R&D IN BATTERIES AT THE UPC

2024

UNIVERSITAT POLITÈCNICA DE CATALUNYA BARCELONATECH

Generalitat de Catalunya

CoFunded by the European Union

CONTENT

01.
THE UPC

The Universitat Politècnica de Catalunya - BarcelonaTech (UPC) is a public institution of research and higher education in the fields of engineering, architecture, sciences and technology, and one of the leading technical universities in Europe.

The UPC participates in the innovation system of
Catalonia with projects and contracts for research,
development, valorisation of knowledge and commercialisation of technology.

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RESEARCH, DEVELOPMENT AND INNOVATION ACTIVITY AT THE UPC IN 2023

141
research groups

15
TECNIO research centres

331
PhD theses

118,9 M€
income from projects

18,35 M€
income from contracts

1.011
R&D projects

1.033
contracts and agreements

14
patents

13
new TBCs*

2.425
articles in scientific journals

*Technology-based companies

02. BATTERIES

Batteries are energy storage systems that can create an electric charge.

In the field of research, development and innovation (RDI), batteries play a key role in the decarbonisation of the economy and the energy transition.

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CONCEPTS

Conventional batteries operate through charge and discharge reactions between electrodes in each of the cells.

The cells consist of a container, which holds a liquid or solid electrolyte, a positive electrode called the cathode and a negative electrode called the anode.

The electrodes are separated by a membrane that allows the flow of ions. The electrolyte is in contact with the electrodes, enabling the generation of a current through oxidation and reduction reactions.

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BATTERY DEMAND SECTORS AND APPLICATIONS

MOBILITY

Vehicles with internal combustion or detonation engines use batteries to supply the electrical energy needed for the operation of the engine and auxiliary components.

Electrification of mobility makes batteries a key element across various fields:

Atomotive engineering

Lightweight mobility

Heavy-duty mobility

ENERGY STORAGE

Stationary batteries provide a constant current over an extended period of time.

They are used in applications such as telecommunications, alarms and security systems, remote control, wind and solar energy systems, power supplies and medical devices, among others.

Housing

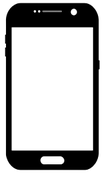
Energy

Industry

ELECTRONICS

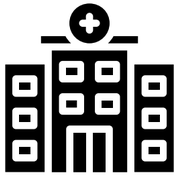
The evolution of mobile technologies is related to the miniaturisation of electronics.

Currently, lithium-ion batteries are prominent as they have allowed a reduction in battery size while providing higher energy density and efficiency.



Mobile phones

Electrical and electronic devices



Medical devices

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STATE OF THE ART – RESEARCH LINES IN THE FIELD OF BATTERIES

BASIC RESEARCH IN BATTERIES

Anode, cathode and electrolyte materials.

BATTERY ASSEMBLY

Prototyping, scaling, industrialisation and encapsulation and packaging processes.

BATTERY CHARACTERISATION

Cycling, modelling, ageing, etc.

BATTERY CONTROL

Battery management system (BMS), determination algorithms for state of charge (SOC), state of health (SOH) and state of function (SOF).

BATTERY APPLICATIONS

Electric vehicles, last-mile mobility, grid services and support for renewables, and as elements in optimisation and energy efficiency algorithms.

SOCIOENVIRONMENTAL IMPACT STUDIES

Life cycle analysis, circular economy, etc.

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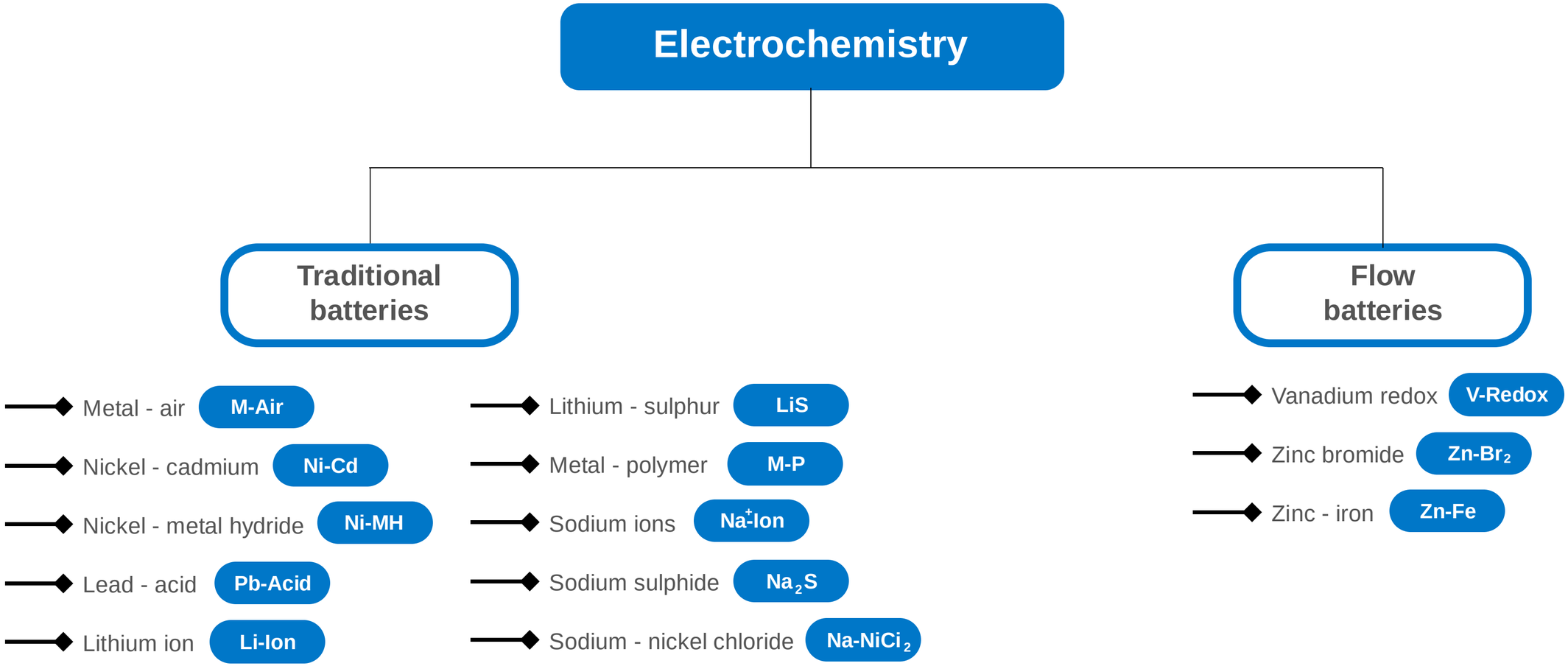
TYPES OF BATTERIES



Source: **Infography own elaboration. Information from ACCIÓ**

03.
RESEARCH AND INNOVATION

Through more than 140 research groups, the UPC develops a leading research activity in its own fields. The University has the facilities and resources to provide its own services in the areas of diagnosis, advice, development, demonstration, training, promotion, support to industry, the public sector and civil society for the promotion and deployment of batteries.

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EXAMPLES OF ACTIVITY I - BATTERIES

Use of artificial intelligence applied to the combination of chemical products used in battery characterisation.

Characterisation of batteries to better understand and optimise the physical and chemical properties, performance and stability of all its components.

Ex situ analysis and failure analysis based on the study of electrochemical side reactions using laser desorption/ionisation imaging.

Monitoring and management of batteries using the battery management system (BMS) control device to optimise energy usage while extending their lifespan.

Development of battery energy systems for communities using renewable energy sources.

Impact reduction study to increase lithium-ion battery production while minimising environmental impact.

Experimentation with new methods and materials to store energy in organic molecules, particularly in their intramolecular degrees of freedom.

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EXAMPLES OF ACTIVITY II - BATTERIES

Integration of processing technologies to ensure a safe, circular and sustainable battery value chain through urban and industrial mining.

Development of a hydrogen fuel cell sizing and application system for electric vehicles.

Development of the next generation of smart high-voltage connectors for substations, with energy autonomy and data transmission capability.

Bioprocess for the recovery of cobalt and lithium from batteries.

Development of a highly integrated on-board charger and inverter traction system to increase power density, reduce volume and weight in electric vehicles (EVs), while ensuring the efficiency and reliability of the power converters used.

Feasibility studies on the battery material recovery industry for electronic devices and motor vehicles in Catalonia.

Development of new non-toxic and biodegradable batteries for medical devices.

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UPC RESEARCH GROUPS IN BATTERIES

Research groups

- **ACaPE** - Advanced Control and Power Electronics Systems
- **CDIF** - Centre de Diagnòstic Industrial i Fluidodinàmica
- **CITCEA-UPC** - Centre d'Innovació Tecnològica en Convertidors Estàtics i Accionaments
- **CTTC** - Centre Tecnològic de Transferència de Calor
- **ENMA** – Enginyeria del Medi Ambient
- **EPIC** - Energy Processing and Integrated Circuits
- **GAECEQS** - Grup d'Accionaments Electromecànics, Conversió de l'Energia i Qualitat del Subministrament
- **GNOM** - Grup d'Optimització Numèrica i Modelització
- **GREP** - Grup de Recerca en Electrònica de Potència
- **IMEM-BRT** - Innovation in Materials and Molecular Engineering - Biomaterials for Regenerative Therapies
- **MCIA** - Motion Control and Industrial Applications Research Group
- **RIIS** - Grup de Recerca en Recursos i Indústries Intel·ligents i Sostenibles
- **SAC** – Sistemes Avançats de Control
- **SEER** – Sistemes Elèctrics en Energia Renovable

UPC SPECIFIC RESEARCH CENTRES IN BATTERIES

BRCMSE

Barcelona Research Center in Multiscale Science and Engineering

The BRCMSE focuses on research, development and innovation in micro- and nanoengineering, nanotechnology and nanoscience. Its main research topics include the manipulation of nanoparticles, the properties of micro- and nanodevices, the analysis of complex processes, the simulation of nanometric systems, the fabrication of nanometric layers, device integration and the energy and environmental applications of nanoparticles.

CER-H2

Specific Centre for Hydrogen Research

The CER-H2 aims to address research and knowledge transfer needs in the field of hydrogen technologies, including hydrogen generation, storage and use across all application areas: energy, industry, transport, housing, etc.

LACÀN

Numerical Methods for Applied Sciences and Engineering

Develops new mathematical models and numerical methods to enable predictive and quantitative science and engineering. It has several research lines:

• Computational Methods and Tools" aims to invent new algorithms to tackle emerging challenges in computational engineering.

• Natural and Manufactured Materials and Structures" combines theory, computer simulations and experiments to understand and leverage the design perspective of materials.

SSR

Smart Sustainable Resources

The SSR’s research focuses on the use of mineral resources, waste and sustainable mining. Aligned with the circular economy, the centre has experts in mineral deposit location, efficient resource use, biotechnology and advanced monitoring systems for the sustainable management of natural resources.

04.
UPC EXCELLENCE PROJECTS

In this document, excellence projects are considered to be those that:

- Follow a rigorous scientific process and adhere to high-quality standards.
- Are strategic and influential.
- Engage with social challenges and have a significant scientific and socioeconomic impact.
- Have repercussions on the local area.
- Involve various entities participating in the quadruple helix, making the projects multidisciplinary.

UPC excellence projects are financed by programmes such as the State Plan or Horizon Europe.

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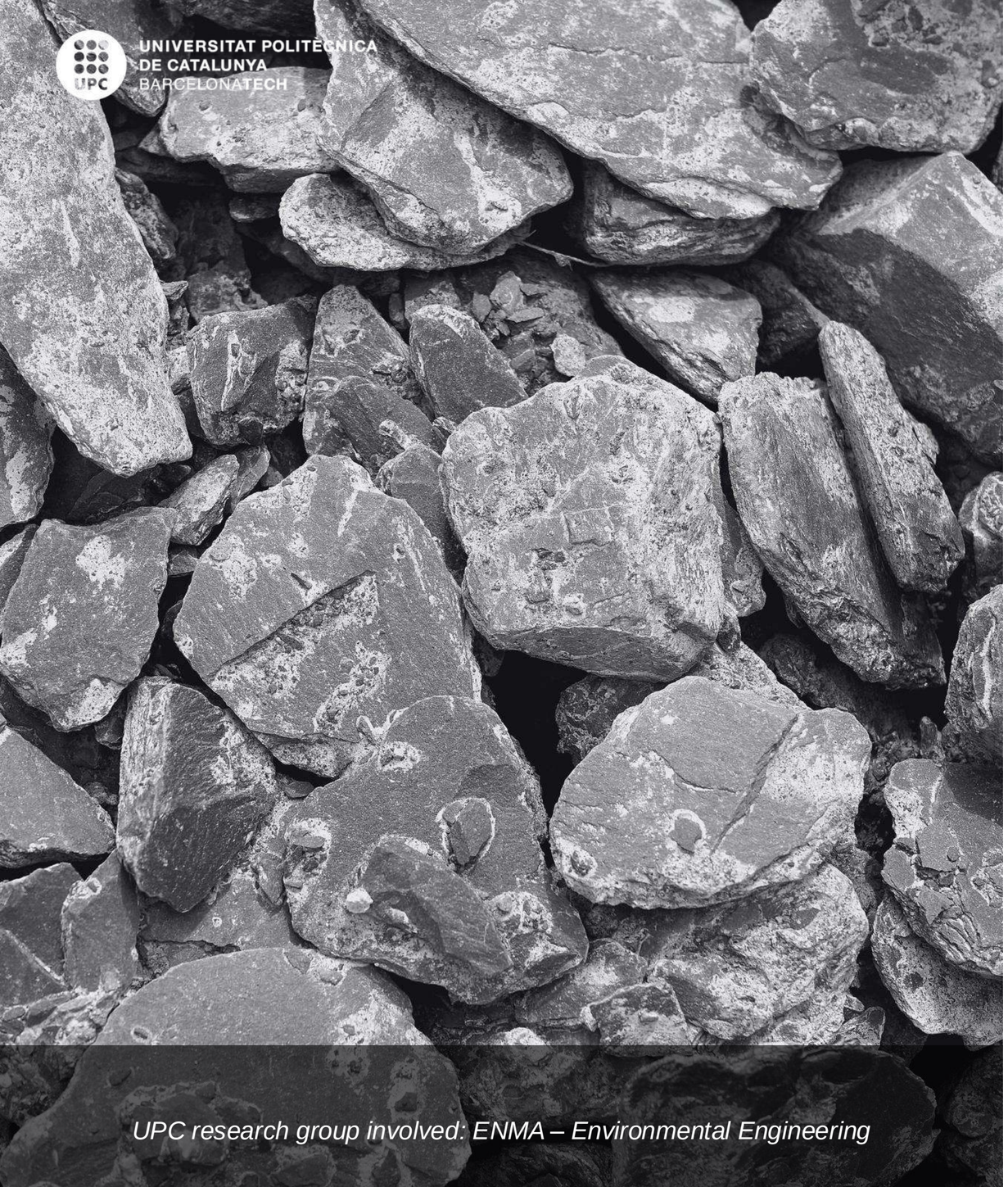
UPC research group involved: RIIS – Research Group on Intelligent and Sustainable Resources and Industries

EXCELLENCE PROJECTS

BIOMETAL - Development of a smart automated biobased process for the recovery of valuable metals from end-of-life phones

Rapid technological advancement is depleting natural resources and jeopardising the supply of essential materials. The project defends the idea that the increasing generation of electronic waste can become an economic opportunity through the recovery of valuable metals. Based on circular economy principles and urban mining, it aims to develop automated bioprocesses controlled by intelligent sensors to recover metals from mobile phones at the end of their life cycle.

The goal is to achieve the cost-effective recovery of strategic metals with an automated biological process, enhancing efficiency and minimising environmental impact.



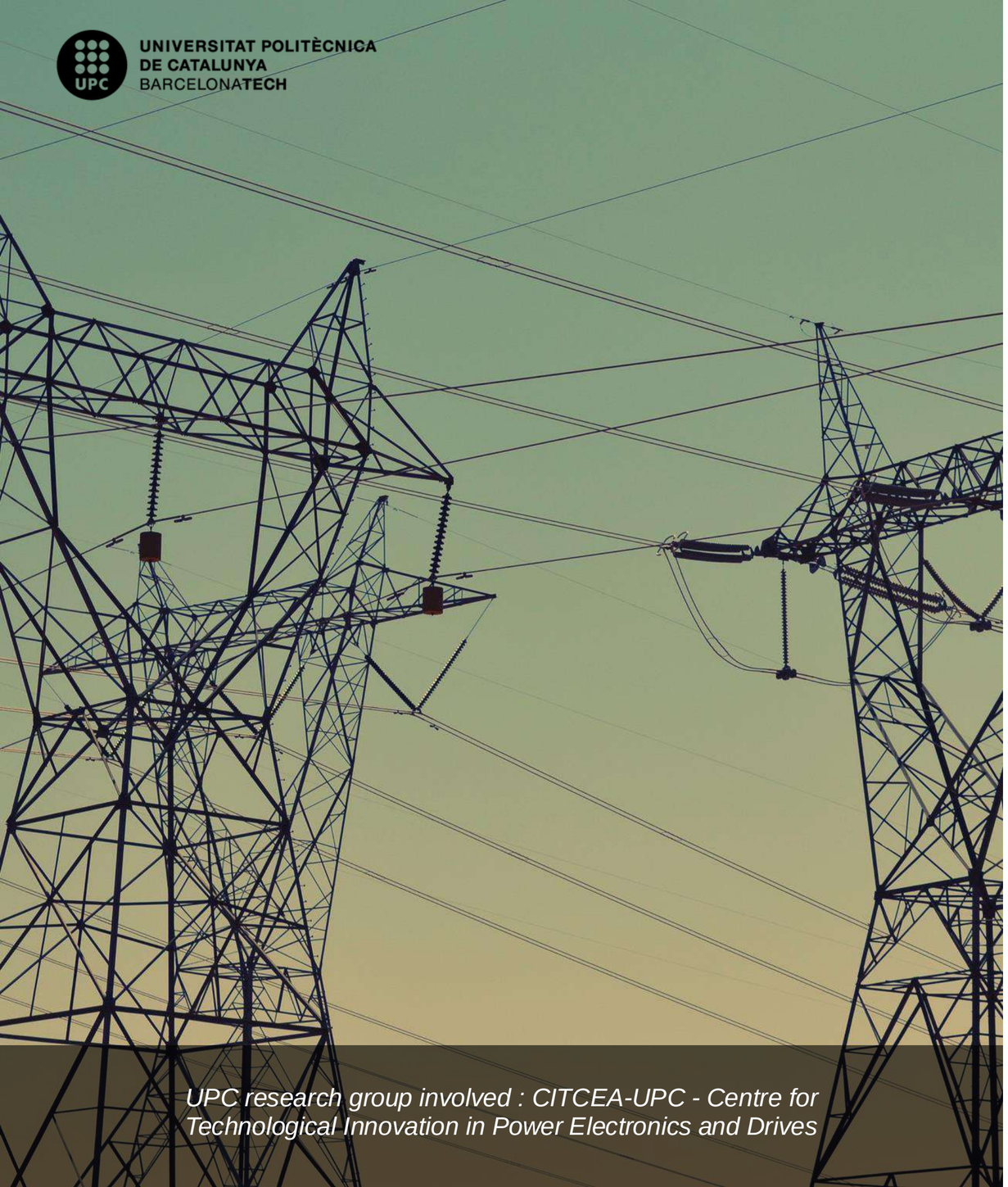
UPC research group involved: ENMA – Environmental Engineering

EXCELLENCE PROJECTS

COBRA - CObalt-free Batteries for FutuRe Automotive Applications

The COBRA project aims to develop a cobalt-free lithium-ion (Li-ion) battery to address the current shortcomings of batteries for electric vehicles (EVs) and create a more cost-effective, sustainable and higher energy density battery system.

The project focuses on improving key components such as the cobalt-free cathode, advanced Si-based anode and electrolyte/separator, as well as the manufacturing and testing of cells and battery packs. The technology will be demonstrated at TRL6 and validated on an EV test bench, ensuring its easy adaptation and adoption in the European market.



UPC research group involved : CITCEA-UPC - Centre for Technological Innovation in Power Electronics and Drives

EXCELLENCE PROJECTS

AGISTIN - Advanced Grid Interfaces for innovative STorage Integration

The AGISTIN project, funded by the EU, aims to advance energy storage solutions to support decarbonisation, the growth of renewable energies and grid stability. It focuses on reducing the impact of demand on the grid and costs for large users through innovative storage technologies such as aqueous electrochemical recuperators, irrigation systems and aluminium-ion batteries.

The project includes demonstrations and testing in hydrogen electrolysis, irrigation pumping and fast charging of electric vehicles. AGISTIN aims to improve grid stability, reduce hydrogen production costs by 10% and support 100% renewable grids, involving a consortium of nine countries.

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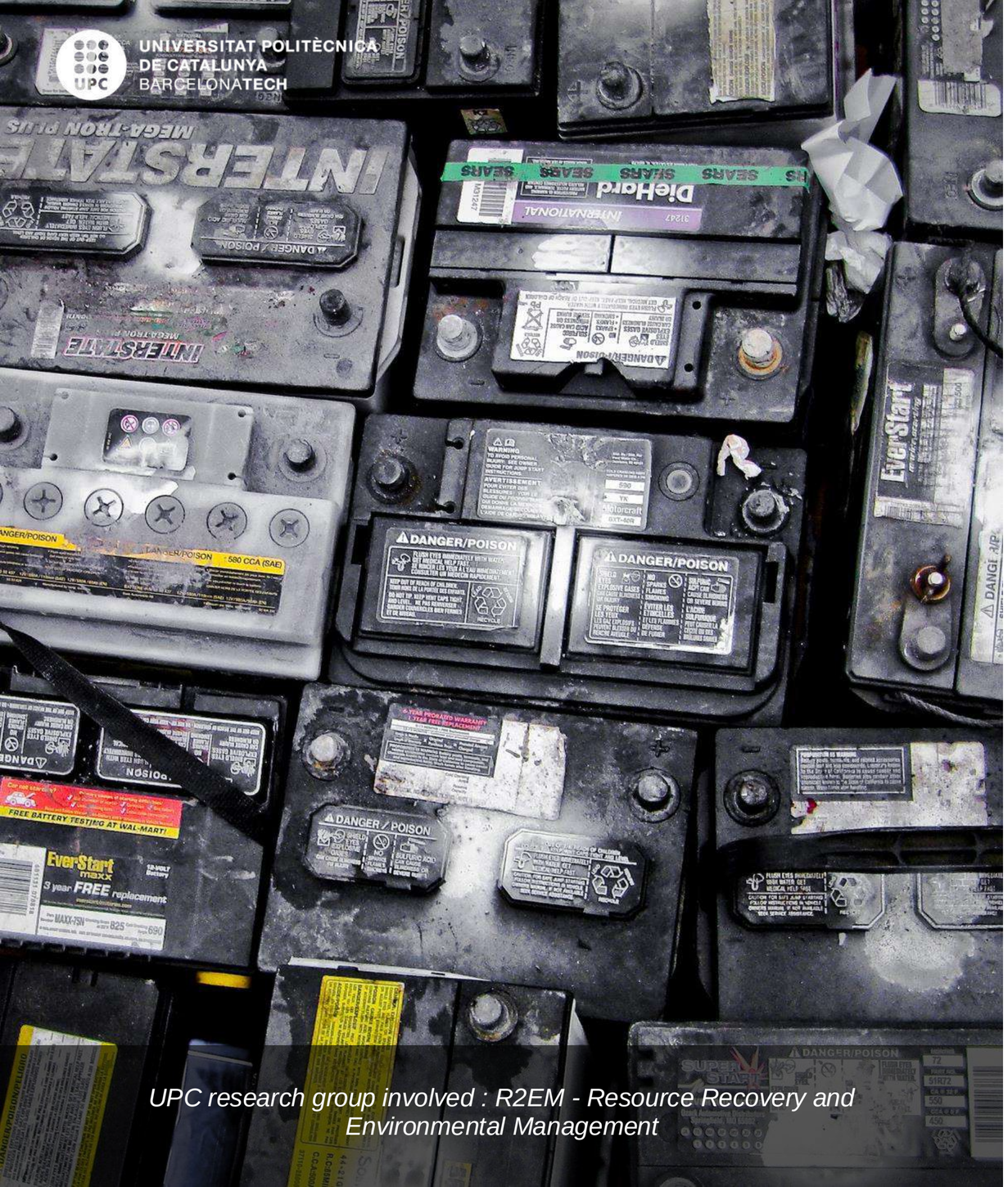
UPC department and research group involved: Department of Electronic Engineering and ACaPE - Advanced Control and Power Electronics Systems

EXCELLENCE PROJECTS

HELIOS - High-pErformance moduLar battery packs for sustaInable urban electrOmobility Services

The HELIOS project aims to develop an intelligent, modular and scalable battery pack for urban electric vehicles, ranging from mid-sized cars to electric buses. It focuses on improving performance, energy density, safety and lifespan and reducing the levelised cost of storage (LCOS).

The project integrates innovative materials, designs, technologies and processes, including advanced electrical and thermal management solutions with both hardware and software. It employs technologies such as large-scale cloud data analysis, artificial intelligence (AI) and the Internet of Things (IoT) to enhance energy density, enable ultra-fast charging, improve safety and extend battery lifespan. The project also focuses on monitoring battery health, carbon footprint and implementing circular economy principles for battery reuse and recycling.



UPC research group involved : R2EM - Resource Recovery and Environmental Management

EXCELLENCE PROJECTS

METALLICO - Demonstration of battery metals recovery from primary and secondary resources through a sustainable processing methodology

The METALLICO project aims to secure the critical materials needed for electric vehicles by focusing on the production of essential metals for batteries (lithium, cobalt, copper, manganese and nickel). Due to their scarcity and global distribution, these materials pose a high supply risk for the EU.

METALLICO will bring together representatives from across the value chain, including primary and secondary metal sources, to test new processes for producing high-quality battery materials. The project includes four case studies in the EU to recover these metals from primary deposits and secondary resources. The goal is to design sustainable processes to increase the production of critical materials, reduce reliance on imports and ensure the EU's competitiveness in the battery sector.

Picture: Joshua Rothhaas - Flickr

UPC research group involved : CDIF – Centre for Industrial Diagnostics and Fluid Dynamics

EXCELLENCE PROJECTS

FLEXHYBAT - Design and control of flexible hydropower plants by hybridisation with 2nd life batteries

In recent years, hydroelectric power plants have expanded their operational range to adapt to grid flexibility, resulting in increased wear on turbines and reducing their lifespan. FLEXHYBAT proposes hybridising these turbines with second-life batteries to enhance their performance and durability.

The project develops performance and aging models for reused batteries, experimentally validating them and standardising their technical specifications to facilitate their reuse through advanced simulations and testing systems. It aims to optimise energy storage design to maximise efficiency and reliability of the grid.

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UPC department and research group involved: Department of Electronic Engineering and ACaPE - Advanced Control and Power Electronics System

EXCELLENCE PROJECTS

SCAPE - Switching-Cell-Array-based Power Electronics conversion for future electric vehicles

SCAPE aims to standardise and modularise power conversion systems for electric vehicles (EVs) using multilevel technology, developing compact and integrated blocks. It also proposes intelligent strategies for modulation, control, online diagnostics and predictive maintenance using machine learning. This approach is expected to reduce costs through economies of scale, enhance performance and facilitate the mass adoption of EVs, increasing their affordability and reducing greenhouse gas emissions.

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SELECTION OF SCIENTIFIC ARTICLES

Canals, L. [et al.]. ***Are electric vehicle batteries being underused? A review of current practices and sources of circularity. "Transport and Environment"*****, January 2023, vol. 114.** **https://doi.org/10.1016/j.jenvman.2023.117814**
Batteries are considered at the end of their useful life with 70-80% health, leading to underutilization. This study reviews circular processes for batteries, recommending prioritising first-life applications and vehicle-to-grid (V2G) over second-life applications. It also proposes a framework for better estimating the functional end of life of batteries.

Dorado, A. [et al.]. ***A high productivity bioprocess for obtaining metallic copper from printed circuit boards (PCBs). "Minerals Engineering",*** **January 2024, vol. 205.** **http://hdl.handle.net/2117/396665**
Proposes a sustainable process for obtaining copper cathodes from obsolete mobile phone PCBs through grinding, leaching in a continuous reactor and iron regeneration in a bioreactor.

Romeral, J. L. [et al.]. ***Flexible Smart Energy-Management Systems Using an Online Tendering Process Framework for Microgrids. "Energies"*****, May 2023, vol. 16.** **https://doi.org/10.3390/en16134914**
Discusses a new intelligent energy management system for microgrids, using a multi-agent framework and an online bidding process to optimise energy distribution and costs, while ensuring system stability and preventing outages.

Busquets-Monge, S. [et al.]. ***Electric vehicle powertrains with modular battery banks tied to multilevel NPC inverters. "Electronics",*** **January 2023, vol. 12, no. 2.** **http://hdl.handle.net/2117/384844**
Analyses the benefits of combining modular battery banks with multilevel NPC traction inverters in electric vehicle powertrains, highlighting potential improvements in efficiency and environmental benefits compared to traditional designs.

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SELECTION OF DOCTORAL THESES

Clemente, A. (2023). ***Modeling and control of a vanadium redox flow battery***
Addresses the use of vanadium redox flow batteries for energy storage, highlighting their advantages and challenges. It presents the operation, modelling and control of these batteries, developing a mathematical model to understand their dynamics and proposing control techniques to improve efficiency and safety. The thesis also includes experimental validation of the results using a specific platform.

Rafiezadeh, R. (2022). ***Contributions to the Characterization and Design Optimization of Power Converters Based on Switching-Cell Arrays***
Explores the optimised design of voltage source power converter legs by combining standard switching cells in active neutral point structures to achieve the desired voltage and current ratings. It formulates different design scenarios, including various conversion configurations (DC-DC and DC-AC) and cell types. The optimisation algorithm used allows for rapid exploration of the best design solutions, integrating both integer and continuous design variables with linear and non-linear constraints.

Salehi, N. (2023). ***Energy Management in Collaborative Power Electronics-Based Microgrid Integrated with Renewable Energies***
Focuses on research into microgrids, with an emphasis on cooperative operation. It analyses energy management strategies, optimisation of individual and community microgrids and examines various control strategies for grid-connected microgrids. The thesis proposes innovative methods such as learning-based clustering, component sizing algorithms and new control methods for power electronics interfaces in microgrids.

Alcázar, D. (2022). ***Model-based design validation and optimization of drive systems in electric, hybrid, plug-in hybrid and fuel cell vehicles***
Contributes to technological development by accelerating the design of eco-friendly vehicles and their integration into smart cities. It describes an adaptable, flexible, expandable, simple and highly accurate methodology capable of maximising vehicle range with minimal computational effort, thanks to a genetic algorithm. Additionally, it provides predictive insights to minimise costs, volume and weight of the powertrain within the vehicle structure, aligning with the designer's preferences.

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FUTURE DOCTORAL THESES

Etxandi-Santolaya, Maite. *"A new approach to end of life estimations in electric vehicle batteries: maximizing battery usage".* (In development, defence expected in the summer of 2024).

Puleston, Thomas Paul. *"Monitoring and optimal operation of redox flow batteries".* (In development, defence expected in 2025).

Martí Florences, Miquel. "*Estimation and descentralized control of hybrid storage systems containing litium-ion bateries".* (In development, defence expected in 2026).

Savona, Enrico. *"Topology optimisation for battery thermal management systems".* (In development).

Zamberlan, Giorgio. *"Enhancing topology optimisation tools of battery thermal management systems using machine learning".* (In development).

Gabarrell, Pau. *"Reinforcement learning for surrogate models of optimised topologies for battery thermal management systems".* (In development).

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PARTNERSHIP

Companies

SEAT

cooltra

SILENCE URBAN ECOMOBILITY

NVISION

deep concept

CELSA GROUP

Volkswagen

RAY ELECTRIC MOTORS

vectortech

AVL

TEKNE

vitesco TECHNOLOGIES

Research centres and institutes and public entities

Barcelona Supercomputing Center
Centro Nacional de Supercomputación

IFISC

Ciemat
Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas

IREC
Shaping Energy for a Sustainable Future

eurecat
Centre Tecnològic de Catalunya

TEKNOLOGISK INSTITUT

CSIC
Consejo Superior de Investigaciones Científicas

European Copper Institute
Copper Alliance

05.
EDUCATION

The UPC of the future is based on three main pillars: bachelor's, master's and doctoral students, with a commitment to training competent professionals who can join the production system and drive the economic progress of our country, putting people's lives and the sustainability of the planet at the centre.

An education of excellence in research and technology transfer that aims to promote young, creative and courageous talent, which will have to face and solve the social and environmental challenges of the future and not so future times.

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BACHELOR'S DEGREES

- Bachelor's degree in Electronic Engineering and Telecommunications (ETSETB)
- Bachelor's degree in Industrial Electronics and Automatic Control Engineering (EEBE, EPSEM, EPSEVG, ESEIAAT)
- Bachelor's degree in Electrical Engineering (EEBE, ESEIAAT)
- Bachelor's degree in Automotive Engineering (EPSEM)
- Bachelor's degree in Energy Engineering (EEBE)
- Bachelor's degree in Mineral Resource Engineering and Mineral Recycling (EPSEM)
- Bachelor's degree in Materials Engineering (EEBE)
- Bachelor's degree in Chemical Engineering (EEBE, EPSEM, ESEIAAT)

More information about degrees

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MASTER'S DEGREES

- Master's degree in Electronic Engineering(ETSETB)
- Master's degree in Semiconductor Engineering and Microelectronic Design (ETSETB)
- Erasmus Mundus master's degree in Advanced Materials Science and Engineering (AMASE)
- Erasmus Mundus master's degree in Sustainable Systems Engineering (EEBE)
- Master's degree in Automotive Engineering(ETSEIB)
- Master's degree in Energy Engineering(ETSEIB)
- Master's degree in Automatic Systems and Industrial Electronics Engineering (ESEIAAT)
- Master's degree in Urban Mobility(ETSECCPB, ETSAB, ETSETB, ETSEIB, FIB)
- Master's degree in Industrial Engineering (ETSEIB)
- Master's degree in Chemical Engineering(EEBE)
- Master's degree in Electric Power Systems and Drives (ETSEIB)
- Master's degree in Interdisciplinary and Innovative Engineering (EEBE)
- Master's degree in Environmental Engineering (ETSECCPB)
- Master's degree in Natural Resource Engineering (EPSEM)

More information about masters

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DOCTORAL PROGRAMMES

- Electronic Engineering
- Electric Energy Systems
- Natural Resources and Environment
- Electrical Engineering
- Chemical Process Engineering
- Materials Science and Engineering

More doctoral programmes

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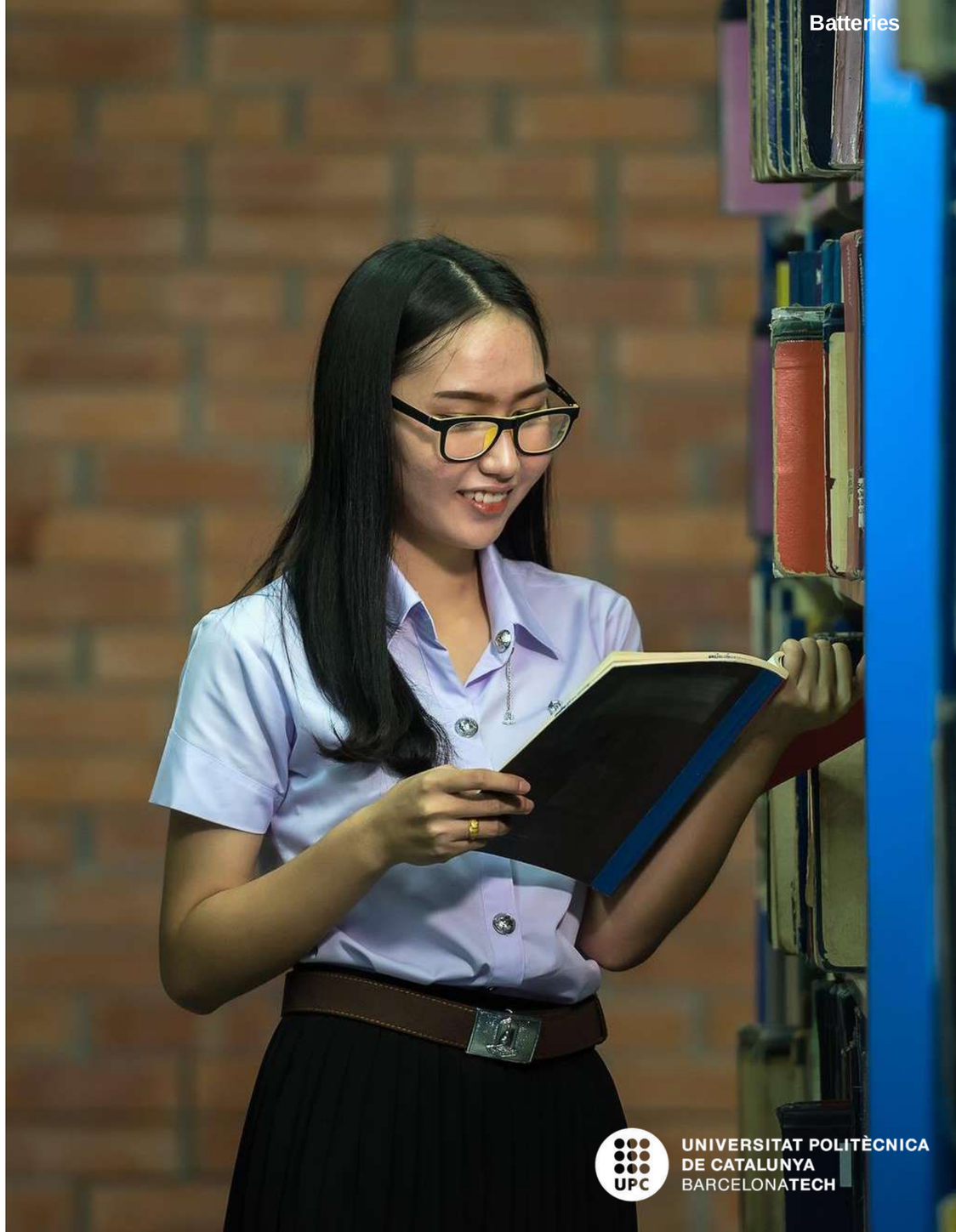
UPC SCHOOL - POSTGRADUATE AND CONTINUING EDUCATION COURSES

- Continuing education master's degree in Mechatronics: Technologies, Industrial Systems and Electric Mobility
- Continuing education master's degree in Smart Energy. Renewable Energies and Digitalization
- Postgraduate course in Elements of Mechatronics Systems
- Postgraduate course in Electric Vehicles and Sustainable Mobility
- Postgraduate course in Flexible Electrical Networks

More information about masters and postgraduate



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