The need for renewable energy in modern society stems from both the finite amount of fossil fuels and the greenhouse effect of carbon dioxide emissions that accompany their usage. This has led researchers to develop new methods of fuel production for transportation, energy production, and other various fossil-fuel dependent industries. In particular, hydrogen as clean fuel has shown great promise with no greenhouse gas emission and has commercial applications already on the market. Hydrogen storage and on-demand production, however, is the main current technological challenge. On a different front, biomass cracking and deoxygenation technology produces fossil-fuel-like hydrocarbons that are fungible in modern combustion engines and research is making this technology more readily available. Both technologies use a metal catalyst to help increase the yield and improve the conditions of the chemical reactions. In our lab we use mass spectrometry (MS) to study these processes and design new, more affordable metal catalysts. Normally MS is used to determine the mass of molecules. Our lab has rare capabilities in that modifications made to MS instruments give us the ability to perform ion-molecule reactions in the gas phase. This allows us to fine-tune the properties of the catalyst in order to maximize the yields and reduce the costs. Two specific energy-related applications will be discussed - gas-phase deoxygenation and cracking of fatty acids and hydrogen production from formic acid. The combination of gas-phase experiments with high-level computational chemistry can provide great insight into the most efficient way to design catalysts for these applications.