynamic attributes with tag 'Temperature' and value 'Lecture Hall'.

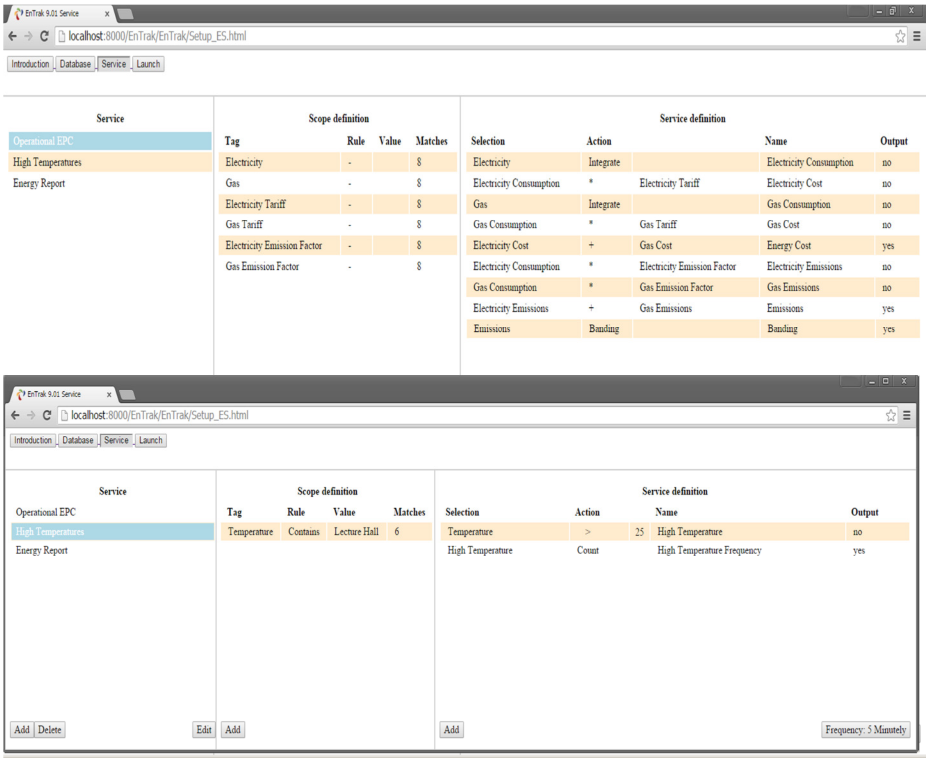

Fig. 7. Defining a service in terms of data processing rules applied to entity attributes.

In the third stage, individual services are started and run at the required frequency (e.g. monthly for the EPC service, 5 minutely for the temperature alert service). This results in the repetitive application of the stage rules to the incoming monitored data until the service is stopped. As shown in Figure 8, the final outcome is delivered as an xml file in order to support alternative delivery formats, styles and devices. In the example shown here, the final delivery platform is a smart phone app developed by a company, who are partnering the university in trial deployments of EnTrak.

To support 'what-if' studies, it is possible to replace the incoming data from field monitoring with prediction time series emanating from simulation, or to mix real and virtual data. In relation to the first service defined in Figure 7, one service may then deliver an operational EPC based on actual performance, while another service delivers a virtual EPC corresponding to some post-upgrade scenario. The difference then quantifies the potential to inform the upgrade decision-making process.

The EnTrak system, including its BuildAX and ESP-r components, has been applied to 75 homes as part of the Innovate UK Future Cities Demonstrator project [8]. Based on the monitoring of energy use, indoor conditions and weather parameters, and stock simulation to generate benchmarks, a service was established to assure the quality of insulation upgrades applied to hard-to-heat homes. Figure 9 depicts the service outcome as delivered to the housing department of Glasgow City Council.

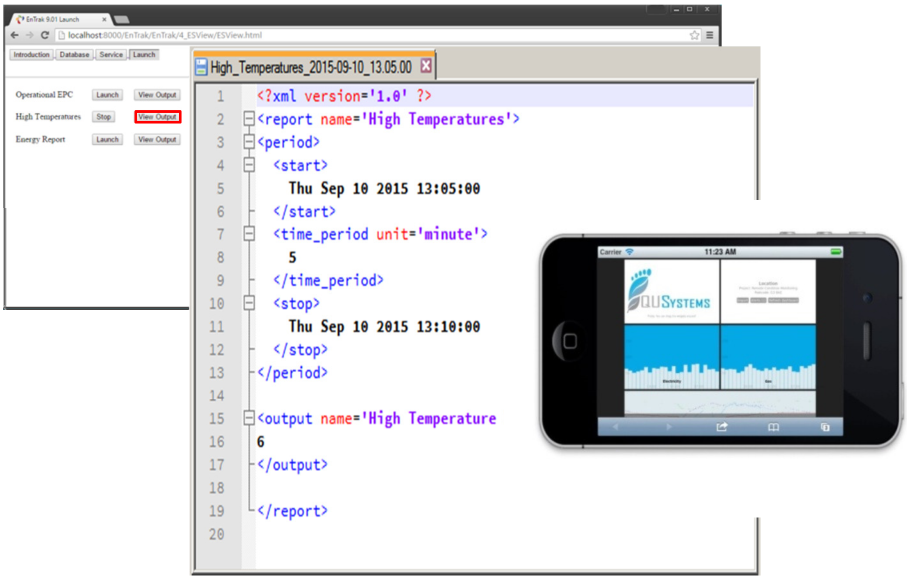

Fig. 8. A service outcome example.

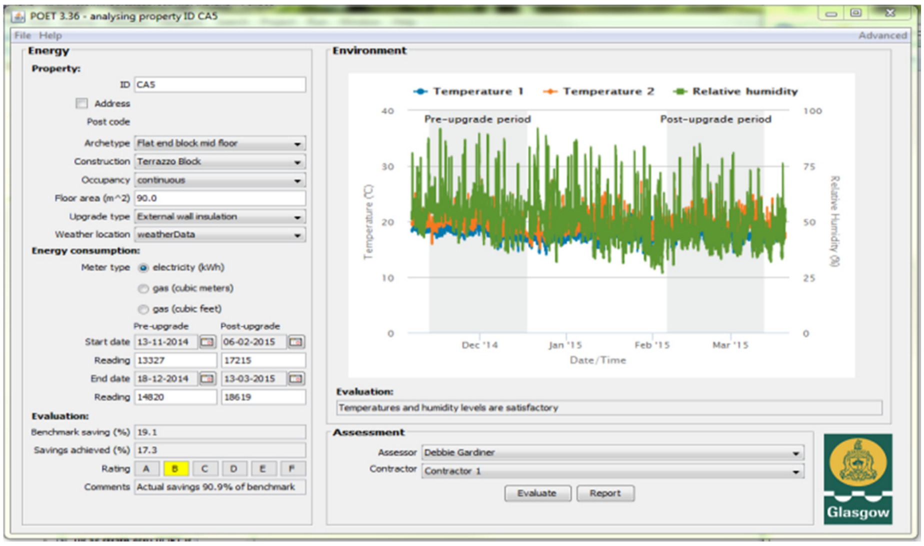

Fig. 9. A housing upgrade quality assurance service as delivered to Glasgow City Council.

Other deployments include 15 commercial buildings undertaken as part of the EPSRC's digital transformation programme targeting digitally mediated occupant negotiation in facilities management; large building stock performance reporting in support of energy action planning and policy formulation; scenario appraisal for future network resilience assessment and active network control in smart grids; and online assessment of novel building designs and systems as deployed within the BRE Innovation Park network.

5 Conclusions

This paper corresponds to a presentation on the EnTrak/BuildAX/ESP-r technologies delivered at the SmarTABCD'15 workshop on Smart Technologies and Applications in Buildings, Cities and Districts delivered at the AIAI'15 conference. The approach, as described, portends a future where the building energy management and performance reporting process is atomised into discrete services, with timely outcomes delivered to a range of stakeholders. The integration of estate monitoring and building performance simulation will allow the data analytics being applied to monitored data to be underpinned by a model of the process that delivers information on the ideal performance target. One goal of the Hit2Gap project is to evolve low cost, open hardware and highly functional simulation tools for performance monitoring, options assessment and new information delivery.

6 Acknowledgements

I am indebted to my ESRU colleagues, who have made crucial inputs to the ESP-r, EnTrak and BuildAX projects, and to colleagues at the University of Newcastle's Culture Lab, who fabricated the BuildAX devices within the above-mentioned EPSRC project.

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Abstract. This paper corresponds to a presentation delivered at the *SmarT-ABCD'15* workshop on *Smart Technologies and Applications in Buildings, Cities and Districts* organised within the framework of the 11th International Conference on Artificial Intelligence Applications and Innovations. It reports outcomes from recent research that established a means to deliver, rapidly and at low cost, energy-related apps corresponding to discrete issues such as inappropriate HVAC system regulation, occupant discomfort avoidance, energy use reporting, upgrade quality assurance and the like.

Keywords: pervasive sensing, data processing, energy services, building performance simulation, benchmarking

1 Introduction

Many technologies and systems are routinely mooted as potential solutions for low energy/carbon cities. Examples include innovative insulation products, advanced glazing, context-aware smart control, combined heat and power plant, heat pumps, solar thermal/electric systems, fuel cells, urban wind power, low energy lighting, smart grids and biomass/district heating. Given the complexity of the problem domain, it is unlikely that fiscal measures alone will bring about solutions comprising effective blends of such technologies. This notion gives rise to two aphorisms.

1. If a proposal is not simulated at the design stage then it is unlikely to deliver the required performance when built.
2. If post occupancy performance is not routinely monitored then the present gap between operational performance and design intent will persist.

These issues may best be addressed by a data-centric approach whereby estate simulation and monitoring is routinely applied; a means to blend the virtual and real outcome data established; and transformation techniques applied to this blend to yield information that may be acted upon by interested stakeholders, including designers, planners, property managers and citizens. Ensuring such a whole-systems approach to the design, commissioning and operation of single or groups of buildings is the intent of the recently launched *Hit2Gap* project [1] as funded under the European Commission's Horizon 2020 R&D programme.

2 Data-centric Approach

Figure 1 summarises the data-centric approach to performance assessment when applied at the city scale. Data is collected from a variety of estate monitoring devices – such as utility meters, weather stations and pervasively deployed environmental sensors – and used to quantify the multi-variate performance of the estate being addressed. These performance data are then delivered to a range of stakeholders in user-specific format, e.g. as spatial maps depicting low carbon technology deployment opportunity at the city level or as timely advisories to building operators. To support action planning, scenario simulations are undertaken to quantify the likely outcome of proposed interventions, such as existing building upgrades, the introduction of demand management/response, or the introduction of a disruptive technology such as electric vehicles.

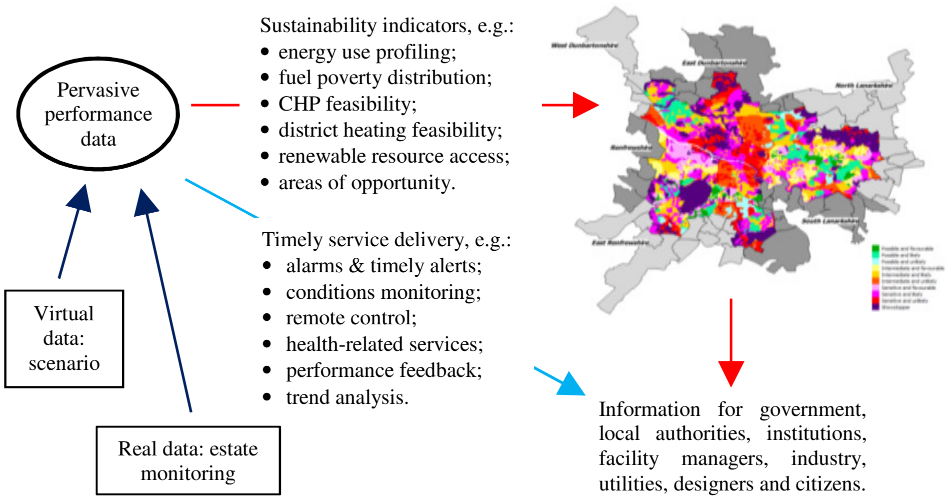

Fig. 1. A data-centred approach to future city management.

As depicted in Figure 2, a significant feature of the simulation approach [2] is its ability to generate disaggregated demand profiles at high resolution (per property, technical system or connected estate for example) for building stock models generated automatically on the basis of rules derived from stock survey [3].

The significant point is that the approach respects the underlying thermodynamic complexity, links energy use considerations to wider issues such as comfort, air quality, emissions *etc*., enables life cycle assessment, and accommodates uncertainty – all while providing an integrated view of the overall, multi-variate performance as depicted in Figure 3. Within the present work, the ESP-r system has been modified to these ends and made compatible with the EnTrak data management system [4].

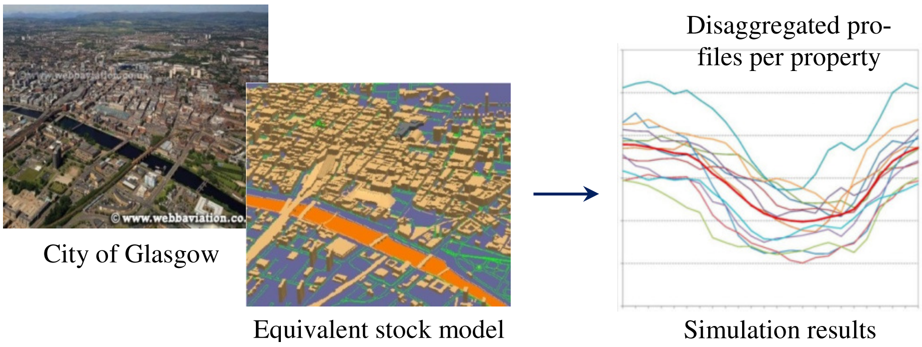

Fig. 2. Disaggregated load profiles generated from a building stock model.

This notion of a virtual reality approach to building performance assessment is encapsulated in the future vision statement as published by the International Building Performance Simulation Association [5] and portends a future wherein proposals may be pre-tested under conditions that emulate the likely future reality.

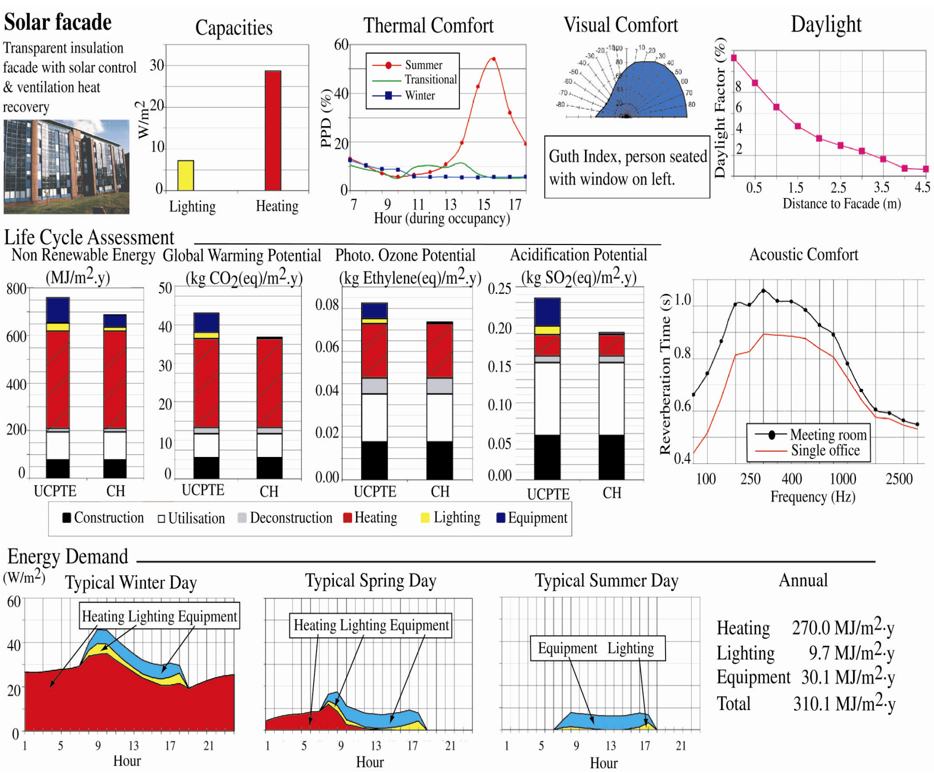

Fig. 3. An integrated view of performance resulting from multi-domain building performance simulation.

3 Estate Monitoring

While it may be expected that building energy management systems are able to provide a portion of the required estate performance information, it is unlikely that the required dataset will be complete in several important respects. Because the focus will be on HVAC system state measurement and control, issues such as occupancy presence and behaviour, the spatial distribution of indoor conditions, disaggregation of load profiles, and local weather will typically be omitted. It is for these reasons that the BuildAX monitoring system, as depicted in Figure 4, was developed within a project funded by the UK Science and Engineering Research Council (project EP/I000739/1) [6].

Fig. 4. A BuildAX logger/router/server (left) and multi-sensor environmental monitor.

The environmental monitor integrates sensors for temperature, relative humidity, movement, illuminance, contact (e.g. door/window opening), and battery state. These data are broadcast to the logger/router wirelessly at 2.4 GHz from whence they may be collected by remote agents as described below. The technology is open and has an established supplied chain. The logger/router encapsulates a Web server that enables immediate display of the monitored data as depicted in Figure 5 for the case of a deployment of 6 monitors at locations throughout an office as shown.

Fig. 5. BuildAX data superimposed on a plan view alongside a graph of the environment state data.

4 Energy Service Definition

Whether the collected data are real or virtual, they must be transformed to useful information. This requires the imposition of data processing rules that depend on the service being enacted. This transformation is performed by the EnTrak system [7] via a three stage process as follows.

As shown in Figure 6, the first stage involves the formal definition of the entities being monitored – here buildings on the Strathclyde University campus. In another application an entity might be a utility meter, a vehicle, a plant component *etc*., or any heterogeneous mix of such objects.

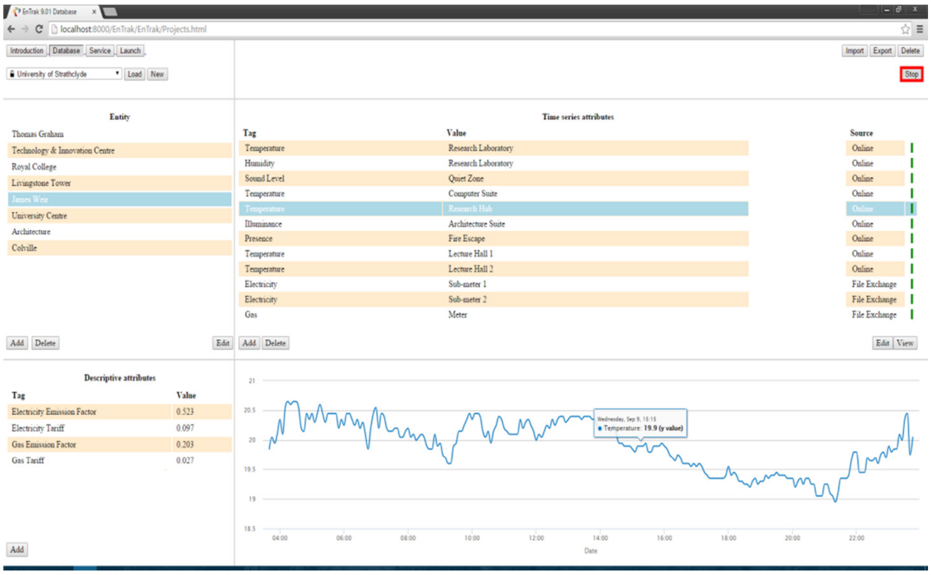

Fig. 6. Data schema definition in EnTrak.

Entities are defined in terms of descriptive and time series attributes, where each attribute is a tuple comprising a tag/value pair. Typically, attribution is restricted to only those data required to enact the targeted service, i.e. EnTrak should not be considered as a general building database system. Each time series attribute has an associate data location definition, such as collection by file exchange with a remote server or by the direct querying of monitoring devices deployed in the field, e.g. a BuildAX logger/router. The required fetch frequency is then specified per attribute and a test connection made; at some later time, usually after completion of stage 2, the overall data monitoring scheme is commenced with all data stored in a mySQL database.

In the second stage, services are established by associating actions with all or part of the data schema as required. For example, in the upper part of Figure 7 an operational Energy Performance Certificate (EPC) has been defined by applying a set of actions to electricity and gas meter readings, while in the lower portion a high temperature alert is defined by range checking all dynamic attributes with tag ‘Temperature’ and value ‘Lecture Hall’.

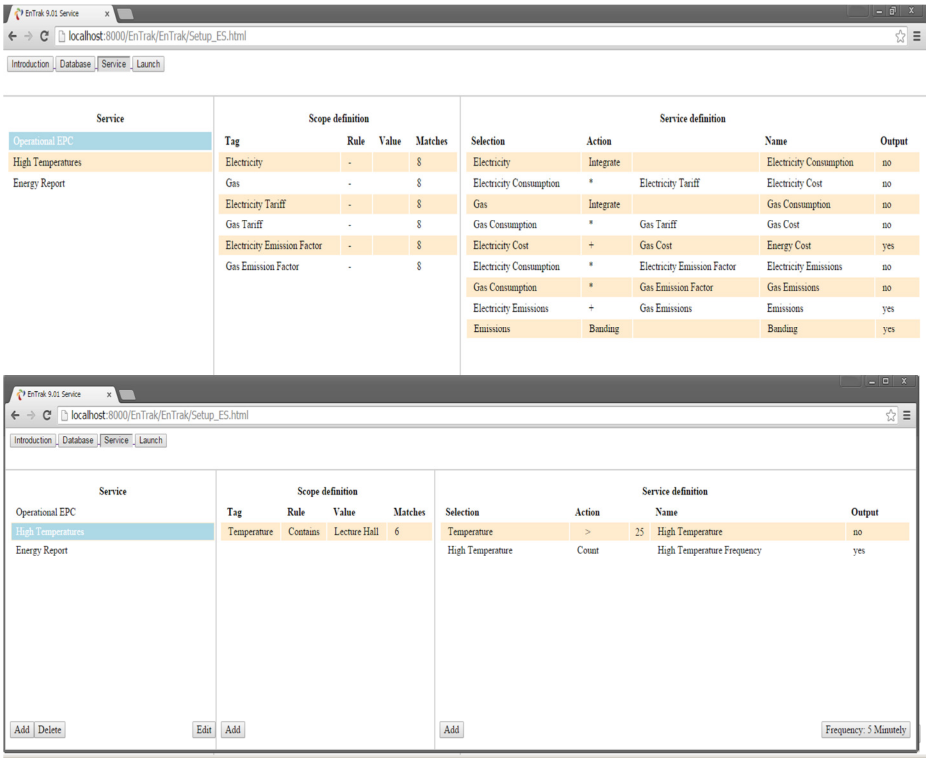

Fig. 7. Defining a service in terms of data processing rules applied to entity attributes.

In the third stage, individual services are started and run at the required frequency (e.g. monthly for the EPC service, 5 minutely for the temperature alert service). This results in the repetitive application of the stage rules to the incoming monitored data until the service is stopped. As shown in Figure 8, the final outcome is delivered as an xml file in order to support alternative delivery formats, styles and devices. In the example shown here, the final delivery platform is a smart phone app developed by a company, who are partnering the university in trial deployments of EnTrak.

To support 'what-if' studies, it is possible to replace the incoming data from field monitoring with prediction time series emanating from simulation, or to mix real and virtual data. In relation to the first service defined in Figure 7, one service may then deliver an operational EPC based on actual performance, while another service delivers a virtual EPC corresponding to some post-upgrade scenario. The difference then quantifies the potential to inform the upgrade decision-making process.

The EnTrak system, including its BuildAX and ESP-r components, has been applied to 75 homes as part of the Innovate UK Future Cities Demonstrator project [8]. Based on the monitoring of energy use, indoor conditions and weather parameters, and stock simulation to generate benchmarks, a service was established to assure the quality of insulation upgrades applied to hard-to-heat homes. Figure 9 depicts the service outcome as delivered to the housing department of Glasgow City Council.

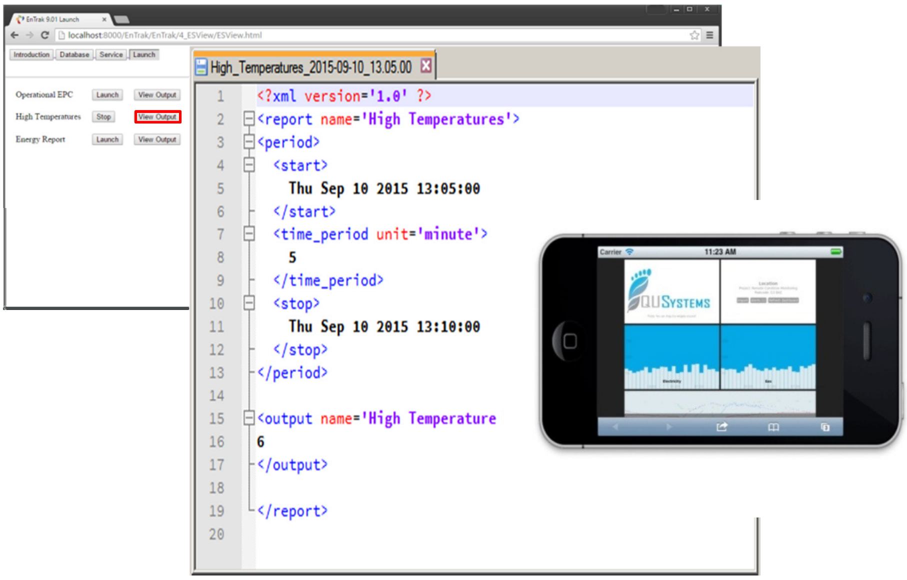

Fig. 8. A service outcome example.

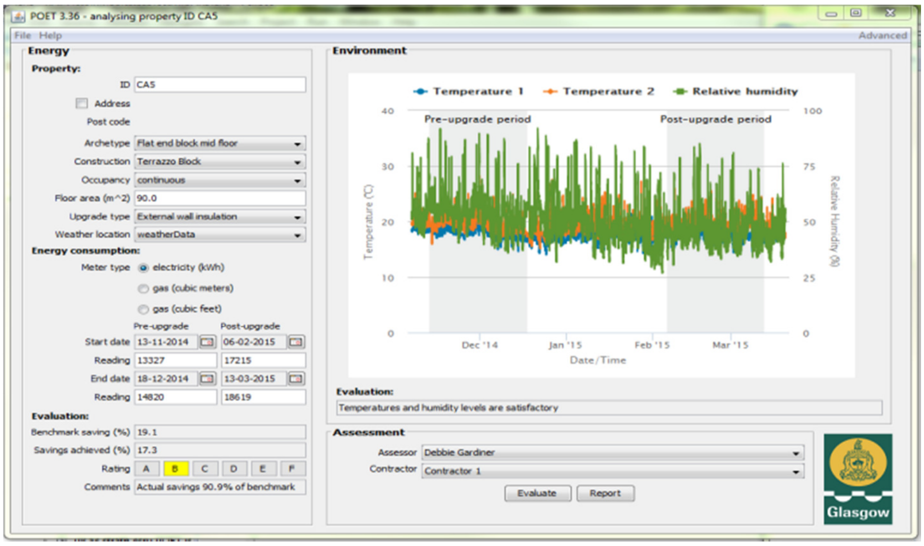

Fig. 9. A housing upgrade quality assurance service as delivered to Glasgow City Council.

Other deployments include 15 commercial buildings undertaken as part of the EPSRC's digital transformation programme targeting digitally mediated occupant negotiation in facilities management; large building stock performance reporting in support of energy action planning and policy formulation; scenario appraisal for future network resilience assessment and active network control in smart grids; and online assessment of novel building designs and systems as deployed within the BRE Innovation Park network.

5 Conclusions

This paper corresponds to a presentation on the EnTrak/BuildAX/ESP-r technologies delivered at the SmarTABCD'15 workshop on Smart Technologies and Applications in Buildings, Cities and Districts delivered at the AIAI'15 conference. The approach, as described, portends a future where the building energy management and performance reporting process is atomised into discrete services, with timely outcomes delivered to a range of stakeholders. The integration of estate monitoring and building performance simulation will allow the data analytics being applied to monitored data to be underpinned by a model of the process that delivers information on the ideal performance target. One goal of the Hit2Gap project is to evolve low cost, open hardware and highly functional simulation tools for performance monitoring, options assessment and new information delivery.

6 Acknowledgements

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