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Biofuels from waste

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In recent years a number of issues prompted increased use of waste as a source of fuel (recovery of energy) or material (recycling). Societal challenges such as waste management, climate change, and environmental concerns regarding pollution and human health as well as diminishing fossil resources represent some of the most important issues to be tackled by our civilization now and in the (near) future. Exploiting waste, as often unwanted and always locally available substance, offers itself as a way to at least partially alleviate these issues. Many countries have realized the importance of treating waste as a resource and have set regulations that help give a 'second life' to waste. For example, the EU imposed a gradual phase out on landfilling of biodegradable waste and defined a share of the municipal solid waste that should be recycled; there is legislation on limiting methane emissions from landfills and a number of other regulations and schemes regarding waste that are aimed at reducing pollution and emission of greenhouse gases (GHGs).

Despite the recent global recession a steady growth of production of municipal solid and all other kinds of waste is evident. In spite of an increasing share of waste which is separately collected for the purpose of recycling and recovery, the quantity of waste that ends up at landfills is still very large. For instance, in the EU on average nearly 41% of the total amount of municipal solid waste (MSW) is delivered to landfills (by comparison only 19% of total MSW is thermally treated) and in many countries in the world (and even still in some countries in Europe) landfilling is the only means of waste disposal. An estimated 90–95% of MSW in developing countries still end up in landfills. Waste disposed of in anything but properly designed and operated sanitary landfills, particularly those located near major cities and settlements, can have a negative impact to human health and the quality of life in general. The landfills in which such waste is disposed of without previous sorting, mechanical treatment and partial recycling, can contribute to increased emissions and represent a lost resource.

One way to diminish the volume of landfilled waste and to reduce its negative impact is to process the waste prior to landfilling to recover the inherent resource values. If left untreated at landfills, MSW, of which biodegradable matter is a large portion, will generate landfill gas (LFG) emissions (about 50% of which is methane, a potent GHG) due to the process of anaerobic decomposition. Without an effective LFG collection, flaring, and/or energy recovery system, such emissions can contribute to global climate change. Even if such systems are installed a significant portion of the LFG formed is still emitted and contributes to the subsequent negative effects on the Earth's climate. Using waste as a fuel can help to destroy or decrease its harmful properties and at the same time extract the chemical energy trapped in it. There are a myriad of possible paths to convert waste to energy, some of them well established and used for hundred years, whereas others are emerging and still unproven for a real life cost-effective application on a commercial scale.

Thermal waste treatment facilities use the organics in MSW as a fuel for the generation of heat or/and electricity. Modern MSW combustion plants (also known as waste-to-energy (WtE) or energy-from-waste (EfW) plants) are much improved from the 'old' incinerators built in the 1960s or 1970s (and sometimes even into the 1980s), incorporating advanced combustion and air emission reduction technologies. The level of toxic emissions (dioxins, furans, other harmful organic compounds and heavy metals) from new WTE plants is almost one thousand times smaller than those from the earlier incinerators. It can be said that modern EfW technology has reached its mature stage even if in some countries it still holds a negative image. The main issues for improvement of EfW technology nowadays concentrate on increasing the energy efficiency of installations as well as the quality of the remaining solid residues. Combustion is also the technology of choice today for other waste materials such as waste wood from construction/demolition projects, packaging, land-clearing projects, and households. Waste fuels (MSW or waste biomass) can sometimes be co-incinerated along with other fuels such as coal or 'clean' biomass in traditional power and heating plants or burned in rotational furnaces used in the cement industry (where more often solid recovered fuels (SRF) and biosolids are used). In all these cases the focus is not the treatment of waste but the utilization of the energy potential in waste. Therefore, appropriate collection schemes and pre-processing of waste is crucial to allow for increased use of waste as a fuel in these types of co-incineration plants.

Another state-of-the-art technology for waste-to-biofuel processing is anaerobic digestion (or more correctly anaerobic decomposition) of biodegradable waste that usually contains a higher percentage of moisture. The preferred way is anaerobic digestion in bio-reactor vessels in which the process takes place more efficiently and with better control of the resulting methane emission (as opposed to LFG extraction where part of the generated LFG may escape collection). Furthermore, the same technology is often used for a treatment of sewage sludge (biosolids). (Note that subject to the technology used dried and even only dewatered biosolids can also be incinerated).

Recently (in the last decade or two) more innovative technologies have been applied for energy recovery of waste. Gasification (thermal and plasma arc), pyrolysis, hydrolysis, etc., nearly all promise lower emissions, higher efficiencies or lower costs. The reality is that complexity of the procedures (and especially the gas cleaning steps) and costs currently limit their wider use. Interestingly enough these technologies (along with others, such as direct liquefaction) can be also applied for production of liquid fuels (i.e. 'biofuels') to be used in transport. Of course only specific waste streams are 100% biogenic and therefore appropriate to be considered as '100% biofuels' (kitchen and garden waste, used cooking oil, etc.). Nevertheless, even if non-biogenic the recovery of energy from waste that cannot be recycled anymore is a very reasonable option. Using waste for production of transport biofuels could alleviate the problem of competition of using biomass for production of fuel instead of food (and feed). The problem of biofuels versus food, which often manifests in increased pressure on food markets and contributes to water scarcity and sometimes depletion of forests, becomes more and more important as the increase in the world population pushes up demand for food (and the amount of land needed to be put under cultivation to satisfy growing demands for both food and biofuel). As a result the EU recently proposed a new policy that will promote greater production of 'advanced biofuels' (i.e. second-generation biofuels) by shifting subsidies away from food crop fuels to residue and waste fuels. Although there is already much attention given to producing liquid fuels from various (production) waste materials there is either a lack of proof of practical applicability for the proposed processes or a lack of solid scientific evidence of the function of the processes applied. In particular, there have been no thorough ecological assessments regarding the energy balance and handling of the pollutant potential contained in the specific waste streams. Additional research is needed to enable a technological advance without compromising environmental standards.

It is not completely clear if the first or second generation biofuels will withstand the challenge of electrification of passenger cars. In the shorter term biofuels could bridge the demand for transport fuel in urban and sub-urban areas although there are findings that suggest there are advantages of using electricity over biofuels on short-haul and light transportation systems. The importance of biofuels (including liquid biomethane) lies in the use for medium- and long-haul (and heavy duty) trucks, ships and aeroplanes. The possibilities of GHG emission reduction from these means of transport are currently almost untapped and represent a substantial part of all GHG emissions (e.g. in the EU 20% of all GHG emissions in 2008 were emissions from the transport sector and they are steady growing despite the higher energy efficiency of vehicles).

It is also known that production and use of biofuels can help to achieve energy security by reducing dependency on oil imports and reducing oil price volatility. Another benefit of biofuels-from-waste (including new synthetic fuels produced by processes such as hydrogenating carbon dioxide recycled from power plant flue gases) is that they can be used for energy storage. This is an advantage over the availability of energy from intermittent renewable energy sources such as wind and solar.

Despite all the positive aspects of biofuels regarding climate protection, this must not be the sole criterion for evaluation of waste as biofuel. One must also consider other environmental impacts. The whole system from a life cycle perspective should be taken into consideration in order to provide the right recommendations from the sustainability point of view, related research and development needs to be supported in order to prevent strategically wrong developments.

These and many other sustainability aspects are addressed in papers published in this special issue of *Waste Management & Research*, most of which were presented at the past two conferences on Sustainable Development of Energy, Water and Environment Systems (SDEWES), which were held in Dubrovnik, Croatia in 2011, and in Ohrid, Macedonia in 2012. The SDEWES Conference, which is sponsored by UNESCO, is a leading conference in the field of energy, sustainable development and environment in the region. The next SDEWES Conference will be held on 22–27 September 2013, in Dubrovnik. It will be dedicated to the improvement and dissemination of knowledge on methods, policies and technologies for increasing the sustainability of development by de-coupling growth from natural resources and advancing towards a knowledge-based economy, taking into account its economic, environmental and social pillars, as well as methods for assessing and measuring sustainability of development, regarding energy, transport, water, environment and food production systems and their many combinations. More details regarding the conference can be found at: http://dubrovnik2013.sdewes.org/.

Daniel R Schneider
Department of Energy, Power Engineering and Environment
Faculty of Mechanical Engineering and Naval Architecture, University of Zagreb, Zagreb, Croatia
Email: daniel.schneider@fsb.hr

Arne M Ragossnig
UTC – Umwelt – Technik – Consult e.U.,
Vienna, Austria
Email: ragossnig@utc.co.at