Model-based design of integrative energy concepts for municipalities

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Kurzfassung

Steigende Energiepreise und veraltete Anlagentechnik stellen die Wohnungswirtschaft vor die Herausforderung, über neue komplexe Systemlösungen inkl. der Nutzung von regenerativer Energie und Speichersysteme nachzudenken. Die Gemeinde Lohmen und die ortsansässige Wohnungsgenossenschaft beauftragten daher EA Systems und das IB Dr. Lerche mit der Erstellung eines integrierten Quartiersenergieversorgungskonzepts für den historischen Ortskern der Gemeinde.
Dieser Beitrag zeigt dabei, wie mit Hilfe des ‚Green Building' Simulationspakets und SimulationX™ unterschiedliche Energieversorgungssystemvarianten für die bestehenden Gebäude modelliert und simuliert werden. Diesbezüglich werden Herausforderungen in der Modellierung, innovative Lösungen sowie einige exemplarische Simulationsergebnisse diskutiert.

Abstract

Increasing energy prizes as well as outdated building systems present housing industry with the challenge of determining new complex system solutions including renewable energy and storage systems. Municipality Lohmen and the local housing association ordered EA Systems and IB Dr. Lerche to develop an integrative energy system concept for the historic town center.
This paper shows modeling and simulation of differing energy system variants for existing building structure using 'Green Building' package and SimulationX™. That way, challenges of modeling, innovative solutions as well as some exemplary simulation results are discussed.

Introduction and Motivation

In Germany, most buildings were erected in times before any heat insulation regulations existed. That way, most of them had to be refurbished from time to time to reduce thermal energy consumption and to adapt them to current legislative requirements (e.g. Energy Saving Ordinance).

Especially in East Germany, last regionwide refurbishment measures took place in the 90's of last century. That way, most buildings still accomplish current energetic requirements. However, the building energy systems installed at that time reach ages around 20 years, normally seen as these systems' end-of-life periods. This way, building owners, however they are private or public, have to think over new refurbishment measures.

Conventional measures to exchange existing, outdated heating systems by more efficient system components (e.g. gas-fired condensing boilers) enable reduction of energy consumption in a signficant way. But increasing energy prizes and upcoming legislative requirements to reduction of carbon dioxide emissions induce that these measures will not be sufficient enough. Innovative ideas, like integrating renewable energy systems and storages, have to be proved regarding applicability for specific building situations.

To meet this chalange, municipality Lohmen and the local housing association ordered EA Systems and IB Dr. Lerche to develop an integrative energy system concept for the historic town center. This way, local characteristics, especially regarding renewable energy availability, have to be scrutinized. Regarding this, applicable energy system variants have to be derived and evaluated regarding energy-efficiency, economical requirements and further ecological aspects.

But given complexity requires new analyzing methods. Renewable energy availability has to be analyzed in combination with strongly usage-dependent energy consumption profiles as well as state-specific applicability of partly new storage systems (e.g. batteries). That way, only dynamic simulation of different energy systems can provide sufficient results for an adaquate system evaluation.

As a newly-developed simulation environment EA Sytems' 'Green Building' simulation package in ITI's SimulationX™ simulation environment was used to fulfill given engineering task. Since it has been developed especilly for such applications, 'Green Building' can be used to easily model complex energy systems including renewables, storages as well as complex building structures in one simulation environment.

‘Green Building’ Simulation Package

Modelica is an equation-based and domain-overall modelling language. That offers the possibility to model complex building energy systems with different domains (e.g. heat, electricity, control) using differential-algebraic equations. These equation systems can be edited and solved within one simulation environment.

That is why EA Systems used Modelica and the versatile simulation environment SimulationX™ to develop ‘Green Building’ for building energy system simulation. Thereby, an approach widely used in the automotive industry was adapted by creating several elements for renewable energy production and heating systems as well as storages and electrical or thermal consumers. Most of the models represent real world objects like vehicles, electrical inverters or valves. Thereby granularity and complexity of each element is in the same range, all in the objective of flexible yet easy modelling. Focus of modeling is on interactive behavior of different energy system components with differing complexity in context of building energy supply, either thermal or electrical. Although, building itself can be modeled using a number of thermal zones as a complex thermal and electrical energy consumer, detailed thermal building simulation, for example to simulate differing thermal conditions in one room, has to be done with more specified tools, like EnergyPlus.

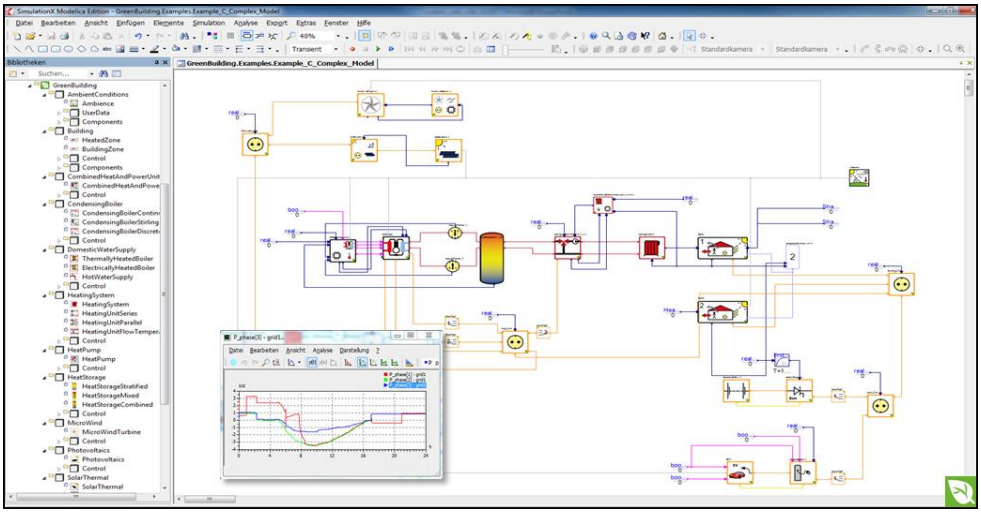

Figure 1: Renewable energy system including building in simulation environment

Figure 1 shows ‘Green Building’ simulation environment in ITI’s SimulationX™ with an comparatively easy model of a single-family home including a heat pump providing heat as well as a micro-wind turbine and a photovoltaic system as renewable energy source.

Modeling municipal area of Lohmen with renewable energy supply

The analyzed municipal area of Lohmen, a small town in the mid of German Free State of Saxony, includes altogether twelve buildings respectively building complexes. Besides ten dwelling houses, built in the 1960's and 70's also the over 500 years old Lohmen castle, office of municipality, as well as the school complex with five separate building parts are in focus of analyzes.

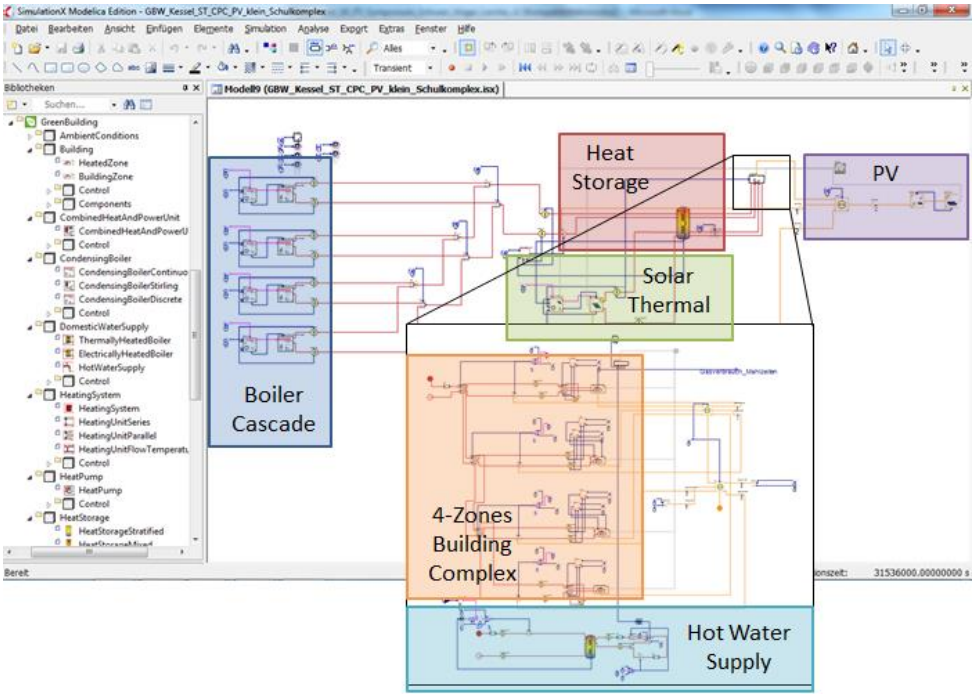

Figure 2: Model of school complex with 4 thermal zones hot water supply as well as energy supply by a boiler cascade, a photovoltaic and solar thermal system

Figure 2 shows one exemplary model of school complex including four building models (with twelve 'Green Building' *BuildingZone*-Models) for all single building parts (e.g. sports hall), a condensing boiler cascade as primary heat supply as well as an additional solar thermal and an photovoltaic system for renewable heat and electricity production. This example shows the chosen modeling paradigm to model electricity and heat consumption including hot water demand in separate submodels. These model parts can be easily connected to different variants for energy supply systems, either with or without renewable system components.

All in all over 70 variants for single building energy supply as well as two major variants for complex energy supply of complete area (e.g. by

heating all building complexes by a water/water heat pump cascade using water of local river Wesenitz as heat source) are simulated.
As an example some special results for single energy supply analyzes for school complex shall be shown in the following. Basically, all variants are designed regarding each building's requirements on heat and electricity. For example, solar thermal systems are dimensioned regarding hot water demand in summer and funding-dependent sizes of heat storages. That ensures minimum initial acquisition costs and maximum system efficiency. Following system variants has been analyzed for school complex:

- Existing building with two 15 years old condensing boilers
- Refurbished energy system (e.g. risen pump efficiency) with some adaptions at building insulation
- New condensing boiler cascade with modulating working burners
- Condensing boiler cascade with small Stirling-CHP
- Condensing boiler cascade with CHP
- Condensing boiler cascade with solar thermal system (CPC)
- Condensing boiler cascade with CPC collectors and small photovoltaic system
- Condensing boiler cascade with small photovoltaic system
- Condensing boiler cascade with big photovoltaic system

These nine variants have been simulated for weather conditions of Lohmen.

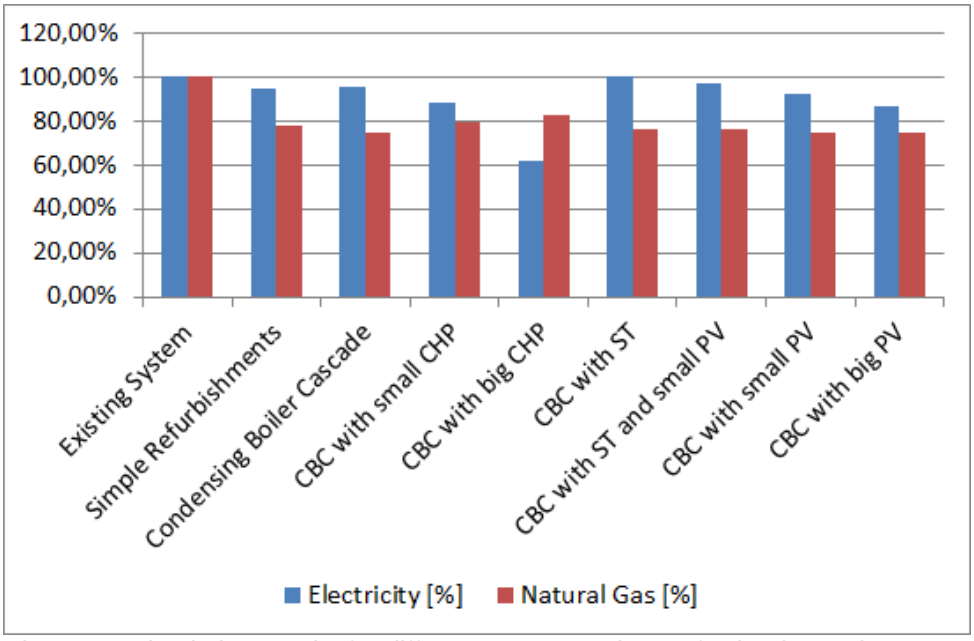

Figure 3: Simulation results for different system variants of school complex

Figure 3 shows the simulation results for electricity and natural gas demand of school complex with different variants of energy system. All results are presented relatively to results of existing old condensing boiler cascade. All variants except exitisting system are simulated with simple refurbishments of building's heat transfer system (e.g. pumps) and building insulation. It can be seen that even the simple refurbishment measures can cause significant reductions of heat and electricity demand. However, variant 3 with the new condensing boiler cascade is the first suitable energy system variant for longer terms decissions because of existing boiler's age.
Furthermore, it is evident that system variant 5 with a big combined heat and power unit (CHP) could be the most interesting variant regarding energy consumption and system efficiency because electricity demand can be significantly reduced without that much increasing natural gas consumption.

Summary

This paper shows how SimulationX™'s 'Green Building' package was used to analyze and to evaluate different suitable building energy system variants of a municipal area. Therefore, some chosen modeling paradigms are presented to depict how to use 'Green Building' in case of simulating larger building complexes. Furthermore, some exemplary simulation results are shown for one single building part. However, during the presented work also more complex system variants including all buildings and centralized energy supply systems were analyzed.
Most of all simulation models are relatively complex. Single building energy system simulation took 0.5 to 4 hours to simulate one year. This way, it is evident that 'Green Building' can be used to economically analyze complex variants of building energy systems. Paralization by using multi-core computing can further improve this aspect.

[1] Schwan, T., Unger, R., Lerche, Dr.-Ing. C.: 1. Zwischenbericht – Erstellung eines integrativen Quartierskonzepts für das Quartier Schloß- und Ringstraße in Lohmen. EA Systems Dresden GmbH, June, 2013.

[2] Unger, R.; Schwan, T.; Mikoleit, B.; Bäker, B.: Bessere regenerative Energieversorgung für Quartiere und Gemeinden durch systemübergreifende Simulation, 5. Internationaler Kongress Bauhaus SOLAR, Erfurt, 13./14. November 2012.