# Bridging the Gap between Information and Communication Technologies and Citizens towards Low Carbon Cities

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## Abstract:

In the process of building future Smart Energy Cities (SEC) towards a low carbon economy, Information and Communication Technologies (ICT) will be a key enabler. ICT are mostly used by energy / facility managers, Energy Service Companies (ESCOs) and specialists, who take decisions based on the information they get. However, the buildings' occupants are excluded from this process. The key issue addressed in this article concerns the engagement of energy end-users in the context of a SEC and the role that advanced technologies could play in improving quality of life for its citizens.

## Keywords:

Smart Energy Cities, Low Carbon Economy, Information and Communication Technologies, Intelligent Energy Management.

## 1. Introduction

Cities are often defined as the next frontier for the development of sustainable energy, where the efforts towards sustainable development and the respective initiatives are localized on a city level – namely the sustainable city. These operations are grounded on the utilization of Information and Communication Technologies (ICT) towards sustainability, eventually leading to an enhanced quality of life via active engagement[1]. Based on IHS Technology[2] , the number of smart cities will be more than tripled over the next decade, at a worldwide level. The modern revolution of Internet of Things (IoT) and the roll-out of numerous smart devices and smart sensors have laid the foundations of developing innovative methodologies and tools for the city authorities and energy managers for monitoring and managing the energy use more efficiently to achieve financial, environmental and social targets.

Smart Energy Cities (SEC), as a core pillar of the smart cities, constitute an emerging urban development strategy, that incorporates these technologies and take advantage of their numerous capabilities in the context of energy efficiency and sustainability, towards a low carbon economy.

Indeed, optimizing the energy use in cities and its buildings is a current research and business trend. Although numerous initiatives and ICT-based solutions exist, most of them focus on energy / facility managers, Energy Service Companies (ESCOs) and specialists, who take decisions based on the information they get. ICT-for-companies are very sophisticated systems (Building Energy Management Systems - BEMS, process analysis, etc.) which cannot be handled by the occupants (incl. households, employees and other buildings' occupants).

[1] KPMG. Dubai – a new paradigm for smart cities, 2015.
[2] IHS Technology. Smart cities to rise fourfold in number from 2013 to 2025. Available at: http://press.ihs.com/press-release/design-supply-chain-media/smart-cities-rise-fourfold-number-2013-2025, 2014 (accessed 15 March 2016).

In order to achieve significant energy savings in the SEC context, appropriate energy efficiency measures have to be adopted by the big majority of the final energy end-users. ICT-based solutions that exploit IoT technologies can contribute significantly to energy saving, by motivating and supporting behavioural change of the buildings' occupants. However, the buildings' occupants are excluded from this process and although they seem to be gaining greater awareness of the value and need for sustainable energy practices, they do not behave in a more energy-conscious way.

ICT technologies, aimed at facilitating the occupants' understanding of the building performance and providing personalised motivation and support, suited to their knowledge and experience, would help them to understand how a change in their behaviour could contribute to energy consumption reduction, thus reduced energy costs. Innovative user-friendly digital applications are necessary, in order to leverage data from smart meters into value for the buildings' occupants, through actionable personalised information, recommendations and incentives for behavioural energy efficiency. These apps would simplify the complexity of the information gathered by those systems, and put it on the hands of energy end-users.

The main aim of this article is to present a "user-centred approach" framework, in order to bridge the gap between ICT-for-companies and occupants, making use of data captured from smart meters, sensors and appliances, as well as energy end-users' feedback. Innovative user-friendly applications are proposed, to convert data from smart meters into value for the buildings' occupants, through actionable personalised information, recommendations and incentives for behavioural energy efficiency.

## 2. The Proposed Framework

It is argued that there is significant influence of a broad variety of energy-related and other data generated and made available in a smart energy city to perform various types of analyses to achieve a significant reduction of energy consumption in city premises.

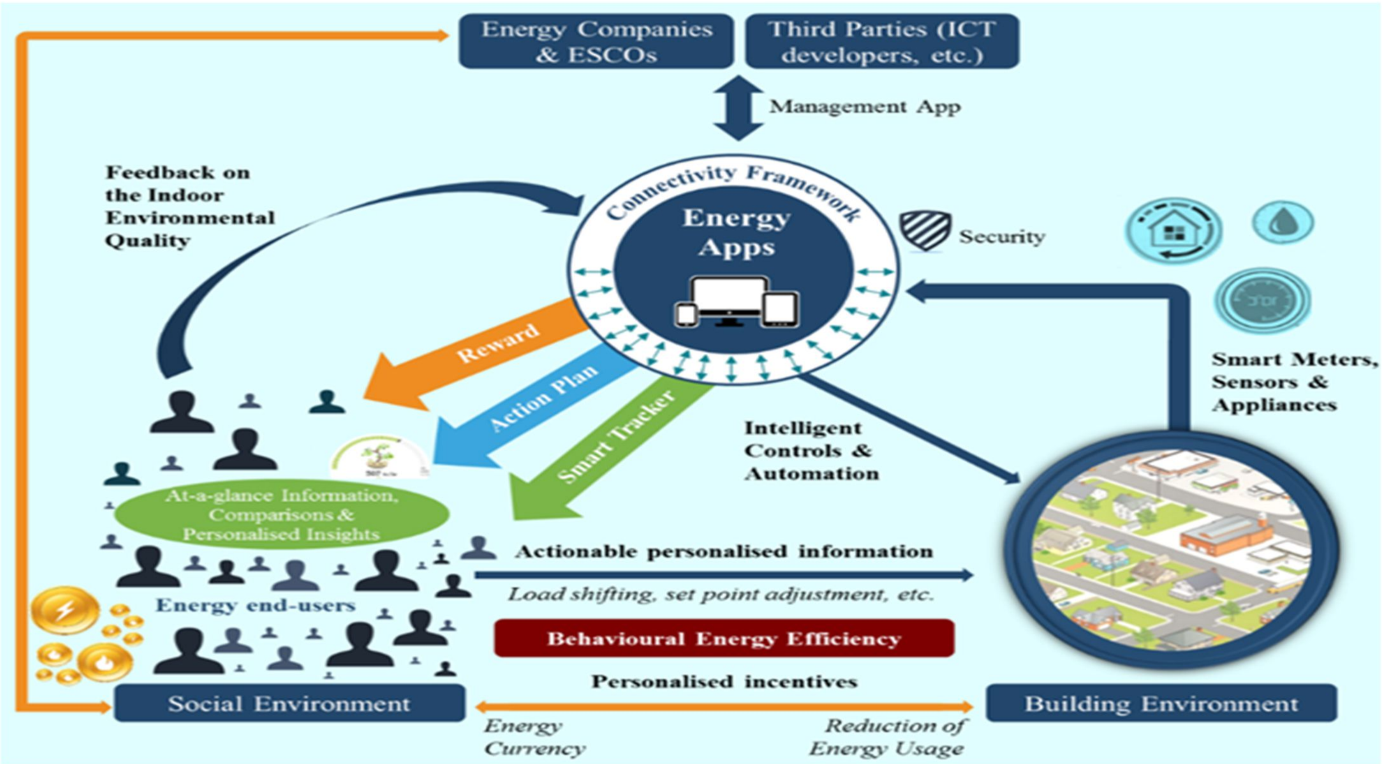


*Figure 1. User-Centred Applications*

The successful combination of smart processes (e.g. real-time consumption management, smart automations, etc.) and smart technologies (e.g. smart meters, intelligent energy management devices, etc.) would enable energy efficiency and savings to be achieved. Moreover, the exploitation of intelligent systems, ICT tools and intelligent energy-related application can prove highly beneficial to citizens by empowering their energy consciousness and their overall understanding about their energy behaviour and its impact.

The energy end-users' engagement in the context of SEC has the potential to produce significant impact on the reduction of energy consumption, energy cost and environmental footprint.data generated through IoT technologies, smart homes, smart vehicles, wearables, smartphones and smart energy meters, along with data about the weather conditions, buildings' energy profiles, feedback provided by occupants, energy prices, energy production and other.

In this context, three user-centred applications are presented which can empower energy end-users to engage in achieving energy efficiency (Figure 1). The personalised energy applications can be easily deployed and integrated with existing systems and infrastructure, in order to motivate and support behavioural energy efficiency. The overall concept is to leverage the available multidisciplinary data and turn that information into value for the end-user through actionable personalised recommendations and incentives for behavioural energy efficiency. The key functionalities of such intelligent applications that are characterised as essential for the energy users' engagement are identified and divided in three main axes, energy monitoring ("Smart Tracker" App), energy management ("Action Plan" App) and incentives for behavioural energy efficiency ("Reward" App).

The user-centred applications can allow energy companies and ESCOs to acquire and retain customers (energy end-users), improve customers' satisfaction through the abovementioned innovative reward program and provide new services. The Management App intends to be a useful tool for energy companies and ESCOs to facilitate the configuration of the user-centred applications in existing and new buildings, as well as for designated third parties (ICT developers and other companies offering energy products) to extend the functionalities of the apps or connect them to third-party products and software (designing new business models).

The Connectivity Framework will facilitate connectivity, integration and interoperability to the millions of devices deployed in the market today. This way, the user-centred applications will be able to interact and communicate with existing systems and data.

## 3. Applications

**The three user-centred applications are described in the following paragraphs.**

### *A. Energy Monitoring ("Smart Tracker" App)*

At-a-glance, real-time or near real-time personalised information needs to be provided to the end-users through easy-to-comprehend visualisations, dashboards and appropriate filters, in terms of:

- Total energy consumption, cost and carbon footprint related to a building.
- Appliance-level energy consumption data.
- Information specific to individuals or behaviours.
- Impact of weather conditions on the energy usage.

The above allow the end-users to learn how much energy is being used by the different appliances, such as lights, consumer electronics or any other specific load and also link the energy consumption with specific individuals, behaviours and weather conditions. Their consciousness and understanding therefore, about the way they consume energy and how that is interpreted in terms of energy cost and carbon footprint is raised. Reliable predictions about energy usage, cost and $CO_2$ emissions on a daily, weekly, monthly, seasonal or yearly basis and comparisons between the actual and predicted values help citizens to identify how much energy has been used and what is the expected usage for the rest of the examined period. Having this information can result in better comprehension about energy consumption seasonality, better arrangement about future activities and early application of suitable actions to reduce the expected energy consumption and prevent exceeding targets or limitations.

Personalised energy insights can be delivered through effective and realistic comparisons of the energy usage with the ones of other citizens in the same location, with similar buildings or others with similar characteristics, so as to understand the position of each citizen in terms of energy efficiency in comparison with others of the same energy profile and identify possible irregular behaviours or efficiency potentials and set feasible targets.

### B. Energy Management ("Action Plan" App)

Having a detailed overview and knowledge about the way the energy is consumed and what is the corresponding cost and carbon footprint is required to raise awareness but it is not sufficient itself to lead to energy efficient behaviour and significant energy savings. The ability for the energy end-users to get persuasive, personalised and realistic saving recommendations and tips, specific to target appliance and period (e.g. when the heating period starts the systems suggests ways to save energy and money on the heating system usage) is really important.

Intelligent data analytics processes based on experts' knowledge, inference rules and energy models, are the key to generate short-term (daily/weekly) or long-term actionable personalised suggestions. These analytics processes can be performed on the various information captured from the building energy monitoring systems, the applied prediction models, the weather data capturing services and other possible data sources. The expected output can be persuasive notifications when energy consumption exceeds a certain threshold, with details on which systems and appliances are driving the excessive usage, along with recommendations for how to reduce it. In addition, it can be based on the users' daily routines, such as recommendations to supervise the load shifting, optimising the boost time of the heating/cooling system taking into account the forecasting of the indoor air temperature and the occupancy levels of the building, scheduling the set-point temperature by taking into consideration thermal comfort as submitted by the occupants and the adaptive comfort concept, scheduling of the amount of outdoor air to be used for cooling the indoor environment, in order to reduce or eliminate the need for mechanical cooling and more.

Highly important for the generation of energy efficiency recommendations, is also the involvement of the end-user, so as to set his preferences, capabilities and constraints. The creation of custom scenarios and rules and their introduction in the analytical processes and the possible automated execution contributes to the feeling of well-being and security. In order to further assure the user's well-being and comfort, his/her feedback about his/her perception of the existing conditions, such as thermal sensation, is also captured and incorporated, along with the potential context awareness of the surrounding environment by the intelligent systems.

### C. Incentives for Behavioural Energy Efficiency ("Reward" App)

Even if the recommendations and guidelines for energy efficiency exist, it is not sufficient and the energy end-users' engagement must proceed one step further. The actual challenge is to provide tangible and meaningful incentives and motivation. This motivation has to really make the difference in terms of materiality for the end-users and go beyond just slightly reducing the energy cost or giving the feeling of environmental contribution, that exist as a form of motivation, but it is not that significant. A relatively new take on incentive mechanisms is the idea of reward programs using coins[3] . A number of related approaches have been proposed for the reduction of CO2 emissions, such as Ergo[4] and CarbonCoin, as well as for the in-feed of renewable energy, most notably SolarCoin. While these proposals address environmental issues, they overlook the energy efficiency sector. So, the connection between energy saving behaviour and coins earning has to be studied and formalised.

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[3] Sgouridis S., Using energy as currency: re-establishing the bridge between the financial and the real world, Netw. Ind. Quart. 14, pp. 8-11, 2012.

[4] Sgouridis S., Kennedy S., Tangible and fungible energy: hybrid energy market and currency system for total energy management.A Masdar City case study, Energy Policy, 2010, 38:1749-1758.

In this context, the reward app is introduced to incentivize behavioural energy efficiency; energy end-users are able to earn coins by reducing or shifting their energy consumption. The coins earned are related with the actual compared to the predicted energy consumption ("Smart Tracker" App) and the daily amount of energy saved by the end-user (as a result of the implementation of the "Action Plan" App personalised information). The value of the coin varies among the end-users, based on their energy profile, the savings, the hour that these saving are achieved (increase value for the ones achieved in peak hour) and is also determined both from the absolute savings of the individual user and the achievements of the rest of the end-users of the specific energy company that applies this App. For every 1 kWh reduced, the end-user earns the respective coins, which can be used to decrease final energy cost by paying part of the bill or all of it to the energy company. This approach enables dynamic billing and allows energy companies to incentivize end users to follow the energy efficiency action plans.

## 3.1 Architecture

**The overall architecture integrates the following modules (Figure 2):**

- **Connectivity Framework:** The Connectivity Framework extends connectivity, integration and interoperability. This module ensures that every subsystem is able to access the required data in a uniform way. Every data request can be passed through this module, which is capable of translating this request into the common format. A set of fully specified APIs and Web Services was implemented and made available to internal or external components, which need to access data, in order to enable a standard way for a high level communication and interaction protocol between diverse tools ensuring thus the necessary interoperability. This enables the desirable independence between the development of the various applications and services and the data access procedure. Consequently, third party applications can connect directly to the middleware using one of the specified standards and at the same time, any possible change at the data access procedure will not require any adoption by the applications.

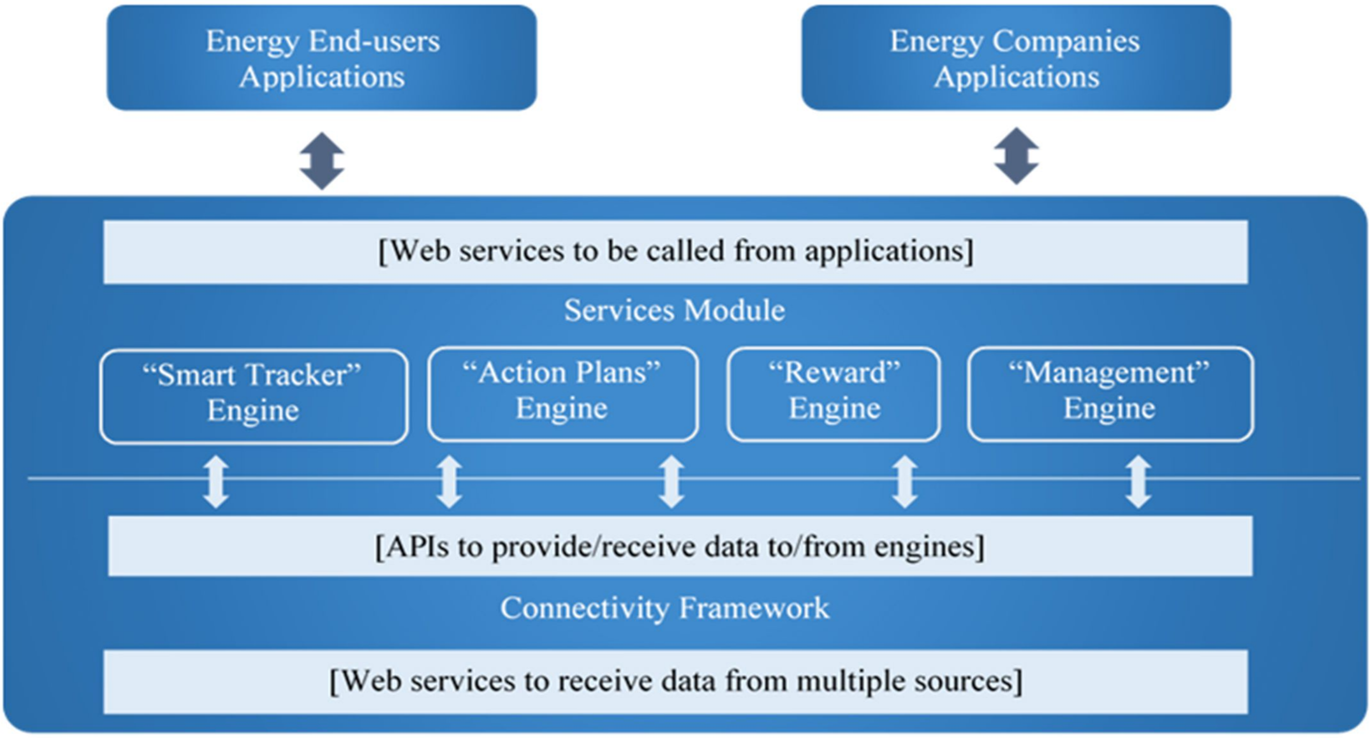


Figure 2. Overall Architecture

- **Engines:** The Engines are a set of multiple independent software components, each responsible for the implementation of a part of the proposed functionality. Each engine provides a fully specified open Web Service to the applications, in order to handle their requests and provide the required results. The Engines are the following: "Smart Tracker" Engine, "Action Plans" Engine, "Reward" Engine and "Management" Engine.
- **Web and Mobile Behavioural Change Apps:** Web and Mobile applications for iOS and Android can be developed with the use of cross platform development frameworks. This relies on JavaScript based technologies that facilitate software development without loss of quality and allow reactive application development. All the applications communicate in a uniform way with the Engines, by using their offered Web Services, all aiming to support the users' behavioural change.

## 4. Conclusion

The multidisciplinary nature of the available data creates the need to develop commonly accepted schemas and structures and enhance connectivity and interoperability between the different data sources, in order to enable their efficient integration. In addition, the ICT solutions should incorporate concepts and technologies from energy behavioural modelling and behavioural change techniques, smart cities, energy optimization and also take into consideration different groups of variables, such as energy-related behaviour, building characteristics, sociodemographic and personality variables and more.

In this context, the role of the proposed digital applications is to bridge the gap between ICT-for-companies and occupants, simplify the complexity of the information gathered by those systems and put it on the hands of energy end-users. The personalised behavioural change applications facilitate energy end-users to:

- Know how much energy is consumed in total and what is the contribution of the specific end-user and other peers to that.
- Get personalized recommendations of action plans for energy conservation and load shifting, along with an estimation of their impact on energy use and user comfort.
- Be motivated towards behavioural change towards energy conservation.

The proposed framework can support energy companies from EU and GCC to acquire and retain energy consumers, as well as improve consumers' satisfaction through the innovative reward program. It constitutes an area of common interest, fostering effective EU-GCC clean energy cooperation, by using an innovative approach for behavioural energy efficiency.

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