# Catalytic processes for the production of hydrogen-rich gas from natural, synthetic and renewable energy sources

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Growing interest in a hydrogen-based energy and wide application of fuel cells dictates necessity for R&D on new methods and technologies for hydrogen (or hydrogen-rich gas) production from natural, synthetic and renewable sources. Besides fuel cells, the hydrogen-rich gas is promising for use in internal combustion engines, exhausts cleanup, metallurgical reduction mixtures, etc. Respective adapting of existing technologies will provide rapid development of an infrastructure for hydrogen-production and upscaling of hydrogen demo projects towards its wide application in various spheres.

This work considers the catalysts, reactors and power plant, as well as specific features of processes for hydrogen-rich gas generation form natural (methane, propane-butane, gasoline, diesel fuel), synthetic (dimethyl ether, methanol) and renewable (water-ethanol mixtures, biodiesel fuel) sources.

Among promising methods for hydrogen-rich gas generation are the reactions of partial oxidation, steam and autothermal reforming of hydrocarbons. Compact reactors based on monolith metal-grid reinforced catalysts have been developed and applied for working out of the technologies for hydrogen-rich gas production form natural and renewable sources (natural gas, propane-butane, gasoline, biodisel fuel). For example, the reactor for methane partial oxidation to hydrogen-rich gas allowed processing of 4 $m^3$ of methane per 1h per 1L of the reactor volume. Partial oxidation of methane to hydrogen-rich gas (syngas) on-board a vehicle and application of the gas produced as an additive to primary fuel provides essential profits. Indeed, compact reactor (volume ≤8 L, syngas output up to 25 $m^3$/h) on-board a "Gazel" minivan provides quick starting − less than 1 min, 15−20% fuel economy, Euro-4 emission level without use of a catalytic converter; engine cold-start ceases to be a problem. It was repeatedly demonstrated that the syngas generated by this process can be successfully used for fueling HT-fuel-cell-based power plants, for $NO_x$ cleanup from diesel engine exhausts, as a component part in metallurgical reduction mixtures.

In recent years, particular attention has been focused on the processes for hydrogen production by steam reforming of alcohols and dimethyl ether, that is explained by considerable R&D progress in HT PEMFC based on a polybenzimidazole thermoplastic doped with phosphoric acid, and high promises of these fuel cells for power generation systems. Based on a 160W HT PEMFC (Zentrum fur Brennstoffen Zellen Technik GmbH Duisbeerg, Germany) integrated with a compact methanol steam reforming reactor, we have developed an autonomous power plant which was successfully demonstrated in various operation modes (including start-stop) at Hanover Fair 2007 (Section "Hydrogen + Fuel Cells").

Production of hydrogen-rich gas from water-ethanol mixtures is extensive studied nowadays. Bioethanol as a 12−14 vol.% ethanol aqueous solution resulting form biochemical conversion of wood and farm residues. In contrast to natural gas and petroleum products, bioethanol is a renewable fuel. No sulfur and high oxygen content in bioethanol avoid toxic emissions when it is used as the source of energy. One of the methods for efficient power generation consists in bioethanol conversion to syngas for fuel cell applications. Active catalysts for this reaction have been developed. Flow schemes of the power plants based on HT PEMFC integrated with bioethanol steam reformer (fuel processor) have been analyzed. It has been shown that the total efficiency of the power plant, calculated as the ratio of the electric power generated to the lowest calorific value of the consumed fuel, approaches 46%.