Modelling of electricity savings in the Danish households sector: from the energy system to the end-user

In this paper, we examine the value of investing in energy-efficient household appliances from both an energy system and end-user perspectives. We consider a set of appliance categories constituting the majority of the electricity consumption in the private household sector, and focus on the stock of products which need to be replaced. First, we look at the energy system and investigate whether investing in improved energy efficiency can compete with the cost of electricity supply from existing or new power plants. To assess the analysis, Balmorel, a linear optimization model for the heat and power sectors, has been extended in order to endogenously determine the best possible investments in more efficient home appliances. Second, we propose a method to relate the optimal energy system solution to the end-user choices by incorporating consumer behaviour and electricity price addition due to taxes. The model is nonexclusively tested on the Danish energy system under different scenarios. Computational experiments show that several energy efficiency measures in the household sector should be regarded as valuable investments (e.g. an efficient lighting system) while others would require some form of support to become profitable. The analysis quantifies energy and economic savings from the consumer side and reveals the impacts on the Danish power system and surrounding countries. Compared to a business-as-usual energy scenario, the end-user attains net economic savings in the range of 30–40 EUR per year, and the system can benefit of an annual electricity demand reduction of 140–150 GWh. The paper enriches the existing literature about energy efficiency modelling in households, contributing with novel models, methods, and findings related to the Danish case.
Integrating load-balancing into multi-dimensional bin-packing problems

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Modeling of electricity savings in the Danish household sector using Balmorel
In this paper we examine the investments in energy-efficient household appliances from an energy system perspective. We consider a set of ten appliances constituting the majority of the electricity consumption in the private household sector, and investigate whether investing in improved energy efficiency can compete with the cost of electricity supply from existing or new power plants. To assess the analysis, Balmorel, a linear optimization model for heat and power sectors, has been extended in order to assess the best possible investments in more efficient household appliances. The model is non-exclusively tested on the Danish energy system under different scenarios, and computational experiments show that several energy efficiency measures in the household sector should be regarded as valuable investments, while others would require some form of support to become profitable.

The analysis also reveals the impact that changes in the Danish electricity consumption would have on the surrounding countries in terms of power system configuration and emission reduction.

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Modeling of electricity savings in the Danish household sector using Balmorel
The load-balanced multi-dimensional bin-packing problem

The bin-packing problem is one of the most investigated and applicable combinatorial optimization problems. In this paper we consider its multi-dimensional version with the practical extension of load balancing, i.e. to find the packing requiring the minimum number of bins while ensuring that the average center of mass of the loaded bins falls as close as possible to an ideal point, for instance, the center of the bin. We formally describe the problem using mixed-integer linear programming models, from the simple case where we want to optimally balance a set of items already assigned to a single bin, to the general balanced bin-packing problem. Given the difficulty for standard solvers to deal even with small size instances, a multi-level local search heuristic is presented. The algorithm takes advantage of the Fekete-Scheppers representation of feasible packings in terms of particular classes of interval graphs, and iteratively improves the load balancing of a bin-packing solution using different search levels. The first level explores the space of transitive orientations of the complement graphs associated with the packing, the second modifies the structure itself of the interval graphs, the third exchanges items between bins repacking proper n-tuples of weakly balanced bins. Computational experiments show very promising results on a set of 3D bin-packing instances from the literature.

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Plans to reduce consumption of fossil fuels and hence emissions of CO2 include substitution to renewable energy sources, increased use of electricity and considerable efficiency improvements. Numerous studies have analysed and shown the feasibility of substitution to and integration of renewable energy sources. However, further studies have proven the existence of the energy-efficiency gap (EEG) and experience from various support and promotion policies have revealed that the EEG is hard to overcome. On the basis of these findings the aim of this project is to identify relevant factors influencing the EEG and to derive recommendations on how to surmount the EEG. An economic engineering approach is used to identify potentials of efficiency improvements. Based on this, we conduct a comprehensive micro-economic analysis of energy-saving investment behaviour of industries and households, i.e. identifying barriers for adoption and incentive schemes to resolve them. Combining potentials, barriers and incentives, strategies for implementing targeted improvements are developed and the trade-off between efficiency improvements and supply from renewable energy sources analysed. To evaluate macro-economic effects of the investments in savings a small macroeconomic model with detailed energy specifications is developed. Using this model, effects on growth, employment and public finances from using various incentive schemes are quantified.

The objectives of the project are to:

- Identify and quantify technical, economic and social barriers for potential energy savings.
- Analyse implementation strategies, evaluate incentives schemes, and find optimal trade-offs between efficiency improvements and additional renewable energy supply.
- Evaluate macro-economic effects of efficiency improvements and alternative incentive schemes.
- Contribute to development of methods and theory in the intersection of energy systems, behavioural economics, energy economics and stochastic programming areas.

Department of Management Engineering
Systems Analysis
Energy Systems Analysis
DTU Climate Centre
Management Science
Dansk Energi
University of Copenhagen
Roskilde Universitet
Statens Byggeforskningsinstitut
Simon Fraser University
Norwegian University of Science and Technology
Danish Energy Agency
Rockwool International A/S

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Project participant:
Henningsen, Geraldine (Intern)
Møller Andersen, Frits (Intern)
Pade, Lise-Lotte (Intern)
Juul, Nina (Intern)
Pisinger, David (Intern)
Bolwig, Simon (Intern)
Petersen, Sebastian Christoph (Intern)
Trivella, Alessio (Intern)
Project Coordinator:
Klinge Jacobsen, Henrik (Intern)

Relations
Publications:
Optimal trade-offs between energy efficiency improvements and additional renewable energy supply: A review of international experiences
Trade-offs between Energy Efficiency improvements and additional Renewable Energy supply: A review of international experiences
Modeling of electricity savings in the Danish household sector using Balmorel
Demand-side management
Danish household load profiles and the effect of savings for appliance categories
Documents:
Project description
Project