Today’s energy systems are undergoing fundamental changes. Due to environmental problems, limitations and distribution challenges of fossil fuels as well as the risks of nuclear power, the process of transformation to a low carbon energy system based on renewable sources is ongoing. This thesis refers mainly to the European and, in particular, to the German electricity system, since rapid energy system changes occurred in the context of the so-called “Energiewende” within recent years. With the transformation of power generation capacities and the entire structure transmission systems, new challenges arise due to the fluctuating nature of wind and solar power. These account for most of the renewable electricity potential in Europe. With a rising need for flexibility, both on the demand and the supply side, the traditional concept of base and peak load power plants is being phased out. Interactions of grid infrastructure, renewable power generation and storage requirements are highly complex. Analyses of their interplay require computer models in high spatial and temporal resolution. Over the past decade, several model approaches have been elaborated aiming to identify least-cost infrastructures of renewable electricity systems and optimize the operation on an hourly basis. Nowadays, a wealth of models for simulating or optimizing Europe’s and Germany’s renewable electricity systems exist.