Introduction to Panel 6
Innovations in buildings and appliances

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Introduction

We need technical advances in buildings and appliances in order to meet goals for reductions in energy use and carbon emissions. The latest European Commission "Roadmap for Moving to a Low-Carbon Economy in 2050" sets a carbon reduction target of 90 % for the built environment. Consequently new European buildings need to achieve a "nearly" zero-energy standard by 2020 – only ten years left! How do we get there, taking into account Europe's diversity in climates, building culture, user habits and requirements? Energy innovations are needed in all stages of a building's life cycle and incorporating both demand and supply sides of buildings.

But what do these technical advances look like? Are they primarily in the form of materials? Hardware? Software? Panel 6 on innovations in buildings and appliances offers a "tour" of both evolutionary and revolutionary changes that are being proposed. It is no surprise that the changes span a wide range of topics and approaches given the breadth of the challenge.

The papers in this panel fall into six groups:

- Market trends.
- Case studies of existing buildings.
- Energy saving potential of control and automation.
- Appliances and smart grids.
- Innovative or optimised components.
- Dynamic simulations for innovations.

We urge you to read these papers in order to appreciate the insights gained from detailed analyses of specific technical and related market problems.

Here, however, we wish to describe some of the unifying themes that we observed in these papers. These observations provide context to help readers understand the importance of the papers. At the same time, we hope that our comments stimulate future research.

1. Energy efficiency, renewables and appliances are being integrated in ways that make the distinctions among them increasingly fuzzy and artificial. It is no longer possible to separate the supply and demand sides into two independent issues. This is particularly true as utilities seek to use demand-side measures in lieu of expensive investments in new supplies.
2. The electrification dilemma needs to be confronted. Electricity is an expensive fuel for providing heat yet electricity is easier to obtain from renewables. Can the high costs of electricity be offset with increased efficiency of conversion to heat? And what is going to stimulate the needed market transformations?
3. Occupants of advanced-technology buildings will still have mundane needs, from making coffee to cleaning clothes. How do we ensure that reducing energy use in these end uses receives as much attention as building wind farms or incorporating photovoltaic panels on buildings?
4. How much cooling do people need or want? Experience from Australia, Japan and the USA have shown how air conditioning places entirely new needs on electricity supply systems. Should Europe plan to follow a similar trajectory? If yes, then what sorts of innovations in designs, codes, and technologies are required?

5. The efficiency gains from "smart" products may be subverted by complex interfaces. When occupants cannot understand controls, they will more likely select inefficient settings and use more energy than necessary.
6. Reducing standby power use remains a challenge in all kinds of buildings. While tremendous improvements have been made in some products, new low power modes and greater reliance on networks have offset many of the gains.
7. Methods to collect and evaluate detailed consumption data remain inadequate. Advances in metering technologies for individual devices, protocols to report the data, and tools to quickly interpret the data, are still needed.

Do we have a sufficient backlog of technical advances in buildings and appliances in order to meet goals for reductions in energy use and carbon emissions? Our conclusion from reviewing these papers (and elsewhere) is definitely NO. There remains enormous work required to develop new energy-saving solutions and translate them into practical, economic, and attractive, technologies.

Market trends

Nick Eyre (6-010 – "Efficiency, demand reduction or electrification?") points out that even the most ambitious energy efficiency programs have to be supplemented by significant changes on the supply side in order to achieve climate goals. Taking the UK as a case study he analyses the socio-economic feasibility of a large-scale electrification of heating demand which is predicted in several studies. Which changes will be needed in consumers' behaviour, in equipment supply chains and in the capacity of electricity generation and distribution systems? He concludes that demand reduction and electrification require huge changes which are not at all happening by themselves but need to be conceptualised, planned and delivered together in order to be successful.

Tina Fawcett elaborate these findings for "The future role of heat pumps in the domestic sector" (6-388). Currently being a niche technology they are expected to significantly increase their market share in the future. But what preconditions have to be met in order to develop a niche technology to a mainstream application? The author concludes that several transitions unrelated to heat pumps have to occur to make this happen: (1) transition to low carbon electricity supply; (2) transition to well-insulated housing stock via retrofit; (3) transition to low temperature household heat distribution systems. Thus a policy promoting heat pumps has to be different, and more complex, than policy supporting energy efficiency.

Case studies of existing buildings

Chris Marney's et al. paper "A green prison: Santa Rita Jail creeps towards zero net energy (ZNE)" (6-100) presents how a massive application of photovoltaics, fuel cells, wind energy, concentrating solar thermal systems and battery backup may convert a 20-year-old 45 ha, 4,000 inmate prison into a showcase how zero energy level may be achieved in the future. A major lesson learned is that optimal combinations of equipment and operating schedules have to be found in order to maximise the use of distributed renewable energy sources and to minimise energy bills. Dedicated computer models may support the systematic search for an optimal combination and replace sub optimal rule of thumb guesses.

Anders Hjorth Jensen and Peter Maagøe Petersen feature a second case study on non-residential buildings: "Energy efficiency in hospitals and laboratories" (6-337). Hospitals have "traditionally" high specific energy consumption for heating and cooling and usually energy efficiency projects yield good results. In contrast the study in our panel focuses on the energy consumption of laboratory equipment and other large-scale devices in hospitals which may account for 20 % to 30 % of the total electricity consumption. The authors find that 70 % to 90 % of the total energy consumption by medical equipment is due to standby power. A large share of these savings may be exploited by updating purchase guidelines, optimising operations and improving power supply systems.

Phil Banfill et al. show "The potential for energy saving in existing solid wall dwellings through mechanical ventilation and heat recovery" (6-031). Their research results are derived from a new experimental house, built to typical 1930s standard. The building has been equipped with a whole house mechanical ventilation system with heat recovery. Intended carbon savings do not at all result automatically due to the currently still high carbon intensity of electricity for the mechanical ventilation. Passive house-like air tightness levels should be achieved, reasonable operation schedules for the mechanical ventilation system applied and electricity with a high share of renewables be used in order to be successful.

Energy saving potential of control and automation

Large buildings and campuses are increasingly installing combined heat and power units, along with solar and storage to supplement power from the grid. The management and optimization of these resources is challenging. Michael Stadler et al. (6-260) describe a model used to collect data and optimize the resource mix to yield the lowest cost or carbon emissions. They applied the model to a campus building and illustrate the range in results depending on the resource mix selected. The model is gradually being shifted to the web since so many of the necessary inputs are imported from outside sources.

Alan Meier et al. report on "Facilitating energy savings through enhanced usability of thermostats" (6-094). Probably everybody has made the acquaintance of confusing controls for heating and cooling systems which may lead to a sub optimal handling and settings as to energy consumption and user comfort. The authors have made substantial progress in developing a methodology for measuring the usability of thermostats. The metric is based on the time a user needs to accomplish a given task, for example setting a specific temperature, and the fraction of test persons actually completing the tasks successfully. Recently the Energy Star program adopted the proposed methodology for its thermostats specification which demonstrates the usability of the authors' work.

Appliances and smart grids

Two papers examine prospects for improving the efficiency of common household appliances. Even a home requiring zero energy for heating and cooling will still be filled with appliances providing a multitude of specialized services. It's difficult to imagine a future without coffee, and Jürg Nipkow et al. (6-172) evaluate the technologies involved in producing a high quality cup of coffee in the home. Coffee-making is a complex process, requiring careful control of temperature and water flow. The machines themselves must operate efficiently in several modes. Standby power consumption is a consideration, too. Aficionados will be relieved to learn that high quality coffee can be brewed with a high efficiency.

Barbara Josephy et al. (6-177) studied the machines in the laundry room—a site of surprisingly intense energy consumption—to find other energy-saving opportunities. The technologies involved in washing and drying clothes continue to improve in efficiency while reducing water consumption. Without question, the introduction of the heat pump drier will bring large energy savings. These driers are mandatory in Switzerland but will consumers elsewhere accept the different drying features that heat pump driers offer?

In Japan, zero-energy homes with integrated solar and battery are being studied prior to widespread deployment. Takahiro Tsurusaki et al. (6-290) simulated various combinations of efficiency, local generation, and storage technologies. The Japanese climate, which requires use of both heating and considerable cooling is a special challenge in correctly sizing equipment. An installation with a solid oxide fuel cell, a rooftop PV collector, and a battery had the best economics. Surprisingly, they delivered more savings than an advanced heat pump water heater and PV.

Developing energy efficiency standards and labels is an expensive process and these costs often impede their adoption. Michael Scholand et al. (6-344) argue that economies can be achieved through sharing of the analyses. Not only does information-sharing lower costs, it can also make available more data about efficiency technologies and their costs. The potential savings from sharing are illustrated with examples from analyses of transformers, televisions, electric motors, and external power supplies.

Standby power consumption remains a challenging target for reduction, requiring an array of strategies. Paul Ryan and Murray Pavia (6-379) describe one such control strategy, a power control device, and the outcome of in-home measurements. These power control devices work best when groups of closely-related products, notably audio-video or PC clusters, can be connected to them. The power control devices saved over 40 % of the total energy use in the clusters; however, the results may not be realistic for many homes.

It is now easier to coordinate supply and demand of electricity thanks to improved communications. The aggregate impacts of these interactions are complex, especially in the case of heating and cooling equipment where dynamic aspects can play a strong role. David Da Silva et al. (6-518) constructed a model to simulate the impacts of real-time tariffs, demand response, and building thermal characteristics on an electrical grid. Electricity demand is sensitive to thermal storage and, if the price signals are not correctly constructed, real-time tariffs may create new peaks during periods of re-heating. But the system works only if the appliances and the utility speak the same language. George Wilkenfeld (6-180) describes a standardised interface suitable for most appliances that can make such communication feasible.

Innovative or optimised components

Johannes Jungbauer et al. focus on "Measurements of individual chiller systems compared to district cooling solutions" (6-061) in commercial and institutional buildings in Europe. Most users or owners of building are unaware of the high cooling energy consumption and related costs because of missing metering and electricity consumption having an unknown share in the total electricity bill. The presented findings from France, Finland and Sweden reveal that real performance of chillers is by far lagging behind theoretical coefficients of performance. District cooling systems may be a more efficient alternative for the cooling of buildings than individual chillers. This is demonstrated by means of presenting primary energy factors for both district cooling systems and individual chillers systems.

Caroline Markusson et al. analyse the electricity consumption of pumps in heating systems, which may reach a significant share in the overall energy consumption of a nearly-zero energy building. Therefore a well pondered "System design for energy efficient pump operation in buildings" (6-365) is desirable. Applying small decentralised micro pumps – the pump being more or less integrated in a radiator's thermostatic valve – instead of a larger centralised pump may have several advantages. This has been tested in a typical Swedish office building. The monitoring results show significant electricity and space heat savings and related cost savings following the switch from central pumps to decentral micro pumps. These savings are mainly due to much better temperature control and a much better fit between heating schedule and office times.

Bruno Harald Philipson et al. investigate "Indoor comfort and energy savings by intelligent solar controlled windows in Southern Europe" (6-289). A roof window has been equipped with a smart control that activates opening and closing of the window and thus provides for natural ventilation. Moreover it activates an external shutter and thus provides shading or additional insulation depending on the context. A lot of thought has been put into the development of a suitable control algorithm which is in line with users expectations, thus avoiding being overridden by the users. The almost-passive system has proven to have a very positive effect both on energy consumption, especially as to cooling needs, as well as on indoor thermal comfort.

Dynamic simulations for innovations

Andreas Jonsson et al. present results of their research on "Optical characterisation and energy simulations on switchable mirrors" (6-110). Again an advanced "almost passive" technology which is mainly meant to reduce unwanted solar gains and cooling needs is spoken of. The "mirror" is a window pane with variable characteristics as to solar gains "(g-value or SHGC) and heat loss (U-value) being activated by different chemical states of the gasochromic coating". These characteristics can be switched between a reflective (mirror) state and an absorbing (transparent) state. Combining these characteristics with a smart control algorithm may result in a much improved energy balance of the window compared to a standard window which is demonstrated by means of simulation results for different office and residential profiles.

Bart de Boer et al. present a very interesting “backcasting” simulation exercise in their paper “Climate adaptive building shells for the future – optimization with an inverse modelling approach” (6-048). The starting point for their analysis is the fact that today’s building shells are usually designed as fairly static systems as to solar heat gain coefficient (g-value, SHGC) and heat loss (U-value). What improvements could be achieved in energy consumption and indoor climate if these parameters could be variable and controlled? An ideal adaptive behaviour of the building shell would make it possible to maximise comfort and to minimise energy demand. The result of this inverse modelling approach reveals a potential to practically eliminate the heat demand and to reduce the total heating and cooling demand by a factor of 10 compared to the state of the art for newly built Dutch office buildings.

Paolo Zangheri et al. assess “How the comfort requirements can be used to assess and design low energy buildings” (6-531) by testing the EN 15251 comfort evaluation procedure in 4 buildings. The main objective of a building is to offer a comfortable environment for human occupation. Recently the new standard EN 15251 has been elaborated with the aim to quantify the indoor environmental parameters. The authors have studied the large-scale applicability of the standard with an extensive field study using four existing buildings in Italy and the possible implications of the comfort targets on the design of zero energy buildings and deep renovations. A major conclusion is that more restrictive comfort requirements may in fact push the application of active systems and thus counteract the application of passive systems which experts consider to be the basis for the design of nearly-zero energy buildings.