

Combined Heat and Power in the Indian Pulp and Paper Sector

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Abstract

The most dominant technology of captive power generation in the Indian pulp and paper sector are steam cycle power plants. Their plant load factors are relatively low with 0.534 indicating fluctuations in heat and electricity demand patterns. A study of the energy consumption of 18 wood based paper mills show that improvements of Combined Heat and Power (CHP) could decrease prime energy consumption dramatically. The overall potential of CHP plants is above 1000 MW_{el}. The majority of it, at least 600 MW_{el}, has not been implemented yet.

1 Introduction

The pulp and paper industry is a significant consumer of energy. Combined Heat and Power (CHP) plants can be designed to meet the mills heat or electricity requirement. In most cases, the captive power plant is designed to satisfy a mills electricity requirement with the remaining heat supplied by low cost package boilers, which results out of island mode operation. To maximize thermal efficiency; the CHP plant should be designed to meet heat demand with excess electricity sold to the grid. Potential for further CHP use in the industry may be limited by economies of scale which make investments in small plants less economical. The ability to sell excess power to the grid may become crucial in making CHP investments more attractive for the industry.

Most energy used in paper-making is for pulping and paper drying. The need for large amounts of steam makes combined heat-and-power (CHP) an attractive technology in this sector, and the Indian paper mills have therefore consciously and increasingly opted for their own CHP unit. The “National Energy Map for India – a technology vision for 2030” reports that 81% of all Indian paper mills use cogeneration within their plants [1]. This statement however may lead to a misinterpretation of reality or a wrong perception of the quality and real penetration of CHP in the sector.

An effort is made in this article to present a more detailed insight on the use and perspectives of CHP in the pulp and paper industry in India. By assessing nationwide figures, this article will show that the prime energy consumption of this sector can be reduced dramatically.

2 Captive Power Generation

The overall electrical consumption of the Indian pulp and paper sector in 2005/2006 was 3,986.47 GWh/a according to a report of the Central Electricity Authority (CEA) that provides data on captive power plants larger than 1 MW [2]. It mentions that the installed captive generating capacity was 862.8 MW as shown in the following table (1).

	Unit	Steam	Diesel	Wind	Total
Installed capacity (as on 31.03.06)	[MW]	736.8	122.5	3.58	862.8
Yearly generation (2005/06)	[GWh]	3451	525	4.92	3980
Load factor	[-]	0.534	0.489	0.157	0.526

Table (1): Generating capacity in the paper industry distributed by generation technology [2]

The reported captive power generation technology in the Indian pulp and paper sector is based on steam turbines accounting for 85% of the sector’s captive generation capacity. The sector is generating about 81% of required power in captive plants while the remaining 19% is purchased from commercial utilities providers. However, generated electricity is used also for non-industrial purposes. In aggregate, 3.2% of power during that year was exported to utilities, and up to 8.2% was used to power auxiliary services, such as employee homes, schools etc.

	Captive generation	Import from grid	Auxiliary consumption	Export to grid	Industrial consumption
[GWh/a]	3980	815	-328	-129	-4338

Table (2) Consumption and generation related to the Indian pulp and paper sector [2]

More than 77% of the captive power generation in the pulp and paper sector is located in only 8 states, namely Tamil Nadu, Andhra Pradesh, Assam, Karnataka, Uttar Pradesh, Madhya Pradesh, Maharashtra and Gujarat as shown in figure 1.

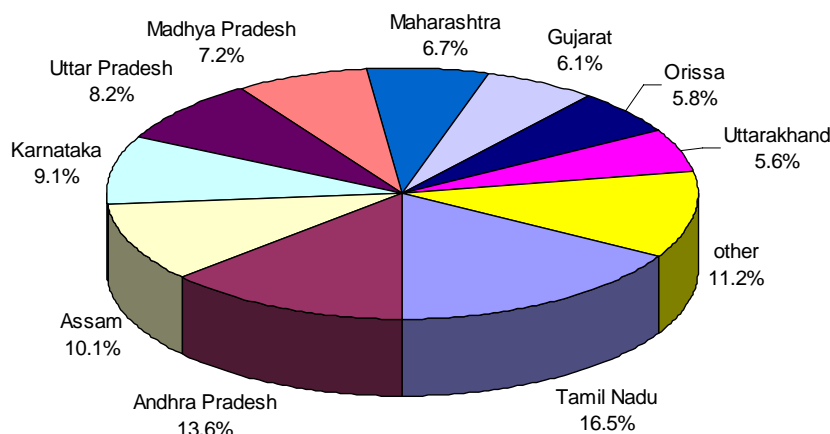


Figure (1) Distribution of captive power generation capacity within the pulp and paper sector in India [2]

3 Penetration of CHP

A detailed analysis of energy consumption and captive generation in 18 Indian wood-based paper mills was carried out by the Central Pulp & Paper Research Institute (CPPRI). The study, which was supported by the Indo-German Energy Programme of GTZ, assessed the energy inputs in these mills (electricity from the grid, purchased fuel and also internal fuel resulting from the process, such as black liquor). Electricity purchased from the grid was calculated on the basis of the required prime energy consumption in a coal power plant for providing the equivalent electricity¹. The data on energy consumption in the paper mills was then split into thermal (process steam²) and electrical consumptions shown in table (3).

	Prod. capacity [t _{paper} /a]	Prime energy consumption					Process energy consumption				Conversion efficiency [%]
		Fuel	Grid*	grid	internal	total	Power	Steam	Total	power to heat ratio	
		[GJ/t]	[GJ/t]	[GJ/t]	[GJ/t]	[GJ/t]	[kWh/t]	[t/t]	[GJ/t]		
Plant 1	89500	39.58	1.90	0.40	20.86	62.34	1724.65	16.80	48.61	0.15	77.97%
Plant 2	100000	42.08	0.86	0.18	18.78	61.72	2019.86	16.10	47.90	0.18	77.62%
Plant 3	85000	46.37	0.81	0.17	23.80	70.98	1740.23	18.54	53.05	0.13	74.75%
Plant 4	108000	18.53	3.33	0.70	34.18	56.04	1181.47	13.32	37.87	0.13	67.57%
Plant 5	115000	18.81	10.48	2.20	14.23	43.52	1441.40	9.57	29.34	0.21	67.43%
Plant 6	47000	24.84	0.38	0.08	22.54	47.76	1271.96	10.90	32.09	0.17	67.18%
Plant 7	100000	46.75	4.00	0.84	21.77	72.52	2072.20	16.12	48.14	0.18	66.39%
Plant 8	186480	21.34	2.00	0.42	23.50	46.84	1323.35	10.35	30.88	0.18	65.94%
Plant 9	137000	23.94	3.00	0.63	25.82	52.76	1417.56	11.55	34.25	0.18	64.92%
Plant 10	33000	40.20	4.81	1.01	23.25	68.26	1715.05	14.84	43.63	0.16	63.91%
Plant 11	100000	26.83	15.00	3.15	4.09	45.92	1807.03	7.75	26.06	0.33	56.76%
Plant 12	46200	22.62	3.52	0.74	20.84	46.98	1291.48	8.60	26.35	0.21	56.09%
Plant 13	182500	23.66	0.71	0.15	14.73	39.10	1201.84	6.67	21.16	0.26	54.11%
Plant 14	61550	54.74	0.71	0.15	21.88	77.33	2031.31	13.50	41.38	0.21	53.51%
Plant 15	70000	51.48	1.71	0.36	18.50	71.69	1564.95	12.30	36.68	0.18	51.16%
Plant 16	180000	34.48	0.10	0.02	17.57	52.15	1527.61	7.00	23.17	0.31	44.43%
Plant 17	105000	78.81	7.86	1.65	8.90	95.57	2252.90	13.15	41.30	0.24	43.21%
Plant 18	98500	31.88	5.57	1.17	25.09	62.54	1291.48	8.60	26.35	0.21	42.14%

Table (3): Energy data of 18 wood based paper mills, * calculated to prime energy consumption in coal fired power plant (* units apply to tons of produced paper)

¹ Assumption: efficiency of coal fired power plant: 30%; transmission losses in grid 30%

² The assumptions for calculating the thermal consumption from steam are given in Annex 1.

A “conversion efficiency”, which is the ratio of used energy in the process to prime energy consumption, can be defined using the above information for providing these energy services. The ‘conversion efficiency’ would be equivalent to the CHP efficiency, if both the heat and electricity are generated by a CHP plant. The ‘conversion efficiencies’ thus calculated for the above mentioned 18 paper mills is plotted in figure 2, along with the power to heat ratio of the consumed energy which helps classifying their consumption patterns. The average ‘conversion efficiency’ of the assessed plants is 60%.

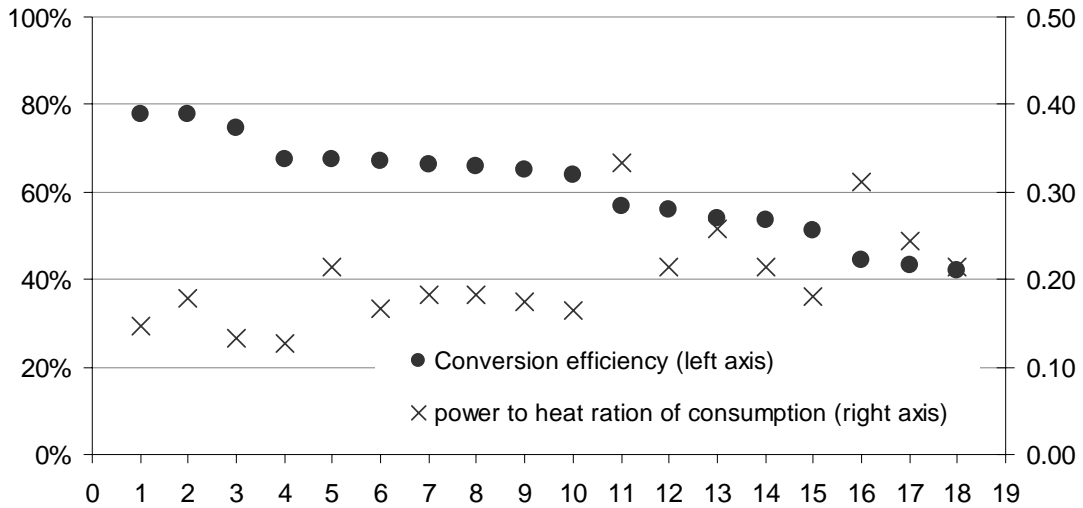


Figure (2) Conversion efficiency and ‘power to heat ratios’ of 18 Indian wood based paper mills

It is easy to observe a trend that the plants with higher ‘power to heat ratio’ have lower ‘conversion efficiencies’. This is primarily due to the reason that generation of electricity requires more prime energy as the generation of steam – at least in conventional generation systems. Figure 2 further indicates that the use of CHP is less in plants with higher ‘power to heat ratio’. However, ‘power to heat ratios’ higher than 0.21 can be implemented (as seen in table 4) with a backpressure turbine delivering steam required in a pulp and paper industry. The conclusion is that larger ‘conversion efficiencies’ are possible leading to reduced prime energy consumption because with state-of-the-art backpressure turbines ‘CHP efficiencies’ are achievable up to 80% and above. This indicates clearly a possible improvement of energy efficiency by increasing layout of CHP plants in the Indian pulp and paper industry. A basis for this improvement, a demand side management of the consumption pattern might also be essential.

Life steam parameters		El. output	Power to heat ratio
Pressure [bar abs.]	Temperature [°C]	[kWh _{el} /t _{steam}]	[-]
11	185	0.00	0.00
20	245	29.21	0.04
40	330	71.47	0.10
60	360	79.69	0.11
80	420	113.77	0.16
100	460	134.69	0.19
114	480	144.15	0.21

Table (4): power to heat ratio with a backpressure turbine (turbine efficiency about 88%) to deliver steam 11 bar abs., 185°C (assumptions are given in Annex 1)

Ten of the 18 assessed plants have a demand side “power to heat” requirement of less than 0.20. By increasing it to 0.20, these plants could generate additional 333 GWh_{el} of cheap and environmental friendly electricity per year. By increasing the ‘conversion efficiency’ to 80%,

the ten companies in question could save 430 TJ of prime energy per year, equivalent to about 260,000 tons of coal³.

One can argue that a correlation between the size of a paper plant in terms of output of paper per year and 'conversion efficiency' does exist due to economies of scale and the increased incidence of the use of CHP within the process. However, the study by the CPPRI did not identify such a trend. This means that higher 'conversion efficiencies' are seen in small and large plants and, vice versa, low 'conversion efficiencies' have been identified also throughout several plants of all sizes within the sector.

The challenge for any pulp and paper mill is to generate the right amount of electricity and heat at the required time of demand. Therefore, to consider also the demand pattern is crucial for each individual plant layout. It is possible to use the grid for balancing electrical demand and the turbine is operated according to the process steam requirement of the paper plant. This may not always be the case due to the reason that grid feed in is not always feasible, economic or desired by the stakeholders. Consequently, many extraction-cum-condensing turbines are installed in order to run the paper plant in 'island' mode. This makes the plant also independent from undesired frequency fluctuations of the grid.

In conclusion, perhaps 81% of the mills follow some CHP cycles, but inference from the above discussion clearly indicates a great potential to increase electrical production via CHP.

4 Estimate of CHP potential

The Indian paper production can be classified in three categories on the basis of raw material used for pulp and paper production: wood-based, agro-based and recycled material-based paper production. Their estimated average heat consumptions are given in table (5).

	Paper prod.	No. of mills	Power consumption		Thermal consumption			Power to heat ratio	Thermal load*	CHP potential
			Specific	Sector	Specific		Sector			
	[Mt/a]	(ca.)	[kWh _{el} /t _{paper}]	[GWh _e /a]	[t _{steam} /t _{paper}]	[kWh _{th} /t _{paper}]	[GWh _{th} /a]	[-]	[MW _{th}]	[MW _{el}]
Wood based	2	20	1400	2800	12	8412	16825	0.166	2086	417
Agro based	2.1	130	1200	2520	9	6309	13250	0.190	1643	329
RCF based	3.3	350	800	2640	5	3505	11567	0.228	1434	287
Average	---	---	1076	---	8.0	5627	---	0.201	---	---
Total	7.4	500	---	7960	---	---	41642	---	5163	1033

Table (5): Energy consumption in the Indian Pulp and Paper Industry and estimated CHP potential (* with assumed plant load factor of 0.92)

In order to estimate the potential of CHP in the pulp and paper industry, this study assumes that the steam for each paper plant is generated via a CHP cycle, with a backpressure turbine delivering a 'power to heat ratio' of 0.20. Capital utilisation factor of the paper industry is assumed to be 0.92 leading to a theoretical full load operation of 8060 hours per year. The resulting CHP potential of the three categories of the paper plants is calculated as follows:

Wood-based plants: 417 MW_{el}
 Agro-based plants: 329 MW_{el}
 Recycling paper plants: 287 MW_{el}

The CHP potential of the entire pulp and paper sector comes out to be 1.033 MW_{el}.

This CHP potential can be considered as a conservative estimate due to the fact that plant load factors estimated as 0.92 are relatively high compared to the average plant load factor of 0.554 of existing steam-based power plants [2]. Additionally, this study is modelled on the basis of state of the art technology, but still with moderate 'power to heat ratio'.

³ Assumed heat rate of coal: 4000 kcal/kg

As seen in table 1, captive steam-based power plants larger than 1 MW_{el} generated 3,451 GWh_{el} of electricity in 2005/2006. Assuming that all these plants are equipped with backpressure turbines with a ‘power to heat ratio’ of 0.20 (which is certainly not the case), these plants would have generated 17,250 GWh_{th} of thermal energy, about 41% of the heat demand of the entire sector (see table 5). Consequently, the remaining heat, 59% of the total, must be generated either in low pressure steam boilers or in CHP plants smaller than 1 MW_{el}. As small CHP plants are rare in India, the not implemented CHP potential within the pulp and paper sector can be estimated to be above 60%. With the above met assumptions, this is equivalent to 600 MW_{el} electrical generation capacity.

Conclusion

The potential of CHP in the Indian pulp and paper sector is significant. More than 60% of the required heat is generated via regular low pressure steam boilers. Additionally, the installed CHP plants could be improved significantly as regards energy efficiency. Consequently, the electrical generating potential in the sector is at least 600 MW_{el}.

A barrier for CHP may be the relatively low plant load factor of 0.534, indicating fluctuations in heat or electricity demand necessitating special care to be taken in plant design and demand side energy management. An optimum plant design and plant operation can be identified by computer simulation leading to the most energy efficient and, therefore, economic solution of CHP plant.

By removing institutional barriers and promoting latest technology and optimum plant layout, the Indian pulp and paper sector could generate electricity via energy efficient CHP mode not only to satisfy its own needs. It could also export electricity to the grid. Therefore, CHP can contribute towards sustaining India’s economic growth and an ecological friendly future.

Bibliography

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Annex 1: Assumptions

temperature of inlet steam	185 °C
pressure of inlet steam (absolute)	11 bar
pressure of condensate (absolute)	1 bar
temperature of condensate	90 °C
recovery rate of condensate (remaining part is lost or used in process)	60 %
temperature of water from water treatment plant	20 °C

Table (6): Assumptions of steam consumed in paper plant for calculation of thermal energy consumption