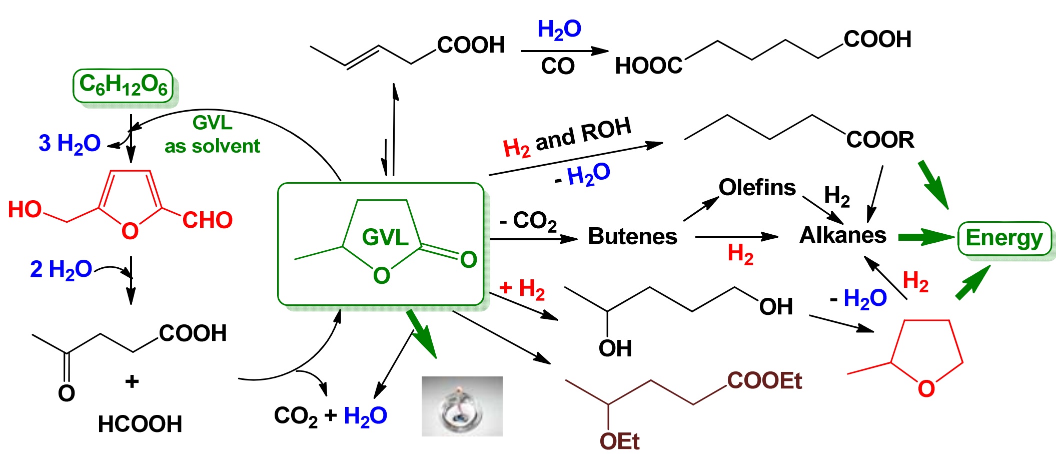
Sustainable Conversion of Carbohydrates to Chemicals and Fuels

István T. Horváth
Department of Biology and Chemistry, City University of Hong Kong

Chemistry has a major role in sustainable developments by providing the fundamental knowledge on how to supply enough energy, food, and chemicals, including carbon-based consumer products, to the increasing population without simultaneously compromising the long-term health of our planet. In order to set deliverable objectives, the use of a measurable definition of sustainability is proposed. ***Resources should be used at a rate at which they can be replaced naturally and the generation of waste cannot be faster than the rate of their remediation.***

This lecture will focus on the conversion of biomass to energy or carbon-based consumer products. Globally, the largest portion of biomass is composed of carbohydrates including C_5- and C_6-monosaccharides, which can be linked together by glycosidic bonds in various combinations to form di- and polysaccharides, which are key components of sugar, starch, lignocellulose, and even some algae. Depolymerization of the glycosidic bonds by catalytic hydrolysis can produce monosaccharides for subsequent conversions. A frequently under-estimated complication of the conversion of glucose or fructose is that both have five molecular isomers in equilibria in solution.[1] Their equilibrium concentrations and reactivity depend on the nature of the solvent, which could be affected by the presence of water. Several intermediates and different reaction paths were identified for the acid catalyzed conversion of fructose and glucose to 5-(hydroxymethyl)-2-furaldehyde (HMF) in different solvents.[1] The acid catalyzed hydration of HMF results in levulinic acid (LA) and formic acid (FA), which can be converted to gamma-valerolactone (GVL) in the presence of the Shvo-catalyst. GVL is considered as a sustainable liquid, since it is renewable and has several very attractive properties.[2] GVL occurs naturally and has been used by the food industry. Its vapor pressure is low even at higher temperatures, does not hydrolyze at neutral pH, and does not form peroxides under air, making it a safe material for large scale use. GVL can be utilized for the production of energy (by adding it to gasoline1 or safely using it as an illuminating or igniting liquid) and carbon-based consumer products:



We have shown that GVL can be produced from fructose[3] or glucose using GVL as a green solvent opening up the opportunity to develop a sustainable process for the production of GVL. Finally, the valorization of food waste[4] was demonstrated by converting white rice, spaghetti, and banana peel to LA and FA in the presence of sulfuric acid in GVL.

[1] Akien, G.; Qi, L.; Horváth, I. T. *Chem. Comm.*, **2012**, *48*, 5850; [2] Horváth, I. T.; Mehdi, H.; Fábos, V.; Boda, L.; Mika, L. T. *Green Chem.* **2008**, *10*, 238; [3] Qi, L.; Horváth, I. T. *ACS Catal.* **2012**, *2*, 2247; [4] Tuck, C. O.; Perez, E.; Horváth, I. T.; Sheldon, R. A.; Poliakoff, M. *Science* **2012**, *337*, 695.