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Review

An overview of renewable hydrogen production from thermochemical process of oil palm solid waste in Malaysia

Seyed Ehsan Hosseini *, Mazlan Abdul Wahid, A. Ganjehkaviri

High-Speed Reacting Flow Laboratory, Faculty of Mechanical Engineering, Universiti Teknologi Malaysia, 81310 UTM Skudai, Johor, Malaysia

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ABSTRACT

Hydrogen is one of the most promising energy carriers for the future of the world due to its tremendous capability of pollution reduction. Hydrogen utilization is free of toxic gases formation as well as carbon dioxide (CO_2) emission. Hydrogen production can be implemented using a wide variety of resources including fossil fuels, nuclear energy and renewable and sustainable energy (RSE). Amongst various RSE resources, biomass has great capacity to be employed for renewable hydrogen production. Hydrogen production from palm solid residue (PSR) via thermochemical process is a perfect candidate for waste-to-well strategy in palm oil mills in Malaysia. In this paper, various characteristics of hydrogen production from thermochemical process of PSR includes pyrolysis and gasification are reviewed. The annual oil palm fruits production in Malaysia is approximately 100 million tonnes which the solid waste of the fruits is capable to generate around 1.05×10^{10} kgH_2 (1.26 EJ) via supercritical water gasification (SCWG) process. The ratio of energy output to energy input of SCWG process of PSR is about 6.56 which demonstrates the priority of SCWG to transform the energy of PSR into a high energy end product. The high moisture of PSR which is the most important barrier for its direct combustion, emerges as an advantage in thermochemical reactions and highly moisturized PSR (even more than 50%) is utilized directly in SCWG without application of any high cost drying process. Implementation of appropriate strategies could lead Malaysia to supply about 40% of its annual energy demand by hydrogen yield from SCWG of PSR.

Contents

Abbreviations: CCS, CO_2 capturing system; CPO, crude palm oil; CS, coconut shell (CS); CFBG, compartmental fluidized bed gasifier; EFB, empty fruit bunches; ER, equivalence ratio; FFB, fresh fruit bunches; GHG, greenhouse gas; GW, global warming; HFC, hydrogen fuel cell; ICA, integrated catalytic adsorption; LHV, lower heating value; MEWC, Ministry of Energy, Water, and Communication; NG, natural gas; NSC, National Steering Committee; MSW, municipal solid waste; OTCE, ocean thermal energy conversion; PKS, palm kernel shell; PTM, Malaysian Energy Centre; PSR, palm solid residue; RSE, renewable and sustainable energy; SCWG, supercritical water gasification; SMR, steam methane reforming; WGSR, Water–gas shift reaction.

* Corresponding author. Tel.: +60 1112600959.
E-mail address: Seyed.ehsan.hosseini@gmail.com (S.E. Hosseini).

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Nomenclature

η	efficiency	Z_C	weight fractions of carbon
η_h	efficiency of pure hydrogen production	Z_{O_2}	weight fractions of oxygen
ΔH_r	reaction heat	Z_{N_2}	weight fractions of nitrogen
ΔH_p	energy generated from products	$LHV_{(H_2)}$	lower heating value of produced hydrogen
Z_{H_2}	weight fractions of hydrogen		

1. Introduction

Increasing rate of fossil fuel consumption is responsible for enhancement of greenhouse gas (GHG) emissions which play crucial role on the environment leading to global warming (GW) and acid rain [1]. Furthermore, the depletion of fossil fuel resources drives the thinking towards alternate energy sources. Enhancement of pollutant formation, climate change, and imbalance between energy demand and supply are three-pronged menace that humankind has confronted [2]. Kazim and Veziroglu [3] stipulated that United Arab Emirates as one of the major oil export countries, would have problem to meet the share in the oil and natural gas (NG) demands by 2015 and 2042, respectively. It has been anticipated that fossil fuel resources in Egypt would be depleted soon [4]. Muda and Pin [5] anticipated that petroleum will be depleted faster than coal and NG in Malaysia. It was pointed out that in Malaysia, NG and coal will substitute petroleum as the main source of energy generation in the next two decades.

The rising energy demands will speed up the depletion of the finite fossil fuels. In response to the two above problems, continuous attempts have been made in exploration of clean, renewable and sustainable alternatives. The increasing enthusiasm for the renewable and sustainable energy (RSE) resources to replace fossil fuels, demonstrates a promising path to emerge clean fuel for transportation and industrial sectors [6,7]. Fuels from biomass are suitable alternatives to the traditional fossil fuels. Waste or

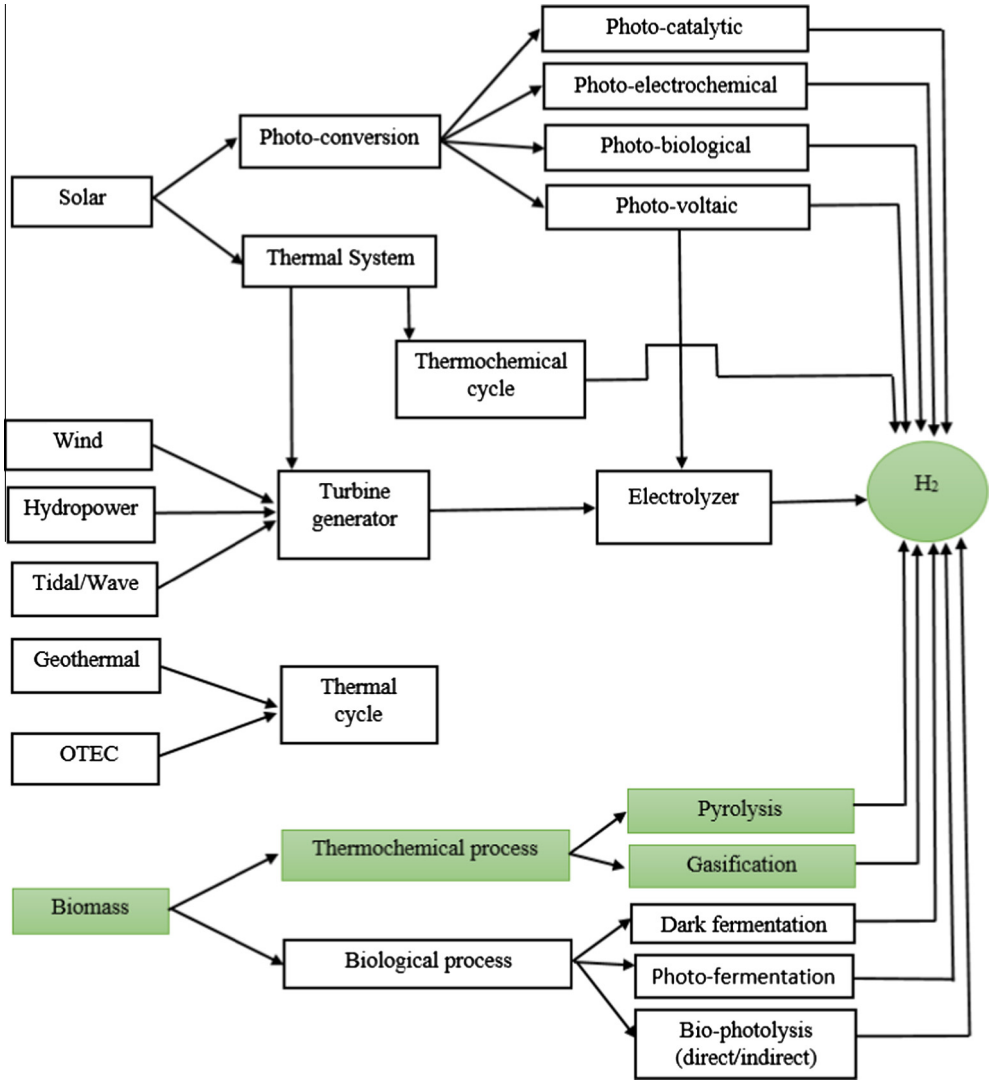

Fig. 1. Renewable hydrogen production processes.