Introduction to Panel 8 Products, systems, and technologies to decarbonize buildings

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Introduction

The panel explores the possible contributions of products, product systems and technologies to climate neutrality of buildings and building stocks. Contributions address the three strategies of energy sufficiency (reduce demand), energy efficiency (operate intelligently) and renewable energies (decarbonise).

From the individual product or technology to whole building stocks, from the roll-out of technologies to their interaction with users, from optimistic views on the potentials of digitalisation to calls for their selective and well-considered use, from case studies to modelling approaches, the panel covers a wide range of topics, perspectives and methods.

Evaluating buildings, products, and technologies

Technologies for more efficient buildings and technologies are continuously being improved. Still, performance gaps often remain between the design performance of a building and its actual performance in the operational phase. Refined methods help to assess the actual energy performance of buildings and technologies, as demonstrated in several contributions. Carton (extended abstract 8-265-24) and Loup (peer-reviewed paper 8-069-24) explore the impact of high-performance windows on building energy performance. While Carton argues that EPBD guidelines for assessing transparent building elements' energy performance should consider factors like solar gains and geographical location as well as U-values, Loup emphasizes that high-performance windows, particularly low-e triple glazed ones, generally offer more CO_2 savings during operation despite their higher embodied CO_2.

Peinturier and Wallom (peer-reviewed paper 8-008-24) present a case study of how digital twin technology can be used to identify the causes for performance gaps in the operational phase of buildings, as compared to the design phase. In a similar vein, Zhang et al. (peer-reviewed paper 8-011-24) compare the performance of a building in two energy models, representing the design and as-built phase. Parameters for the as-built phase stem from a test house that has been constructed and measured in a climate chamber.

Rolling out efficient buildings, products, and technologies

Yet, technological progress is but one side of the coin. Rolling out technological innovations can be a challenge, influenced by factors such as economy, culture, established infrastructures or consumer acceptance. Various policy instruments may be needed to support the roll-out. Contributions explore these challenges for different technologies. Niknafs et al. (peer-reviewed paper 8-019-24) explore barriers to and drivers for increased use of wood-based materials in the construction industry. They combine a mapping of wood flows with insights from stakeholder interviews of the construction sector. Singhal et al. (peer-reviewed paper 8-144-24) deal with efficient fans, given the pivotal importance of cooling technologies for an emerging economy in a hot climate like India. They explain the approach of a real estate company for testing such fans on-site and rolling them out in their properties. Siderius et al. (peer-reviewed paper 8-001-24) present an overview of policies for rolling out efficient data centres and estimate their savings potential. They

also do a deep dive into metrics for the energy efficiency of data centres which could serve as a basis for such policies.

Among the technologies for decarbonizing buildings, heat pumps play an especially prominent role. However, in many countries, obstacles for their widespread deployment must still be overcome. Roy et al. (extended abstract 8-096-24) explore the potentials of micro heat pumps for multi-family homes in the United States and describe efforts to accelerate their market uptake by coordinated stakeholder action. Also, for the United States, Outcault et al. (peer-reviewed paper 8-298-24) analyse, based on an expert survey, adoptability factors for heat pumps. Those factors include economical, technical and informational issues as well as environmental and non-energy impacts. The other way round, Wahlström and Jangsten (peer-reviewed paper 8-261-24) start from the observation that air-to-air heat pumps are already well established in North America. They discuss whether this could serve as an example for single-family homes in Sweden, drawing on a case study of energy efficiency and profitability.

Building energy supply options

Seasonal storage, heat recovery and CO_2-neutral energy sources are important key technologies on the way to decarbonizing future building heat supply.

Köhler and Ganal (peer-reviewed paper 8-230-24) assess the seasonal thermal energy storage demand in three German urban district heating systems, focusing on utilizing surplus heat from zero-/low-emission sources during summer and exploring Aquifer Thermal Energy Storage potential to minimize non-renewable energy demand.

Sevela et al. (peer-reviewed paper 8-094-24) identify Waste-Water Heat-Recovery (WWHR) technology as pivotal in reducing energy demand for domestic hot water, particularly in showering applications, offering up to 40 % energy savings with minimal material and monetary requirements.

Senkpiel et al. (peer-reviewed paper 8-278-24) examine the impact of integrating results from explorative bottom-up models into cross-sectoral energy system models, focusing on the buildings sector. They reveal challenges in achieving cost-optimal solutions due to high shares of biomass in the heating systems and emphasize the importance of sectoral attributions to avoid resource bottlenecks.

Building Stocks

Rapid transformation of the building stock, including both energy-efficient renovation and smart (re-)use, is key to achieving climate goals and saving resources. Drafting effective strategies depends, among other things, on our ability to provide an accurate picture of the structure and performance of the existing stock. Several contributions deal with improving the database and our understanding of the stock. Alibaş and Yu (peer-reviewed paper 8-299-24) develop a comprehensive building stock model for Germany, integrating various data sources to analyse and model the decarbonization of the building sector, providing the base for future regionalized energy demand projections.

Karczewski et al. (peer-reviewed paper 8-068-24) dig deeper into non-domestic buildings. They develop and test a methodology for assessing the energy consumption of buildings with different usage zones, using average usage profiles.

Arnold-Keifer et al. (peer-reviewed paper 8-135-24) explore energy efficiency potentials in Germany's tertiary sector, employing an integrated bottom-up and top-down approach to analyze specific energy applications and highlighting the importance of understanding methodological choices and input data dependencies in assessing future energy-saving potentials.

Shifting the focus, Thema et al. (peer-reviewed paper 8-050-24) move from building structure to building occupation. They offer insights into the ongoing development of a model that will project future patterns of occupation, providing a basis for assessing the effects of policies on distribution of living space.

Gaspard et al. (peer-reviewed paper 8-264-24), in turn, evaluate the French modeling community related to the building sector, highlighting strengths in capturing energy-related challenges but emphasizing the need for further development, particularly in integrating environmental impacts and reflecting on resilience to social and economic trends.

Finally, Bagheri et al. (peer-reviewed paper 8-240-24) move from stocktaking to drafting pathways: They reflect on an exercise of participative development of qualitative scenarios for a climate-neutral building sector in Germany.

Dynamics of consumption: less is more?

Strategies for a net-zero building sector need to respond to user needs and consider the impact of user behaviour on the energy consumption of buildings and appliances. Ben and Walker (extended abstract 8-067-24) explore the energy saving potential of adaptive thermal comfort strategies. They can show a consistent impact of such strategies on energy savings in office buildings under various insulation levels. On the other hand, Vrain and Wilson (extended abstract 8-171-24) analyse a case with more mixed effects. In a living lab trial on automated floor cleaning, they can show both positive effects on distribution of household chores, and energy consumption rebound triggered by higher cleanliness standards.

Energy sufficiency is a strategy to address rebound. Instruments to foster it are increasingly under discussion. Lage (extended abstract 8-268-24) presents one such instrument: minimum occupancy requirements for apartments in Swiss housing cooperatives and some municipalities. Based on qualitative interviews, its perception, acceptance and effects are evaluated. Finally, Wiese et al. (extended abstract 8-227-24) broaden the picture, proposing a cross-sectoral sufficiency strategy for Germany. In their contribution, they analyse current trends from a sufficiency perspective and formulate visions and concrete targets for energy demand reduction.

Smart, intelligent, digital?

Digital applications can help saving energy by controlling equipment, giving feedback or optimising processes. On the other hand, they consume energy themselves (including for servers and networks) and can trigger rebound. Three contributions explore potential positive and negative effects. Based on a meta-analysis, Wilson et al. (peer-reviewed paper 8-199-24) map the various mechanisms by which digital tools can affect energy use and assess the potential sizes of energy savings – or

increases. Soares et al. (extended abstract 8-290-24) and Bergman (extended abstract 8-164-24) deal with the relationship between legacy technologies and digitalisation from different angles. Soares presents a home energy management system that can manage non-smart equipment and appliances, and models its potentials to deliver demand-side flexibility. More sceptical of the benefits of digitalisation, Bergman suggests in his concept note considerations that can help to identify the "optimal" level of digitalisation, again building on a perspective of sufficiency.

The broad range of topics covered by the submissions to this panel shows that products, systems or technologies are no longer considered in isolation. Their contribution to energy savings and carbon mitigation is increasingly discussed with regard to their context of implementation – be it a building's operational phase in real life, interaction with user practices, a regulatory or economic context, or the place of such technologies in a broader sectoral mitigation scenario. Thus, these papers build bridges to other Summer Study topics such as policies, scenarios, or dynamics of consumption.