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Smart sustainable cities – Exploring ICT solutions for reduced energy use in cities☆

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ABSTRACT

This article explores the opportunities of using ICT as an enabling technology to reduce energy use in cities. An analytical framework is developed in which a typology of ICT opportunities is combined with a typology of household functions, *i.e.* all the activities that require energy. The energy used for household functions is calculated using a consumption-based lifecycle perspective. The analytical framework is intended to be of use to researchers, city and regional authorities and ICT companies interested in acquiring a better understanding of how ICT investments could contribute to reduce energy use in cities.

1. Introduction

The way cities are developed and managed is of fundamental importance for sustainable development (Egger, 2006). Several initiatives have highlighted how ICT can be used to achieve cities' climate targets by lowering energy use and greenhouse gas (GHG) emissions from other sectors. The initiatives include proposals such as dematerialisation and demobilisation, as well as comprehensive concepts for smart logistics and smart cities (Mitchell, 2000; GeSI, 2008). Drawing on Hilty et al. (2011), ICT can be seen as an enabling technology for improving or substituting processes in other sectors. In these, ICT can be used to optimise the design, production, use and end-of-life treatment of other products. In 2012, GeSI published a report that focused on the potential for reducing GHG emissions in six different sectors: power, transportation, agriculture, building, manufacturing and consumer and services (GeSI, 2012). Based on a business-as-usual scenario in 2020, the study also calculated potential emissions savings from each of these sectors, resulting in an overall reduction potential of 16.5% of total global GHG emissions. Other studies, such as the one published by Bio Intelligence Service (2008), have however pointed at significantly lower potentials – a 4.6% decrease within EU-27.

When discussing ICT solutions for cities, reference is often made to the concept of a "smart city". This concept has been used for the last 20 years and has been seen as a strategic concept combining modern urban production factors within a common framework (Caragliu et al., 2009). The adjective "smart" and the concept "smart city" are used to highlight the importance and potential of ICT in helping the city to develop a competitive advantage and implies positive urban-based technological innovation and change *via* ICT (Caragliu et al., 2009; Hollands, 2008), such as smart transportation, smart environment, smart healthcare, smart energy, smart education, smart safety *etc.* (Nam and Pardo, 2011).

Today, cities with strong environmental ambitions and telecommunication industries are seeking to understand how best to utilise ICT as an enabler for reducing energy use. For cities, it is a matter of having a better understanding of what types of ICT investments provide the best benefits for environment and society. Telecommunications industries are also interested in understanding which enabling technologies their customers most need and

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want. The Climate Group (2011), however, points to the fact that different cities have different needs because of their unique challenges. Therefore, a multitude of solutions are required along with adjustments to specific demands and prerequisites.

The aim of this paper is to explore how ICT can support the development towards low-energy cities. The ways this can be achieved will hereafter be referred to as ICT solutions, incorporating ICT *per se* (such as the automation of heating systems) and ICT-enabled solutions (such as lift-sharing). The ambition of this study is to develop a supporting framework for city and regional authorities who want to understand and capitalise on the possibilities presented by ICT to reach their climate targets by reducing energy use. There are many initiatives for the use of ICT solutions in cities, but without an overarching guiding framework there is a risk that efforts are being directed in the wrong areas. To minimise this risk, the aim is to demonstrate clearly where the 'hot spots' are for ICT investments to reduce energy use. A 'hot spot' is defined here as an activity with high energy use where there are one or more ICT solutions available for decreasing this energy use. The hot spots are thus identified by combining an assessment of the most energy-consuming household activities with an assessment of what types of ICT solutions exist that could have an impact on these activities.

While acknowledging that sustainability comprises a variety of interrelated environmental, social and economic concerns, in this paper the decision has been taken to focus solely on energy use. For a full environmental impact assessment, this would need to be complemented by other impact categories, for instance those included in the ISO system for lifecycle analysis (ISO 14044 2006) or systems for assessing urban sustainability (see *e.g.* Sharafi and Murayama, 2012). In this paper, a citizen consumption-based lifecycle perspective is used for allocating and calculating energy use (Kramers et al., 2013). A consumption perspective means that energy use is allocated based on where the consumption takes place, in contrast to a production-based perspective. At an individual level, this means that all the energy used to produce products or services is allocated to the person consuming that product or service. Kramers et al. (2013) define two kinds of consumer perspectives – one based on the all consumption by the citizens of the city, one based on consumption within the city. The citizen perspective means that all the energy used by everyone living in the city (*i.e.* its citizens) is allocated to the city, regardless of where the production or consumption takes place. Therefore energy use for activities by citizens that take place outside the city's borders (*e.g.* hotels, travel and other consumption) is also included. Moreover, the use of a lifecycle perspective means that for all consumed products and services, all energy use from resource extraction to waste treatment is included in the calculation. A consumption-based lifecycle perspective therefore implies a wider span of relevant ICT solutions than if the focus were only on activities that take place within a city's geo-political boundaries.

2. Smart cities

2.1. Smart cities – sustainable cities?

Drawing on Caragliu et al. (2009), the concept of a "smart city" can be understood as highlighting the importance and potential of ICT to help the city to get a competitive advantage. While this points to the reason why a city would like to use the concept, it says little about whether there needs to be any substance behind the claim of being "smart" or how that links to sustainability. The Intelligent Community Forum (ICF) has listed five 'successful factors' for an intelligent community which they use to rank the level of smartness of different cities each year (ICF, 2012) and can be seen as an implicit definition of what a smart city is. These are broadband connectivity, knowledge workforce, digital inclusion, innovation, and marketing and advocacy. The Climate Group et al. (2011) have a definition that in parts is both narrower and wider than this. It is narrower in the sense that it defines a smart city as a city using ICT *for its own administration*, but is wider in that it also includes infrastructures. According to the Climate Group, a smart city is a city that uses data, information and communication technologies strategically to provide efficient services to citizens, monitor policy outcomes, manage and optimise existing infrastructure, employ cross-sector collaboration and enable new business models. Similarly, Schaffers et al. (2011) see the three key domains of potential smart city applications to be the innovation economy, city infrastructure and utilities, and governance. They also argue that in order to become smart, a city needs to 1) create a rich environment of broadband networks that support digital applications, and 2) initiate large-scale participatory innovation processes for the creation of applications. Meanwhile, Washburn and Sindhu (2010) places all the emphasis on infrastructure and highlights that it is the use of 'smart computing' within seven critical infrastructure components and services that makes a city smart. Here, smart computing includes the use of software systems, server infrastructure, network infrastructure and client devices. The infrastructures and services mentioned are city administration, education, healthcare, public safety, real estate, transportation and utilities. A more comprehensive definition is provided by Nam and Pardo (2011) who describe the smart city using different clusters that can be divided into three dimensions: technology (hardware and software infrastructures), people (creativity, diversity and education) and institutions (governance and policy). According to Nam and Pardo (2011), the technology dimension can be clustered into six different definitions: the digital city, the intelligent city, the ubiquitous city, the wired city, the hybrid city and the information city. The human dimension of "people" is described in four clusters: the creative city, the learning city, the humane city and the knowledge city. The institution dimension has two different definitions: the smart community and smart growth. An equally comprehensive approach is put forward by the Smart European Cities initiative that includes smart economy, smart people, smart governance, smart mobility, smart environment and smart living in their list of smart city characteristics. Furthermore, they point out that awareness, which is an integral part of all of these aspects, is fundamentally important since "certain potentials can only be mobilised if inhabitants, companies or the administration are aware of the cities' position – knowing the city from the inside, but also being aware of the surroundings and the system of cities the city is located in" (Centre for Regional Science 2007). It is noteworthy that other than the Smart European Cities initiative, none of the definitions identified include issues of ecological sustainability. Instead social and economic aspects prevail. Thus it can be concluded that the concept of a smart city says little about the environmental performance of cities.

2.2. ICT solutions for smart sustainable cities

Despite the lack of a connection between smart and sustainable cities, it is clear that ICT has great potential for supporting the transition to more sustainable cities, both as regards the management of urban systems and offering more support for sustainable urban lifestyles. A number of comprehensive studies of ICT solutions are presented below. For example Mitchell (2000) has defined five main opportunities for how ICT can contribute to the reduction of energy use in cities. Four of these have direct effects and one has indirect effects on the reduction of energy use. The first opportunity is *dematerialisation*, where physical products (CD records) or