Biomass and Bioenergy 97 (2017) 155–161

Contents lists available at ScienceDirect

Biomass and Bioenergy

journal homepage: http://www.elsevier.com/locate/biombioe

Research paper

A comparative economic analysis of torrefied pellet production based on state-of-the-art pellets

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ARTICLE INFO

Article history:
Received 28 February 2016
Received in revised form
1 December 2016
Accepted 22 December 2016

Keywords:
Torrefaction
Economics
Pellets
Torrefied pellets
Wood pellets
Biocoal

ABSTRACT

Torrefied pellets have fuel properties superior to those of conventional wood pellets and potentially allow greater rates of co-firing and thus larger reductions in net CO_2 emissions. Despite the growing amount of scientific output on torrefaction, the economic feasibility of torrefied pellet production is still a topic of considerable uncertainty. This is an obstacle for decision makers looking to implement sustainable energy policies.

This paper compares the economics of torrefied pellets to conventional wood pellets. Working backwards from demonstrated pellet properties, this work attempts to answer the following question: Based on state-of-the-art torrefied pellets, what would be the maximum capital investment required for a torrefied pellet plant so that production is economically viable?

Herein, the production costs of torrefied pellets are calculated based on inputs in production. The market value of the produced pellets is estimated and a cash-flow analysis is carried out. Three economic indicators are calculated and compared for a torrefied and conventional pellet production scenario. A sensitivity analysis is carried out for selected process inputs and the cost of CO_2 through co-firing pellets is estimated. The results indicate that state-of-the-art torrefied pellet production cannot compete with conventional pellets even with transatlantic product transport distances. A high capital investment cost and a low heating value are the main barriers to economic feasibility of state-of-the-art torrefied pellets.

1. Introduction

Torrefaction is the partial pyrolysis of wood carried out using a temperature of 220–320 °C in an inert atmosphere [1]. Torrefied wood potentially allows a greater co-firing rate at pulverised-fuel power plants primarily because of its enhanced grindability. This enables CO_2 emission reductions from existing coal plants without retrofitting. This is the primary application of torrefied fuels at present. Torrefied wood can be pelletised to produce pellets with a superior energy density to that of conventional wood pellets [2,3]. Improving the energy density of pellets reduces the CO_2-equivalent emissions from their transportation. This reduction combined with enhanced grindability results in lower overall emissions from torrefied pellet production at longer transport distances [4].

Both academic and commercial interest in torrefaction has sky rocketed in the last decade. This is reflected in the output of peer-reviewed journal publications on the topic as the number of publication returns from a ScienceDirect (www.sciencedirect.com) search using *torrefaction* as the search term (Fig. 1).

Much of the interest in torrefaction can be traced back to two reports published by the Energy Centre of the Netherlands (ECN) in 2005 [5,6]. ECN's combined torrefaction and pelletisation process is known as the TOP Process. The torrefied pellets specifications described in these reports have been widely cited and used in subsequent studies [7–13]. The conclusions reached in the economic analysis, which compared torrefied pellet production with conventional pellet production, stated a clear economic benefit of torrefaction [6]. The economic feasibility hinged on the condition that the superior fuel properties of torrefied pellets outweighed the extra cost needed to produce them.

The costs associated with conventional pellet production from lignocellulosic feedstock are reasonably well established [14–18]. Wood pellet production is most cost-effective when feedstock is cheap and requires no drying. If drying is required, the most economical method depends on the cost of available fuels. Costs are minimised, however, when heat can be supplied through the

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http://dx.doi.org/10.1016/j.biombioe.2016.12.019
0961-9534/

combustion of wet feedstock [14,15]. In the case of stand-alone production, the economy of scale favours large pellet plants. After more than a decade of torrefaction research, the economics of torrefied pellet production is still very much an open question. This is partly due to the diversity of process technologies currently under development [12]. Moreover, proprietary interests of those commercialising their technology has surely been a reason for the lack of transparency in process and technical specifications.

The minimum of information required for an economic evaluation of pellet production includes: the amount of capital invested and the lifetime of a production plant, the quantity of consumable goods used in production, the thermal balance of the production process and the market value of produced pellets.

Commercially produced fuel pellets must fulfil international production standards for pellet quality. Pelletisation of torrefied wood is by no means trivial. Extreme torrefaction conditions maximise heating value, grindability and hydrophobicity of wood [19]. They also make the pelletisation process difficult, resulting in pellets with inferior durability [2,3]. Therefore, torrefaction benefits are limited by the durability requirements of pellet standards (EN 15210). It is a good time, therefore, to revisit the economics of torrefied pellet production with up-to-date specifications on state-of-the-art pellets.

1.1. Purpose

The purpose of this paper is to compare the economics of producing state-of-the-art torrefied pellets to conventional wood pellets. The main aim is to estimate pellet production costs and determine the maximum amount of capital investment needed for torrefied pellet production that would be economically feasible. Additionally, the sensitivity of the results to selected production inputs is to be determined.

2. Materials and methods

This economic analysis is carried out using a common production scenario along with published data on torrefied pellet properties and consumable inputs used in their production.

2.1. Production scenario

In the production scenario, pellets are produced and shipped to their end-use location. This scenario uses a port-to-port shipping distance of 11 450 km — roughly the distance from Brazil to Finland or from South Africa to The Netherlands. This distance is much greater than any intra-European shipping distance within the present day EU.

2.2. Economic evaluation

The capital recovery factor (CRF) is found from Equation (1). It is a function of interest rate i and a utilisation period n measured in years [15].

$$CRF = \left[\frac{i(1+i)^n}{(1+i)^n+1}\right] \tag{1}$$

The product of the CRF and the total financed capital is the annual loan amortisation. Linear depreciation C_D is calculated from the difference in the capital investment C_0 and the end-of-life value of the investment C_S divided by the lifetime of the investment t_D.

$$C_D = \frac{C_o - C_s}{t_D} \tag{2}$$

2.3. Logistics costs

Logistics and transport costs can be broken down into individual operations with regard to packaging, storing, loading and shipping of the product. The cost of most logistics operations depends only on the volume of product. Product volume depends on annual tonnage of produced pellets and on bulk density. The annually produced amount of torrefied pellets has less volume than produced conventional pellets because their annual tonnage is less and their bulk density is greater. Logistical costs for torrefied pellets are consequently lower. How much lower depends on how effectively the feedstock can be pelletised.

The ratio of product volume (i.e. volume of torrefied pellets/volume of conventional pellets) was used by ECN to scale the

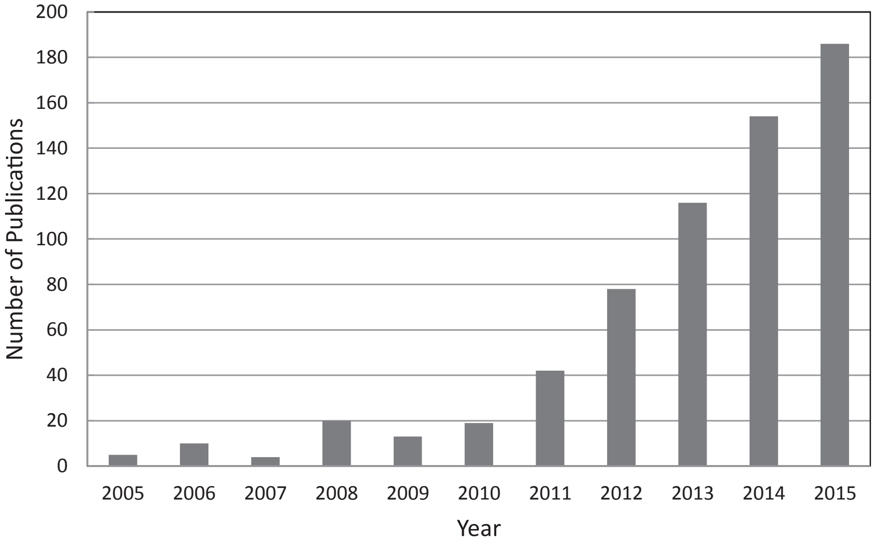

Fig. 1. The number of peer-reviewed journal publications between 2005 and 2015 based on the search term “torrefaction” from ScienceDirect.