Renewable and Sustainable Energy Reviews 54 (2016) 74–83

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

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

The Used Cooking Oil-to-biodiesel chain in Europe assessment of best practices and environmental performance

T.D. Tsoutsos [a,*], S. Tournaki [a], O. Paraíba [b], S.D. Kaminaris [a]

[a] Renewable and Sustainable Energy Lab, School of Environmental Engineering-Technical University of Crete, Kounoupidiana, GR-73100 Chania, Greece
[b] Energy Agency of Arrábida, Avenida Belo Horizonte, Ed. Escarpas Santos Nicolau, 2910-422 Setúbal, Portugal

ARTICLE INFO

Article history:
Received 20 March 2015
Received in revised form
1 June 2015
Accepted 18 September 2015
Available online 11 November 2015

Keywords:
Biodiesel
Used Cooking Oil
Transesterification
Best practices
Environmental impact

ABSTRACT

Inappropriate disposal of Used Cooking Oils (UCOs) can generate major problems, such as the operational problems occurring in wastewater treatment plants when discharged into sewerage systems. In this paper the best methods to process the UCO-to-biodiesel chain are reviewed putting emphasis on the most critical technical and practical guidelines including best practices, quality characteristics of the collected UCO, potential implications, environmental performance and risks, and at the same time highlighting the strong and weak points of each analyzed route. The most common transesterification processes (homogeneous-catalyzed, heterogeneous-catalyzed, enzymatic, supercritical methanol, non-catalyzed) are evaluated according to environmental, technical, health and safety, market and EU policy criteria.

Contents

1. Introduction

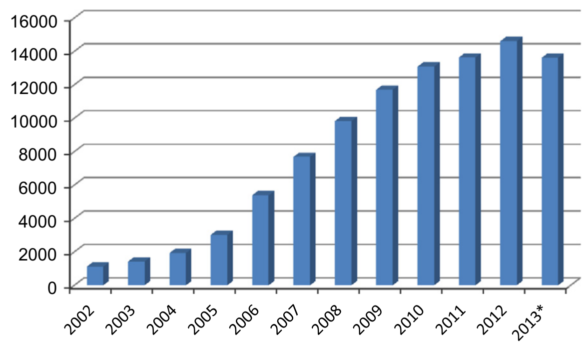
Compared with petroleum-based diesel, biodiesel has considerable environmental and economic advantages [1]. Studies present that the biodiesel burning emits, on average, 48% less CO; 47% less particulate material and 67% less HCs [2–4]. The European biodiesel market is one of the largest throughout the world accounting for nearly 80% of the total biofuel production in European Union (EU). Actually, the EU biodiesel market is the largest one globally and, in addition, the third-largest global biofuel market. Both biodiesel production and consumption have increased in the past decade in the European market (Table 1) [5]. By exploiting local resources to produce biodiesel exist economic benefits for the rural areas by creating jobs, the process industry by creating added value from raw sources and for the State by income taxes and reduction of the country's dependency on crude oil imports [6].

* Corresponding author. Tel.: +30 2821037825; fax: +30 2821037861.
E-mail address: theocharis.tsoutsos@enveng.tuc.gr (T.D. Tsoutsos).

http://dx.doi.org/10.1016/j.rser.2015.09.039
1364-0321/

Table 1
EU Biodiesel production and capacity [5].

YEAR	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
EU biodiesel production (kts)	1065	1034	1933.4	3183.4	4890	5713	7755	9046	9570	8607	8927	10,367	N/A
EU biodiesel production capacity (kts)	N/A	2048	2246	4228	6069	10,289	16,000	20,909	21,904	22,117	23,538	24,216	23,093



*estimation

Fig. 1. Biofuel consumption for transport in the EU-28 (ktoe) [7].

Table 2
Production capacity of the main EU biodiesel producers in Europe in 2013 (ts) [6].

Company	Country	Number of plants in 2013	Production capacity in 2013 (ts)
Diester Industrie & Diester Industrie International (Sofiproteol)	France	France (5),Germany (1), Italy (1), Belgium (1)	2,500,000
Neste Oil	Finland	Finland (2), Netherlands (1)	1,180,000
Biopetrol Industries	Switzerland	Germany (2), Netherlands (1)	1,000,000
ADM Biodiesel	Germany	Germany (3)	975,000
Infnita (Musim Mas)	Spain	Spain (2)	900,000
Marseglia Group (Ital Green Oil and Ital Bi Oil)	Italy	Italy (2)	560,000
Verbio AG	Germany	Germany (2)	450,000
Cargill/Agravis	Germany	Germany (2)	250,000
Petrotec	Germany	Germany (2), Spain (1)	185,000

The EU has supported the increase of biofuel consumption in transport as means of reducing the emissions of Greenhouse Gases (GHGs), as well as supporting the security of energy supply, technological development, economic development at regional scale and job creation. Fig. 1 shows the biofuels consumption in transport in EU.

The major actors in the EU biodiesel market are shown in Table 2·[7]. Since 2009, all EU Member States (MS) have been subject to the Renewable Energy Directive (RED) [8], which requires MS to comply with a target of 10% of renewable energy in the transport sector by 2020, the majority deriving from biofuels, predominantly biodiesel. The EU is, also, committed to reduce GHG emissions to 80–95% below 1990 levels by 2050. The “Energy Roadmap 2050” adopted on 15 December 2011 [9] provides directions towards a future European sustainable energy system. Furthermore, according to the Communication of 8 March 2011, “A Roadmap for moving to a competitive low carbon economy in 2050" [10] the EU should prepare for cutbacks in its domestic GHG emissions by 40% by 2030, and by 80% by 2050, calculated with respect to 1990 levels. Sectoral strategies should accompany this roadmap supporting technological innovations.

The exploitation of Used Cooking Oils (UCOs) to produce biodiesel is in line with the RED, covering GHGs, biodiversity and carbon stock. UCOs and tallow (excluding category 3 tallow) use the EC default value for ‘waste vegetable and animal oil’. For the use of the UCOs in the fatty acid methyl esters (FAME) production the Carbon Saving is 83% [11] to 85% [12,13].

UCO is a waste produced in the domestic sector, canteens, hotels, restaurants and food industry, existing in edible vegetable oil, which is used for frying food. Inappropriate disposal of UCO may generate major problems, such as operational problems occurring in wastewater treatment plants when discharged into sewerage systems [14].

A Strengths, Weaknesses, Opportunities and Threats (SWOT) Analysis of Sustainable Management of UCOs is given below (Table 3).

This paper displays the best methods to process the UCO-to-biodiesel chain putting emphasis on the most critical technical and practical guidelines including best practices, quality characteristics of the collected UCO, potential implications, environmental performance and risks, highlighting the strong and weak points of each analyzed route. Based on the field work, as well the verification of the existing literature done during the project period the most common transesterification processes (homogeneous-catalyzed, heterogeneous-catalyzed, enzymatic, supercritical methanol, non-catalyzed) are evaluated according to environmental, technical, health and safety, market, EU policy criteria.

2. Existing processing technologies and practices

2.1. Biodiesel producing procedure

Biodiesel can be blended with petrodiesel at any percentage even though pure biodiesel ('B100') is equally suitable for diesel engines. Either primary (i.e. straight or virgin) oils or secondary (used) oils can be used with no discernible difference in the product. Fig. 2 shows the