Clean Energy: Steam Reformation Technology

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One possible solution for clean energy production is to produce energy products from waste and biomass feedstocks by effective Biomass/Waste-to-Energy technology applications. Typically, the waste is sent to landfills and the energy in waste is essentially lost, creating mountains of trash, and emitting harmful pollutants into our air, water and soil. In a landfill the biodegradable components of waste decompose and emit methane – a greenhouse gas, which is at least 21 times more harmful than carbon dioxide and the cause of significant environmental problems [1].

In addition, landfill fires, earth movements, and groundwater flows contribute to landfill leachate, which eventually leak and contaminate nearby ecosystems. In response to global environmental challenges, there have been requirements towards Waste-to-Energy technologies to produce clean/alternative energy from waste feedstocks (e.g. Municipal Solid Waste (MSW), industrial waste, biomass waste, sewage sludge, plastics used tires, etc.) and biomass.

Both biomass and waste feedstocks contain carbonaceous materials. There are extensive biomass resources, such as forestry residues, energy crops, manufacturing wood waste, olive husks, grasses, livestock and food processing residues. Wood is the most commonly used biomass fuel. The most economic sources of wood for fuel are wood residues from manufacturers, discarded wood products diverted from landfills, and wood debris from construction and demolition activities. Fast-growing energy crops (e.g., short rotation hardwoods) show promise for the future, since they have the potential to be genetically tailored to grow fast, resist drought and be easily harvested.

The primary challenge of clean energy production is the heterogeneous nature of waste and biomass, which creates a widely varying chemical constituency of the energy products generated from these processes. Feedstocks can be converted to higher value products by the physico-chemical (including biochemical) interactions, such as thermo-chemical and/or biological processes, without or with additional reactants (e.g. water, oxygen, air, etc.) [2, 3]. The produced product type depends on the types of feedstocks and reactants, and the applied physico-chemical interaction conditions in the system. The higher value products created from waste can be transformed to various forms of clean energy correspondingly to the application/ market requirements. The steam reformation technology could successfully be used to convert biomass and waste feedstocks into clean energy products.

Steam Reformation

Steam Reformation is a thermo-chemical process and is based on carbonaceous materials reaction with steam without the participation of oxygen or air at elevated temperatures above 700°C. The main product of the reactions is a synthesis gas (syngas) containing mostly hydrogen and carbon monoxide, and a smaller amount of methane, carbon dioxide, water vapour, and other hydrocarbons. Usually, the steam reformation process is used for production of hydrogen from natural gas. Biomass/waste steam reformation is based on reactions of carbonaceous materials content of feedstocks (e.g. biomass, MSW, sewage sludge, plastics) with steam.

The steam reformation technology represents a potential alternative for the traditional waste and biomass treatments to produce higher energy content syngas, which contains no noxious oxides and higher hydrogen concentration than products produced by gasification [3]. The chemistry is different due to the high concentration of steam as a reactant and the total exclusion of air, and therefore oxygen, from the steam reformation process. The produced pollutants should be removed to produce clean energy products. Contaminates (e.g. tar, acid gases, ammonia, and particulate matter) are easier to remove from the syngas because it is not diluted by excess air or nitrogen and products of combustion.

The steam reformation technology eliminates the formation of dioxins, furans and nitrous and sulfur oxides within the conversion process. Additionally, the steam conversion method significantly reduces the volume of the original waste feedstock converting carbonaceous materials into usable energy products.

Utilizing an indirectly heated kiln, the waste steam reformation technology is a novel and unconventional Waste-to-Energy technology, which allows for robust operation of various heterogeneous feedstocks (e.g. MSW, industrial waste, sewage sludge, biomass, plastic, used tires and medical waste) with high moisture content and significantly reduces the requirements for pre-processing feedstock [4]. The developed unique conversion of carbonaceous materials and a scrubbing/cleaning system produce clean syngas and reduce water and land contamination to protect air, water, and land. The produced syngas has a high hydrogen content syngas – up to 50% by volume, an H2/CO ratio over 2, and a high heating value, which is typically higher than syngas produced by competitor technologies.

The high quality of the produced syngas and residual waste heat could be used to power combined cycle gas turbines, reciprocating gas engines or fuel cells for the generation of electricity and “green” hydrogen. In addition, because of high hydrogen to carbon monoxide ratio of the syngas, the technology can potentially be coupled with a Gas-to-Liquids technology (e.g. Fischer – Tropsch process) to produce higher value liquid synthetic fuels, such as synthetic diesel, methanol, and “green” chemicals. A combination of the waste (biomass) steam reformation as a Biomass/Waste-to-Gas technology with a Gas-to-Liquids technology could become an economic and environmentally viable method of the clean energy production.

Conclusion

The waste/biomass steam reformation technology has a number of advantages over traditional Waste-to-Energy technologies, including robust operation of various heterogeneous feedstocks, a production of high quality syngas, and reduction of the produced usable gas and residual waste volumes. The steam reformation of waste/biomass is more efficient than other thermo-chemical and bio-chemical technologies. The technology is able to convert both biodegradable and also non-biodegradable carbonaceous waste contents into higher value clean/renewable energy products. Therefore, the steam reforming can potentially be combined with anaerobic digestion to convert non-biodegradable product – digestate into fuels [3].

The Waste-to-Energy technology can be optimized by analysing interactions in material system and modifying physico-chemical interactions, chemical bonds and reactants to produce new products having clean usable energy content. Additionally, the goal is to separate the contaminations from the produced energy products to produce clean energy and segregate the toxic components (e.g. heavy metal compounds) in the smaller volume of the produced solid residue. If contaminants are not above the application specification limits, the main part of produced solid residue can be utilized (e.g. construction aggregate materials).

The physical-chemical interactions of waste and biomass feedstocks with steam, as a reactant, is one of the most promising pathways of energy production as a thermo-chemical conversion of feedstocks into clean and renewable energy. The biomass/waste steam reformation technology can convert various heterogeneous feedstocks and divert waste materials from landfills producing clean energy and significantly reduce environmental impacts versus other waste disposal and waste conversion methods. The steam reformation technology could change waste to a clean energy source, replace a portion of fossil fuels, and provide cost effective and environmentally sound supply of clean energy.

References

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Zoltan Kish has a Ph.D. in Chemistry/Materials Science from the N. S. Kurnakov Institute of General & Inorganic Chemistry, Academy of Sciences in Moscow, Russia. He has over 25 years of diverse industrial and academic experience and has contributed to more than 70 scientific publications. Dr. Kish has been the Director of Research & Development at two major Canadian energy companies, where he focused on Waste-to-Gas & Gas-to-Liquids technologies, gasification of biomass, waste reformation into syngas, unique scrubbing and gas cleaning systems, mass & energy balances, clean energy, catalysts, and gas chemistry for power generation and higher value products, such as hydrogen, synthetic liquid bio-fuels and chemicals. He also contributed to the advanced materials developments for many fields of applications, such as CleanTech, ceramic engine components, materials processing, and electronics. Dr. Kish provides science and technology assessments and technical due-diligence in the fields of Clean Technology & Energy, Materials Science, Chemistry, Environmental Science, Sustainable Products, and Advanced Materials Applications. He works as a consultant for Lee Enterprises Consulting and Principal of Quasar ScienceTech in Canada.