Introduction to Panel 5 Energy use in buildings: projects, technologies and innovation

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Introduction

Buildings are responsible for 40 % of the energy use in Europe; thus energy savings in the building sector are key to achieving Europe's energy and climate change policy goals. Unlocking the immense energy saving potential of buildings requires not only ambitious legislative frameworks and policy programmes (see Panel 6), but also the continued research and development of innovative building techniques and technologies and the dissemination of learnings from real-world best-practice projects. To address the challenges of transforming the energy use in buildings and to allow for their better integration into future energy systems, a long-term and multi-dimensional perspective is required. The presentations in Panel 5 fall into seven themes:

- **Energy performance of buildings: programmes and measures** – the papers in this theme present evidence and share learnings on the implementation and delivery of programmes and measures that improve the energy performance of buildings.
- **Towards nZEB and deep renovation: what has and hasn't worked?** showcases a number of in-depth case studies which investigate the technological challenges for (deep) renovation and the experiences of pursuing the nearly zero-energy building (nZEB) standard.
- **Improving energy modelling, data collection and large scale monitoring of energy consumption** presents studies that showcase best practice in data collection, large scale monitoring of energy consumption and studies that use data to improve our modelling capabilities.
- **Understanding energy consumption and load patterns in the residential sector** presents a variety of innovative research studies that use the emerging large datasets comprising of smart meter data, environmental monitoring and surveys to advance our understanding of energy consumption and load patterns in buildings.
- **Smart homes, smart consumers and retrofit support** is dedicated to the presentation of the most up-to-date research into the diverse opportunities presented by smart energy monitoring technologies. The topics covered include the potential role and effectiveness of smart meters in promoting energy savings; novel approaches using smart meter data to infer human behaviour and thus provide tailored advice; and wider issues of influence and control in the domestic setting.
- **Balancing energy production and consumption** presents new research and case studies which study buildings as an integral and active part of the energy system as a whole; exploring the relationship between electricity supply design, demand side management and the integration of renewable energy into the built environment.
- **Capacity building and standardisation** focuses on the capacity building that will be required to design and implement an ambitious programme of change that promotes efficient energy use in buildings.

Energy performance of buildings: programmes and measures

A group of papers give a retrospective view on the existing programmes and measures to increase energy performance of Europe's building stock. Marie-Hélène Laurent et al. (5-291-15)

present the story of the past 40 years for the refurbishment of old (built before 1975) French dwellings. Understanding the past benefits of retrofitting is important to forecast future consumption as well as to design future policies. Faidra Filippidou et al. (5-093-15) describe the energy efficiency measures applied in the Dutch non-profit housing sector. The analysis examines the impacts of specific measures and brings a valuable recommendation for future choices by the housing associations. Ebru Acuner and Sermin Onaygil (5-220-15) present the results of the *EUbuild Energy Efficiency (EE) Project* conducted in Albania, Bosnia & Herzegovina, Macedonia, Montenegro, Serbia and Turkey. The authors address the question of whether the energy efficiency measures applied in the Balkan region deliver the necessary change.

Towards nZEB and deep renovation: what has and hasn't worked?

Demonstration projects and empirical studies can help capture and evaluate the difference between a building system's in-use performance and the design's intended performance. Marina Topouzi (5-368-15) presents the results from 26 properties from a low-carbon 'whole- house' deep refurbishment through the UK Retrofit for the Future (RfF) scheme. The author argues that installation failures decrease best practice performance and increase the operational complexities of occupants' interactions with building systems at the in-use stage. Mariam Kapsali and Rajat Gupta (5-165-15) explore 6 case study dwellings in new low/zero energy social housing developments; the authors will elaborate why despite being designed to high energy standards, the actual energy use exceeds design expectations by a factor of three. Peter Foldbjerg et al. (5-213-15) deal with post occupancy evaluation and measurements of indoor climate in five houses, which are part of the Model Home 2020 project. The results focus not only on high energy performance, but also indoor air quality and environment.

Improving energy modelling, data collection and large scale monitoring of energy consumption

An informed policy making process requires a good understanding of energy consumption patterns in buildings. There are multiple ways of collecting new quantitative data, from surveys to smart metering systems. A best practice example of a large survey and monitoring study to collect data on domestic energy use is given by Jack Hulme (5-177-15). The Energy Follow-Up Survey (EFUS) undertaken in England provides essential information to understand, monitor and respond to changing patterns of energy use in households, including hours of heating, use of secondary heating and what temperatures are being achieved in households. Geoff Hunter et al. (5-235-15) use real-time wireless sensor data to verify actual, measured heating patterns and corresponding room temperatures, allowing direct comparison to Ireland's normative energy model, the Dwelling Energy Assessment Procedure (DEAP), which is currently used to calculate the energy performance rating of dwellings. Finally, Katarína Korytárová et al. (5-374-15) showcase how to use energy audits and self-reported consumption data for large scale monitoring of energy consumption in public buildings in Slovakia.

Understanding energy consumption and load patterns in the residential sector

The emergence of large energy and environmental monitoring data sets, along with survey data, some of which are publicly available on the web, has allowed for innovative research projects into energy consumption and load patterns. An in-depth regression analysis of the EFUS data has been undertaken by Gesche Huebner et al. (5-083-15), and has shone light on the question of which class of variable (building factors, socio-demographics, attitudes and self-reported behaviours) contribute most to explaining energy use in buildings. Knowing the relative importance of these different predictors can help shape the most effective policy interventions. Tobias Boßman et al. (5-270-15) use a large publicly available smart meter data set and survey data from Ireland to econometrically estimate end-use specific load profiles, controlling for demographic and building characteristics. João Pedro Gouveia et al. (5-054-15) focus on electricity consumption patterns in Southwest European households, using a fusion of data from smart meters and door-to-door surveys.

Smart homes, smart consumers and retrofit support

An overview of the current evidence on the energy savings achievable by smart meters is given by Henk van Elburg (5-053-15). Results from recent large scale trials undertaken in the Netherlands are presented and contrasted with previous trials that have been undertaken in the EU and internationally. How best to use smart meter data, as well as other energy data, to best support retrofit decisions? Tom Kane et al. (5-139-15) test the impact of different ways of communicating energy efficiency advice to householders. In particular it looks at impacts of visualisation of actual hourly and daily energy use gained from smart meters, compared to information gained as part of a UK Green Deal assessment.

Charlie Wilson et al. (5-046-15) describe and demonstrate a novel approach for the use of smart meter data along with individual appliance plug monitors and environmental sensors to identify energy use in terms of specific 'activities'. They argue that understanding energy use through activities provides a lens through which energy feedback to households can be made salient and understandable.

Understanding energy consumption through human behaviour is also the centre of a project presented by Zhining Liao et al. (5-175-15). The authors introduce an innovative new system which is being developed to use the outputs of multiple sensors within houses (ultra wideband radar as well as energy monitoring) to infer a model of human behaviour. This will be used to generate policies that can be used by the end-user to reduce consumption via automation, whilst still retaining desirable levels of occupants' comfort.

However, these technologies also raise the question: what effect will smart meters and smart homes more generally have on influence and control within the domestic setting? Tom Hargreaves et al. (5-151-15) present innovative sociological research into the implications of these emerging technologies. Far from merely controlling appliances, Hargreaves et al. present evidence that householders were concerned about many broader understandings of control relating, for example, to

control over security, independence, hectic schedules and even over other household members such as through parenting or care relationships.

Two papers present new interactive tools which provide tailored energy efficiency advice. The tool described by Erik Mazmanian and Sian Evans (5-287-15) has been developed specifically for small to medium sized enterprises (SMEs). It uses energy data analytics to provide customised insights and savings advice. The paper discuss key factors to consider in delivering personalized engagement tools that support energy management across large sets of business customers. Shen Wei et al. (5-131-15) introduce a new tool for householders (under development) called the Energy Efficiency Educator (EEE), which is being developed as part of the Energy Visualization for Carbon Reduction (eViz) research project in the UK. The EEE aims to combine dynamic building simulation with a user-friendly interface to allow exploration of tailored energy efficiency options for their homes, which leads to better decisions in non-experts.

Balancing energy production and consumption

This theme showcases research and case studies that consider buildings as an integral and active part of the energy system as a whole; exploring the relationship between electricity supply design, demand side management and the integration of renewable energy into the built environment. Rasmus Luthander et al. (5-117-15) investigate how battery storage and the storage capacity of electric vehicles can be used to increase the on-site use (or self-consumption) of the electricity produced by PV s. In the context of advances in PV electricity generation, semiconductor power electronics and growing direct current, Brock Glasgo et al. (5-332-15) consider the feasibility, energy savings, and economics of wiring domestic premises with DC circuits to reduce power conversion and facilitate a transition to more efficient DC appliances. Finally, C. Birk Jones et al. (5-490-15) present results from two case studies of microgrid remote optimisation, using a software as-a-service (SaaS) configuration, of complex and highly efficient buildings in New Mexico. The case studies showcase huge solar arrays, absorption chillers and thermal storage for both heating and cooling.

Capacity building and standardisation

Building codes and supporting standards are among the key drivers to energy performance improvement in the buildings sector. Girish Ghatikar et al. (5-002-15) argue that there is a growing need to standardise the automation of demand responsiveness and grid transactions. The new Title 24 code for new construction and retrofit conditions (set forth by the California Energy Commission) showcases how standards can be used to lower the technology cost and enable buildings and grid interoperability. The author highlights the need to educate building owners, vendors, and code officials on the intent of these new codes for electric grid transactions, and to engage electric utilities to take advantage of the demand response automation capabilities in new buildings. Capacity building is the central topic in the paper by Philippe de Rougemont and Vivek Gilani (5-201-15). Even if strict building codes were passed into law and seriously enforced, the lack of a skilled workforce to design and carry out the construction work would be a serious liability. He demonstrate how to bridge the knowledge gap and make the workforce ready to reduce to the minimum the cooling load of future and existing buildings in India.

Georg Vogt and Strahil Birav (5-236-15) present a replicable strategy to recruit citizens to use ICT for saving energy in public buildings. The strategy was developed as part of SmartSpaces, a European project launched in January 2012 with the aim of developing innovative ICT-based energy decision support and awareness services along with (automated) management service components in public buildings. Successful elements of the strategy included using the concept of "champions", using the organisational structure to communicate, creation of tailored messages and slogans and conceptualising a consistent branding strategy.