Lithium (Li), renowned for its exceptional properties, has risen as a **critical raw material** especially in energy storage. Li is crucial for powering various technological advancements, as Li-ion batteries have become the preferred choice for powering portable electronics, modern electric vehicles, and renewable energy storage systems. In 2022, around 74% of global Li production was consumed by the Li-ion batteries, underscoring its central role. Moreover, Li is also utilized in ceramics, glass, lubricants, and aerospace materials, owing to its low density and high heat capacity. Ongoing research in nuclear fusion further highlights Li's significance as a key component for tritium generation.

Traditionally, Li extraction was based mainly on mining methods and extraction from Li-bearing minerals. While nowadays the focus has been shifted to Li extraction from brines (**direct Li extraction - DLE**) particularly in the so called Li Triangle (Chile, Bolivia, and Argentina) due to cost-effectiveness and environmental friendliness of the process. DLE is expected to transform the Li sector, offering a sustainable path for meeting the global Li demand. DLE is a straightforward and efficient operational process, with broad applicability to various brine resources and significant economic benefits, but its efficiency is strongly dependent on **Li-selective adsorbents**. These materials are used to separate Li from brines. Particularly, the Al-based adsorbents including layered double hydroxides (LDHs) like LiAl-LDHs, are identified as the most favored for industrial Li extraction. This is due to their technological maturity, low costs, ease of fabrication and regeneration under neutral media. Still, before their industrial implementation further developments are needed to increase the adsorption capacity and most importantly the adsorbent stability over multicycle use for prolonged operation.

We aim to tackle these challenges by smart engineering at the atomic level (structure tuning) and at the macro level (3D shaping). We aim to achieve the best combination of Li adsorption features in terms of superior capacity, selectivity and long term stability. The engineered LiAl-LDHs powders will be 3D-shaped as microspheres, fibers or monoliths, with tuned surface and internal porosity to overcome diffusion limitations and achieve an overall improved performance. This will enable the use of LDH adsorbents for continuous Li separation in real conditions. Thus, a multiscale development approach is here proposed to obtain engineered 3D-shaped LiAl-LDH based adsorbents. At nano-scale level by fine-control of the synthesis conditions, and continues to the meso- to millimeter scale levels through 3D shaping and demonstration of the materials' efficiency for Li extraction in dynamic flow-through conditions.

The project will be led by research groups at the **AGH University (Poland)**, **University of Antwerp (Belgium)** and **VITO Flemish Institute for Technological Research (Belgium)**. All groups have extensive experience concerning the synthesis, characterization and testing of 2D layered materials for adsorption and separation. We strongly believe that our cooperation will result in knowledge increase on Li extraction by new selective adsorbents. The project novelty involves the studies on Li separation in dynamic flow-through conditions using 3D-shaped LDH materials. This will give insight into materials' efficiency, stability, recyclability and Li separation mechanisms. These aspects are of great importance for the future development of Li production technologies. The research project aims to make an original contribution in the discipline of materials engineering within the domain of LDH materials.