Renewable and Sustainable Energy Reviews 33 (2014) 578–588

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

An overview on the production of bio-methanol as potential renewable energy

N.S. Shamsul [a], S.K. Kamarudin [a,b,*], N.A. Rahman [b], N.T. Kofli [b]

[a] Fuel Cell Institute, Universiti Kebangsaan Malaysia, 43600 UKM Bangi, Selangor, Malaysia
[b] Department of Chemical and Process Engineering, Universiti Kebangsaan Malaysia, 43600 UKM Bangi, Selangor, Malaysia

ARTICLE INFO

Article history:
Received 4 September 2012
Received in revised form
6 February 2014
Accepted 15 February 2014
Available online 12 March 2014

Keywords:
Bio-methanol
Biomass
Waste
Techno-economy

ABSTRACT

The depletion of the fossil fuel supply and the environmental pollution caused by fossil fuel combustion have become major worldwide problems. Biomass is a renewable resource that has the potential to replace fossil fuels. One of the valuable biomass products is bio-methanol, which can be used to generate electricity and power for portable applications. This paper discusses the potential of bio-methanol as a renewable resource taking into account the world demand, economic assessment, power density and possible applications. It therefore presents the unique properties of bio-methanol as a potential energy resource. It also discusses the various types of biomass that can be obtained from waste products and the different processes that have been developed for the production of bio-methanol fln addition, it discusses the current problems facing bio-methanol production and the further technological improvements that are needed to support the future energy requirements. Overall, the yield of bio-methanol depends on the type of process used and the associated kinetic parameters of the conversion process. Catalysts have been used in the thermo-chemical and bio-chemical conversion of carbon dioxide into bio-methanol. Several advanced methods have been recently introduced to enhance the production of methanol, but further research is required before these can be used for large-scale bio-methanol production.

Contents

* Corresponding author. Tel.: +60 389216422; fax: +60 389216148.
E-mail address: ctie@vlsi.eng.ukm.my (S.K. Kamarudin).

http://dx.doi.org/10.1016/j.rser.2014.02.024
1364-0321

1. Introduction

Technology enhancements and human development contribute to the continuous increase in the worldwide energy demand [1–3]. There are three categories of energy sources: fossil fuels, renewable and nuclear energy. Fossil fuels, such as coal, petroleum and natural gas, are non-renewable energy sources that will be depleted in the next few years [4–6]. The renewable energy sources include solar, wind, hydroelectric, biomass and geothermal energy, whereas nuclear energy is derived from fission and fusion reactions [6]. Fossil fuel source depletion has increased the need to reduce the consumption of fossil fuels [7–9]. However, the depletion is not the only current concern with fossil fuel use. The environmental degradation caused by burning fossil fuels and the waste products produced have created an imbalance in the atmospheric carbon dioxide (CO_2) levels, which has become the major contributor to global warming [10]. In addition, the municipal solid wastes from human and animal activities have also contributed to the environmental degradation. Therefore, it has been suggested that this waste should be recycled or converted into energy [11–14].

The disposal of agricultural, human and animal waste (solid) that is categorised as biomass material is yet another problem that should be addressed. In addition to its use as a plant fertiliser, animal waste can be converted via a chemical reaction and thus has the potential to be used as a chemical feedstock. The fossil fuel emission during fuel processing has prompted the search for renewable sources that emit zero or low pollution. The use of bio-methanol from biomass is more advantageous than fossil products because of its low pollution emission and raw material availability; furthermore, the characteristics of this alcohol are identical to those of fossil fuel. Hence, biomass is a renewable energy source that can potentially replace fossil fuels [7,15,16]. It is well-known in certain countries, such as Brazil and the US, that bio-methanol from biomass can produce electrical energy [17]. This paper discusses the various types of biomass that can be obtained from waste, the different processes that are available for methanol production and the current problems that are involved in the production of methanol. In essence, this paper will discuss the potential of bio-methanol as a renewable power resource.

2. The potential of methanol as a future renewable energy source

2.1. World demand for methanol

In 2000, approximately 6.2 billion tons of carbon was emitted into the atmosphere as CO_2 and approximately 40% of this was emitted during the production of electricity. A survey from the U.S. Department of Energy revealed that the consumption of electricity, which increases significantly every year, is projected to increase by 44% from 2006 to 2030 [18]. By 2050, road transportation is expected to be the largest contributor to greenhouse emissions. In Europe, the renewable energy target for 2010 was approximately 5.75% of the transport fuels sold, and this target will likely increase to 10% in 2020. If this trend continues, the renewable energy target for the transport fuels sold should reach 27% by 2025. Compared with the gasoline and fossil diesel demands (51% and 22%, respectively), biofuels are expected to constitute 75% of the total demand [19].

Natural gas comprises approximately 80% of the total cost of methanol production in Western European methanol plants [20]. In fact, the total cost of methanol production from CO_2 is 500–600 € t^{-1}; however, the cost of producing methanol from biomass is approximately 300–400 € t^{-1} of methanol [21]. Thus, biomass processing is the most cost-effective of the processes that have been developed for the production of methanol from renewable sources [19]. The production cost of bio-methanol is lower than that of light oil, which is used in power stations [7]. Hasegawa et al. [17] reported that the U.S. and Brazil currently monopolise the biomass processes for bio-ethanol production using grain or the combination of sugar cane and corn. However, because the feedstock (corn) for these bio-ethanol products is a food product, this practice has attracted criticism given the increasing food prices and the global food shortage. Although both methanol and ethanol are liquid hydrocarbons, ethanol is twice as expensive as methanol. However, the location, capacity, mode of operation, operating conditions and the purity grade of the final product are factors that affect the economics of methanol production.

2.2. Economy assessment of methanol

As one of alternative compound, more than 75% of methanol produced by natural gas, synthesis from the syngas. Today, about 90 methanol plants generated with a total annual capacity of more than 50 million tons. Fig. 1 presents the price for production of methanol from fossil resources. The price of methanol is not stable from year 2006 until 2009 but after that, the price is increased until year 2011. Therefore, as demand for the methanol increased, it is expected that the price of methanol will also increase in next future [22].

Adamson et al. claimed that about 3.13 USD GJ^{-1} in year 1990 required for production of methanol via electrolysis process with hydropower feedstock. While for gasification of biomass, plant size

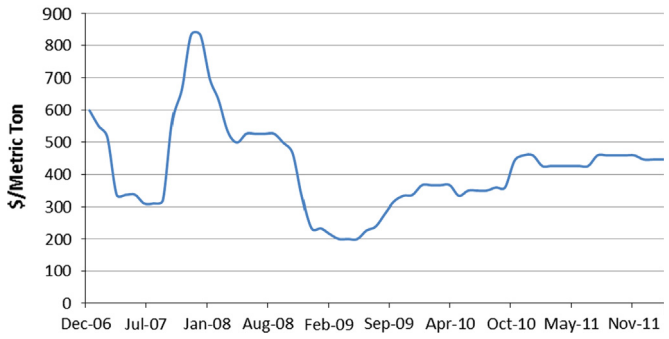

Fig. 1. Methanex non-discounted reference price of methanol (MNDRP) [22].