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Waste-to-energy: A way from renewable energy sources to sustainable development

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ABSTRACT

Nowadays, energy is key consideration in discussions of sustainable development. So, sustainable development requires a sustainable supply of clean and affordable renewable energy sources that do not cause negative societal impacts. Energy sources such as solar radiation, the winds, waves and tides are generally considered renewable and, therefore, sustainable over the relatively long term. Wastes and biomass fuels are usually viewed as sustainable energy sources. Wastes are convertible to useful energy forms like hydrogen (biohydrogen), biogas, bioalcohol, etc., through waste-to-energy technologies.

In this article, possible future energy utilization patterns and related environmental impacts, potential solutions to current environmental problems and renewable energy technologies and their relation to sustainable development are discussed with great emphasis on waste-to-energy routes (WTERs).

Contents

1. Introduction

Investigations of alternative energy strategies have recently become important, particularly for future world stability. The most important property of alternative energy source is their environmental compatibility. Inline with this characteristic, renewable energy sources (mainly organic waste materials to energy) likely will become one of the most attractive substitutes in the near future.

Renewable waste materials from agriculture [1–5], industries [6–12] and domestic [13–18] sources are convertible to useful energy forms like biohydrogen, biogas, bioalcohols, etc., through waste-to-energy routes (WTERs) for sustainable growth of the world.

Normally, framework of four energy paths is considered to attain sustainability with existing and alternative routes. These energy paths are: Path (1), continuation of current energy use technologies with amendments; Path (2), universal adoption of advanced energy technologies for transportation and electricity generation; Path (3), the production of alternative renewable energy sources from waste and biomass resources to supplement conventional energy production processes; and Path (4), the development of centralized clean energy production routes and distribution systems.

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The purpose of this study was to review the potential associated with Path 3 for energy resource sustainability within the context of energy resource production routes (microbial conversion routes-fermentation), the adoption of WTER technologies for transportation and electricity generation, and the production of alternative fuels including biogas and hydrogen gas (H_2) and techno-economic growth and limitations for selected WTER.

2. World global problems and renewable energy

Effects of the utilization of fossil fuels, such as global climate change, world energy conflicts and energy source shortages, have increasingly threatened world stability. Their negative effects are observed at all levels of the society, i.e. locally, regionally and globally. These global world problems can be summarized through the following three sections:

- Decrease in fossil fuel reserves due to world population growth and increasing energy demand.
- Global climate change due to the increase of CO_2 concentration in the atmosphere.
- Increase in levels of wastes (solid/liquid) due to increase in population among world.

Various types of wastes from agricultural (plant and animal wastes), industrial (sugar refinery, dairy wastes, confectionary waste, pulp and paper, tanneries and slaughter houses) and residential (kitchen waste and garden waste) sectors are the potential renewable energy sources to attain sustainability and for switchover to waste-to-energy routes (WTERs).

All over the world lots of R&D is going to solve the local, regional and global problems, discussed in above sections. Most of the researchers show their reliance on renewable energy technologies (RET) for sustainable development and long lasting life on this planet earth for their daily energy needs through waste-to-energy routes (WTERs), that do not cause negative societal impacts. Among all the countries of the world, European Union countries showed a remarkable R&D work on this (RET), for example, Meyer et al. were calculated a scenario for sustainable development through renewable energy sources for Denmark, Norway and Sweden separately for 2030 [19]. Similarly, Panoutsou et al. [20] reviewed the future potential of biomass resources (a renewable source) in Europe based on various sectors like agriculture, industrial, etc. This article also highlights the cut in waste generation amount in EU countries, through new waste prevention initiatives, better use of resources and encouraging a shift to more sustainable consumption patterns.

Energy sources such as solar radiation, the winds, waves and tides are generally considered renewable and therefore, sustainable over the relatively long term. Sustainable energy sources that are abundantly available can:

- Reduce or stop conflicts among countries regarding energy reserves.
- Facilitate or necessitate the development of new technologies through WTER.
- Reduce air, water and land pollution and the loss of forests.
- Reduce energy-related illnesses and deaths.

Accordingly, the transition to a sustainable renewable resource should be encouraged, and developing countries, in particular, should increase investments in renewable waste-to-energy routes (WTERs) from various sectors.

3. Potential substitutes of waste-to-energy routes (WTERs)

World requirements for energy will increase by a factor of about six times by 2100. If this demand is bifurcated between developed and developing countries than in the developed countries, there is no shortage of power. Whereas, in the developing countries like India and China, the ratio of energy available to energy required is highly incompatible. This uneven energy distribution in the world, a technology needs to be developed to serve as a secondary source of energy and mitigate energy crisis. It would be wise to develop other fuels, which do not give so much carbon dioxide and can be easily produced with the use of environmental waste. WTER technology may be perceived as a potential alternative as it not only provides renewable source of energy but also utilizes recycling potential of degradable-organic portion of solid waste generated by a numerous activities. Here, only two potential substitutes for WTER technology are considered and reviewed in this article.

3.1. Biogas technology (BT)

In 1776, for the first time, the Italian Physicist, Volta, demonstrated methane in the marsh gas, generated from organic matter in bottom sediments of ponds and stream. Under anaerobic conditions, the organic materials are converted through microbiological reactions in to gases (biogas) and organic fertilizer (manure). Biogas and manure are the end products obtained from BT whereas conventional composting process produces only manure as the product after decomposition of solid organic waste. Thus, comparatively BT could be considered as better option for its compactness, cleaner operation and better product range (i.e. both gas as energy source and processed solid waste as manure). Methane is the main constituent of biogas. About 90% of energy of substrate is retained in methane. It is used mainly for cooking, lighting and in internal combustion engines to power water pumps and electric generators. The most economical benefits are minimizing environmental pollution and meeting the demand of energy for various purposes. In India, the Ministry of New and Renewable Energy (MNRE) (Government of India) has declared a National Master Plan in 1994, which incorporates BT as one of the major waste-to-energy options to be developed and adopted in the country [21].

3.1.1. Efficient feedstocks

A variety of waste sources like urban, agriculture, industrial sectors, vegetable markets, etc., generate huge quantities of solid waste containing a sizeable proportion of biodegradable-organic matter with municipal solid waste (MSW) having largest proportion. This material, if processed anaerobically, will not only generate significant quantity of biogas, i.e. about 250–350 m^3/tonne of waste (NEERI Report, 1996) and manure but will also reduce the load on landfilling and will in turn prevent the degradation of environmental quality due to uncontrolled decomposition of organic matter in the landfills. Bouallagui et al. studied both fruit and vegetable wastes together for biogas production [5,22]. Similar type of studies were done by Ranade et al. [23], Mataalvarez et al. [24] and Pavan et al. [25] taken market waste (rotten vegetables, fruit skins, potatoes, onion, etc.) and household solid waste respectively intensively used for methane production. Demirel and Scherer [26] did the laboratory-scale study was to investigate the long-term anaerobic fermentation of an extremely sour substrate, an energy crop, for continuous production of methane (CH_4) as a source of renewable energy. The sugar beet silage was used as the mono-substrate, which had a low pH of around 3.3–3.4, without the addition of manure. The mesophilic biogas digester was operated in a hydraulic retention