ICT supporting energy efficiency improvements in urban and rural neighbourhoods

Mari Sepponen
VTT Technical Research Centre of Finland, Technologies and Services for Buildings, Espoo, Finland
mari.sepponen@vtt.fi

Martine Tommis
Manchester City Council, Digital Development Agency, Manchester, United Kingdom (UK)
M.Tommis@manchesterdda.com

ABSTRACT: Energy efficiency is an increasingly important issue in the built environment for both urban and rural areas of Europe. To date the focus has been typically at the building level, but is increasingly concentrating on broader systems, such as neighbourhood and city levels. ICT can significantly contribute to the energy efficiency of neighbourhoods through a range of systems, tools and solutions. Achieving truly energy efficient neighbourhoods requires a holistic approach to include all the energy systems of a neighbourhood, such as buildings, infrastructure, transportation, energy distribution and production, as well as the involvement of citizens. All these areas have an impact on energy efficiency, and it can be supported by ICT in the following technology areas: 1) planning, designing and operation, 2) decision support, 3) energy management, and 4) integration technologies. This paper presents the key findings of IREEN (ICT roadmap for energy efficient neighbourhoods) project funded by European Commission's 7th Framework Programme.

1 INTRODUCTION

1.1 *The scope of the paper*

In this paper energy efficiency is discussed from holistic point of view, meaning that the entire energy chain from sustainable energy production and distribution to the efficient energy demand is considered. Energy efficiency at the neighbourhood level is increasingly focused for both urban and rural areas in Europe with the majority interested in improving their neighbourhoods' energy efficiency through various development projects in both new and existing areas. This paper presents the ways ICT can contribute to the future development in the planning and operation of a range of neighbourhood systems. Achieving truly energy efficient neighbourhood requires co-operation and communication between the different of stakeholder groups and associated energy systems.

The purpose of this paper is two-fold. The first objective to present the key findings collected from experts contributing to the energy efficiency of neighbourhoods. The second is to present a summary of how different areas of ICT can support the improved energy efficiency of neighbourhoods. These objectives form part of the main goal of the IREEN project (ICT Roadmap for Energy Efficient Neighbourhoods). This is to develop strategic research agenda with recommendations for implementation on ways to achieve energy efficient districts.

1.2 *Background*

Information harnessed from earlier roadmaps from the same field has been used to form the foundations to develop an ICT roadmap for energy efficient neighbourhood. These focus primarily on energy efficiency at the building level. Hannus M. et al (2010) developed the first version of ICT supporting energy efficiency roadmap in construction via a European Commis-

sion funded project REEB (Roadmap for Energy Efficient Buildings). This work suggested development actions over the short, medium and long term for 1) energy efficient design and production management; 2) intelligent and integrated control; 3) user awareness and decision support; 4) energy management and trading; 5) integration technologies. The REEB roadmap was later updated by the ICT 4 E2B Forum (ICT For Energy Efficient Buildings Forum) project which focused on a European stakeholders' forum. The forum supported crossing value and innovation chains to explore needs, challenges and opportunities in further research and integration of ICT systems for Energy Efficiency in Buildings (Carosia S. et al 2013). Current trends are towards broader approaches at neighbourhood and even city levels. In this holistic approach, energy efficiency is made up of numerous elements, including buildings and infrastructures, transportation, energy supply, storages and distribution. In addition the involvement of people and the end-users' perspective are identified as a significant element and these elements are addressed in this paper.

2 METHODS

2.1 *Overview of the iterative roadmapping process*

A first task for the IREEN project prior to developing the roadmap was to identify the relevant operation fields. Previous roadmapping work by Hannus M. et al (2010) and Carosia S. et al (2013) identified the key elements of energy efficiency at the district level and hence provided a starting point. From this, the key, focus areas were identified and classified to create the IREEN scoping matrix as presented in Table 1.

Table 1. IREEN scoping matrix presenting application and technology areas (Sepponen et al, 2013).

		Application Areas																			
		Neighborhoods - Urban and Rural Communities																			
		Holistic Urban and Rural systems	Transport			Buildings, Infrastructures & Open Spaces					Energy Production & Storage			Energy Distribution			People Involvement			
			Public Transport	Transport Infrastructures	Electric Vehicle Networks	Buildings	Parks, Squares, Greenery and Open Spaces	Public Lightning	Water and Waste Management	Rural infrastructures	Holistic Energy Systems	Electricity Production & Storages	Heating and Cooling Production & Storages	Electricity Systems	District Heating & Cooling Systems	Gas Network	Civic Commitment & Public Participation	Public Information, Education and Training	Privacy and Security	People Behaviour & Consumption Patterns
Technology Areas	**Design, Planning & Realisation**																				
	Design																				
	Modelling																				
	Performance Estimation																				
	Construction and Maintenance Management																				
	Decision Support																				
	Performance Management																				
	Visualisation of Energy Use & Production																				
	Behavioural Change																				
	Energy Management																				
	Intelligent Monitoring and Control																				
	Energy Brokering Systems																				
	Energy Hub																				
	Smart Grids																				
	EE Services: business concepts and financing																				
	Integration Technologies																				
	Process Integration																				
	System Integration & Open Data																				
	Interoperability & Standards																				
	Knowledge Sharing																				
	Virtualisation of the Built Environment																				
	Communication																				

The application fields of the scoping matrix represent energy consumers (buildings, transportation and the entire neighbourhood), energy distribution, production and storage. A category was also allocated to people and their involvement.

In the next phase the aim was to identify and assess the development needs for ICT, considering factors such as: technology maturity, drivers, value chains, partnership, deployment challenges and stakeholder development. This paper includes an overview of key RTD topics for energy efficiency of neighbourhoods, as reported by Sepponen et al, 2013.

Key to the process is the collaboration and communication between stakeholders and end-users of the ICT systems in a neighbourhood. These include residents, buildings owners and users, land and infrastructure owners, designers, operators, energy companies, decision makers and facility managers, to name but a few.

Many experts from different knowledge fields have contributed to the IREEN roadmap via a combination of workshops and interviews. The experts have supported the IREEN consortium through an iterative development process, commenting and developing ideas alongside validation of the work. For example, IREEN consortium partners interviewed 24 city representatives from across expertise fields during early 2013. These interviews were then mapped to the field of ICT and energy efficient neighbourhoods. The interviewees represented both urban conurbations, as well as smaller rural towns and districts from across Europe.

2.2 *Key principles of energy efficiency at a neighbourhood level*

IREEN presents a vision for maximised energy efficiency for the entire optimal energy system in a neighbourhood. This requires a holistic approach, including the energy chain and all forms of energy. Accordingly within IREEN, the energy system of a neighbourhood is planned and operated as efficiently as possible in each local surrounding and circumstances.

The key principles for achieving this are: 1) minimisation of energy consumption (enabled with high energy efficiency), 2) energy efficient distribution, and 3) energy efficient energy production and storage.

The intention is that ICT solutions integrate the energy sub-systems of a neighbourhood into a holistically optimised and efficiently operating energy system. From this the entire energy chain of a neighbourhood, from energy consumption to distribution and production are integrated through ICT.

2.3 *Special characteristics of rural areas*

IREEN's vision is relevant for both urban and rural areas. In rural areas the focus is on villages and small towns in adjoining rural and semi-rural areas. Particularly interesting from this point of view is the increase of low carbon and renewable energy solutions, along with decentralized energy production and micro-CHP. Whilst there are overlapping issues between urban and rural systems, the rural context presents unique challenges, as was reported by experts in workshop held in conjunction with the Future of Rural Energy in Europe (FREE) initiative (FREE, 2010).

The IREEN workshops addressed several similar issues in urban and rural areas, such as the need for local approaches, new business and financing models as well as the challenge of behaviour change and raising inhabitants' awareness about energy efficiency. Similarly many buildings are in the need of renovation and people want guidance to selecting the best solutions. It was noted that in rural areas buildings are often less energy efficient than in cities due to age and restrictions (for example, heritage classification).

The unique aspects of rural areas were also identified by IREEN experts. Buildings are often isolated and connecting them to the surrounding environment is difficult and often not feasible. Related to that, lower densities of population raise mobility challenges. Mobility patterns are also very different in rural areas where the use of individual cars cannot be substituted. This leads to comparatively high transport fuel costs and different energy consumption needs than in urban areas (FREE, 2012). On the positive side, rural areas have good potential for renewable energy production with more physical space available. Rural areas are not only characterised by a large potential for renewable energy production but also by low densitites in energy consumption. Potentially rural areas could become energy-independent, eventually supplying urban areas with energy (FREE, 2012). Reliability of supply was also raised as an issue by the experts.

The decentralisation of energy systems offer a way forward and the importance of non-grid options in rural areas.

Energy poverty can be more acute for rural households and issues such as lower income levels and energy poverty were raised. Typically people living in rural communities need to be more self-supporting and independent. They can also have stronger sense of individualism and they can be more resistance to change. Other structural challenges include rural depopulation and the increase in the elderly along with a significant seasonal population of tourists and second home owners.

3 RESULTS

3.1 *Communication and collaboration of planning and operation at the neighbourhood level*

Integration and the collaboration of different sectors and expert areas were identified as one of the key aspects for achieving holistic energy efficiency. Traditionally different sectors of municipalities have operated independently. This is typical also for energy, construction and ICT companies. Communication and co-operation between the stakeholder network is often difficult due to diffused operation and different expertise vocabularies, rendering basics such as a common understanding a challenge in itself. This can lead to sub-optimised decisions, when planning, operation and controlling are not synchronized and may not interact. Information exchange can also be slow and complex.

IREEN aims to identify how ICT can support the overall energy efficiency of neighbourhoods. This is complex, because it involves a broad network of different stakeholders and organisations. There is a clear need for easier information exchange across traditional operation borders and the improved collaboration of various expertise sectors, and inhabitants of the area already from the start of the planning process. ICT can provide capability to support this.. An important aspect is ensuring support for decision makers to understand the different options and their impacts, as well as the added value of ICT investments in relation to the long term and life cycle of the neighbourhood systems. Decision support tools for performance assessment and visualisation of options and their impacts are therefore essential.

3.2 *Priorities for the development of ICT supporting energy efficiency in neighbourhoods*

The aim of IREEN is to identify the priorities for the research and technical development of ICT supporting energy efficiency in different segments of neighbourhoods. A synopsis of main development needs is presented here. These findings are summarised from various inputs from city representative interviews, IREEN expert workshops and partners' expertise.

At a neighbourhood level, integrated city planning and management is the key for transformation towards smart cities. It is important to plan flexible hybrid systems rather than focusing on either small or large scale systems. The retrofitting of existing neighbourhoods is important issue. City representatives expressed enthusiasm for access to and use of 3D models (e.g. for analysing the shading caused from buildings to solar panels), use of Geographic Information System (GIS) for spatial analysis and urban planning, and simplified CO_2 calculations to identify trends. One of the keys to providing a holistic view point is the integration of different experts into the planning process from the initial phase.

Improvements to the energy efficiency of transportation were reviewed from the view point of how to decrease the transportation needs within a district by providing alternatives. These include encouraging people to bicycle or walk. A key issue is the role of the urban planning process as a means to manage and decrease the transportation demand in an area. In the planning phase other traffic solutions need to be considered that can compete with the ease and comfort of private car use. Initiatives such as remote working also have much to contribute. The issue of differing mobility patterns for rural areas was also raised.

Within IREEN buildings are considered from the view point of their interconnections within neighbourhoods and not as single entities (this has been raised in other projects, such as Hannus M. et al (2010)). The development needs for improving the energy efficiency of buildings are many. Retrofit actions and associated efficiencies were raised by numerous city representatives. There is a need for data about the impact of actions. In addition monitoring is essential, both to

comparing the real performance in relation to energy targets along with remote monitoring and control of other infrastructures, such as street lighting (for example dimming). Other topics raised were the integration of renewables in buildings and the ability to balance of energy loads.

Related to energy supply and distribution systems, the topic of neighbourhood self-sufficiency and "energy positiveness" was highlighted. This is where an energy efficient district or area has the ability to generate more energy via sustainable energy sources than is required by demand. This could be achieved for example with increased local and distributed energy production and waste-to-energy utilisation. The example of rural areas was stated earlier. The optimisation of energy systems and remote management at the city level were raised by experts. A key point is the need for energy flows to be visualised to citizens and stakeholders. At a district level energy management, there is need for real time energy data supporting decision making and new energy trading and markets.

People involvement is essential for energy efficiency. The inclusion of local inhabitants at in the planning phase is crucial. Increasing the awareness of energy usage and possibility for technologies to support people on a day to day basis are part of this. People are genuinely interested in meaningful visualised monitoring that can give them control as well as an ability to see the real time energy use. They want to understand the financial savings of their energy efficiency actions and the amount of local or even their own energy production.

The development of many integration technologies was identified. Urban and energy system planning and management tools need interoperability, access to accurate data and the ability to use data. There is a need for information exchange from the many different expertise areas involved and data locations, such as urban plans, Building Information Model (BIM), Geographical Information Systems (GIS), weather and climate conditions, wind and solar conditions, type of terrain, soil and ground water areas, spatial data, transport plans, energy distribution network maps, demographics, energy consumption of buildings and used energy sources, among others. At the same time it is important to not omit governance issues and ensure privacy and security receive careful consideration.

3.3 *Holistic energy management system at the neighbourhood level*

Municipalities are interested in local energy sources, increasing their share of renewable energy, and/or self-sufficiency as well as taking steps towards the energy positive performance of buildings, neighbourhoods and entire cities. However, they have a lack of know-how about how to do this and where to start, especially when access to financing is often limited. Technology can support this by providing guidelines, tools, data sharing platforms and data mining opportunities. ICT can also provide decision support systems, benchmarking tools, performance estimation and the analysis of sustainability impacts (economic, environmental, and social impacts) with easy-to-understand visualisation of analyses and impacts.

The IREEN vision is that the smart energy management of a neighbourhood would enable the optimum energy supply and distribution and balancing of all energy flows. The management of distributed energy systems – where energy is produced close to where it is being used – needs new types of analysis tools to design and to optimise energy chains extending from generation sites (both large and small scale) to consumption points (IntUBE 2011). Neighbourhood Energy Management System (NEMS) have the ability to aggregate and control largely autonomously energy supplies along with demand-side resources. In a self-sustainable neighbourhood, a well-designed energy supply and management system could potentially provide enough energy to meet the energy demands of the users. This can also support goals, such as reliability of energy supply, carbon emission reduction, the diversification of energy sources and cost reductions.

NEMS take into account the whole neighbourhood offering a significant impact on the future energy systems and the associated control network. It could provide an efficient and economical mean to manage and deliver energy within a neighbourhood in real time. A key goal of NEMS is to maximise economic and environmental benefits to smart energy system users, while also minimising energy distribution losses. Additional savings can be achieved through efficient energy utilisation (management of fluctuating energy production) and higher efficiency of distributed energy production, e.g. through solar, wind and CHP plants. NEMS is therefore able to of-

fer flexible services to the overlay grid, enhancing the possibility to establish new markets and improving the overall efficiency in energy supply.

3.4 *Economic challenges and new potential business opportunities*

Economic issues were frequently raised in the course of the IREEN project. City representatives face a challenge to finance energy efficiency measures and source ICT investments as well as understand the costs and benefits (return of investment - ROI) of solutions. There were inevitable concerns about long pay back times. One city representative stated that "it is hard to convince people that energy efficiency measures will generate revenues in the future, and pay back investment costs". There is a therefore s need for new business and financing models.

The need for new business models for operation processes was also raised. One of the future scenarios developed during the project was that of an energy broker, who would sell and buy energy on behalf of its customers. These would be energy consumers, prosumers (an energy consumer who also produces energy) and distributed energy producers. The energy broker balances the energy supply and demand in the neighbourhood in real time. Some of the distributed energy production would be from fluctuating energy sources, such as solar and wind energy. The broker has several means for balancing, such as demand side management (as agreed with customers), control of non-fluctuating energy production sources (from renewable energy sources), and local energy storage (including electric vehicles). The energy broker model is illustrated in Figure 1 and concept is presented in a more detailed level in the IREEN document by Cricchio F. et al (2013).

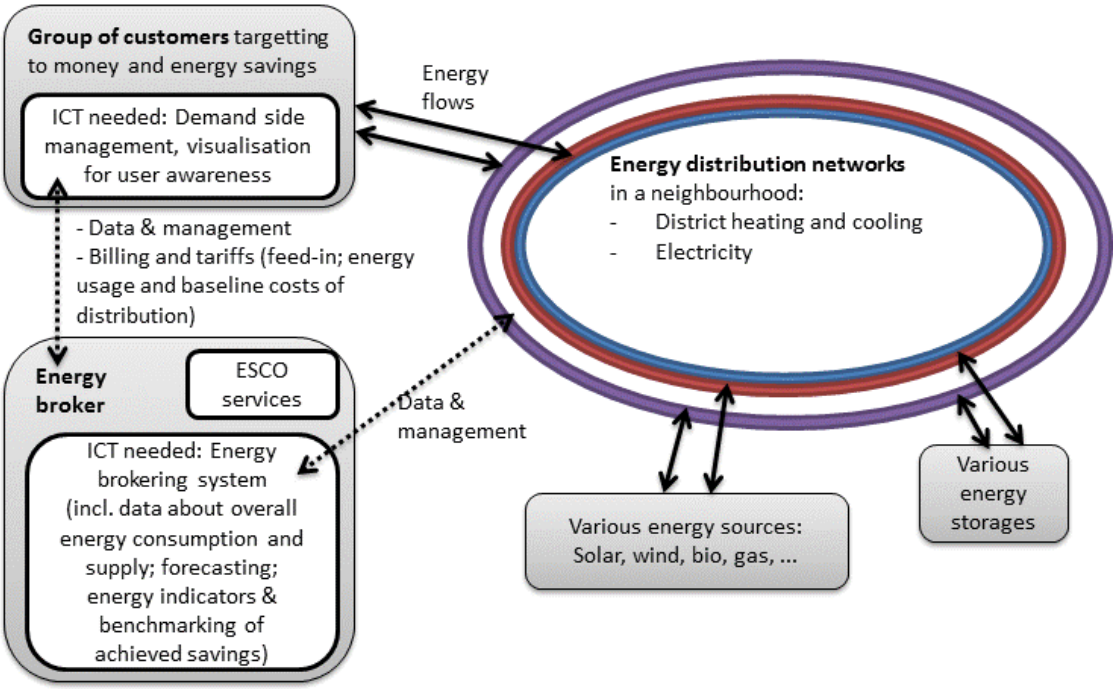

Figure 1. Illustration of the operational network from the energy broker scenario Cricchio F. et al (2013).

3.5 *Highlights of the development needs from the rural energy view point*

Experts contributing to IREEN have stated that the ICT solutions supporting urban and rural communities are similar and hence separation is not necessarily required. Despite the fact that the physical solutions in rural areas are clearly different than the ones in urban areas, when it comes to ICT solutions, such as control systems, there are few differences. Transportation and associated systems present the biggest variance between the development needs of urban and rural areas. Rural areas have lower densities of population and it is more challenging to increase the energy efficiency of transportation by means of neighbourhood planning (as in urban areas). The profitability of public transportation is also challenging. Longer distances between buildings make it difficult to connect their energy systems into the surrounding neighbourhood

and questionable if it is worthwhile. On the other hand, rural areas offer a large potential for renewable and distributed energy production due to the availability of physical space and geographical terrain, for example elevations suitable for wind power.

One of the technology benefits identified by the IREEN for rural areas is technologies shortening distances and hence the importance of good broadband connectivity. ICT need broadband and many rural areas are not well served. ICT can also play an important role in smart funding models, such as crowd funding.

4 CONCLUSION AND DISCUSSION

The IREEN vision is that the smart energy management of a neighbourhood enables optimum energy distribution and balancing of all energy flows, resulting in maximised economic and environmental benefits. The majority of cities have a large amount of existing infrastructure i.e. buildings and in some cases entire neighbourhoods which require renovation and modernisation in the not too distant future. Therefore the development needs of ICT supported district level energy efficiency focus on two distinct levels in the initial steps towards smarter cities: firstly the development of entirely new areas. Secondly the renovation/upgrading/modernisation of existing neighbourhoods, Many municipalities are also interested in local energy sources, increasing their share of renewable energy supply, and/or self-sufficiency and in some cases, energy positive performance of buildings, neighbourhoods and even entire cities. However there is often a lack of know-how on how to realise these ambitions.

IREEN aims to identify how ICT can support the overall energy efficiency of neighbourhoods. This is relatively complex due to the broad range of stakeholders and organisations involved. The integration and collaboration of different sectors and expert areas has been identified as one of the key aspects of achieving holistic energy efficiency at a neighbourhood level. Traditionally the different sectors of municipalities have operated relatively independently, as is often the case for energy, construction and ICT companies. This can lead to sub-optimised decisions, when planning, operation and controlling are not synchronised and in some cases not be connected. Alongside this information exchange can be inefficient.

There is a clear need for easier information exchange over traditional operational borders and for improved collaboration by the expertise sectors. This should include the inhabitants of the area at the onset of the planning process. ICT can provide the capability to support this. It can also support municipalities in the challenges related to improving energy efficiency by providing guidelines, tools, data sharing platforms and data mining.

An important aspect is to provide support for decision makers for analysis of different options and understanding their impacts, as well as help to comprehend the added value of ICT investments over the long term and life cycle of the neighbourhood. Here decision support tools play a crucial role for performance assessment, benchmarking and easy-to-understand visualisation of sustainability impacts (economic, environmental, and social impacts).

Integration technologies are an important area for ICT for energy efficient neighbourhoods. Open communication, ease of access to and utilisation of a range of data sources is a priority development topic. The synergies between different expertise fields need to be taken into account. The creation of truly energy efficient (or even net energy or energy positive neighbourhoods) requires effective collaboration, participation and knowledge exchange between stakeholders from the different expertise fields. For example, the stakeholder network needs to include urban, district and neighbourhood planners, transport system designers, energy companies and designers, ICT experts, and local people living and/or working in the area. In addition, governance issues, namely privacy and security should be borne in mind.

The project has focused on both urban and rural communities and the challenges they face to create energy efficient environments. In many ways ICT for both urban and rural communities are similar. Transport is significantly different between urban and rural areas due to the dispersed infrastructures and population. As a result is it challenging to improve the energy efficiency by transport planning in rural areas. However rural areas do offer a greater potential for renewable and distributed energy supply.

A clear message from city representatives has been that RTD and innovation of ICT itself is not enough, and that emphasis should also be given to economic related challenges and ROI, as

well as ways to access financial support. These present opportunities for new business models. Another important aspect is the need to increase the energy efficiency awareness of end users, urban planners and other designer, and create citizens opportunities to take part in the planning process.

The findings presented in this paper form the basis for the development of the IREEN roadmap (a strategic research agenda) for ICT supporting energy efficient neigbhourhood over the short, medium and long term. This will be followed by tangible implementation recommendations for each stakeholder group with a role in realising district level energy efficiency and the upgrading of the built environment towards smart city aspirations. The IREEN roadmap aims to support future research needs and actions, as well as providing implementation recommendations, targets and ideas for a range of stakeholders.

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