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Carbon emissions reduction potentials in pulp and paper mills by applying cogeneration technologies

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Abstract

Pulp and paper production is a highly energy intensive process and improvement of energy efficiency in this process is considered as promising measures for reducing industrial greenhouse gases emissions (GHG). This study focuses the Pakistan's pulp and paper industry which consumes around 7% of the country's industrial energy and contributes to over 317,269 tonnes of CO_2 emissions. With rising demands for fuels and consequently as harp increase in CO_2 emissions due to the growth of the paper sector in Pakistan, this article aims to analyse the energy efficiency and carbon dioxide emissions reductions potential through the incorporation of cogeneration technologies. The cogeneration technologies studied are agas turbine, steam turbine and combined cycle and are evaluated from the energetic and economic point of view to propose a best suitable technology for each paper mill. The proposed cogeneration technologies are selected on the basis of high energy utilisation factor, as implepayback period of five years or less with least Annualised life cycle cost. The result shows that a theoretical energy saving potential equivalent to 16.9% of the actual thermal energy requirement of mills can be achieved through cogeneration which will lead to 14.3% reduction of the present carbon emissions levels in Pakistan's paper sector.

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*Keywords:*Cogeneration; Paper mills; CO_2emissions; Energy utilisation factor; Annualised life cycle cost; Payback period

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1. Introduction

Energy efficiency is one of the most important and cost-effective means for reducing industrial energy consumption and carbon dioxide (CO_2) emissions in the coming decades [1]. Industrial energy efficiency and CO_2emissions reduction can be achieved by various means, including replacing older inefficient technologies with current Best Available Technologies (BAT), switching from fossils fuel to low-carbon energy sources and through the use of industrial CO_2 capture and storage plants [2].

Nomenclature

$\dot{m}_s$	mass flow rate of steam (kg/s)	P	pressure
T	temperature	W_p	work done by pump (kW)
Q_{bl}	energy input (kW)	W_{net}	net work done (kW)
m_{gas}	mass flow rate of gas (kg/s)	m_{air}	mass flow rate of air (kg/s)
η_{gt}	gas turbine efficiency	η_c	compressor efficiency
Q_{econ}	Energy input in economiser (kW)	Q_{evap}	Energy input in evaporator(kW)
$LMTD_{econ}$	log mean temperature difference of economiser		
$LMTD_{evap}$	log mean temperature difference of evaporator		

According to the International Energy Agency (IEA) [3], pulp and paper industry is the world's fourth largest industrial energy user as it consumes around 6% of total world industrial energy and produces 2% of global industrial CO_2 emissions [3]. It is an energy-intensive industry in which one-third of total energy is used for process heating [4-5] in the form of saturated steam and remaining energy is used in the form of electricity for mechanical drives (pumps, conveyors, paper machine and fans) and general lighting. The continuous simultaneous need for heat and electricity makes it an ideal applicant for an overall energy saving through the implementation of cogeneration technologies. Heat produced during electricity generation by conventional power stations are often lost into the environment, this waste energy can be avoided by using cogeneration systems where most of this thermal energy is recovered as useful heat for process heat requirement in the industry [6].

Many recent studies have examined opportunities to reduce the pulp and paper industry's energy consumption and CO_2 emissions by employing different CHP technologies. Sharma et al. [7] estimated the potential of solar industrial process heating to reduce CO_2 emissions in Indian paper industry. Paper can be produced from virgin pulp (wood or agriculture residue i.e. wheat straw, rice straw, cotton linter etc.) and through recycle pulp (recycle paper) depending upon the regional availability of raw material and type of paper product required. Pulp production through virgin fibre also yields an additional fuel source called black liquor which can alternatively be used to generate electricity using cogeneration technologies which results in CO_2 emission reduction, as described by Consonni et al. [8], and by Maunsbach et al. [9]. Similarly, Khrushch et al. [10] defined the CO_2 emission reduction potential in the US chemicals and pulp and paper industries by applying CHP technologies based on the assumption that CHP electricity production replaces electricity purchased from the grid. The result of the study shows significant CO_2 emission reduction potentials at negative cost. In another study, cogeneration potential of pulp and paper industry of Vietnam is evaluated by Bhattacharyya and Thuy 2005 [11], where results show that cogeneration is an attractive option for the paper industry of Vietnam even without the sale of power to the grid. Mollersten et al. [12] investigated the potential of CO_2 reduction through energy measures in Swedish pulp and paper industry by employing cogeneration. The results show that through utilisation of black liquor to power gas turbines can result in potential reductions in CO_2 emissions by up to 6%. The literature review reveals the fact that implementation of cogeneration technologies in paper mills guarantees the reduction in CO_2 emissions due to high energy utilisation factor as a result of low fuel consumption and on-site electric generation.

Pakistan's pulp and paper industry accounted for 7% of the total industry energy demand in the country in 2010 [13]. Pakistan is a developing country with a growing population of over 180 million people and currently faces a power supply shortage of 5GW [14]however, continuous growth of pulp and paper industry is still taking place and therefore it is chosen as the target sector in this study. It has been reported [15] that energy deficiency has cost the