Summary

The building stock is a major contributor to carbon emissions worldwide. For this reason, multiple actors worldwide have identified the building sector as fundamental for climate change mitigation. This research tackles the two principal components which are pivotal for the energy transition of the building stock, i.e., the renovation of existing buildings and the installation of Renewable Energy Sources for meeting the energy demand.

Regarding the renovation of existing buildings, the European Union has issued different directives, in the context of the European Green Deal, requiring the identification of worst-performing buildings, and more in general a global assessment of the current state of energy performance across the continent. The Energy Performance of Buildings Directive (EPBD) recast reinforced the role of Energy Performance Certificates (EPCs) as a common certification scheme across the European Union, but its coverage is limited to a third of the building stock. Therefore, professionals and Public Administrations lack efficient and effective tools for wide-scale energy classification. As a result, policy-makers face systematic difficulties in drafting science-based policies for an effective improvement of the current state.

This research fills this gap by introducing a method based on the estimation of the quality of the building envelope from aerial thermography. Recognising the key role of the envelope in energy performance classification, buildings are ordered according to the surface temperature – from the least performing, the warmest, to the most performing, the coolest – the energy performance class distribution was observed in a training EPC dataset and replicated. This method, whose accuracy was calculated to be around 70%, was refined by a further 10% through the introduction of segmentation. Going beyond the classification, although recognised as the key indicator of energy performance at the European level, it is possible to compute the final energy demand. As multiple authors have pointed out, EPCs show systematic errors in the quantification of energy consumption. For this reason, a Correction Factor was calculated for each segment by comparing EPC estimates with metered consumption data. Specific energy consumption was calculated based on the building segment and attributed class, extracting data from the EPCs. The application of Correction Factors decreased the discrepancy between simulated and validation results by 94%.

The second part of the thesis focuses on renewable energy production. As the EPBD introduced the requirement for the installation of photovoltaic panels, the potential of this technology is explored through GIS-based tools. The tools embedded in both QGIS and ArcGIS Pro, the most widely used software, are assessed. After having realised a supporting dataset from validated open-access data, the output variability range is assessed with 28 tests carried out with QGIS r.sun.insoltime. Then, the number of tests is reduced to 7 in order to compare QGIS r.sun with ArcGIS Pro Raster Solar Radiation and assess the accuracy of the tools against PVGIS. Results demonstrate the higher accuracy of QGIS compared to ArcGIS, despite seasonal differences. This study fills a gap observed in the literature, the lack of studies on the precision and accuracy of GIS-based photovoltaic potential estimations. Tool-specific metrics on both the output variability range (based on input variation) and the accuracy compared to PVGIS are produced, thus providing clear guidelines for the interpretation of the results of future GIS-based studies on the photovoltaic potential.

Overall, this thesis provides a comprehensive methodology for the evaluation of the current state of the building stock, considering both demand and production. Its accuracy, flexibility and scalability represent an added value to make the procedure operational and replicable, thus attractive for Public Administrations.