INTEGRATED ASSESSMENT OF ENERGY EFFICIENCY MEASURES IN AN INDUSTRIAL ENERGY SUPPLY SYSTEM – A CASE STUDY OF THE GERMAN PLASTIC PROCESSING INDUSTRY

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Overview

In the context of the german energy transition the german government set a variety of ambitious goals. Regarding energy efficiency these are i. a. the reduction of the primary energy consumption by 50 % until 2050 compared to 2008 as well as an annual increase of the final energy productivity by 2.1 % from 2008 until 2050. Analyses of the German Federal Ministry for Economic Affairs and Energy [1] show that at this point it is very unlikely that Germany is able to reach these goals. Therefore it requires additional efforts regarding the identification and evaluation of energy efficiency potentials (EEP) [1]. In 2015 the German industry had a share of 29 % of the total finaly energy consumption in Germany thus being of particular importance when trying to reach the proclaimed energy efficiency goals [2]. When evaluating the benefits of energy efficiency measures (EEM) industrial decision-makers depend on detailed information regarding the costs and energy saving potentials as well as possible interactions of EEM with the rest of the production system that influence the EEP [3]. At this point, there is no method for the holistic assessment of EEM considering the dynamic system behaviour as well as the interactions between EEM [4,5]. Therefore an energy demand model for the german plastic processing industry focussing on the integrated assessment of EEM for cross-sectional technologies has been developed. It is combined with an heuristic optimization approach. First results show that considering the interactions between EEM has a significant impact on the resulting EEP.

Methods

The model developed for this analysis is a deterministic, technology-oriented bottom-up energy demand model using a modular hierarchy structure, non-linear programming and a heuristic optimization approach. The scope of the energy demand model is the german plastic processing industry. Typicall plastic goods (i. a. frames, technical components) are produced in sector-specific production processes (i. a. extrusion, injection moulding). The demand for final energy is derived from the demand for those goods. Industrial production processes are commonly described in an hierarchical structure [6]. Within the scope of this study we mainly distinguish between the production process itself, including those processes that are directly involved in the processing or handling of the granulate (e. g. transport, drying, blending, extrusion, injection moulding), and the industrial energy supply system, including all the cross-sectional technologies providing usefull energy to the production process (e. g. cooling, heating, hydraulic, mechanic work). Within the energy demand model, the following cross-sectional technologies are implemented: electric motors, pumps, ventilation, compressed air, lightning, process cooling and air conditioning (heating and cooling). The modular structure allows an easy adaptation when modelling different industrial production processes. In order to consider the heterogeneous structure of the plastics industry, different representative companies with individual production processes are implemented. Based on the production process and the demand for a specific good the consumer specific synthetic load profiles for useful energy (and consequently the demand for final energy) are calculated endogeniously. The evaluation of the energy consumption of an industrial production processes requires the consideration of the production schedules [4] as well as spare capacities, as those determine the utilitsation of the different cross-sectional technologies in the industrial energy supply system. Therefore, the energy demand model uses a high time resolution considering partial load as well as full load. As the efficiency of most cross-sectional technologies decreases when operated at partial load, generic efficiency diagrams are derived from an extensive literature review and implemented in the energy demand model. Furthermore the energy consumption (as well as the EEP of the identified EEM) of the cross-sectional technologies is influenced by the used control concept. Therefore the most common control systems for the previously mentioned cross-sectional technologes are implemented in the energy demand model (e. g. for a pump one can choose between throttle control, bypass control, on-off control and using a frequency inverter for speed control).

As for the evaluation of EEM, when accouting for dynamic system behaviour and interactions between EEM, it is necessary to evaluate not only different combinations but also the order of implementation of EEM. This will be explained using the example of a pumping system. The energy consumption is mainly derived from the volume flow and the flow resistance in the piping system. If a more efficient pump of the same sizing is implemented first and the flow resistance of the piping system is reduced afterwards, the pump might be oversized. If on the other hand the flow resistance is reduced first one can choose a more efficient and properly sized pump that matches the reduced demand. Consequently it is necessary to evaluate all permutations of EEM making it a combinatorial optimization problem. Due to limited computing resources, calculating all permutations is only possible for a limited number of EEM. Therefore the previously described energy demand model uses an heuristic optimization approach considering technical restrictions, path-dependencies and strategic decision making. Those permutations where the EEM do not interact in the first place, that are not possible from a technical perspective or that make no sense from a strategic perspective are eliminated. The remaining permutations are evaluated and the one leading to the optimal solution, e. g. in terms of the maxium accumulated net present value (NPV) of the EEM, is selected.

Results

The previously presented approach for the integrated assessment of EEM is used to evaluated the EEP of a typical company producing technical components using the injection moulding process. First results show, that the economic EEP for the cross-sectional technologies amounts to 13.8 % of their final energy demand. Due to interactions between EEM the cumulated technical and economical EEP is reduced by 9.2 % and 8.3 %. Significant interactions are i. a. found when evaluating the EEP of pumping- and ventilation systems that mainly operate in partial load. For certain individual EEM the EEP is reduced by more than 50 % due to interactions. Extrapolating the results onto the national level leads to an economic EEP for companies producing technical components using the injection moulding process of 11.9 to 15.4 %.

Conclusions

Assessing the EEP of EEM in an industrial context requires new modelling methods and evaluation algorithms to account for the dynamic system behaviour as well as the interactions between EEM. The presented method for the integrated assessment of EEM is used for the evaluation of the EEP of cross-sectional technologies in the german plastic processing industry but is also applicable for the evaluation of different industries as well as technologies. First results show, that considering the interactions between EEM has a significant impact on the resulting EEP. Neglegting interactions when evaluating EEM might lead to imprecise information regarding the EEP, thus hindering the implementation of EEM due to the high requirements in the industrial context regarding the economic efficiency of EEM (e. g. in terms of amortisation).

References

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