Introduction to Panel 5
Buildings and construction technologies and systems

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Introduction

The last IPCC report states that the energy sector plays a key role to reach the 2 °C-target, and concludes that global emissions from the energy sector must reduce by 90 % or more relative to 2010-level, within the period of 2040–2070. Buildings are responsible for 40 % of energy consumption and over a third of CO_2 emissions in the EU. Thus, energy savings in the building sector are key to achieving Europe's energy and climate change policy goals and buildings also need to become nearly 100 % renewable in the near future. In order to meet these challenges, it is not sufficient that new buildings are energy efficient. Cost effective renovation strategies and concepts are necessary for the existing building stock, along with more research, demonstration of innovative solutions, and facilitating their roll-out into the mass market. Furthermore, integration of renewable energy production calls for buildings to become more flexible, by reducing their energy need especially at peak hours. The challenge is how to make the buildings "smart-grid ready" with automatic controls that enable interaction with the surrounding energy system to reduce CO_2-emissions.

Potential for energy efficiency and cost savings

In order for policy makers to make realistic goals for energy efficiency and demand response, it is of vital importance to have methodologies that can estimate their potentials. The growing availability of data from smart home devices such as smart thermostats and smart electric meters, may increase the possibility of quantifying the potential for energy efficiency and demand response.

Newsham et al. (5-065-17) use statistical analysis of over 500 dwellings in Canada to gain insights into household energy use characteristics. Based on a regression approach Newsham et al. are able to disaggregate the electricity use by three purposes; refrigeration and phantom loads, air conditioning, and furnace fans. Through estimating the relative thermal efficiency of the house structure, they are able to bench-mark and identify households that have high efficiency potential.

Severinsen and Holst (5-157-17) have gathered hourly electricity measurements of 132 retail stores in Norway. Through a statistical approach, the data is used to arrange the stores regarding their energy efficiency performance, and thereby benchmark their energy efficiency potential. The findings show that it is important to take outdoor temperature into account.

To reach the energy efficiency goals of the existing building stock, estimating energy consumption by purpose is important as this enables more accurate estimates of energy savings, and thereby helps the building owner to decide the priority of energy efficiency measures. Yamaguchi and Iwafune (5-373-17) investigate non-residential buildings in Japan, and present a methodology to separate energy consumption by purpose (e.g. air conditioning, lighting, and water heating) from commonly available energy measurement data. The methodology uses pattern recognition of daily average energy consumption.

Case studies of cost optimal renovation

The Energy Performance of Buildings Directive states that minimum requirements should be set when buildings undergo a major renovation, to the extent that this is technically, functionally and economically feasible. But what kind of measure may be used to reach that goal and how much energy efficiency is possible to reach with cost optimal solutions?

Fonseca et al. (5-063-17) are following the renovation at University of Coimbra which has been a testbed for the installation of new technologies. The building was constructed in 1996 and, in the last five years, the lighting was gradually replaced by LEDs. Additionally, the Building Management System also achieved significant electricity savings of about 10 % of the total building electricity consumption. The next step was to transform the building into a nearly Zero Energy Building, by installing PV panels. Twenty percent of energy savings were achieved with 37 % of the consumed energy ensured by onsite photovoltaic generation.

Gustavsson and Dodoo (5-133-17) have explored the profitability of different energy renovation measures for a 1970s Swedish multi-family building. A method considering total and marginal investment costs for analysis of cost-effectiveness is used. The results show that the economic viability of the retrofit measures is sensitive to parameters used, including real discount rates, energy price increases and technical lifetime of retrofit measures. Still, about 34–51 % reduction of final heat demands is economically viable. Resource-efficient taps is the most cost-effective measure while improved thermal envelope insulation for exterior walls is the least cost-effective.

Moura et al. (5-122-17) investigates three nZEB renovation projects for the Municipality of Coimbra. The renovation designs were mainly focused on the retrofit of lighting and HVAC and on integration of photovoltaic generation. It will be possible to achieve savings on the final net energy consumption of over 80 % and over 70 % of the consumed energy will be ensured by renewable energy sources. For the buildings, a type of ESCO contract can be feasible with 5 % annual yield. The suggested financing plan is a mix of ESCO equity, senior debt and VAT facility.

Improving PV self-consumption potential and peak shaving

Bruce-Konuah and Gupta (5-091-17) investigate PV self-consumption with and without batteries for 44 households in the south-eastern part of England. The analysis shows that if a battery is available, the self-consumption of PV electricity increases by 6 % and 12 % in the summer and winter periods respectively, and the peak load of the community is reduced by 6 % and 3 % respectively.

Teichtmann and Klingler (5-160-17) take self-consumption further, and present a model to ensure optimal operation of a home management system with PV and battery. The model consists of three parts; 1) forecasting the hourly electricity demand and PV generation by using artificial neural networks, 2) calculating the optimal energy flows by using optimisation that maximises self-consumption, and 3) adjusting the actual energy flows if the forecast deviates from reality through a control algorithm. The results show higher grid feed-in during hours of high prices, and an increased amount of stored energy during hours of low prices, resulting in 23 % higher utilisation of the battery.

Lind et al. (5-327-17) demonstrate how big-data, coupled with simulation of local energy production and storage, can contribute to reduce electricity costs by utilising on-site PV electricity and battery storage during peak hours. This is demonstrated by using hourly meter readings from 600 Norwegian stores. The analysis shows that the economic gain from installing PV and battery storage systems mostly relates to evening out the variable electric load, although the revenue is still very small with the current electricity prices in Norway.

Maggiore and Gallanti (5-014-17) explain the details of the reformation process of the electric tariff for domestic end users in Italy and illustrate the results of the analyses carried out comparing the old tariff to the new one, for a representative residential home equipped with a PV power plant. The new tariff allows the "all electric" solution (i.e. in which electricity is used to satisfy all energy demands) with a PV power plant to be both more energetically advantageous and economically profitable than the "traditional" solution.

Understanding load patterns and energy consumption

This section contains papers that investigate load patterns to identify either energy efficiency potential or segmentation of energy use. Understanding building occupancy is important for sustainable building operations, as the building's load profile is related to its occupancy level. Howard et al. (5-412-17) investigate different methods to determine the occupancy level within an office building, where the two most promising are based on data from 1) access control data to the building, or 2) the number of Wi-Fi connected mobile devices. The Wi-Fi connected mobile devices also provide high spatial resolution occupancy data which can be used to control ventilation by predicting occupied and unoccupied spaces throughout the building.

Hanmer et al. (5-192-17) examine how patterns of heating operation in individual homes influence the aggregate daily patterns of heating consumption using measurements from 337 UK homes with smart heating controllers. The quantitative data analysis was combined with interviews with householders. The paper finds that the peak level of space heating demand is higher in the morning than the evening. This is relevant to electricity network operators if the heat sector is to be decarbonised by heat pumps. The paper points out in the end that better understanding of current household thermal routines is needed in order to identify options that reduce the negative impacts on system demand peaks.

Economic feasibility of renovation

Can cost optimal energy efficiency measures easily be chosen during renovation? How should we analyse if the measures are economically feasible, and do we need to consider other factors that influence the decisions? In this section, three different methods are presented for how to present the economic feasibility.

Bonakdar and Kalagasidis (5-165-17) have investigated optimal and cost-effective energy renovation of single-family houses in Sweden with a net present value method. The results indicate that the space heat demand in houses of 1970 can be reduced by 25–28 %. For the houses of 1990 the scenarios suggest "do nothing". The optimum cost-effective component for renovation is of attics for the houses built during early 1970s followed by the attics of the houses built during 1980s. Renovation of exterior walls and windows are not cost-effective, regardless the year of construction.

Azcarate-Aguerre et al. (5-166-17) present a prefabricated façade module that improves energy performance, while ensuring minimum disturbance for the occupants, during renovation of post-war buildings. In order to outline an attractive business case the financial performance of a zero-energy renovation investment is calculated for three different apartment properties with diverse market values. The analysis shows that, for properties with an intermediate to high market value, the investment can be attractive.

Orshoven (5-374-17) shows in a graphical manner the different factors that influence the cost optimal insulation thickness such as the initial minimum cost of insulation, the marginal cost of extra thickness, the energy price and the upgrading of an already semi-insulated component. The analysis shows that when components are (initially or during renovation) insulated, the full cost optimal insulation level should be achieved at once and it seems unlikely that passive house insulation levels are not effective from a strictly economic point of view.

Buildings as active players in the electricity market

In the literature, utilisation of flexible demand is referred to as both Demand Side Management (DSM) and Demand Response (DR). Although it is not clearly defined, DSM mostly relates to enabling of flexible loads through changed end-user-behaviour within a longer time-frame (i.e. minutes to several hours), whereas DR relates to automatic activation of flexible loads on a shorter time-frame (i.e. seconds, and up to one hour).

Wohlfarth et al. (5-326-17) investigates barriers for enabling demand response (DR) in the service sector in Germany. The sub-sectors trade, restaurants and hotels, and office-like buildings were identified as the most promising sub-sectors. The reason is (1) that these sectors consume 65 % of the energy consumption in the service sector that is assumed to be flexible (e.g. cold processes, air conditioning or space heating), and (2) based on a survey, that these sectors have high availability of technologies with high flexibility potential. Thereafter, to identify the most important barriers to DR, stakeholder interviews of 14 companies within these three sub-sectors were performed. The most important barriers identified were lack of awareness, having no persons in charge, financial issues, worries about quality, loss of work or products, regulatory circumstances and concerns about data security.

Gillich et al. (5-301-17) investigate a concept of offering demand response (DR) services from a system consisting of two campus buildings, two heat pumps, gas boilers and a shared heating network between the buildings. The revenues from offering three different DR services are calculated both separately and combined; Firm frequency response (FFR), Short-term operating reserve and Network use of system charges. The results show that the total heating costs of the system (HP and gas boilers) by utilising DR services are 20 % lower than compared to a typical operation of the system.

Stensson and Piette (5-367-17) propose a conceptual framework for how a Californian forecasting tool could be adapted in a Swedish demand response potential study. Electricity generation from wind and solar is increasing, which are less predictable and controllable and introduces new challenges for the energy system. Consequently, demand side management is gaining increased attention for its conceivable potential of providing needed operational flexibility to the energy system.

Design strategies with a wider approach

To design buildings that will meet the future requirements of sustainability requires a wide approach and long term strategies. Consideration needs to be taken of the actual building and the best design in future climate scenarios, the district it is situated in and possibilities for local energy production as well as life cycle energy use.

Rooth et al. (5-093-17) are demonstrating next generation buildings in developed city districts in the Netherlands, France and Sweden. The plans include a combination of well insulated dwellings, smart local grids and local production of renewable energy. The energy use of the residents is monitored and the residents' experiences are collected. Final energy use in the different cities is from 43 to 24 kWh/m^{2}yr.

Hofer et al. (5-189-17) describe the process for selecting alternative heat supply concepts for a new urban settlement in Vienna. Locally available renewable resources and infrastructures set the basis for the identification of technically feasible options. Main outcome shows that alternative concepts with heat pumps and geothermal probes as main elements have similar life cycle costs to district heating. These concepts have a high share of locally produced renewable energy and can meet local 2,000 Watt targets.

Tettey et al. (5-342-17) analyse design strategies to minimise heating and cooling demands of a multi-storey residential building in Sweden under different climate change scenarios. Results show that space heating demand reduces, while cooling demand and risk of overheating increases in future climate scenarios. The most important design strategies are efficient household equipment and technical installations, solar shading, bypass of heat recovery, window u- and g-values. Total energy demand decreased by 40–51 % and overheating is avoided under the considered climate scenarios when all the strategies are implemented.

Dodoo et al. (5-135-17) analyse the life cycle primary energy use of a recently constructed Swedish apartment building and compare it to variants of low-energy buildings. The results show that the relative significance of the production phase increases as buildings are made to achieve very low operational energy use. The production phase accounts for 17 % of the total primary energy use for production, operation and demolition of the constructed building for a 50-year lifespan. The corresponding values for the nearly-zero energy and low-energy building variants ranges between 30 and 31 %.

Haase and Ampenberger (5-069-17) investigate how energy efficiency measures for lighting affect the heat and cooling demand of the building. The case study is performed on a shopping centre situated in Norway, where three lighting retrofit cases are investigated. The results show that reducing electricity consumption for lighting increased the need for heating and cooling, but that the total primary energy consumption for the building decreased.

Challenges with technical and non-technical implementation of energy efficient measures

This section presents a collection of papers that in different ways tackle practical challenges with technical and non-technical implementation of energy efficient measures.

Osojnik (5-235-17) presents challenges for unlocking the energy efficiency potential of multi-family houses, as the performance of many existing central heating systems are unsatisfactory. The paper points out that the key ingredients for optimal operation and performance of hydronic heating distribution systems are individual indoor room temperature control, and dynamic hydronic balancing (including continuous control of flow and pressure). The paper demonstrates that although the challenges and solutions are known, they still remain unsolved in the field in many places.

Isaksson (5-125-17) highlight the usefulness of seeing the technologies for buildings from the users' point of view in a new energy efficient house. From a social practice perspective and the concept of domestication the paper examines uncertainties encountered by occupants when managing technologies for buildings, such as bedrock heat pump, photovoltaic panels and LED-lighting. The result demonstrates that instead of assuming that carrying out this practice is straightforward, it would be better to work on an approach where this is not the case.

Imbault et al. (5-058-17) explain how difficult it is to define, measure, record and analyse the data related to energy performance evaluation. A suggestion of standard protocol is suggested, for the industry and building sectors, that in more detail than ISO 50001, describes how a measurement and monitoring plan should be implemented in practice.

Apritasari (5-428-17) examine the use of light shelves. The results show that with right design of light shelves, we can expand daylighting areas that meet visual comfort, minimize glare and increase energy saving in an office.