Service design for smart energy management: simulation tools and energy maps

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Abstract. Within the complex and interrelated nature of the smart city concept, the importance of considering both the potential contribute of informed end-users and the impacts of a more organized – district based – approach to energy management are rising as relevant topics. This paper reports the progress of a research aimed to map energy use at district level, translating the zoning concept to balance actions to be delivered in different areas into a city level perspective. The adoption of energy maps is aimed to facilitate the understanding and the communication of the potential impacts in order to increase end-users and key-players awareness on the energy issue as well as to support decision makers to prioritize actions according to a shared systemic approach.

Keywords: Service design, Smart energy management, Zoning approach

Context and research framework

A number of studies and evidences carried out by the EU Building Stock Observatory, Eurostat, Buildings Performance Institute Europe, currently attribute 40% of total European energy consumption, which corresponds to about 1/3 of CO_2 emissions, to the built environment and the European Union (EU) is spending huge efforts to boost energy saving measures to meet the goal of achieving neutral energy districts by 2050 (European Union, 2012). However, population growth in cities, metropolis and - globally speaking - in megacities contributes not only to the direct increase energy demand but also generates new kind of problems such as waste management, traffic congestion, use of land and resources - just to mention some very evident examples - which are responsible of indirect energy demand streams and of huge environmental impacts. The different nature of such issues and the different socio-political contexts typically originate complex interrelated challenges involving a number of different stakeholders from decision makers to end-users that make quite hard to adopt reliable predictive models and find exportable and replicable solutions. The urgency to provide effective pathways to face these challenges and the related complexity is triggering many cities to find smarter solutions under the umbrella of the "smart city". Despite the concept has known a rapid diffusion, a shared and consistent definition is still lacking within practitioners and academia creating a quite heterogeneous understanding of what smart city is or may be. According to Chourabi (Chourabi et al., 2012), smart cities can be associated to different characteristics depending on the disciplinary approach the phenomenon is approached, but generally they are associated to:

- a forward looking way in managing social, economic, environmental, mobility, liveability issues based on the increase of citizens awareness and their active participation in the processes (Giffinger, 2007);
- a capability of monitoring and integrated data dealing with major infrastructures with the aim to enable service improvements to the citizens (Hall, 2000);
- a connection between physical infrastructures and IT infrastructure to leverage the collective intelligence of the city (Harrison et al., 2010);
- a commitment to be smart with reference to create more efficient, sustainable, liveable conditions;
- a capacity to integrate city management complexity within an ICT and web based real to speed up processes and services (Toppeta, 2010);
- a use of Smart Computing technologies to make infrastructures and components more intelligent, interconnected and efficient (Washburn, 2010).

A wide and extensive literature review (Anthopoulos, 2012; Neirotti, 2014), related to several disciplinary sectors, allows to focus on the complex nature of smart cities development where a number of critical factors, such as management and organization, technological availability and access, governance and policies, people and communities engagement, economic trends, infrastructures and services, interact each other making very hard to provide a coherent vision to coordinate all potential actions running at city level.

Despite this plurality of topics - to which several definitions are related - making a city "smart" is frequently associated with the energy challenge within an ICT integrated approach. This is mainly due to the interlinked understanding of smart grids that significantly contributed in the recent past to evolve the energy efficiency topic at city level becoming a main asset of several projects at different levels.

However, the smart city approach is also emerging as a strategy to mitigate the problems generated by the urban population growth and rapid urbanization in a broader perspective. If on the one hand great effort has been spent to foster technological solutions and infrastructures with the purpose of driving the progresses in the energy sector, on the other one less advances were achieved in creating tools and measures to define planning and management integrated solutions able to support decision and policy makers as well as the key players to address actions in the mid-long term. This systems integration is useful to align innovation activities, products and services with regulations, policy, industry and investors needs, business models, and to facilitate the assessment of the potential risks and innovation impacts.

The emerging smart city vision integrates large and small scales energy initiatives and solutions, including major infrastructure investments, improvements in energy efficiency, fuel poverty resolution, users' behaviours awareness increasing. A key issue is therefore to define a proper scale according to the specific local conditions. The Energy Efficient Building European Initiative (E2B EI), promoted by the European Construction Technology Platform

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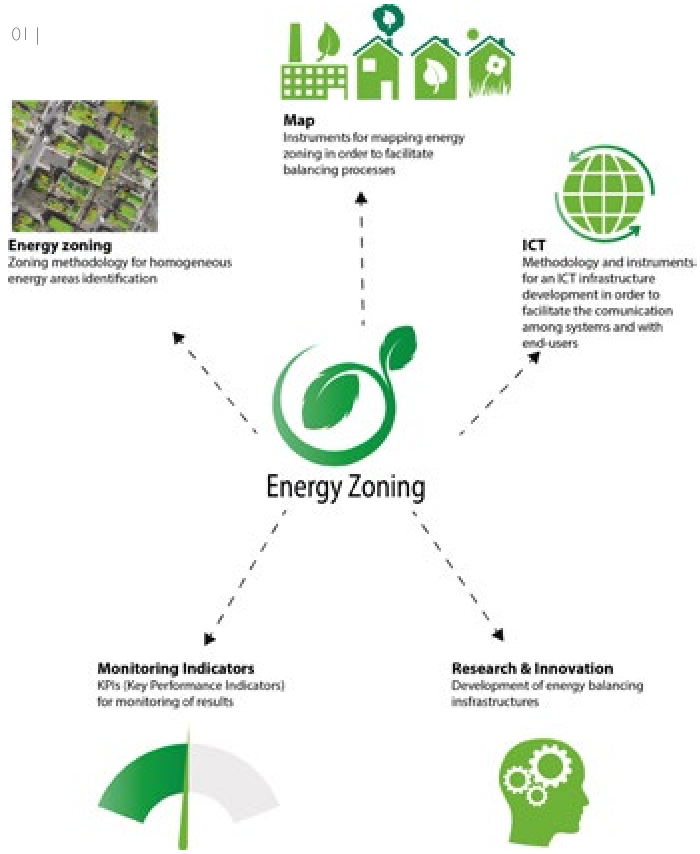

(ECTP), considers the urban scale and, in particular, the concept of district the ideal experimentation field for connecting the city as a whole while maximizing the benefit obtained at the small-medium scale.
This points out another critical element dealing with the notion of district which is often traditionally associated with administrative or geographical boundaries or organizational model, based on the optimization of production processes according to partnerships, relations, logistics among different entities, rather than to established communities or unconventional relations dealing with people or activities interactions. In the last decade, district has been associated to a more dynamic concept, going beyond structured institutional models, which can assume variable boundaries according to thematic approaches.
Considering the complexity and interdisciplinary nature of the described framework, this paper reports the progress of a research aimed to support energy management at district scale using simulation tools and energy maps.

A contribution for innovation

The city of Bologna has a recognised position in national smart city ranking and developed many initiatives to improve smart solution at different levels and established a quite consolidated cooperation with the University of Bologna in delivering smart city oriented projects particularly dealing with the energy topic. Within these initiatives the research team of Technology for Architecture of the Department of Architecture (UNIBO-DA) was involved in different projects from building to city scale detecting a lack of a systematic approach in creating synergies between the ongoing or envisaged actions that is probably due to the differentiated nature of funding schemes as well as of political umbrella. Nevertheless, this lack of interconnection, which also depends on the different scale of projects and allocated resources, represents a significant barrier to achieve a coherent and updated vision of the potential impacts that the combination of any single action may produce on the city as a whole in the mid-long term.
The main contribution the research team intends to pursue for innovating (Marceau, 2008) the approach at city scale is to integrate existing technologies, solutions and strategies in a more complex system of analysis and management of the urban fabric with the scope to reveal those urban areas characterized by energy homogeneity and balance them into a system based on a logic of compensation and connection.
This concept moves the city vision from the individual action logic to a comprehensive one at city level where the notion of district is associated to homogeneous energy areas. This is connected with energy use and with the building stock consistency and typologies (especially from a constructive point of view) but also it strongly deals with key-players awareness and participation within the process. The research proposition is indeed connected with investigating how service design can be applied to support smart city planning, development and management with a specific focus on energy system and considering community services and innovative business opportunities.
«From a service logic perspective, innovative services are not defined in terms of their new features, but in terms of how they change customer thinking, participation and capabilities to create and realize value» (Teixeira, 2012). Thus, the transition towards a more sustainable, smart and integrated urban system requires important changes in design system, smart technologies and services for "energy consumers", operation phase, regulations, etc., involving actors and engaging consumers in the process, as SET Plan foresees. The most effective plans (Trencher, 2017) demonstrate how energy-related services are connected to city priorities such as social inclusivity, economic development and environmental protection, establishing a new framework to promote best-practices in green procurement. In other words, the team is involved in matching solutions that make energy demand more efficient considering sustainable energy resources, developing a systemic architecture capable of processing multiple and complex data and planning both the efficiency and the maintenance intervention on the built environment.
With this purpose, a key-role is played by the definition of a communication infrastructure for exchanging and processing data related to energy management to identify integrated urban district models and achieve the optimization of neutral districts. This approach is particularly relevant in the peripheral/suburban urban areas where deep renovations can take place and the

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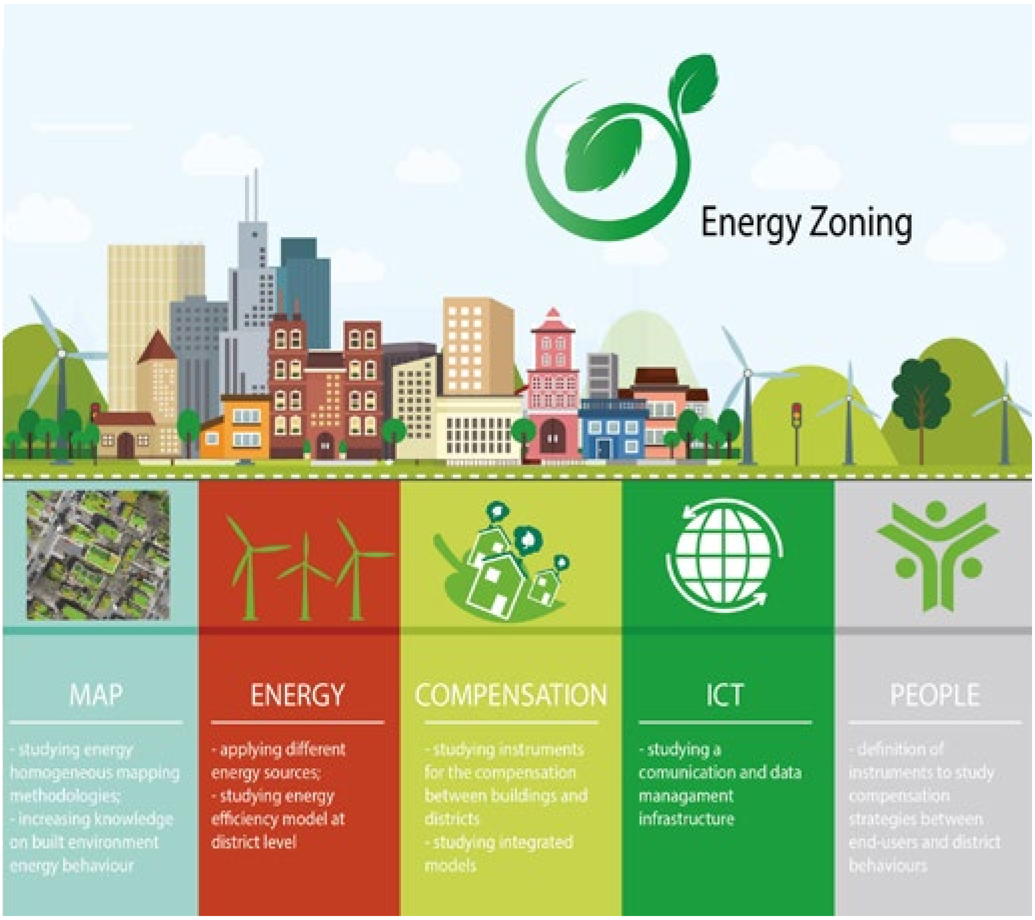

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energy plus of the “virtuous” areas (positive energy districts) can compensate the energy needs of non-renovated areas, creating “neutral” districts, through a Smart Connected Districts approach and a related energy zoning at city level (Fig. 1).
Integrated facility management models aimed at the environmentally sustainable management of buildings and urban areas can facilitate the transition to low-carbon and resilient urban districts.

Research methodology

This research methodology is based on the concept of zoning, assuming the dimension of the districts as a unit of reference. District energy planning requires an assessment of current energy needs and the likely evolution over time of this factor. To define the consumption trends of the district a set of indicators dealing with technical and economic parameters as well as the social and environmental dimensions is needed. Therefore, a multi-parameter matrix supports the definition of demand profiles while each of these parameters requires a specific analysis within the data management process. The definition of the characteristics of the communication infrastructure to manage the collected data, through the analysis of the overall scenario, is important to appropriately identify (both in terms of typology and density) the different urban objects (buildings) as well as the typologies of information that each of them generate. In this framework, network architecture plays a fundamental role.
Furthermore, the communication infrastructure is comprehensive of information deriving from citizens/users of buildings, and achieved through the analysis of specific social investigation tools and techniques. These tools include survey about users’ satisfaction, about their living conditions, analysis of their behaviour through direct observation and sensors, effects on the energy bills, etc. These information are used to obtain a complete frame about the living environment conditions, and the involvement of users in this monitoring campaign is the first step to increase their awareness about their consumes, possible energy savings and energy expenditures. The acquired data become part of the following phase adopting a user driven approach.
This approach is intended as multi-criteria and trans-disciplinary (architecture technology, ICT, smart grids and infrastructures) work, and it is the basis of service design for smart energy management. In particular, indicators typically linked to buildings with a systemic vision on an urban scale are to be correlated through ICT based systems. The use of ICT technologies is used to manage energy demand more efficiently, linking the concept of energy efficiency to the broader topic of Smart Cities. This implies the need to put in relation the energy characteristics of the city and the habits of citizens/users, optimizing energy and information flows management.
The idea is to create a set of maps with a user-friendly interface able to combine different layers:

- technical layers, visualizing data output deriving from sensors, digital elaborations, etc.;
- social layers, including the data deriving from surveys, direct observations, collaborative meetings results.

The intersection between different sources of data facilitate the understanding of relations between the energy performance of buildings (whole districts) and the human perceptions about comfort, opinions about energy services, etc.

This first set of maps can be progressively integrated by new layers, about context conditions, statistical information, data deriving from innovative and sophisticated sensors and monitoring systems, localization of constraints for the improvement of energy performances, etc.

The final aim is to obtain a flexible urban tool, able to help the city management in the identification of potential "energy districts", integrating the energy issues in the urban design, analysing energy impacts, state of maintenance of the infrastructure, conditions to promote energy communities, etc. and, at the same time, to offer an easy communication tool to visualize the "human interaction" at district scale (Fig. 2).

Discussion and further developments

Although the research is not concluded yet, the first outcomes on the adopted methodology and the implementation of the systemic approach to enable energy maps generation encourage to positively consider the potentialities of the study in improving synergies creation and in addressing actions into a more organised transition vision.

Maps to support integrated facility management models are helpful to visualize future energy demands based on medium-long-term scenarios of socioeconomic, technological and demographic development at urban scale. Energy demand can be disaggregated into a large number of end-use categories corresponding to different goods and services. The influences of social, economic and technological driving factors are estimated starting from given scenarios. Thanks to these visualizations is possible to achieve an overall picture of future energy demand growth at district and city scale. This also open some market opportunities in providing dedicated services that may be addressed to end-users, companies or decision makers in order to effectively benefit of the available information and optimization procedures.

The originality of this research is tied with its scalable approach and methodology, which is not addressed to map single interventions but their effects at district/city level. This can be of help in defining the public authorities' priorities and also in connecting actions to their impacts on the local communities creating informed target groups able to support the transition toward a low carbon society.

As the scope of the study is to translate the zoning approach into services for the community, and not only into a supporting tool for the public authorities to assign priorities and connect actions, a feedback on the general concept, on the potential deriving impacts and on the relate market opportunities was asked to an independent subject - not directly involved in the project - in order to embed remarks, suggestions and comments into the monitoring of the project advance. The feedback from Manutencoop, a leading facility management company operating on Bologna territory and in many others Italian cities, is: «On one hand, this improved awareness may better inform the decisions that players in the energy sector need to face and on the other hand, could foster the generation of brand-new services, adding value to the energy demand profiling that is a potential valuable asset in the green market. Looking forward to the implementation of the National Energy Strategy recently issued in Italy by the Ministry of Economic Development, energy demand and energy capacity planning seem to play a dramatic role in meeting the high-level expectation of a better energy consumption and a more efficient energy production: in view of that, such research project can cast new light on potential new business case that may arise by including energy priorities with urban development and city management. Surely, this process must consider the possible issues involving data management and protection, but we are confident that these can be overcome through the adoption of a district-level-scale data source, allowing working with aggregated figures. An insight for further development of this research is the creation of focus groups, ideally including some industrial players/suppliers, in order to pinpoint the design of new services and to explore their market exploitation. This should certainly be of help in the case the research's team intends to provide solid indications on how to translate the outcomes of the study into business opportunities, not just limited to IoT applications and other technologic aspects that already are deeply rooted in the literature of Smart Cities research, but also including the service management dimension at urban level».

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Manutencoop

The study addresses a very relevant issue taking into account real impacts stemming from every single action and the role they play into the process for the achievement of a comprehensive smart city dimension.

Since corrective measures to manage such differentiated initiatives, that also involves heterogeneous forms of financial backing, could hardly become a feasible solution in the short run, the idea of working on the concept of energy zoning seems noteworthy from a stakeholder perspective. This process could be initiated right away, undertaken by collecting data or processing existing ones and ultimately providing useful visual outputs (i.e. maps) easily understandable for everyone concerned, whether they be decision makers, administrators or laypersons. In the near future, such sharing of information among all the stakeholders seems to be a crucial capability for change management in citizens and policy makers perceptions and for improvement of their reciprocal relationships.

A more relevant concern to face within a replicability perspective is represented by the different "size" homogeneous energy districts may have, according to the city typology: this may be adjusted once the experimentation on Bologna pilot will been completed and assessed even though it still fosters the idea of a valuable service management layer which is able to interconnect different city areas with different needs, requirements and features to provide and effective city management proposition.

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