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Towards Grid Friendly Zero Energy Buildings

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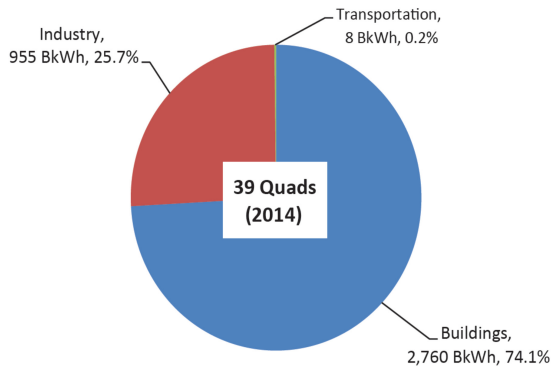
Fig. 1. US Annual Electricity Use 2014

Fig. 2. System Boundary

Fig. 3. Pareto Front Family Battery System
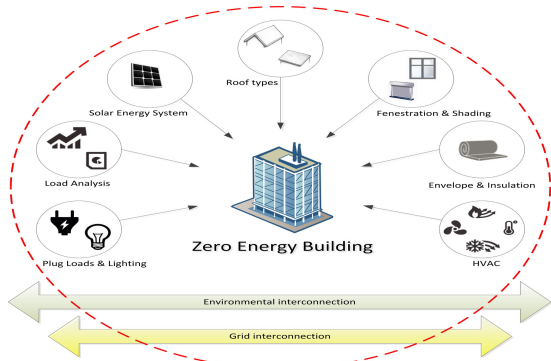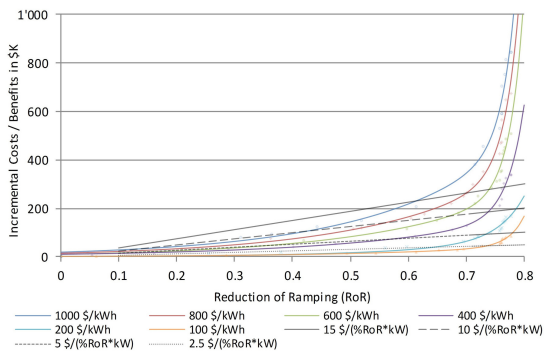
Introduction: The building sector in the U.S. consumes approximately 41 % of the nation's total primary energy use. Additionally, the building sector is by far the largest consumer of electricity, representing 74 % of annual electricity sales (Fig. 1). Considering that 66% of the total electricity production (primary energy) is coming from carbon dioxide emitting coal and natural gas, makes the greenhouse gas footprint of buildings even worse. Undoubtedly, there is a high potential in improvement opportunities. One of them are zero energy buildings (ZEB): Using very efficient appliances, daylight optimized designs, high performance envelopes and windows reduce their energy consumption to a Minimum. Furthermore, supplementary on-site energy production systems decrease the annual energy consumption to zero or lead to a positive net production. Aside from all advantages there is one major drawback: high residual loads. Electricity grid operators who provide and maintain the electrical grid do not gain a profit at the end of the year, and even worse, they have to ensure grid stability which is jeopardized by the highly volatile residual loads of zero energy buildings.

Objective: The first objective was an analysis of a zero energy building. Hence, different building shapes, envelope alternatives, insulation types, orientations and other variations have been considered. The second objective included an analysis of the dynamic residual electrical loads and appropriate strategies for their mitigation and reduction. Fig. 2 shows the system boundary.

Result: Even though OpenStudio does not provide the same functionality as EnergyPlus yet, it was possible to design and simulate a highly efficient building with an advanced HVAC system in the OpenStudio environment. Combining the building model with the photovoltaic model finally showed that the building not only reaches net zero, it even reaches net positive. Further analyses about the residual loads as wells as strategies for their reduction, nicely showed where the real potential lies. The main research topic of this project was to analyze a ZEB and its residual loads. Using a multiple objective optimization approach in combination with simplified storage models allowed comparing different strategies for residual load reduction. Although it is not profitable yet, the pareto front family for a battery storage shown in Fig. 3 illustrates what benefits would be needed at different battery system price scenarios.