Summary

The objective of this thesis is to investigate the application of novel machine learning techniques to reduce energy inefficiencies in the power consumption of residential buildings and facilitate the integration of solar resources into electricity grids. Particular attention was given to the analysis of the electrical behavior of household appliances and their individual contribution to the overall energy demand of the house. In parallel, I also investigated innovative methods for predicting the energy performance of solar panels, which could significantly reduce the uncertainty associated with their energy supply.

For the purpose of reducing energy inefficiencies, I presented a Non-Intrusive Load Monitoring algorithm to estimate the energy consumption of individual electrical devices from the analysis of the whole-house load. The proposed algorithm has the important advantage of avoiding the impractical use of appliance level training data, which are expensive to retrieve and limit the generalization capabilities of disaggregation algorithms. With the same goal, I also introduced a methodology to recognize different home appliance programs by clustering their power profiles in a completely unsupervised way, which can further increase consumers' awareness of their energy consumption. Related to this topic, I also introduced a new methodology to identify electrical faults in household appliances by detecting variations in their expected power signatures. As a bridge between the issues of energy saving and solar resources, I proposed a new residential load model that simulates the energy profiles of typical Italian households. Among other applications, the simulator can be useful to optimize the integration of photovoltaics and batteries into home energy systems. Finally, I presented two deep learning models capable of processing multi-spectral satellite images and forecast future solar irradiance in the short-term. The proposed methodology can be potentially applied in multiple geographic locations without requiring additional ground-based data thanks to the global coverage of geostationary satellites.