Bioresource Technology 169 (2014) 742–749

Contents lists available at ScienceDirect

Bioresource Technology

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

Review

A mini review on renewable sources for biofuel

Dang P. Ho [a], Huu Hao Ngo [b,*], Wenshan Guo [b]

[a] *Advanced Water Management Centre, School of Chemical Engineering, University of Queensland, Brisbane, Australia*
[b] *Centre for Technology in Water and Wastewater, School of Civil and Environmental Engineering, University of Technology, Sydney, P.O. Box 123, Broadway, NSW 2007, Australia*

HIGHLIGHTS

- The use of food-crop related biomass for 1st generation biofuel is unsustainable.
- 2nd generation lignocellulosic biomass are ready for full commercial exploitation.
- 3rd generation algal biomass represents potential renewable source.
- A combination of three generations will need to be met growing energy demand.

ARTICLE INFO

Article history:
Received 27 May 2014
Received in revised form 4 July 2014
Accepted 5 July 2014
Available online 11 July 2014

Keywords:
Bioenergy
Agricultural residues
Organic wastes
Biomass
Energy crops

ABSTRACT

Rapid growth in both global energy demand and carbon dioxide emissions associated with the use of fossil fuels has driven the search for alternative sources which are renewable and have a lower environmental impact. This paper reviews the availability and bioenergy potentials of the current biomass feedstocks. These include (i) food crops such as sugarcane, corn and vegetable oils, classified as the first generation feedstocks, and (ii) lignocellulosic biomass derived from agricultural and forestry residues and municipal waste, as second generation feedstocks. The environmental and socioeconomic limitations of the first generation feedstocks have placed greater emphasis on the lignocellulosic biomass, of which the conversion technologies still faces major constraints to full commercial deployment. Key technical challenges and opportunities of the lignocellulosic biomass-to-bioenergy production are discussed in comparison with the first generation technologies. The potential of the emerging third generation biofuel from algal biomass is also reviewed.

1. Introduction

As global demand for energy continues to rise, carbon dioxide emissions are expected to reach new record high, increasing from 31 Gt in 2011 to approximately 37 Gt in 2035 (IPCC, 2013). The need for climate change adaptation and the growing concerns over energy security are the main drivers behind the policies of many countries (belonging to the Organisation for Economic Co-operation and Development (OECD)) that encourage the growth of renewable energy. Today, renewable energy contributes 13% of the total global energy consumption, in which bioenergy accounts for approximately 10% (Fig. 1). Bioenergy refers to the energy content in solid, liquid and gaseous products derived from biological raw materials (biomass) (IEA, 2010). This includes biofuels for transport (e.g. bioethanol and biodiesel), products to produce electricity and heat (e.g. wood chips and pellets), as well as biogas (e.g. biomethane and biohydrogen) produced from processing of biological materials from municipal and industrial waste (IEA, 2013).

Biofuels for transport represent the major fraction of bioenergy production worldwide. Biofuels are primarily produced from food crops with high content of sugar and starch, such as corn and sugarcane to produce ethanol, and oil seeds to produce biodiesel (IEA, 2010). These first generation technologies have been the first significant step of transition away from the traditional fossil fuels. It has then moved forward to the next generations of biofuels produced from non-food biomass, including residues of crops or forestry production (e.g. forest thinning, sawdust, etc.), dedicated energy crops (e.g. switchgrass, poplar, and miscanthus), lignocellulosic fraction of municipal and industrial solid waste, and algal biomass (Gupta et al., 2014; Sims et al., 2010).

More than two-thirds of bioenergy comes from the first generation land-based feedstocks (Fig. 1), leading to growing concerns over competition for land and water for food and fibre production

* Corresponding author. Address: School of Civil and Environmental Engineering, University of Technology, Sydney (UTS), P.O. Box 123, Broadway, NSW 2007, Australia. Tel.: +61 2 9514 2745; fax: +61 2 9514 2633.
E-mail address: ngohuuhao121@gmail.com (H.H. Ngo).

http://dx.doi.org/10.1016/j.biortech.2014.07.022
0960-8524/

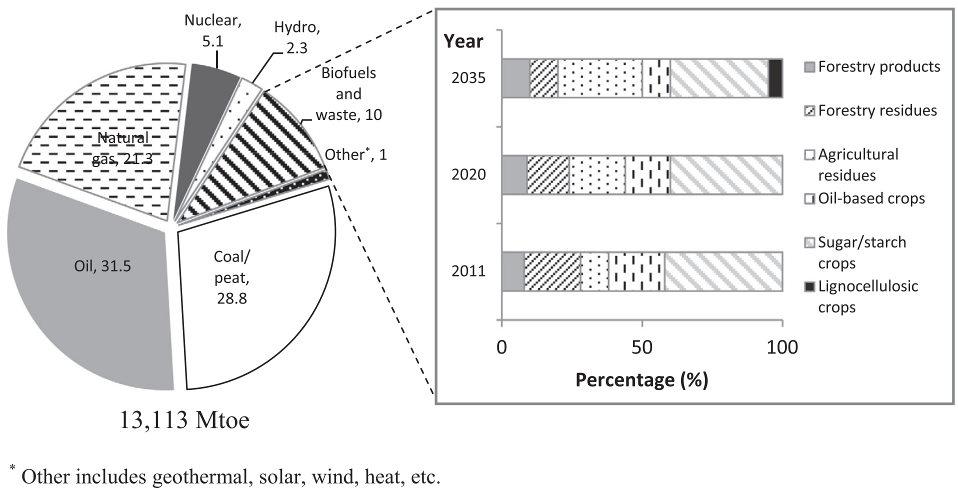

Fig. 1. World primary energy demand in 2011 (left; IEA, 2013) and share of solid biomass supply for biofuels and power generation by feedstocks in 2011 and in the New Policies Scenario (right; WEO, 2012).

and other environmental issues related to land-use changes (Gasparatos et al., 2013; IEA, 2010). Therefore, the use of residues and wastes for bioenergy production has attracted more interest as they are often readily and locally available in most of the countries. Potential of lignocellulosic biomass varies and depends on the type, abundance and cost of biomass feedstocks, efficiency of the available processing technologies, and the pattern of energy demand. This paper reviews different existing and potential biomass sources with emphasis on lignocellulosic biomass, and identifies the challenges in the deployment of second generation technologies to meet future energy targets.

2. Biomass resources and their bioenergy potential

2.1. First generation feedstocks

Biofuel production has been increasing rapidly in the last decade and currently supplies 3.4% of global road transport fuel requirements, with a considerable share in Brazil (21%), and an increasing share in the United State (US; 4%) and the European Union (EU; 3%) (IEA, 2013). Around 40 million gross ha (2.5% of global cropland) (FAOSTAT, 2011) are used for bioenergy crops, mainly for biofuel production as bioethanol and biodiesel, and biogas, all involving arable food crops. The traditional feedstocks for first generation biofuels can be categorised as starch and sugar crops (for bioethanol), and oil seeds (for biodiesel).

2.1.1. Starch/sugar crops for bioethanol

The first generation bioethanol is produced by fermentation of crops high in sugar (e.g. sugarcane, sugar beet, and sweet sorghum) or by a series of hydrolysis/fermentation steps for starchy crops (e.g. corn, wheat, and cassava). Corn-based ethanol is dominating the global market with approximately 60 billion litres produced in 2012 with the US being the largest supplier, followed by sugarcane-based ethanol at 20 billion litres produced mainly by Brazil (REN21, 2013). Other marginal feedstocks that are used to produce bioethanol include but are not limited to sugar beet (EU), maize, sweet sorghum (China, US, Brazil), cereal (Canada, EU), and cassava (Nigeria, Brazil, Thailand, and Indonesia) (Table 1).

The process to convert sugar-based biomass to ethanol is rather simple, involving the fermentation of C_6 sugars (mostly glucose) using yeast species such as *Saccharomyces cerevisiae* or *Zymomonas mobilis* (Lin and Tanaka, 2006). Fermentation of starch is more complex than fermentation of sugars because starch must first be hydrolysed to fermentable sugars with the aid of enzymes (α-amylase) (Lin and Tanaka, 2006). As a result, the energy requirement for starch-based ethanol is significantly greater than that for sugar-based ethanol. The by-products of ethanol conversion processes, such as dried distillers' grains and solubles (DDGS), can be used as protein-rich sources for animal feed, adding to the overall profitability of the whole process.

There are about 650 ethanol plants operating globally, together providing a total annual capacity of 100 billion litres (REN21, 2013). A litre of ethanol contains approximately 66% of the energy that provided by a litre of petrol (Wang et al., 1999). Ethanol can be burned directly or blended with petrol to improve fuel combustion in vehicles, resulting in lower CO_2 emission, reduction in petroleum use as well as fossil energy use. In particular, the use of E10, a commercial product having 10% ethanol blended with regular petrol, achieves 6% reduction in petroleum use, 2% reduction in GHG emissions, and 3% reduction in fossil energy use (Wang et al., 1999).

2.1.2. Oil crops for biodiesel

Biodiesel can be produced by combining oil extracted from seeds and oil-rich nuts with an alcohol through a chemical process known as transesterification (Balat and Balat, 2010). The most common oil crops are rapeseed in EU, soybean in US and Latin America, and palm and coconut oil in tropical Asian countries (such as Malaysia and Indonesia). The oil content in rapeseed and soybean is 35% and 21%, respectively (Ramos et al., 2009). Palm oil with 40% of oil content has the highest oil yield per area (~5 tons/ha) as compared to other oilseeds (e.g. 1 tons/ha for rapeseed and 0.52 tons/ha for soybean) (Balat and Balat, 2010). Additionally, beef tallow and used cooking oil can also be used as feedstocks for biodiesel conversion. Global biodiesel production in 2012 was 22.5 billion litres, with the EU (led by Germany) accounted for 41% of total production, followed by the US (16%), Argentina, Brazil and China (>10% each) (REN21, 2013).

The major difference between various oil feedstocks is the types of fatty acids attached in the triacylglycerols (TAG), which determine degree of saturation/unsaturation and molecular structure (Ramos et al., 2009). All these factors, in turn, affect production processes, quality and costs of the biodiesel products (Ramos et al., 2009). The transesterification of oil to biodiesel is a stepwise reaction of TAG with an alcohol (mostly methanol) to form esters