Heterogeneous catalysis serves as a crucial technology in transitioning from a society reliant on fossil fuels to one that embraces renewable energy sources. One of the most important heterogeneous catalysts are zeolites, their importance is evidenced by the current annual consumption of 1 million metric tons of zeolite catalyst by the refining and petrochemical industries. Zeolites belong to the group of crystalline aluminosilicates with special properties arising from their framework structure with micropores of molecular dimensions (below 1 nm). It is expected that zeolites will play a key role in the production of fuels and valuable chemicals from biomethanol, captured CO_2, or biogas monetization.

The main goal of the proposed project is to develop improved catalysts based on layered (two-dimensional) zeolites for key catalytic processes that can address urgent social and environmental needs. One such process is the Dry Reforming of Methane (DRM). This process is important because it can convert two harmful greenhouse gases, carbon dioxide and methane, into a useful gas mixture called syngas. Syngas can then be used to make a variety of chemicals and fuels.

The benefits of this process are many. It can help reduce the emission of greenhouse gases, create valuable products, and utilize otherwise waste materials. Therefore, it has the potential to play a key role in combating climate change.

However, DRM is a challenging process. It requires high temperatures and pressure, and under these harsh conditions, the active components of the catalysts, known as metal nanoparticles, tend to clump together into large clusters. This leads to the catalysts becoming less effective over time.

To overcome this problem, the project aims to design new catalysts that can better withstand these harsh conditions. This is where the layered zeolites come in, as they can provide a stable support for the metal nanoparticles, preventing them from coalescing. This project is all about creating a new type of catalysts in the lab, which is the first step towards making more complex catalysts for industrial use. The main goals are to stabilize tiny particles of metal, finding materials that are cost-effective, and identifying the best conditions for the chemical reactions to take place.

To do this, we are going to make a series of special materials called 2D zeolites, being extremely thin crystals, with surfaces that are covered by silanol groups (Si-OH) that can anchor metal clusters. The way zeolite layers are arranged and what types of silanols are present (or how well they can be engineered) affect how well metal nanoparticles can be attached to the surface and how effectively they can be stabilized. This is different from the catalysts that are currently in use.

We will test these new catalysts under conditions that are similar to what they would experience in a real chemical reaction. This will help fine-tuning the process to make catalysts that are resistant to coalescence of nanoparticles. We will use various methods to study these materials in detail, including electron microscopy, which lets us see the size, location, and behavior of the nanoparticles.

Our team includes experts from Poland and the Czech Republic, who are leaders in the field of 2D zeolites synthesis, and a partner from Korea, who is experienced in developing metal catalysts for activating and converting molecules with one carbon atom, like methane and carbon dioxide.

We know that making these catalysts is both economically and methodologically challenging, but we believe these are necessary steps in addressing the environmental crisis caused by harmful anthropogenic emissions.