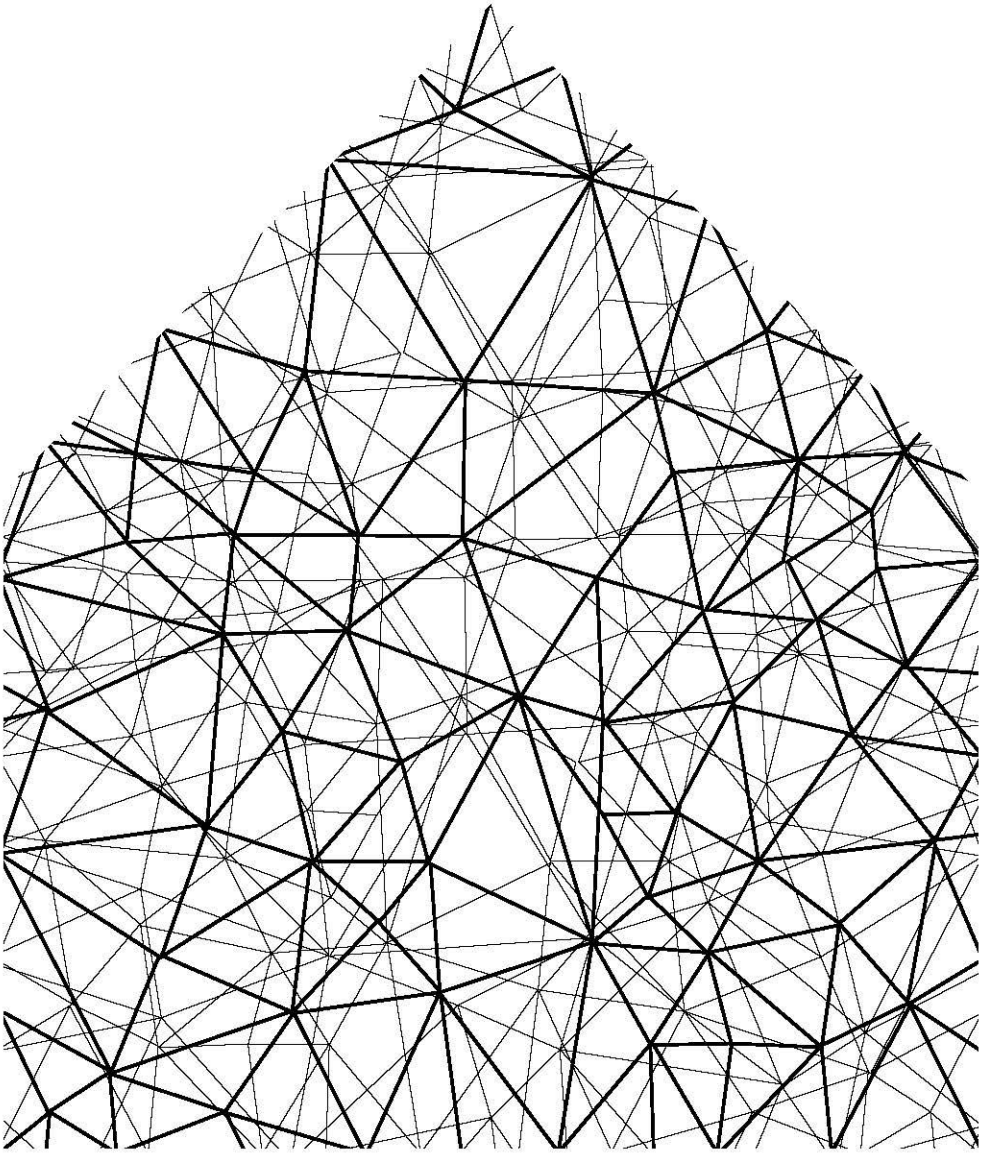
Buildings as intelligent components in the energy system

Load management potential of buildings in the context of the future energy supply structure in Germany



Buildings as intelligent components of the energy system

Load management potential of buildings in the context of the
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Abstract

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1 Introduction

The increasing share of renewable energies in Germany (see Figure 1.1) brings new challenges for the electrical power system. One approach to integrate the fluctuating renewable energy production is the modification of consumer demand (demand-side management, DSM). This project investigates the DSM potential of heating systems for buildings and its effect on the power system.

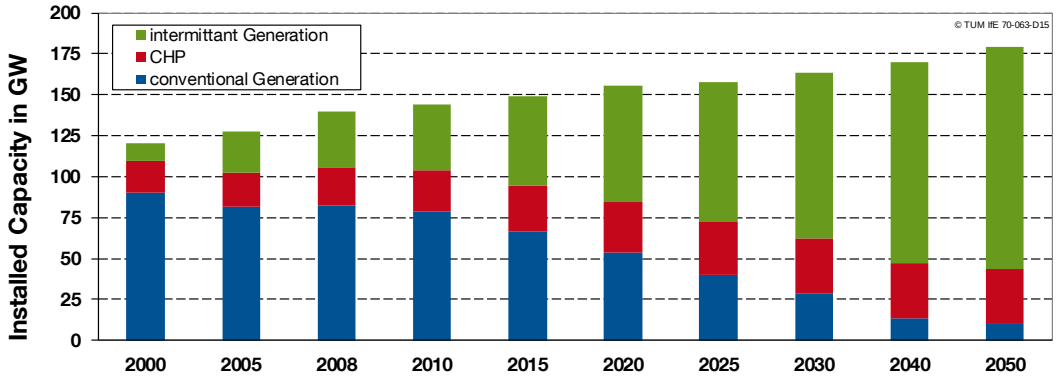

Figure 1.1 Development of the installed power capacity in Germany with an increasing share of variable renewable energy and a decrease of controllable power plants [1]

2 Aim of the research project

In this project a combined simulation approach is used to investigate the influence of heating systems on the electric power sector. Detailed building models including the control system are coupled with an energy system model (see Figure 2.1). Thus, the influence of buildings on the power system can be investigated in detail.

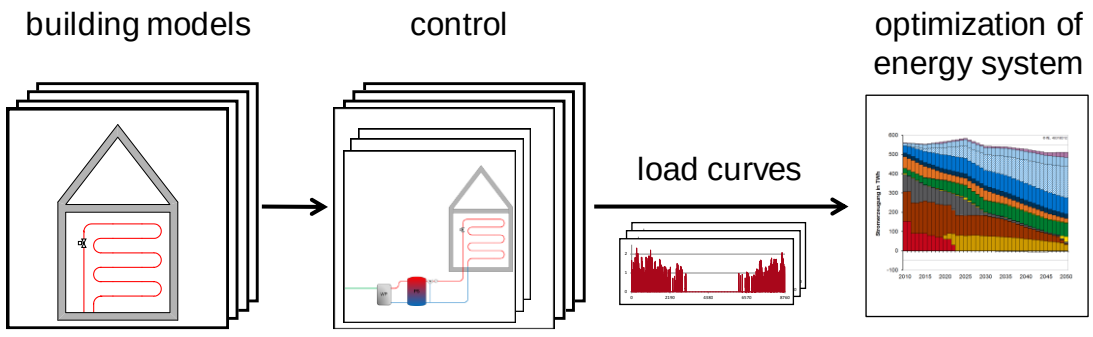

Figure 2.1 Buidling models and controller coupled with the energy system model

The building models are divided into the building types “single-family house” (SFH), “apartment building” (APB) and “office building” (OFB), based on the classification carried out in [2]. By considering these building types up to 75% of the overall final energy consumption for heating in Germany is assessed. Each type is further divided into the energy efficiency categories “Old Building”, “Old Building +”, “New Building” and “New Building +”, which represent the building standards given in Table 2.1.

Building type	**Energy efficiency category**			
	Old Building	**Old Building +**	**New Building**	**New Building +**
SFH				
APB				
OFB	BAK 1: until 1976 Source: [4]	BAK 3: 1984-94 or 2nd WschVO Source: [4]		

BAK (*Baualtersklasse)*: Building Age Group; WschVO *(Wärmeschutzverordnung)*: Thermal Protection Regulation; EnEV *(Energieeinsparverordnung):* Energy Saving Regulation; KfW (Kreditanstalt für Wiederaufbau): Reconstruction Loan Corporation

Table 2.1 Definition of the energy efficiency categories used in this project

For the different building types various heat transfer systems, such as radiators and underfloor heating systems are considered. Each transfer system can be combined with a possible heat generation system. Thus, conventional heating systems, such as oil and gas fired boilers as well as electrical heat pumps are taken into account.

In order to analyze the influence of the building performance on the energy system up to the year 2050, the evolution of the building stock composition regarding building types and their heating systems is assessed under consideration of demolition, retrofitting and new construction rates. To this end, a software tool was developed, which defines the state of the building stock by making decisions about its transformation, based on costs and scenario dependent specifications. Figure 2.2 shows the structure of the software tool. Starting from the existing composition of the building stock [5] [6], the demolition rate and new construction rate are initially applied. Subsequently a defined percentage of the buildings are upgraded, comprising a constructive specific retrofit as well as an exchange of heating systems. This results in a new composition of building types and heating systems and enables the calculation of the overall electric load profile of the resulting building stock, which is finally used within the energy system model.

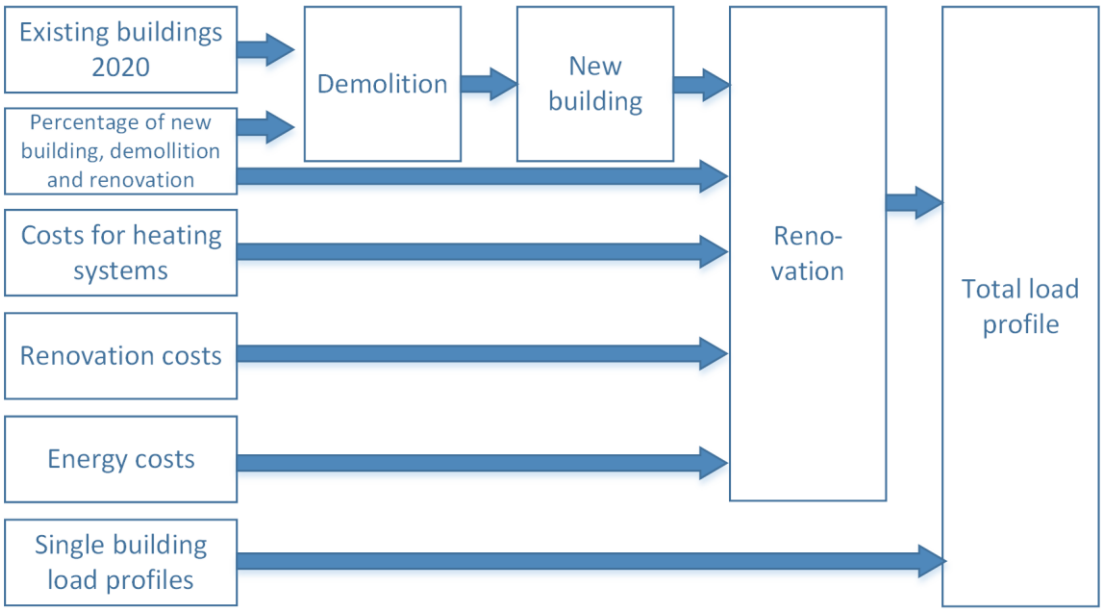

Figure 2.2 Structure of the software tool for making renovation decisions and calculating the total load profile

The energy system model IMAKUS [7] uses the load profile mentioned above to investigate the DSM potential of buildings. IMAKUS is a model for optimal expansion and dispatch of power plants and storages with the objective of covering a given electricity demand by minimal costs. The general structure of IMAKUS is presented in Figure 2.3.

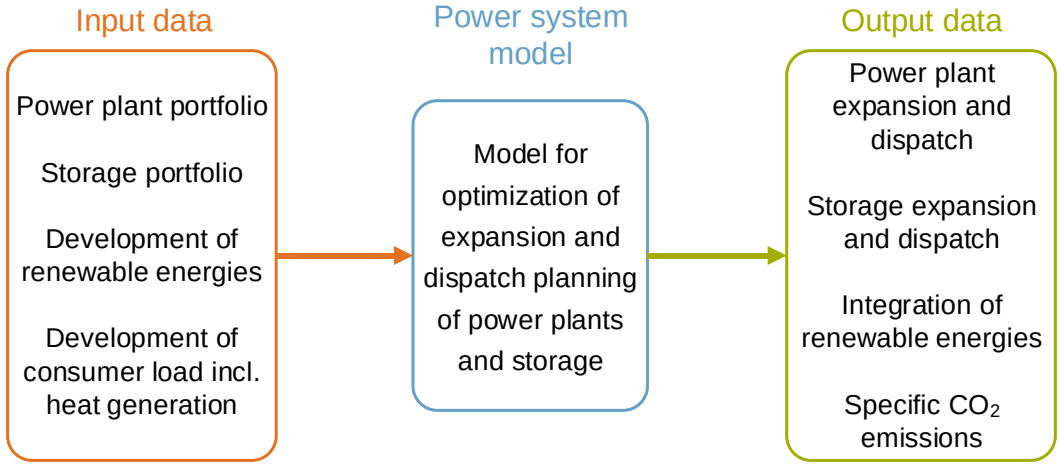

Figure 2.3 General structure of the energy system model IMAKUS [8]

Inputs to IMAKUS are the existing power plants and pumped hydro energy storages in Germany. The development of renewable energy and combined heat and power (CHP) systems is predefined and the energy produced by them has to be used.

Based on the described approach, different scenarios are analyzed. In the “Base” scenario, the building stock transformation is defined to be cost driven, whereas in the “Heat pump” and “Old building – heat pump” scenarios, the implementation of solely heat pumps in retrofitted buildings and new constructions is predefined. In the “Old building –

heat pump" scenario, additionally, only buildings of the energy efficiency category "old building" can be retrofitted. The resulting electric load curves are shown in Figure 2.4.

The scenarios based exclusively on heat pumps, were analyzed by implementing an "optimal control", which shifts the power consumption of the buildings based on a given electricity price signal. The results were compared to those from the analysis carried out using a "non-optimal control".

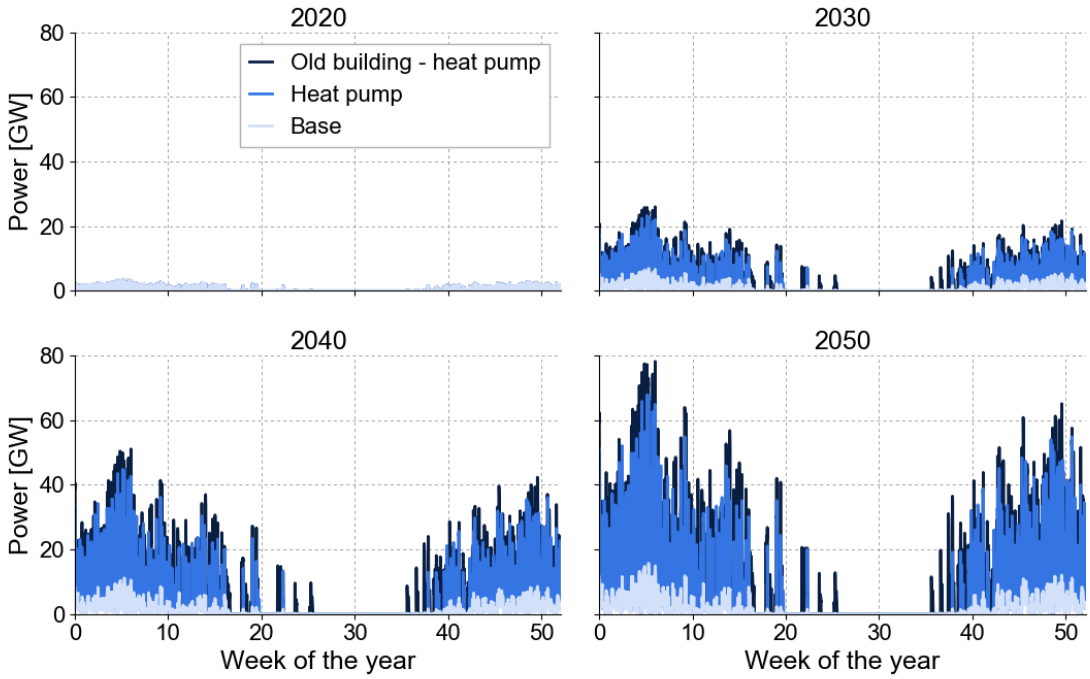

Figure 2.4 Total load profile of all buildings for the years 202, 2030, 2040, 2050 and the scenarios "Base", "Heat pump" and "Old building – heat pump"

3 Summary

In this project, the influence of electric heat generation in buildings on the electric power system was investigated using combined simulation models.

The results were evaluated regarding the composition of the electric energy mix, the installation of energy storages and the development of the CO_2 emissions. The increasing electricity demand caused by the electrification of the heating system can mainly be covered by renewable energies. The emissions from electric heating systems are significantly lower than for conventional gas boilers (see Figure 3.1). The optimal control of the heating systems decreases the emission even further. Additionally, the installed capacity of energy storages can be reduced and storage losses can be

minimized by using the produced renewable energies directly. The results of this project show, that increasing the share of electric heating systems has generally a positive influence on the energy system.

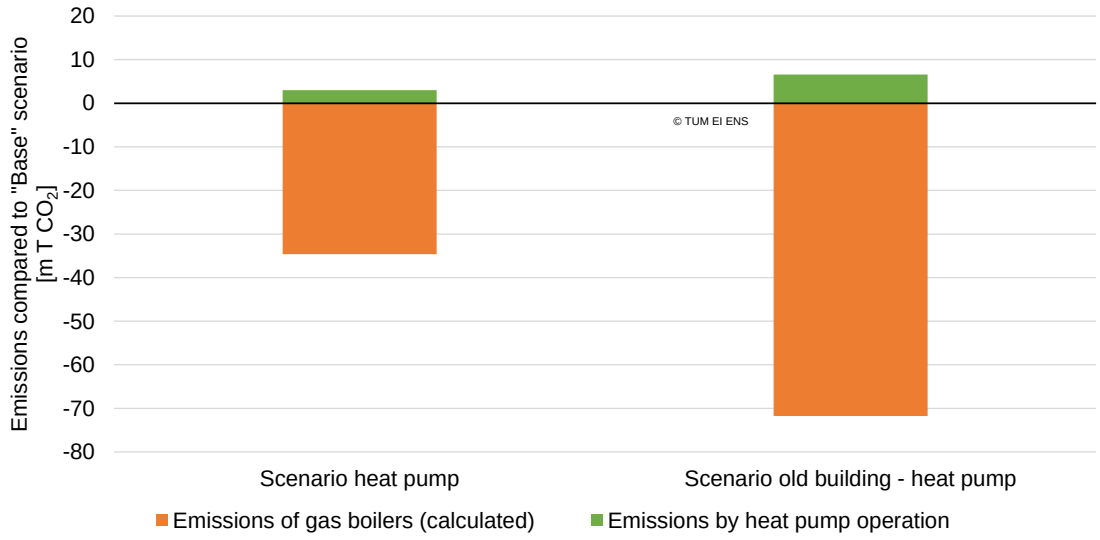

Figure 3.1 Compariosn of the substituded CO_2 emissions

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