# Hydrogen and Carbon Nanotubes (CNT) Co-Production via Gasification of Waste Tyres and Waste Biomass: A Techno-economic Study

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## Abstract

Waste gasification as an alternative renewable energy source has been regarded as a viable thermochemical conversion process to pyrolysis and combustion. Gasification technology involves the process by which air, oxygen, $CO_2$, and/or steam reacts with solid fuels (tyres, plastics, biomass, etc.) to produce gaseous product such as Syngas and Hydrogen and by-products such as $CO_2$, char and hydrocarbons (HC). Previous studies by researchers have shown that solid carbon by-products from gasification and co-gasification processes have not been put into viable use, hence, there is a need to investigate this research area. The key objective of this study is to perform a techno-economic analysis that will ascertain both the technological feasibility of the production process as well as the economic viability.

In the proposed production route, five major processes were identified. They include Gasification followed by Syngas cleaning to purify the syngas stream by removing toxic gases (COS, $H_2S$ and $CO_2$); Water-gas shift to improve Hydrogen conversion; Membrane separation to separate Hydrogen from the process and Chemical vapour deposition (CVD) to synthesize the CNT from the HC components. To maximize production, a detailed sensitivity analysis was investigated to check the effect of feed ratio, temperature, and gasifying agent. The results show that feedstocks with high carbon have the tendency to produce more CNT. The best combination of tyre-to-biomass was found to be 75:25. In addition, high steam and moderate oxygen improve feed conversion. At the best condition, 1kg of waste feed can produce ~0.17kg of Hydrogen and ~35kg of CNT.

From the process economic, the capital-intensive processes were found to be the syngas cleaning and the CVD. These two processes can slow down production in a pilot scale process, however, on an industrial scale, the co-production process has a good ROI (>30%) and NPV (>$50M). In addition, the minimum selling price (MSP) of the Hydrogen produced from the process was $2.5/kg which also ascertains the economic viability of the gasification production route when compared to other Hydrogen production technologies. The sensitivity analysis from the economics was also performed to ascertain that any slight variation in economic parameters will not have a significant effect that could hinder continuous production over the next 20 years. The result from the analysis shows that the MSP of both Hydrogen and CNT, the Operating Expenditure (OPEX), Loan interest rate and Inflation Rate have the most effect on the economic feasibility of the process.

**Keywords**: *CNT; Hydrogen; Gasification; Waste Tyres; Biomass; Economic Analysis*