Energy Conversion and Management xxx (2016) xxx–xxx

Contents lists available at ScienceDirect

Energy Conversion and Management

journal homepage: www.elsevier.com/locate/enconman

Defining and operationalising the concept of an energy positive neighbourhood

Mia Ala-Juusela [a,*], Tracey Crosbie [b], Mari Hukkalainen [a]

[a] VTT Technical Research Centre of Finland, Espoo, Finland
[b] Technology Futures Institute, Teesside University, Middlesbrough, UK

ARTICLE INFO

Article history:
Received 16 November 2015
Received in revised form 15 April 2016
Accepted 19 May 2016
Available online xxxx

Keywords:
Energy Positive Neighbourhoods (EPNs)
Key Performance Indicators (KPIs)
Energy positivity label
Urban planning decision support tool
Neighbourhood

ABSTRACT

The increase in distributed renewable energy supply offers new opportunities to improve the performance of local energy systems. In line with this, research and development has begun to broaden its scope from the building scale towards the neighbourhood and district scales. The formulation and comparison of potential energy solutions in different contexts at different scales of analysis demands well-defined concepts and robust decision support tools. This paper studies the concept of energy positive neighbourhoods, which it defines as areas "*in which the annual energy demand is lower than annual energy supply from local renewable energy sources. . . . The aim is to support the integration of distributed renewable energy generation into wider energy networks and provide a functional, healthy, user friendly environment with as low energy demand and little environmental impact as possible.*" Key performance indicators for energy positive neighbourhoods are proposed along with an 'energy positivity label'. A decision support tool, called AtLas, designed to inform the long term planning of neighbourhood energy solutions is described and used to evaluate the energy positivity level of a Finnish residential neighbourhood and part of a French university campus.

1. Introduction

The realisation of CO_2 emissions reduction targets for the built environment, along with wider sustainability targets, requires an integrated approach. Municipal decision making plays a key role in reducing emissions [1] and improving overall energy efficiency through urban planning and land use policies [2] along with the development of sustainable energy and transport systems [3]. It is widely recognised that urban and energy system planning should be linked early in the planning process [4] to achieve efficient low carbon urban developments. However, currently there is a lack of well-defined concepts [5], metrics [6] and robust decision support tools [7] to enable the formulation and comparison of potential sustainable energy solutions. The research presented in this paper presents a contribution to the development of such concepts, metrics and decision support tools: In doing so it moves beyond previous work in the field by defining and operationalising the concept of an Energy Positive Neighbourhood (EPN).

Recent nearly zero energy building policies set by the European Commission [8] are driving an increase in local renewable energy production in buildings and neighbourhoods. These developments are leading to a paradigm shift in energy systems: from national systems with centralised energy supply and one-way energy distribution towards local energy systems that utilise hybrid energy sources with significantly increased share of distributed renewable energy supply from buildings and districts [9].

In line with changes in energy systems, research into the energy performance of the built environment is broadening its scope from the building scale towards neighbourhood and district scales. For example, recent research explores the concept of net-positive energy by considering the role of a building in adding value to the setting and systems in which it is situated [10]. Thus, moving beyond the notion that single buildings are the most effective unit to make meaningful energy gains [11]. This research highlights the significance of increasing the boundaries of energy analysis from the building scale. It also highlights the requirement for new methods and metrics to gauge the success of sustainable urban development initiatives and the need for a shift from annual timeframes to a lifecycle approach in energy analysis [10].

The importance of long term integrated urban energy planning is widely recognised [12]. In line with this integrated energy planning has become increasingly important and popular in cities and territories [13] and there is a consensus that municipalities are to play a more pronounced role during the implementation of the

* Corresponding author.
E-mail addresses: mia.ala-juusela@vtt.fi (M. Ala-Juusela), T.Crosbie@tees.ac.uk (T. Crosbie), mari.hukkalainen@vtt.fi (M. Hukkalainen).

http://dx.doi.org/10.1016/j.enconman.2016.05.052
0196-8904/

Nomenclature

CHP	Combined Heat and Power
EPN	Energy Positive Neighbourhood
KPI	Key Performance Indicator
OER	On-site Energy Ratio
AMR	Annual Mismatch Ratio
MHS	Maximum Hourly Surplus
MHD	Maximum Hourly Deficit
RPL	Monthly Ratio of Peak hourly demand to Lowest hourly demand
OEF	On-site Energy Fraction
HMR	Hourly Mismatch Ratio

future energy systems [14]. This makes logical sense as strategic planning at the level of the municipality offers the opportunity to connect buildings and energy systems enabling consideration of 'urban energy systems' as a whole [14] by acknowledging the interactions and interdependencies between their different components [12]. When analysing 'urban energy systems', different synergies and benefits can be recognised for optimal energy efficiency and energy performance [15]. It must also be noted that 'urban energy systems' analysis requires consideration of the whole energy supply chain: that is energy production, distribution, storage and end use [16].

There is no clear or simple strategy that can be applied to achieve low-carbon urban development. Rather, those involved in urban planning, construction and renovation need to identify suitable strategies within their particular geographical context and operational environment [17].

The research presented was conducted as part of a recently concluded project called "IDEAS – Intelligent NeighbourhooD Energy Allocation and Supervision". The main goal of the IDEAS project was to develop and validate the technologies and business models required for the cost effective and incremental implementation of EPNs. The project was part of a cluster of smart city projects.[1] These projects are indicative of the notion that within Europe the concept of net energy positive design beyond the building scale is coalescing around the concept of an EPN.

The phrase EPN is widely used, however it is not clearly defined in earlier work. What is meant by the phrase EPN is frequently vaguely expressed or taken for granted. If the concept of an EPN is to offer a meaningful contribution to achieving net energy positive design and development in the built environment it must be clearly defined, operationalised and easily communicated to the relevant academic, government and community stakeholders.

A definition of an EPN is proposed in Section 2 in this paper. To operationalise the proposed definition, a number of Key Performance Indicators (KPIs) is developed (Section 3) to enable the assessment of how adequately a neighbourhood is satisfying the definition of EPN, that is to say the neighbourhood 'energy positivity level'. Furthermore, for the concept of an EPN to provide an impetus towards net energy positive design in the built environment, it is necessary to have a method for clearly communicating the 'energy positivity level' of a neighbourhood. To enable this, an 'energy positivity label' is proposed in Section 4. This label provides a clear and easily understood method of visualising the energy performance of a neighbourhood. The calculation of the KPIs for the energy positivity label are presented in Section 5.

As part of the work conducted in the IDEAS project into defining an EPN and developing relevant KPIs, a decision support tool called AtLas was developed to support energy efficient urban planning and site renovation, as described in Section 6. AtLas enables the comparison of different sustainable energy solutions, for both new and existing urban developments, and an understanding of the long-term impacts of these different solutions [18,19]. The development of the tool is based on the key requirements of the intended users [20] and the findings of a review of existing tools.[2] The AtLas tool seeks to overcome the following problems associated with existing tools: Their complexity, the detailed energy and building related knowledge required as data input, their fixed geographical scale, a lack of clarity in the data and calculation methods they employ and the lack of time and cost analysis functionality.

The AtLas tool is used to evaluate the potential future scenarios for two pilot sites: a Finnish residential neighbourhood in Porvoo and part of a French university campus in Bordeaux. The Finnish demonstration site was selected because it is representative of 75% of European building stock which is residential [23]. In addition, as is common practice in Northern and Eastern Europe, the buildings at the Finnish site are heated by a CHP plant [24]. The second demonstration site at a French university was selected because it is representative of some 17% of non-residential European buildings which are schools colleges and universities [23]. The second demonstration site is also similar to hospitals, which constitute 7% of the European building stock [23]. The demonstration sites are described in Section 7 of this paper, along with the main results of the results from AtLas simulations.

2. Definition of energy positive neighbourhoods

According to Cole [11], "*Net-positive approaches... emphasize how buildings work collectively within networks. A key issue, therefore, is how new buildings fit into and work with the existing building stock*". As such, the concept of net-positive energy demands that the function of buildings is reconceptualised to see them as adding value to the setting and infrastructures of the area in which they are situated [7]. This in turn demands that debate is moved from defining energy positive buildings to defining energy positive building contexts and their energy infrastructures. In line with this approach, the definition of an EPN was developed [24], and updated according to discussions with the researchers developing ICTs to support EPNs in the following projects co-financed by the European Commission: COOPERATE, EPIC-HUB, URB-Grade, EEPOS, ODYSSEUS, NRG4Cast ORIGIN and SMARTKYE, E+.

The Thematic Working Group on ICT for energy efficiency [25] stated that: "*Energy-positive buildings and neighbourhoods are those that generate more power than their needs. They include the management of local energy sources (mainly renewable, e.g. solar, fuel cells, micro-turbines) and the connection to the power grid in order to sell energy if there is excess or, conversely, to buy energy when their own is not sufficient*". In the COOPERaTE project[3] [26], an EPN is defined as "*a neighbourhood which can maximize usage of local and renewable energy resources whilst positively contributing to the optimization and security of the wider electricity grid*".

[1] The IDEAS sister project and other EU projects in this field include: COOPERATE, ODYSSEUS, EPIC-HUB, NRG4Cast, ORIGIN, SMARTKYE, E+, URB-Grade and EEPOS.

[2] This was based on expert knowledge and in-depth analysis of existing tools and earlier analyses [21,22].

[3] http://www.cooperate-fp7.eu/.

Please cite this article in press as: Ala-Juusela M et al. Defining and operationalising the concept of an energy positive neighbourhood. Energy Convers Manage (2016), http://dx.doi.org/10.1016/j.enconman.2016.05.052