Polygeneration is the combined production of work, heat, and chemical products in a single reactor. In this work an internal combustion engine was used as a reactor for the partial oxidation of methane. This process is examined theoretically and experimentally.

The experiments were performed in a single-cylinder engine originally designed for liquid-fuel octane-number measurements. The engine was fueled with lean and rich CH4/air mixtures at equivalence ratios between 0.7 and 3.2. Both spark ignition (SI) and, for very rich mixtures, homogeneous charge compression ignition (HCCI) were investigated. Methane with its low reactivity is not an appropriate fuel for HCCI in this engine. Thus, small amounts of n-heptane were added to increase reactivity and the intake air was heated, which together enabled compression ignition. In addition to the crank-angle resolved in-cylinder pressure, the chemical product output was speciated with a commercial exhaust-gas analyzer detecting CO, CO2, CH4, H2, O2 and C2H4 (as a representative of higher hydrocarbons), while soot was measured as the filter smoke number.

The measurements were accompanied by corresponding zero-dimensional simulations. A single-zone model with a detailed reaction mechanism was used to simulate the process. In order to model spark ignition, the radical concentration was increased for a short period. The concept of exergy (available energy) was used to assess engine performance at different operation points. The product-gas composition, work, and heat output by the engine as well as thermal and exergetic efficiencies were calculated and compared to the results from the experiments.

In SI mode, the maximum product-gas mole fractions of 9 % CO and 8 % H2 were achieved at an equivalence ratio of 1.5. At higher equivalence ratios the number of misfires increased markedly. To enable rich combustion without misfires at equivalence ratios greater than 1.5, HCCI was performed instead, yielding 16 mol-% CO and 18 mol-% H2 in the product gas. A work output between 150 and 200 J per stroke was obtained with both lean and rich combustion, but the exergetic efficiency with fuel-rich combustion was considerably higher than with lean mixtures. Experiment and simulation were in good agreement for operating points without frequent misfires. Thus, polygeneration in internal combustion engines may prove to be a competitive alternative to the generation of work, heat, and chemicals in separate processes.