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THE TRADE-OFF BETWENN HEAT AND ELECTRICITY DEMAND REDUCTION AND COMFORT IN COMMERCIAL BUILDINGS – CONSEQUENCES FOR ENERGY MODELLING

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Overview

In energy policy analysis, results of sectoral energy models are used as important information. The type of models used to estimate the energy demand of the buildings' sectors are mostly process-oriented, often called as „bottom-up models". In these models energy demand is basically the product of the specific energy demand per square meter and the corresponding area. Input data for specific energy demand is based either on data derived from surveys or on more or less simple calculation or on building models. The latter are also used to estimate the effect of policy measures and programmes (e.g. insulation subsidy programs). More sophisticated bottom-up models include cost considerations of particular investments on energy-efficiency or heat protection. However, further economic implications like the valuation of co-benefits such as increased comfort or adverse effects of decreased thermal comfort are mostly neglected.

In order to calculate the physical implications of energy-efficiency (e-e) measures in more detail, they are often elaborated by using building physics models or methods (that are related to building standards and norms such as the Swiss SIA 380/1, i.e. SN EN 832). So far, policy measures and programmes aiming at reducing either the demand of heat and related fuel energy or of electrical energy were addressed more or less independently by the bottom up models (Aebischer et al 2006). Traditionally, interactions between e-e measures or investments for more comfort acting on different types of energy services such as heating, lighting, ventilation, air conditioning etc. are usually neglected (sometimes those implemented in SN EN 832 considered). This approximation might be acceptable for the residential sector and if the intensity level of the efficiency measures is not very extensive.

However, in many building types of the commercial sector there are significant interaction effects between the different types of energy services. Many e-e measures are multi-functional and act on two or more types of energy service. For instance, glazing or sun protections have an impact on lighting, heating and cooling demand. In particular, heat loss is reduced but also solar gains, cooling demand is intended to be reduced, but lighting demand and corresponding heat load is increased. In some cases, the interaction effect can even be greater than the intended e-e effect, particularly at the primary energy level. Further, e-e measures at the building envelop might have a considerable impact on thermal comfort. Comfort is improved during the heating periods, but could be substantially decreased during sunny periods (overheating). As a consequence, additional cooling might be necessary if comfort requirements are to be met, leading to additional electricity demand. The interaction effects have also a considerable impact on specific costs of energy-efficiency measures (average costs, marginal costs).

The paper reports on extensive research results (Jakob, Jochem et al. 2006) and points out the impact of interaction effects on input data and results of sectoral energy bottom-up models.

Methods

To estimate the impact of e-e measures on the structure and level of final energy demand of commercial buildings we use two models: the first model is a building physics simulation model (IDA-ICE). The second model is a typical bottom up model

(1) To take the physical interaction effects into focus a comprehensive building physics simulation model was used (IDA-ICE, similar to DOE 2). For each (dynamic) time step the model estimates the relevant heat and cooling energy and radiation flows including lighting demand as a function of available daylight. Reverting to this type of building physics models it is possible to take into account the interaction of different types of e-e measures. With this model, we calculate the specific energy demand on some typified commercial buildings (with different automation degree, different uses, and different shares of window area).

(2) The second model is a sectoral bottom-up cohort model. This model takes as input the specific fuel demand and the specific electricity demand of six different branches of the service sector and of three different levels of building use/automation, and data of the Swiss building stock.

To evaluate the interaction effects on the on medium and long term sectoral energy demand, we build three scenarios: a reference scenario and two scenarios to reflect the same efficiency policy measures, but using different sets of input data. In the first set of input data interaction effects are neglected. This set reflects the usual (traditional) approach. In the second set of input data, interaction effects are included, by using results from the building physics simulation model. The results are compared at the national level. The comparison of the results stemming from the two sets of input data are described and discussed.

Results

The simulated heat protection policies have rather distinct impacts on electricity demand and thermal comfort, particularly in buildings with high internal heat loads stemming from lighting, information and communication equipment, freezers, and users (customers, visitors). The impact on additional electricity demand increases in particular for buildings with cooling or in cases, where comfort requirements call additional cooling. On the other hand, it is also shown, how this increase in electricity demand can be reduced by intelligent control techniques, efficient illumination or other electrical appliances. As the reduction of electricity demand reduces the heat dissipation in the building, there may be some extra heat demand in winter depending on the total design of the efficiency investment.

Roughly spoken, a decrease of one kWh of heating energy demand by heat protection measures causes an increase of electricity demand of about one third to one half of a kWh for certain building types (in particular those with high internal loads). On the other hand, a decrease of one kWh of electricity by certain types e-e measures such as efficient lighting or light control strategies causes an increase of about one to three quarters of a kWh of heating energy demand, but also a further decrease of electricity demand for cooling (in buildings with cooling), and an increase of thermal comfort. For buildings with cooling, electricity demand. Other electricity e-e measures such as ventilation control strategies reduce electricity and heating energy demand simultaneously.

The impact of these results from the building physics model on the input data of the bottom-up models (including cost-curves) and on the results on the national level will be shown.

Conclusions

The results hint to the need that the bottom up models simulating the service sectors have to absorb the new knowledge stemming from the physical models in order to come up with more realistic results. The traditional bottom up models are likely to underestimate the additional electricity demand and the need to develop highly efficient building equipment and intelligent building constructions to diminish the trend of increasing electricity demand.