

Electrochemical capacitors are increasingly recognised as one of the key technologies enabling Europe's transition to clean and sustainable energy. These devices can deliver high power in a very short time, recharge within seconds, and operate for hundreds of thousands of cycles. As a result, they are highly effective in stabilising the variability of energy production from renewable sources such as wind and solar power. However, currently used electrochemical capacitors still rely on materials that are difficult to recycle and harmful to the environment—including petroleum-derived carbons, toxic solvents, and metal current collectors. To meaningfully support Europe's energy transition, new, more environmentally friendly energy-storage solutions are urgently needed.

The CARBONEX-S project aims to develop a new generation of sustainable, flexible electrochemical capacitors using environmentally responsible materials at every stage of the device. The central concept is to combine advanced boron-doped carbon nanowalls (BCNWs) with natural cellulose nanofibrils (CNFs) and activated carbon derived from agricultural waste (BBAC). This unique combination will enable high electrochemical performance while maintaining flexibility, mechanical strength, and a low environmental footprint. CNFs will serve both as structural components and as biodegradable separators, replacing synthetic plastics. The project also involves developing metal-free current collectors produced by laser-induced graphene (LIG) directly on carbon-rich substrates using an energy-efficient laser process. Ultimately, only safe aqueous or CNF-based gel electrolytes will be used, eliminating toxic organic solvents.

The project brings together leading research teams from Poland, Brazil, Sweden, and the United Kingdom, forming a unique international consortium that jointly addresses global energy and environmental challenges. The expected outcomes include new sustainable electrode and collector materials, flexible device prototypes, and validated methods for their fabrication. In the long term, these efforts may accelerate the development of environmentally friendly energy-storage systems for wearable electronics, electric vehicles, renewable-energy grids, and smart textiles—supporting Europe's leadership in the transition toward a low-emission and circular economy.