Modularized Production of Value-Added Products and Fuels from Distributed Waste Carbon-Rich Feedstocks

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Modularized Production of Value-Added Products and Fuels from Distributed Waste Carbon-Rich Feedstocks

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ABSTRACT
We have adapted and characterized electrolysis reactors to complement the conversion of regional- and community-scale quantities of waste into fuel or chemicals. The overall process must be able to contend with a wide range of feedstocks, must be inherently safe, and should not rely on external facilities for co-reactants or heat rejection and supply. Our current approach is based on the upgrading of bio-oil produced by the hydrothermal liquefaction (HTL) of carbon-containing waste feedstocks. HTL can convert a variety of feedstocks into a bio-oil that requires much less upgrading than the products of other ways of deconstructing biomass. We are now investigating the use of electrochemical processes for the further conversions needed to transform the bio-oil from HTL into fuel or higher value chemicals. We, and others, have shown that electrochemical reduction can offer adequate reaction rates and at least some of the necessary generality. In addition, an electrochemical reactor necessarily both oxidizes (removes electrons) on one side of the reactor and reduces (adds electrons) on the other side. Therefore, the two types of reactions could, in principle, be coupled to upgrade the bio-oil and simultaneously polish the water that is employed as a reactant and a carrier in the upstream HTL. Here, we overview a notional process, the possible conversion chemistry, and the economics of an HTL-electrochemical process.

1. Introduction

If waste, exemplified here as urban waste[†], could be converted into a liquid fuel or a chemical product, then, in principle and in aggregate, it could displace a noticeable fraction of the petroleum now consumed in the world (Table 1) [1–3]. More significantly, it would transform a costly problem of disposal (from less than 20 to over 200 USD$\cdot$ t^{-1}, depending on population density [4]) into a positive economic resource. The values in the table for the now-wasted resources represent their total enthalpy of combustion; their conversion to fuel would yield a significantly smaller (~50%) energy stream.

Table 1
Comparison of the heating value of petroleum products consumed and urban waste materials generated, on average, per person per year consumed and generated per year.

Region	$E_{petroleum}$ (GJ · (person· a)$^{-1}$)	E_{waste} (GJ · (person· a)$^{-1}$)	$E_{waste}/E_{petroleum}$
World	28	6	20%
China	17	5	30%
United States	134	14	10%

$E_{petroleum}$ is the heating value of the consumed, refined petroleum products [1]; E_{waste} is the heating value of the organic, paper, and plastic components of urban waste [2,3].

† The amount and production rates of waste are expressed here in terms of heating value to aid the comparison with petroleum use. The heating value of waste is highly variable, but the global average for the organic fraction of urban waste is 16 MJ·kg^{-1} compared with 40 MJ·kg^{-1} for petroleum. The global average mass throughputs of waste and petroleum are 440 kg and 620 kg per person per year, respectively. In 2016, the world population was about 7.3 billion.