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A Hybrid Biomass Hydrothermal Gasification- Solid Oxide Fuel Cell System Combined with Improved CHP Plant for Sustainable Power Generation

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Abstract

The most popular technique, so far, for biomass waste to energy conversion has been incineration, but this technique has raised a lot of objection among nature activists due to the release of particulate matter and pollutants like nitrogen oxides (NOx) into the atmosphere. However, advanced non-incineration conversion methods like pyrolysis, thermal gasification, and plasma-arc gasification are providing ways of generating energy from waste that avoid many of the pollution concerns around incineration, and may provide better economics for waste-to-energy as well. This paper describes a combined hydrothermal gasification of biomass in sub or supercritical water, integrated with a solid oxide fuel cell which can be fuelled with both constituents of the syngas (Carbon monoxide and hydrogen). Full analysis of the hybrid cycle and expected improvements in efficiency are presented, together with elaborate discussion of the technological and strategic pros and cons.

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*Keywords:*nitrogen oxides (NOx);biomass hydrothermal gasification; Municipal Solid Waste (MSW); Supercritical water (SCW) gasification; Syngas

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1. Introduction

Demand for energy is increasing at an unprecedented rate due to increasing human population, emerging industries and rising standards of living. At the same time, resources of fossil fuels are becoming more expensive and finite, nuclear sources are becoming less secure and concerns over harmful emissions and greenhouse gases are mounting, which motivate the search for more sustainable and environment friendly energy sources.

Nomenclature

SCW	Supercritical water gasification
CHP	Combined Heat and Power Cycle
SOFC	Solid Oxide Fuel Cell
BHG	Biomass Hydrothermal Gasification
MGT	Micro Gas Turbine

Hydrogen as a clean fuel has been considered significantly in recent years. However, hydrogen can be produced from either fossil fuels or renewable resources. Current hydrogen production methods are producing greenhouse gases as much as fossil fuel systems do. Thus, to consider hydrogen as a clean energy resource, it is essential that hydrogen be supplied from carbon neutral sources [1]. In order to address these issues, new approaches in the utilization of energy sources should be adopted.

One important source of energy is biomass, which has the potential to provide 14% of the world's energy needs and at the same time, reduce the increase of carbon dioxide in the atmosphere[2][3], this way addressing three sets of environmental issues at one stroke: providing a valuable and sustainable source of energy, reducing land use and pollution from landfills, and mitigating the well-known environmental jeopardy of fossil fuels. Climatic conventions such as (Kyoto, Buenos Aires and Paris) and the European Union's white paper demand a substantial increase in the use of biomass, which can be achieved only if new applications for the use of biomass, such as electric power generation from biomass, are developed[4].

As far as bio-waste is concerned, the most popular technique, so far, for waste to energy conversion has been incineration, but this technique has raised a lot of objections among nature activists due to the release of particulate matter and pollutants like nitrogen oxides (NO_x) into the atmosphere. However, advanced non-incineration conversion methods like pyrolysis, thermal gasification, and plasma-arc gasification are providing ways of generating energy from waste that avoid many of the pollution concerns around incineration, and may provide better economics for waste-to-energy as well[5]. Furthermore, Waste-to-energy systems could provide a more sustainable solution if waste-to-energy systems, like thermal gasification-based waste conversion plants,were fitted with direct Hydrogen/Syngas generation, hence enabling other clean technologies like fuel cells, which have the capability of operating using hydrogen or carbon monoxide as the input fuel. Between all types of fuel calls, solid oxide fuel cells (SOFC) are more promising; due to their high working temperature range (800–1000 °C), type of electrolyte (ceramic), and compatibility with different types of fuels. Another advantage of the SOFC is the fact that its efficiency rises when pressurized under high temperatures, which also enables them to be used as a heat source for a gas turbine[1].

It is observed that research and development efforts are moving towards efficient and sustainable small scale Combined Heat and Power (CHP) systems incorporating biomass gasification, SOFCs and MGTs, although, small scale CHP plants present lower electrical efficiency in comparison to large scale ones, particularly when biomass fuels are used[6]. Research shows that the gasification/SOFC cycle has a higher efficiency than the gasification/MGT system. Also it was concluded that 50% efficiency is achievable from gasification/SOFC/MGT hybrid cycle [7] .

In this work a combined hydrothermal gasification of biomass in sub or supercritical water, integrated with a gas turbine and a high temperature solid oxide fuel cell, which can be fueled with both constituents of the syngas (Carbon monoxide and hydrogen) is described. This configuration offers a viable power supply solution for medium sized communities at urban and suburban locations.