In an era of increasing energy demand challenges combined with simultaneous environmental protection, the idea of photocatalytic generation of hydrogen on a large scale is undoubtedly one of the biggest and, at the same time, the most fascinating scientific challenges, that may lead to the next unprecedented technological revolution in 21st century. Unlike conventional catalysis, where the chemical transformations driven by the catalyst require high temperature, pressure, or the application of bias, the photocatalysts literary harvest photons and transform their energy into the energy of chemical reactions. Amongst all available options, the largest renewable energy resource is provided by sun. The average amount of energy supply from the sun to the Earth's surface on a daily basis is about 10^{22} J, covering up the annual global demands for energy. Therefore, solar energy has the greatest potential to meet future energy demands, assuming sustainability and environmentally benign processing routes. Hydrogen is commonly regarded as the most promising future fuel and potentially an ideal energy carrier due to its highest gravimetric energy and zero emission of carbon dioxide. Nevertheless, before our world can challenge the new energy scenario, there are several issues that must be solved. Amongst them, the realization of an efficient H_2 generation process that meets industrial expectations is the most essential step. Such a method should assure a long–term supply of H_2 and take into account the environmental issues such as minimization or the entire elimination of any waste products, paying particular attention to CO_2 or any other greenhouse gas.

Localized surface plasmonic resonance (LSPR) is an intimate physical phenomenon that can be described as collective oscillations of free electrons confined to a surface in a conducting nanomaterial caused by an incident electromagnetic wave. It has been recently demonstrated that LSPR–driven chemical reactions in a gas phase can achieve remarkable quantum efficiency, even two orders of magnitude higher than typical values reported for conventional photocatalysis. In addition, the LSPR–driven reactions can be carried out in the excited state of molecules overcoming thermodynamic limitations of very challenging and extremely important endothermic reactions such as reforming of methane. This paves the way for developing very efficient and sustainable H_2 generation technology based on LSPR–enhanced (thermo)photocatalysis.

Aerogels are a diverse class of porous translucent materials that exhibit an uncanny array of extreme properties. Due to their porosity reaching up to 99% aerogels are the lightest solid materials known to a man. Aerogel monoliths are capable of both light and heat trapping; therefore, embedding plasmonic nanoparticles (NPs) into their structure is expected to result in even higher quantum efficiency and (thermo)photocatalytic activity of such novel systems.

Inspired by recent progress in plasmonic photochemistry as well as our first successful synthesis of aerogel–plasmonic NPs systems, we are going to design, fabricate and demonstrate the performance of such novel hybrid systems for sustainable generation of H_2 from a gas phase hydrogen carrier. **The main goal of the proposed project is to create transparent aerogel monolithic sceleton containing plasmonic NPs which is highly efficient (thermo)photocatalytic system for H_2 production under visible light illumination**. To achieve this goal, we are going to investigate the correlations between chemical and phase composition of the aerogel, its morphology, the plasmonic response of NPs, and the (thermo)photocatalytic efficiency under simulated solar light irradiation. We will investigate an intricate physics and chemistry associated with LSPR coupled to optically active aerogel structure using a combination of powerful experimental techniques and theoretical tools. Ultimately, we are going to demonstrate the performance of our novel systems by conducting the photocatalytic reforming of methane as a model reaction.

We are convinced that the results obtained within this project will broaden the knowledge about (thermo)photocatalytic hydrogen generation from a gas phase as well as will have a strong impact on the development of materials science, chemical engineering and heterogeneous photocatalysis. We do believe that results of the fundamental research of this project will create the foundation for the scalable and economically justified technology of photocatalytic H_2 production on a large scale. This is a key factor for successful realization of a green and sustainable hydrogen–based economy.