# Project PROPHECY – PROcess concepts for PHotocatalytic $CO_2$ reduction associated with lifE-CYcle analysis

*Nikolaos Moustakas, Leibniz-Institut für Katalyse (LIKAT), Rostock, Germany; Tim Peppel, Leibniz-Institut für Katalyse (LIKAT), Rostock, Germany; Jennifer Strunk, Leibniz-Institut für Katalyse (LIKAT), Rostock, Germany; Enno Gent, Institut für Chemie, Universität Oldenburg, Oldenburg, Germany; Josefine Hildebrand, Institut für Chemie, Universität Oldenburg, Oldenburg, Germany; Michael Wark, Institut für Chemie, Universität Oldenburg, Oldenburg, Germany; Andreas Patyk, Institut für Technikfolgenabschätzung und Systemanalyse (ITAS) – Karlsruher Institut für Technologie (KIT), Karlsruhe, Germany; Dominik Poncette, Institut für Technikfolgenabschätzung und Systemanalyse (ITAS) – Karlsruher Institut für Technologie (KIT), Karlsruhe, Germany; Minoo Tasbihi, Institut für Chemie, Technische Universität Berlin (TUB), Berlin, Germany; Reinhard Schomäcker, Institut für Chemie, Technische Universität Berlin (TUB), Berlin, Germany.*

The increasing energy needs of the developing and developed countries along with the atmospheric $CO_2$ concentration stabilizing over 400 ppm in recent years are two important factors greatly affecting the world's climate causing extreme weather phenomena. Among the various ”green” energy conversion technologies utilizing the abundant solar and wind energy, photocatalytic $CO_2$ conversion (or artificial photosynthesis) to useful chemicals (solar fuels) appears to be a promising alternative for direct solar energy storage to chemical bonds simultaneously combating both the energy crisis and the greenhouse effect.

Despite the fact that in the last decade many research teams around the world focused on understanding the mechanism behind photocatalytic $CO_2$ reduction and on synthesizing novel materials, the reported yields are still too low and not suitable for large scale industrially relevant applications. Additionally, the products of the $CO_2$ conversion process can vary quantitatively and qualitatively depending on the photocatalytic system and on the experimental conditions, so special efforts should be focused on the selectivity of these systems towards ideally a single product.$CH_4$ is often obtained as main product, but higher-value products such as ethylene or methanol would be desirable.

In terms of materials' development, photocatalysts with high surface area should be preferred as they offer more area for the $CO_2$ reduction reactions to take place. Another important aspect while designing novel photocatalytic materials should be their visible light activity. Since most widely studied semiconductors (e.g. $TiO_2$) are only active under ultra-violet irradiation, which only accounts for 4% of the solar spectrum, an extended - light absorption range to longer wavelengths could possibly lead to improved efficiencies and more sustainable processes.

The project PROPHECY was initiated to develop new processes in which the yield of useful chemicals is greatly increased. Prof. M. Wark's group explores new synthetic routes and optimization techniques for new photocatalytic structures and materials (ZnO, $TiO_2$, titanates, etc.) with extensive light absorption capabilities, easily scalable and in principle viable for industrial scale production. The group of Prof. J. Strunk studies alternative process conditions using renewable additives (e.g. $H_2$ from solar powered water electrolysis or bioethanol) in the gas feed of mainly $CO_2$ and $H_2O$, to increase the yields and modify the product distribution in a high-purity gas-phase photoreactor. The group of Prof. R. Schomäcker studies the mechanism of photocatalytic dry-reforming of methane ($CH_4$ + $CO_2$) with variable reaction conditions to identify the rate-limiting steps and the most important intermediates. Also, the scaling up of the photocatalytic reactor will be studied. Finally, Dr. A. Patyk and his team perform life cycle analysis (LCA) and sustainability considerations on the newly developed catalysts and reaction conditions to evaluate the required product concentration and the optimum parameters to make the process sustainable and economically viable.

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