WORKING PAPER SERIES

EFFICIENCY MEASURES IN ENERGY INTENSIVE INDUSTRIES IN INDIA: AN ANALYSIS OF ABATEMENT COSTS

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GCP/JU/12/03
Dated 09/12/2012

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Introduction:

National Action Plan on Climate Change (NAPCC 2008) identifies measures that promote India's development objectives while yielding co-benefits for addressing climate change effectively. The pledge is to reduce CO_2 intensity of Gross Domestic Product (GDP) of the country by 20%-25% as compared to 2005 level by 2020. Seven industries are identified by Bureau of Energy Efficiency (BEE) as most energy intensive manufacturing sectors in India (Aluminium, Cement, Chemical, Fertilizer, Iron and Steel, Pulp and paper, Textile). These industries are given lower energy intensity (energy use/output) targets to achieve under the scheme Perform, Achieve and Trade (PAT) (Roy 2010). Aggregate target is to reduce energy use by 6.6 Metric Ton of Oil Equivalent at the end of 1st Cycle of PAT (April 2011 –March 2014). The importance and benefits of energy efficiency, however, is being emphasized by the Government of the country since the last decade. The Energy Conservation Act, 2001 (EC Act 2001) came into force in 2002 and under the provisions of this Act, BEE was established. Given the penetration coming from the EC Act, 2001, several energy efficiency measures are being undertaken by different sectors including the industrial sector. This paper makes an attempt to understand the CO_2 emission mitigation potential and related abatement costs of such energy efficiency measures implemented by the Indian industries in response to the EC Act, 2001.

Improvement of energy efficiency:

There has been a declining trend of the energy intensity observed in these industries over past few decades. The magnitude of such decline is captured in Table 1.

Table 1: Decline in energy intensity in selected Indian industries:

Industry	**Specification**	**1985**	**1991**	**1995**	**2006**	**2007**	**2009**	**Source**
Aluminium	Specific Final Energy Consumption	112.8 GJ/MT		90 GJ/MT			85 GJ/MT	http://www.cseindia.org/userfiles/57-66%20Aluminium(1).pdf (last accessed on 10.08.2012)

Cement	Thermal power in clinker production		876 Kcal/kg of clinker	815 Kcal/kg of clinker			726 Kcal/kg of clinker	www.iea.org/work/2010/india_bee/saxena.pdf. (last accessed on 05.06.2012)
	Electricity in cement production		120 kWh/ tonne of cement	112 kWh/ tonne of cement			79 kWh/ tonne of cement	
Chemical						37.5 GJ/tonne of ammonia		Sathaye et al. 2005
Fertilizer		49.06 GJ/t of total fertilizer		34.20 GJ/t of total fertilizer				Sathaye et al. 2005
Iron and Steel		45 GJ/tcs (excluding energy used for coke making)		35 GJ/tcs (excluding energy used for coke making))	29.1 GJ/tcs (excluding energy used for coke making)			http://www.nistads.res.in/indiasnt2010-11/T3_Industry/An%20Analysis%20of%20Energy%20Efficiency%20in%20Indian%20Industries.pdf (last accessed on 10.10.2012) http://india.lbl.gov/sites/default/files/US-India-EETC_2009.pdf (last accessed on

								10.20.2012)
Pulp and paper				51.55-79.97 GJ/tonne of paper				Schumacher and Sathaye, 1999
textile	Thermal					3000-16100kcal/kg		Schumacher and Sathaye, 1999
	Electricity					0.25-10kWh/kg		Schumacher and Sathaye, 1999

Data:

One of the voluntary innovative schemes, initiated by the Government of India, Ministry of Power, to promote energy conservation has been the Energy Conservation Awards in collaboration with BEE. BEE publishes (http://www.beeindia.in/) the nature and cost of the energy efficiency measures adopted by the winners of the National Awards on Energy Conservations in different years. The current dataset comprises of the energy efficiency measures implemented by Aluminium, Cement, Chemical, Integrated Steel Plant, Pulp and Paper and Textile industry in India during the period 2007-2012. Respectively, 26, 42, 62, 30, 46 and 75 different energy efficiency measures are considered.

Methodology:

Data are extracted from BEE on the year of investment; capital cost of the technology (K), energy conservation measure adopted and avoided energy use. Lifetime of the measure (x) is determined through expert consultations[1] and the rate of interest (i) is taken to be 8% per annum.

The annualized fixed cost of the technology (a) = $\left(\frac{i}{(1+i)^x-1}+i\right)*K$

Operation and maintenance cost (c) is taken to be 10% of annualized cost

Total annualized cost (C_a)[2] = $a+c$

[1] The work is in progress and the lifetime of the measures unless specified by experts in assumed to be 10 years

Avoided energy use data are provided either in terms of

(a) Avoided energy cost per year (E_c) in INR or
(b) Avoided energy use per year (E_e) in kWh

There are some measures for which both E_c and E_e are furnished. From such observations avoided cost per unit of energy = (E_c/ E_e) is calculated and it is found that on an average the value is close to INR 4.99 (USD 0.09)[3] per kWh of electricity. Using this conversion ratio and E_c, E_e is calculated for all the measures as (E_c/4.99).

In India, on an average 0.94 Kilogram of CO_2 is emitted per kWh of electricity generation (Raghuvanshi et al 2006). Using this emission factor,

Total avoided CO_2 emission per year (in kilogram) (A) = (E_e * 0.94)

Cost per kilogram avoided CO_2 emission is calculated as = (C_a/A)

Cost per tonne of avoided CO_2 emission is then calculated as = (C_a/A)* 1000

A comparison of cost per tonne of avoided CO_2 emission with the annualized cost of the energy efficiency measure implemented is made to understand the effectiveness of low cost energy efficiency measures in emission mitigation.

Results:

The results are represented in Figure 1 and 2. Figure 1 represents the percentage distribution of per unit CO_2 emission reduction cost of energy efficiency measures for different industries. The figure shows that in all the industries considered here for largest proportion of measures cost incurred by industries to avoid per tonne of CO_2 emission belongs to the range of 0-20 USD which is the lowest range (Figure 1). Figure 2 shows the range of costs (per tonne of CO_2 emission) for different industries. While the costliest measure varied across industries there exist certain costless/almost costless measures (mostly behavioural in nature) for every industry (Figure 2). One more interesting finding is that there exist some low cost measures which are more effective in terms of emission reduction as compared to their costlier counterparts.

[2] For some measures annualized investment is directly provided
[3] 1 USD=54.05 INR on 28.1.2013, 23:40 PM, source www.xe.com

Figure 1: Cost incurred by industries to avoid CO_2 Emission (in USD/tonne of CO_2)

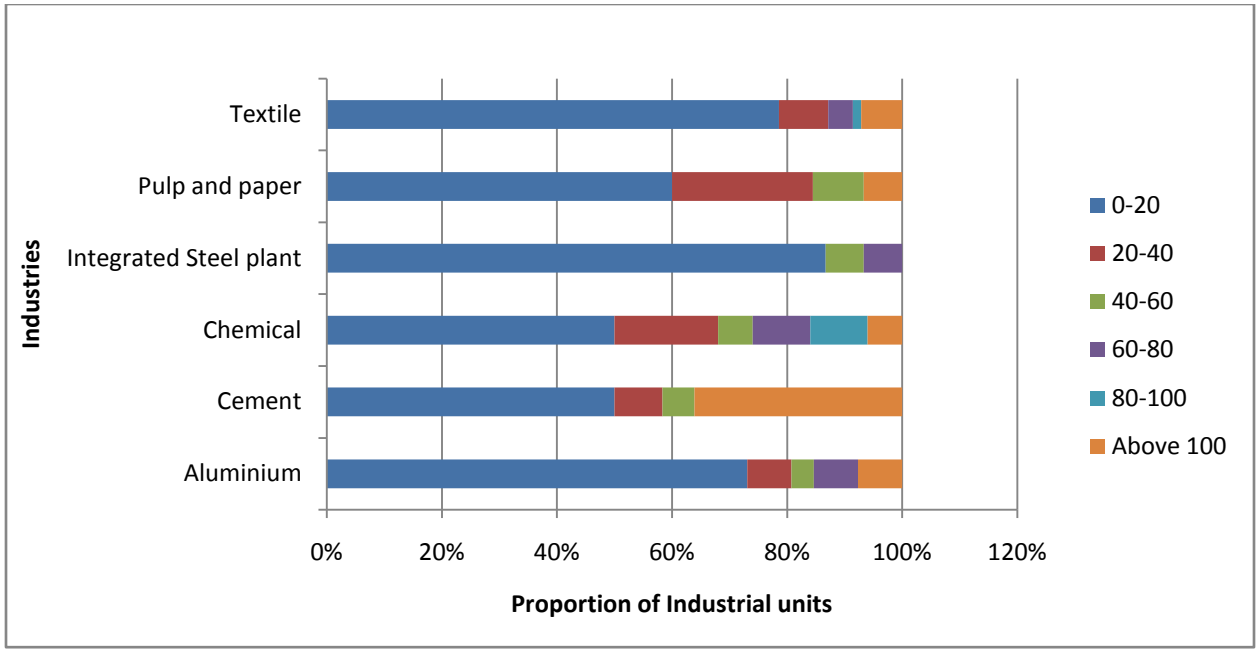
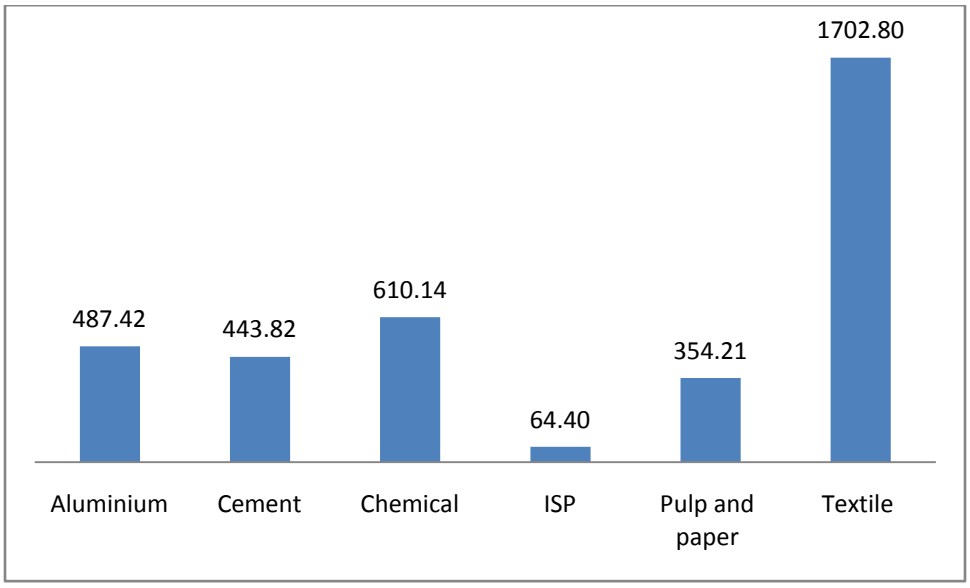


Figure 2: Maximum cost incurred to avoid per unit of CO emission (in USD/tonne of CO2)



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