Renewable and Sustainable Energy Reviews 58 (2016) 267–286

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

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

Biomass to liquid transportation fuel via Fischer Tropsch synthesis – Technology review and current scenario

Snehesh Shivananda Ail, S. Dasappa*

Center for Sustainable Technologies, Indian Institute of Science, Bangalore 560 012, India

A R T I C L E I N F O

Article history:
Received 16 June 2014
Received in revised form
29 October 2015
Accepted 17 December 2015

Keywords:
Fischer Tropsch
BTL
Catalysts
FT kinetics
FT reactors
BTL economics

A B S T R A C T

Current global energy scenario and the environmental deterioration aspect motivates substituting fossil fuel with a renewable energy resource – especially transport fuel. This paper reviews the current status of trending biomass to liquid (BTL) conversion processes and focuses on the technological developments in Fischer Tropsch (FT) process. FT catalysts in use, and recent understanding of FT kinetics are explored. Liquid fuels produced via FT process from biomass derived syngas promises an attractive, clean, carbon-neutral and sustainable energy source for the transportation sector. Performance of the FT process with various catalysts, operating conditions and its influence on the FT products are also presented. Experience from large scale commercial installations of FT plants, primarily utilizing coal based gasifiers, are discussed. Though biomass gasification plants exist for power generation via gas engines with power output of about 2 MW_e; there are only a few equivalent sized FT plants for biomass derived syngas. This paper discusses the recent developments in conversion of biomass to liquid (BTL) transportation fuels via FT reaction and worldwide attempts to commercialize this process. All the data presented and analysed here have been consolidated from research experiences at laboratory scale as well as from industrial systems. Economic aspects of BTL are reviewed and compared.

Contents

* Corresponding author. Tel.: +91 80 23600536; fax: +91 80 23601692.
E-mail addresses: snehesh.s@gmail.com (S.S. Ail), dasappa@cgpl.iisc.ernet.in (S. Dasappa).

http://dx.doi.org/10.1016/j.rser.2015.12.143
1364-0321/

1. Introduction

On one hand fossil fuel price is increasing with time and on the other hand, the cost of renewable energy based systems is gradually decreasing due to the increased available sustainable technologies relating to renewable energy. The exhaustive use of fossil fuels is one of the prime reasons for global warming leading to climate change [1]. Worldwide energy usage in the transportation sector is second only to the industrial sector in terms of gross end-use energy consumption. According to International Energy Outlook-2011 [2], the estimated fraction of global transportation fuel consumption surges from 54% in 2008 to 60% in 2035 accounting for 82% of the total increase in world liquid fuel consumption. Fig. 1 shows the increased use of all energy sources with time. Liquid fuel consumption increases at an average rate of 1% from 2008 to 2035 whereas total energy demand increases by 1.6% annually. Liquid fuels are expected to continue dominating the transportation sector despite rising prices. Global consumption of renewable sources rises by 2.8% annually, as shown in Fig. 2. Non-OECD (Organization for Economic Co-operation and Development) transportation energy use increases by 2.6% per year, compared with 0.3% per year projected for the OECD nations [2]. Current use of fossil fuels in different sectors continues to threaten global stability and sustainability. Sustainable energy sources are required due to limited availability of fossil fuel reserves and unavoidable environmental impacts of their utilization [3].

Use of renewable energy is called for primarily owing to the increased concentration of anthropogenic greenhouse gases (GHG) in the atmosphere. Emissions due to the combustion of fossil fuels for heat and electricity generation and transportation are two dominant sources of GHG emissions. These accounted for 47% and 23% respectively of total fossil fuel related CO_2 emissions in 2004 [4]. In OECD, 30% of the overall GHG emissions are from the transport sector. In the European Union (EU), average emissions for cars, in 2009, were set to 154 gCO_2/km. This limit is targeted to be further reduced, by 2020, to 95 gCO_2/km, thus counteracting the predicted GHG increase due to road transport. A fraction of this reduction could be brought about by the use of fuel efficient cars. However, the fuels in use should itself be less carbon intensive to achieve the objective [5].

Amongst the alternative energy sources, biomass plays a major role in the energy sector. The only natural, renewable carbon resource and large fraction of substitute for fossil fuels is biomass. A wide range of biomass based materials has been proposed for use, which include crop residue, agro-crops, and several tree species. These products can be burnt directly for energy and can also be processed further for conversion to liquid fuels like ethanol and diesel [6]. Thermal processes offer an effective means for the conversion of the energy content of the wood and other lignocellulosic biomass. Wood constitutes 80% or more of volatile matter and nearly 20% char can be converted to gaseous fuels. Biomass to liquid (BTL) is suggested to be a positive route to reducing the inclination towards fossil transportation fuels and is also a key to keeping the environment clean [7]. For 20% of the total liquid fuels produced from carbon neutral sources, like biomass, 15% CO_2 emissions reduction could be achieved – just by fuel replacement [8].

Processes which have been positively experimented for conversion of biomass to liquid transportation fuels include fast pyrolysis of biomass, direct liquefaction of biomass, transesterification of vegetable oils to produce diesel fuel, production of bio-ethanol from agricultural crops to blend with gasoline, production of bio-oil from algae, and most recently the FT process for conversion of biomass derived syngas to higher hydrocarbons. It is indisputable that under the current energy and environmental scenario, the global consumption of biomass derived energy which include electricity and liquid fuels would increase and most likely comprise 30% of the total energy by 2050 [9].

This paper discusses the technical details involving Fischer Tropsch process along with its recent developments and presents

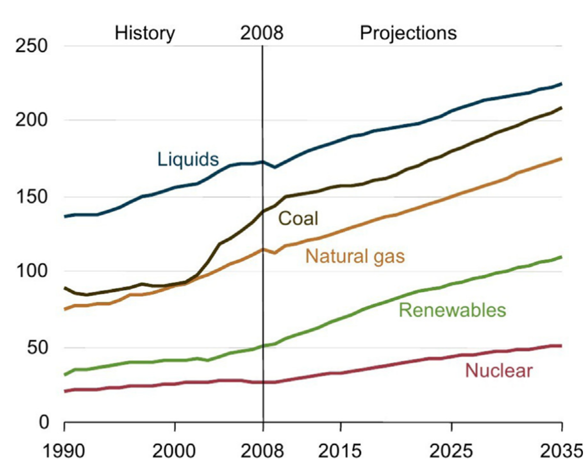

Fig. 1. World energy consumption: 1990–2035 [2].

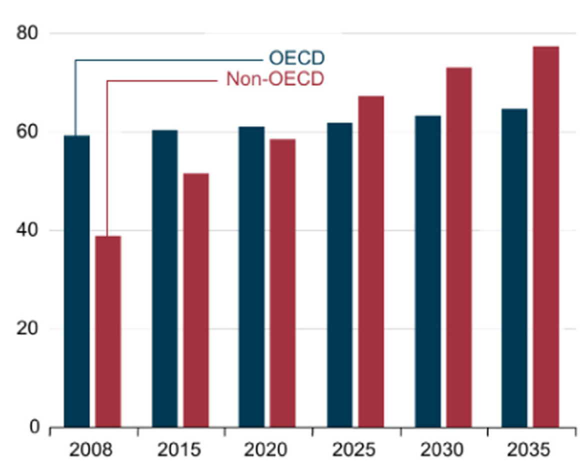

Fig. 2. World transportation energy consumption (quadrillion BTU) [2].