# *CONNECTING THE HEAT AND ELECTRICITY MARKET TO ACCOMODATE RENEWABLE ENERGY*

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## Overview

Renewable capacity growth is substantial around the world. Particularly the fluctuating renewable energy sources of wind and photovoltaics form the main pillars of future electricity generation. This strong renewable development comes along with distinctive challenges for technical and market integration. A key issue is to find reasonable use for excess fluctuating renewable electricity generation.

The idea is to equip conventional options for heat production with options to produce heat with electricity. This holds great promise for addressing the vexing challenge of matching an increasing share of electricity supply from fluctuating renewable energy sources with an inelastic energy demand. The objective is to find out whether there is a intrinsic micro-economic benefit for consumers and producers to shift electricity consumption for heating purposes in dependency of the momentary requirements and market signals. This connection of the heat and electricity market is further analyzed for macro-economic value and market interaction effects. The chosen approach combines two focus areas of current scientific research in order to integrate renewable electricity generation: flexibility on the demand side and market-based operation.

## Methods

The model analyzes the potential of heat production with electricity for definite framework conditions of the heat and electricity market. 1st, the study draws on empiric data of the electricity market for Germany. Following current scientific knowledge a reproducible model based on the residual load is applied. This multivariate short-term price model, which includes a deterministic and a stochastic part, is developed to reflect the functional correlation of electricity prices and fluctuating renewable electricity generation. 2nd, heat demand is modelled using empiric data for residential and district heating as well for a paper and a chemical company. At the end, two models are combined: The model of price formation in the electricity market and the decision model for the heat producer. The combination of two models for simulations and the essential use of empiric data are distinguishing features of the paper.

The applied approach is based on the idea to equip conventional capacities with additional power to heat systems, and to shift operation times to renewable electricity. The market-driven operation of power to heat is in the focus of this paper. From an economic perspective, the electricity demand for heating purposes must compete with conventional heat production cost in the investigated sectors. Short-run marginal cost curves for heat production are calculated for conventional and power to heat systems. A short-run marginal cost curve represents the relation between incremental cost in the short-run of a good and the quantity of output produced. Hourly specific spread patterns for 22 years for diverse applications in the different sectors are processed.

## Results

First, the paper shows that it is technically feasible to produce heat with electricity in the investigated sectors and that the heat market can be yielded for excess supply from renewable energy. Technical complexity is highest for the industry sector. Electrode boilers are suitable for providing process steam, but the high process steam requirements make downstream superheaters necessary. Nonetheless, the corresponding economy of scale effect decreases average specific investment cost in the paper and chemical industry. Specific investment cost are higher for district heating despite modest technical requirements. A higher the norm standard of a residential building improves thermal efficiency, which lowers the thermal demand for heating purposes. The optimal design for power to heat systems is shifted to smaller capacities, which also lowers the potential for electric heat production within the residential sector.

A trans-sectoral economic comparison is the focus of the second section. Analysis show that in all application fields the levelized cost of heat are competitive with the conventional heat production cost. As shown in **Fig. 1** a comparison with conventional heat production reveal distinctive marginal revenues, if electricity is used for heat production in times of low electricity prices. However, these results are restricted to the exclusion of state-induced price components. In Germany, the benefits in electricity use for heating purposes will be small, if the full extent of taxes and levies on electricity consumption is considered. Economic operation is limited to the paper and chemical company due to prevalent tax exceptions for energy intensive industries.

Subsequent section of the paper describes market interaction effects. Flexible demand interacts with the electricity market and has an electricity price stabilizing effect. Higher electricity prices inhibit the economic efficiency of heat production with electricity that accompany a self-stabilizing effect.

Final investigation with focus on macro-economic criteria shows that distinctive advantages come with the connection of the heat and electricity market. 1st, heat production with electricity increases the use of renewable electricity generation. 2nd, it leads to higher short-term electricity prices. 3rd, heat production with electricity promotes a solution for the strong fossil fuel dependency of the heat market. **Fig. 1** shows the substantial final energy consumption for electric heat production. Heat production with electricity has an efficiency of almost 100 % and substituting conventional heat in a more efficient way implies that total final energy consumption declines. The reduction of $CO_2$-emissions by using renewable electricity for heat production rather than gas as fossil energy source is moreover illustrated in **Fig. 1**. Substitution of fossil combustion with renewable sources is indispensable in order to fulfill national, European or global $CO_2$-emissions obligations. It is especially efficient in the heating sector, where decarbonization has been sluggish.

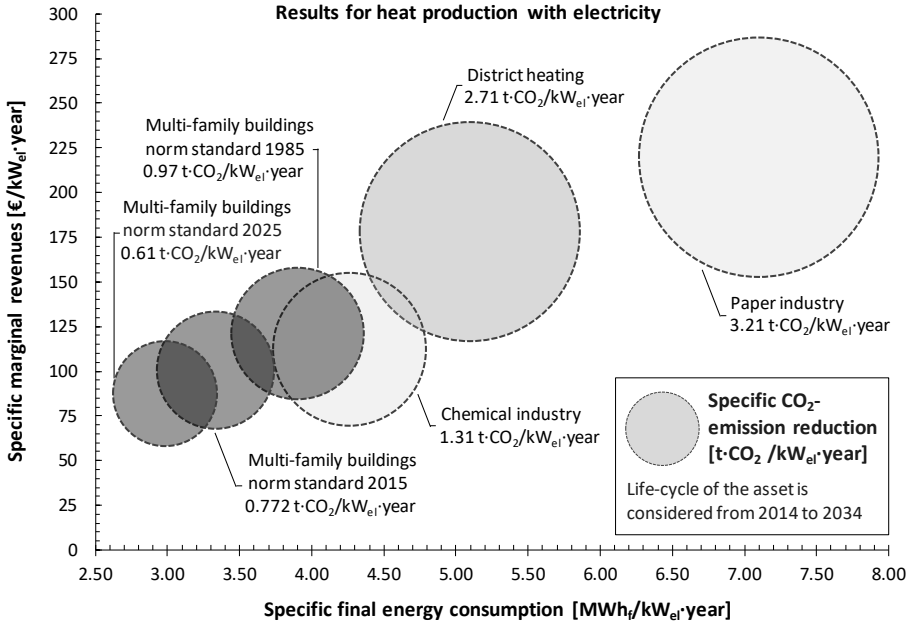


***Fig.1:*** *Impact of heat production with electricity on marginal revenues, final energy consumption and $CO_2$-emission reduction; without state induced price components for electricity purchase, moderate price scenario, gas as source for conventional heat production, sector specific parameters are implemented in the simulation model*

## Conclusions

Among the key findings is that economic performance for heat production with electricity depends strongly on the regulatory framework, especially as regards taxes and levies. Policy-relevant conclusion is that government intervention will be required to reach a socially optimal level. Matching flexible demand with a fixed structure of state-induced components is not adequate. Regulatory intervention is advised to establish a time-variable tax structure, reflecting the system stability situation. Especially a transparent electricity market price is further recommended to overcome barriers for market integration.

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