Studying eco-friendly systems for applications in the energy and sensor sectors is crucial in addressing today's global environmental challenges. With increasing concerns over resource depletion, pollution, and climate change, developing sustainable materials and technologies becomes essential to reduce ecological footprints. Eco-friendly systems not only offer renewable and less toxic alternatives but also enhance efficiency and longevity in energy harvesting and sensing devices. This approach supports the transition toward greener industries, promoting innovation that aligns with environmental preservation and societal well-being.

During the PhD thesis has been investigated the design and fabrication of sustainable materials and systems for wearable electronics and energy storage devices. The PhD thesis is divided in three different chapter:

Chapter 1 presents an overview of the fabrication of polymer and natural cellulose fiber-based sensors designed for energetic applications or physiological monitoring, specifically respiration and heart activity. Polyaniline (PANI) and poly(2-acrylamido-2-methyl-1-propanesulfonic acid) (PAMPSA) doping to enhance conductivity and sensitivity and polyvinyl alcohol (PVA)-based hydrogel supercapacitor have been investigated as starting material for preparing wearable sensors or pseudo capacitors, highlighting its electrochemical performance and potential integration into wearable electronic devices. The results obtained from these researchers have been published and are listed in the appendix.

Chapter 2 details the research conducted during the industrial placement at Bettery srl, an Italian Innovative Startup founded in January 2018, Spin-off of the Alma Mater Studiorum Università di Bologna. The research was focused on lithium–oxygen ($Li–O_2$) battery testing and concerned the synthesis and preparation of cathode and membrane materials, as well as the design and implementation of a customized experimental setup optimized for reliable and precise performance evaluation of $Li–O_2$ cells.

Chapter 3 presents the research carried out at Friedrich Schiller University Jena, Germany, c.o. Institute for Technical Chemistry and Environmental Chemistry/Center for Energy and Environmental Chemistry, under the supervision of Professor Andrea Balducci. The research focused on the development of a bio-based, sustainable electrolyte for lithium-ion capacitors. The study outlines the preparation and formulation of the electrolyte using renewable and environmentally friendly materials, followed by a thorough physicochemical characterization to

assess its structural and thermal stability. Cell assembly and electrochemical analysis, have been investigated demonstrating the electrolyte's promising potential to improve both the sustainability and efficiency of next-generation energy storage systems.

Part of this work has been presented at ISE 76th annual meeting, September 2025, Mainz, Germany and SPOKE1, September 2025, Bologna, Italy.

Collectively, the results obtained during this PhD thesis contributes to advancing the field of sustainable materials and electrochemical systems by integrating eco-friendly, renewable, and high-performance components for use in wearable technologies and energy storage applications.