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# Solid oxide fuel cell operating with biomass derived producer gas: Status and challenges

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ABSTRACT

Solid oxide fuel cell as a conversion device is finding importance in the energy sector due to its high efficiency, low emissions and fuel flexibility. The use of producer gas as a fuel is gaining importance due to certain advantages over the conventional fuels while challenges lie in its usage due to the inherent contaminants present. This paper consolidates the efforts carried out using fossil fuels and highlights the challenges, and further, the progress made in the use of producer gas is critically examined. The effects of contaminants such as tar, particulate matter, $H_2S$ etc. on anode materials are highlighted, and the published results are consolidated to examine whether the maximum tolerance limits of the contaminants be identified. However, it is observed that due to many inexorable factors viz., differences in the electrode material, microstructure, diverse operating conditions, the conclusions obtained are diverse and it is difficult to predict the general behavior of a particular contaminant. The need for a comprehensive study having both experimental and theoretical components focusing on the role of contaminants under the same operating conditions and using the same materials is highlighted as a major conclusion of this study.



**Contents**



## 1. Introduction

Rising energy consumptions and higher emissions from combustion devices operating with conventional fuels demand

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alternate energy sources, and Solid oxide fuel cell (SOFC) being an efficient, environment friendly, fuel flexible energy conversion technology is able to attract the attention of researchers [1]. Over the last two decades, significant progress has been made on SOFC, especially on the materials to support high temperature operations and different fuels [2]. However, commercialization of the technology is hindered by a few important factors, and the production and storage of hydrogen ($H_2$) which is being considered as an ideal fuel are major challenges [3]. As an alternative, the use of renewable fuels is desirable, and producer gas (PG)/syngas generated from biomass has received widespread attention due to its carbon neutrality nature [4].

Biomass generates both liquid and gaseous fuels; however the conversion efficiency of biomass to liquid is low (Fig. 1) [5], and this makes the use of gaseous fuel more prevalent. IC engine is the most common route due to the simple design and lower capital cost. Significant efforts have gone on using diesel engine on dual fuel mode [6–8] and gas engines on PG alone mode [9–12]. It must be emphasized that significant research towards operating the engine with PG has been carried out and the required gas quality for engine application has been established. Attempts have also been made in the use of gasifier for micro-gas turbine (mGT) applications [13]. However, recent attention is focused on fuel cell (FC) for it being more efficient than IC engines, and SOFC receives significant attention (Fig. 2) [14].

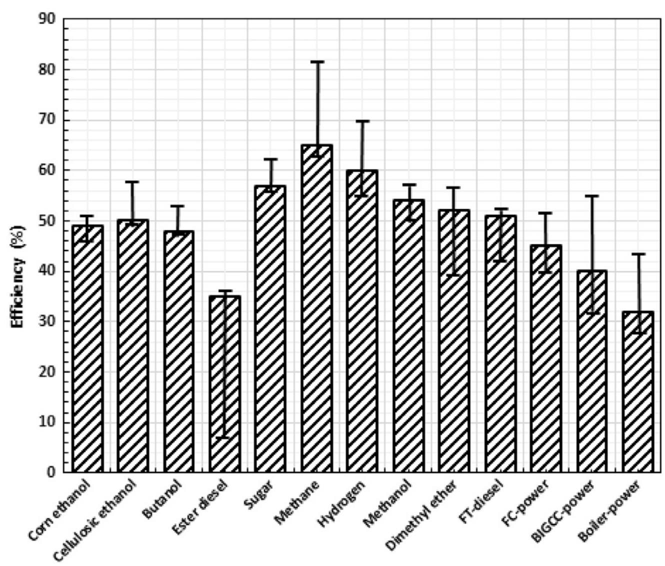


**Fig. 1.** Comparison of biomass to fuel efficiency in the bio-refineries or power stations [5].

Coupling of FC with a gasifier is a recent concept, and various research groups have investigated the possible trouble in handling the contaminants: tar, $H_2S$, HCl, etc., of the gases, and their short-term impact on cell components has been reported. However, the existing literature does not provide a future roadmap; since the results obtained are diverse due to differences in methods, materials and operating conditions. Use of SOFC with PG as a fuel is not well documented although there are many review reports wherein the SOFC is discussed in general or from the materials point of view. This paper attempts to consolidate the experimental and numerical studies reported in the literature towards arriving at specifications of PG for SOFC, based on the current experience available. Challenges and issues addressed in the choice of material and its behavior under various operating conditions are also reported.

The paper is structured as follows. First, a background on the need for SOFC is discussed followed by a brief introduction to the producer gas fueled SOFC in Section 2. Section 3 summarizes the progress in the materials development. Section 4 highlights the aspects of biomass gasification and the performance of the systems for power generation and Section 5 focusing on the experience in using biomass gasification for SOFC and presents the status of the technological advancements. Section 6 provides the conclusions with respect to the use of gasifiers for SOFC applications and highlights the challenges and possible roadmap.

## 2. Solid oxide fuel cell with PG: electrochemical reactions

SOFC working with PG can utilize three different fuels viz., $H_2$, carbon monoxide (CO) and methane ($CH_4$), unlike PEMFC working with $H_2$, and the literature on general view of FC and its working principle is largely available in many textbooks and reports [2,14–22]. In the use of PG as fuel, the additional anode side reactions (equations (3) and (4)) need to be considered. Fig. 3 illustrates the working of the producer gas fueled solid oxide fuel cell.

**Cathode side:** $O_2 + 4e^- \rightarrow 2O^{2-}$ (1)

**Anode side:** $2H_2 + 2O^{2-} \rightarrow 2H_2O + 4e^-$ (2)

**Anode side:** $CO + O^{2-} \rightarrow CO_2 + 2e^-$ (3)

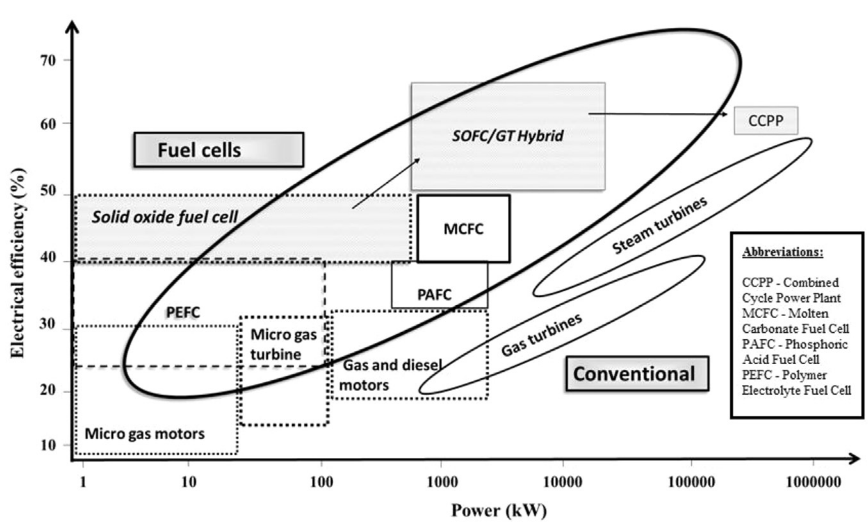


**Fig. 2.** Efficiency potential of various power generation technologies [14].