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Introduction

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Abstract

The energy continues to be produced by exhaustible and polluting fossil fuels endangering the health of citizens and of the surrounding ecosystems. People around the world are concentrating in big urban centres resulting in an even greater demand of energy stressing the existing supply systems and the environment. This book is about the course of the iURBAN project which developed and validated sustainable energy management systems applied in two European cities using novel ICT technologies.

Keywords: Energy management systems, ICT technology, Energy efficiency, Decision support system.

Today, roughly half of the world's population lives in urban areas, consuming two-thirds of total primary energy and generating over 70% of global energy-related carbon dioxide (CO_2) emissions. By 2030, it is estimated that around 60% of the world's population projected 8.2 billion people will be housed in urban areas. This means that residents who live and work within a city will consume around 75% of the world's annual energy demand. If most of this demand continues to be met by fossil fuels, then cities maintaining a business-as-usual approach will experience large increases in CO_2 emissions, greatly endangering the health of citizens and surrounding ecosystems. Fortunately, many European Union (EU) cities are setting examples to follow in their quest to become energy independent, such as the Swedish city of Växjö, which meets over 54% of its energy demand with local renewable energy and Copenhagen which covers 43% of its energy needs.

The popularity of singular household-powering solar panel systems has increased notably in Europe and worldwide with many buildings to generate a considerable proportion of energy enough to cover energy needs while reduce their carbon footprint. Technology has been a key driver for such investments and the global shift to alternatives for cleaner and renewable energy sources. Additionally, Information and Communications Technology (ICT) tools assist in the management aspects of the energy production and consumption. In particular, software development, smart meters, actuators, sensors, and user-friendly interfaces help managers, household owners, and tenants to create their own energy plans for exploiting optimally the energy generation and control consumption. ICT tools can increase awareness on energy issues and empower users in all energy related decisions. Likewise, individual energy plans can be combined with data from nearby power plants to create energy "shopping lists" for an entire city. The main output is creating more efficient urban system powered by new and interactive relationships between citizens, energy companies, and local government.

iURBAN project created an intelligent "brain" that helps households, businesses, and public buildings to make their energy shopping lists. The project developed and validated a software platform that integrates different ICT energy management systems (both hardware and software) in two pilot cities, providing useful data to a novel decision support system that makes available the necessary parameters for the generation and further operation of new business models. The business models contribute at a global level to efficiently manage and distribute the energy produced and consumed at a local level (city or neighborhood), incorporating behavioral aspects of the users into the software platform and in general prosumers.[1]

iURBAN project aimed to achieve the following objectives in different phases (Figure 1.1):

1. **Integration phase**: To integrate existing and new smart metering systems for water, heating, gas, and electricity. During this phase, a complete monitoring and synchronization between the metering devices with the *Smart City Database* (SCDB) has been carried out.
2. **Smart decision support system development and citizen empowerment phase**: To develop a SCDB network where all the energy-related data generated in the city has been stored and a decentralized energy decision support system that collects real-time or near real-time data, aggregates, analyses, and suggest actions of energy consumption and production. These tools support contractual demand control schemes,

[1]Consumers and producers.

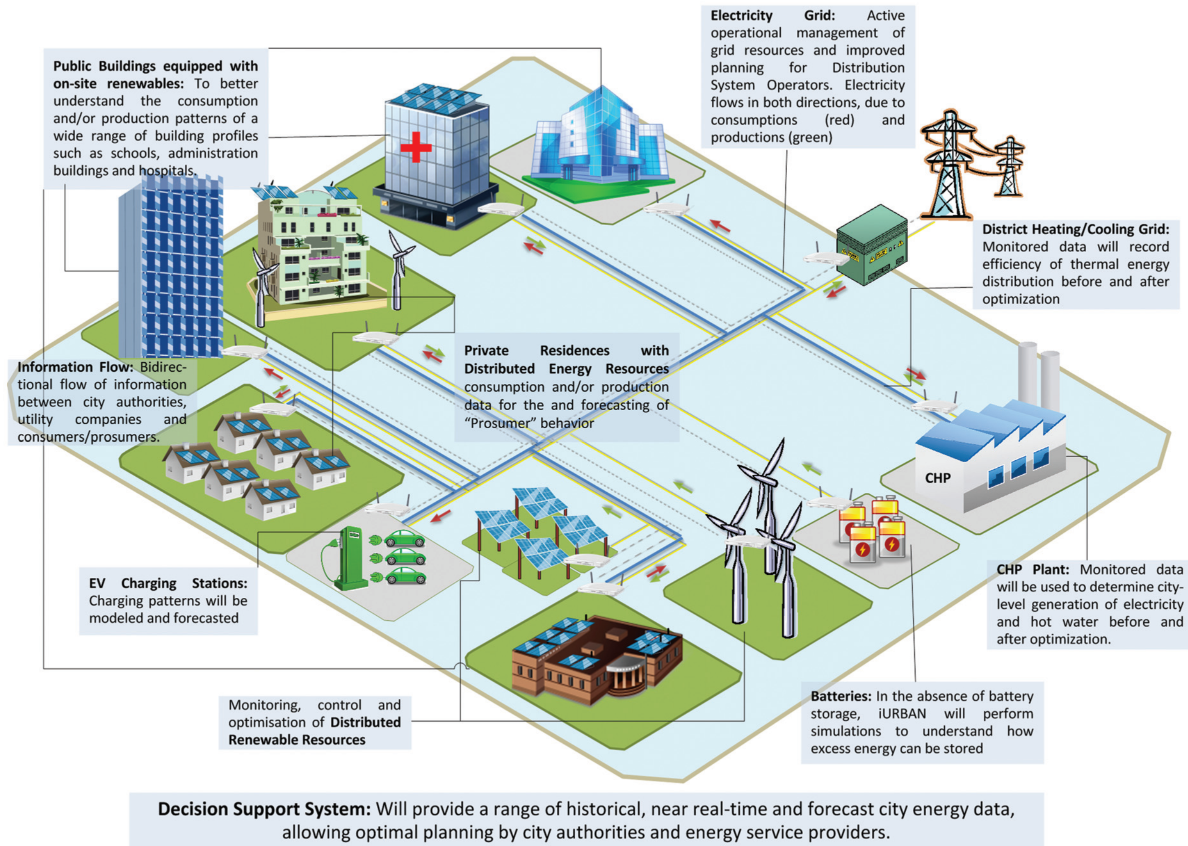

Figure 1.1 Overall scenario of the iURBAN project.

dynamic multi-tariffs, opportunities for load shifting, load shedding, storage utilization, prioritization of renewable energy, etc.

3. **ICT and socioeconomic evaluation phase**: To validate and evaluate the ICT tools together with the socioeconomic initiatives.

iURBAN project has conceived a SMART urban decision support system (smartDSS), i.e., a customized energy management and control platform in the framework of a city. The smartDSS adapts existing ICT and Building Energy Management Systems (BEMS) in a city and deploy it where necessary. The iURBAN smartDSS allows for scalability and incorporates a two-level decision support system:

1. *Local Decision Support System (LDSS)*.
   LDSS engages consumers and prosumers by capturing near real-time data related to their energy consumption, as well as energy production from their installed distributed energy resources (DER), displaying it on a user-friendly interface via smart phones, tablets, PCs, etc., and provides support for decision making.
2. *Centralized Decision Support System (CDSS)*
   CDSS aggregates data from all LDSSs to provide city-level decision support to authorities and energy service providers. The *CDSS* generates a number of parameters, including citywide energy production and consumption forecasts. For example, the integrated utility in a city uses the CDSS which generates a forecasting for the next 24-hour consumptions and renewable productions in the different districts of the city, as well as advises for local energy market prices. Thus, the CDSS helps to balance citywide supply and demand with electricity generated by local renewable sources and requesting little energy from distant power plants.

   The LDSS communicates directly with the CDSS in order to exchange information for the decision making process. For instance, the LDSS receives the next-day energy prices and recommends to the end user that it is more cost efficient to wash her clothes between 10:00 am and 12:00 pm the next day.

The two-level *smartDSS* is a concrete solution comprised of the following:

1. A tool to measure, predict, and balance energy production, demand, and storage.
2. A tool to measure and verify reductions in energy consumption and greenhouse gas (GHG) emissions resulting from city energy use.

3. And user-friendly Web portals and functions that inspire new business models for all stakeholders (consumers, prosumers, city authorities, energy service providers, telecommunication companies, etc.). The decision support system leverages the cities' intelligent electrical and thermal grids to empower all of the actors involved and enable optimal distribution and trading of decentralized renewable energies production in a city, as well as the integration of combined heat and power (CHP) plants connected to the smart district heating and cooling grid.

The iURBAN *smartDSS* is an open software platform integrating local, intelligent energy systems and available communication infrastructures. Based on the nAssist[2] middleware, it serves as an interoperable data and information network, acting as a bridge between stakeholders. Interoperability with existing city infrastructure is ensured as well as taking into account new communication standards for electricity metering created by the International Electrotechnical Commission. *smartDSS* collects, aggregates, and analyses real-time or near real-time data from public and private city areas, integrating the ICT infrastructure which monitors and controls a wide range of energy-related devices found in European cities: low-voltage demand loads, distributed generation/storage resources,[3] smart district heating/cooling grids, weather data, smart meters, actuators, and electric vehicle charging stations. Outputs from the data analysis includes near real-time consumption and production data for each endpoint, from smart street lighting systems to a CHP plant to a commercial building, together with forecasts of demand response (DR) capabilities and consumption and DER production (Figure 1.2).

The *smartDSS* integrates all possible types of city endpoints. The endpoints in our two city pilots are found in various areas of the city and cannot be isolated on a single microgrid. Thus, DER units have been aggregated under the concept of a virtual power plant (VPP), where dispersed DERs have been integrated into one system. In addition, a simulation framework supports "virtual units" such as batteries, EV charging stations, and other distributed resources, inside the decision support system in order to analyze

[2]The nAssist© middleware platform is commercial property of Sensing and Control S.L. and is the basis of the iURBAN project adapted to accommodate city energy management, as well as the future integration of other city services such as security, health, transport, and waste management. http://www.sensingcontrol.com/es/.

[3]According to the IEC, electrical energy storage systems are considered to be a key enabler for wide-scale uptake of DER.

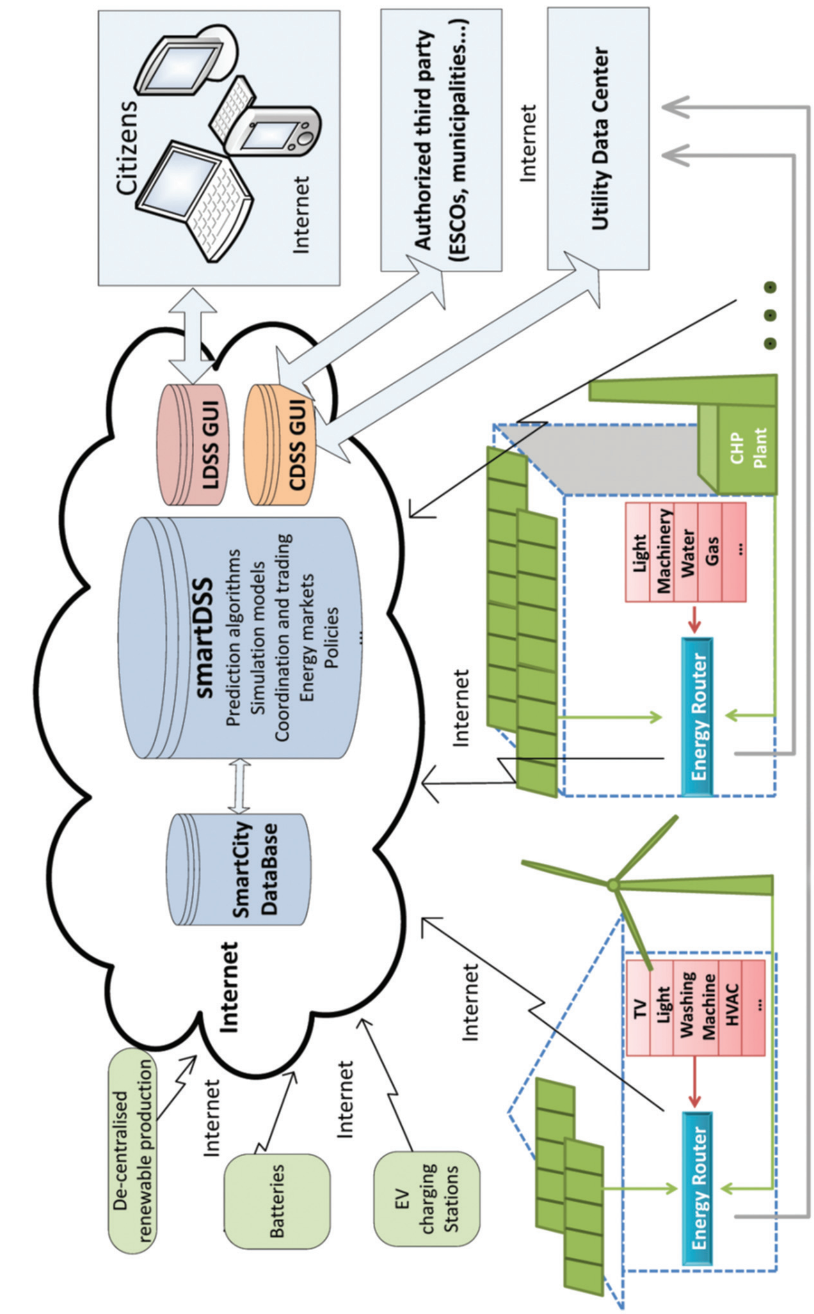

Figure 1.2 The iURBAN smartDSS architecture.

and understand how these virtual units could affect the current energy situation of the city in terms of consumption, production, CO_2 emissions, etc. These models are driven by external information and artificial intelligence (AI) models, and serve to complement the project's city pilot cases.

A key objective of the project was to develop and carry out a systematic procedure for the validation and evaluation of the impacts resulting from the deployment of the iURBAN smartDSS (Chapter 4).[4] Economic, environmental, and social key performance indicators (KPIs) have been drawn from the widely used International Performance Measurement and Verification Protocol (IPMVP)[5] and a social cost-benefit analysis has been performed, allowing for robust comparisons across heterogeneous European cities.[6] Moreover, this evaluation procedure aims to aid in the future exploitation of the system by demonstrating the system's return on investment (ROI) and its potential as a powerful political tool that city governments can utilize to justify energy policy decisions.

User engagement and openness are fundamental elements and serve as drivers for the design of the smartDSS. A major goal of the project was to enable city authorities to be able to provide to local actors, for instance energy agencies or energy service companies, with a wide range of data sets related to energy production, consumption, and infrastructure investments (i.e., the impact of investing in novel electricity storage units). Moreover, the project leverages knowledge from the behavioral science and behavioral economics fields that allowed the development of novel user-centric business models. Throughout the implementation of the project, surveys and focus groups have been carried out to identify and analyze all aspects that influence the acceptance of new business models in each pilot city, such as the actors' needs, cultural concerns, regulatory conditions, and data security issues. However, this book aims only on particular developments and focuses on the technological achievements of this 3-year work.

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[4]smartDSS is an open software platform integrating local, intelligent energy systems and available communication infrastructures.

[5]"International Performance Measurement and Verification Protocol," International Performance Measurement & Verification Protocol Committee, 2002. http://www.nrel.gov/docs/fy02osti/31505.pdf.

[6]The cost-benefit analysis and key performance indicators included in this project are in accordance with EU Directive 2009/72/EC and are based on the methodology outlined the JRC Reference Report: *Guidelines for conducting a cost-benefit analysis of smart grid projects* (2012). The methodology includes indicators such as city-level economic impact of lower consumer utility bills, reduced healthcare costs due to less incidences of GHG-related respiratory problems, reduced congestion in the electrical grid and local job creation.