Good Practices Manual

Green House Gases Emission Reduction

Pulp and Paper Sector

Prepared by

National Productivity Council

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Department of Industry and Policy Promotion

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PREFACE

It is now widely accepted that we have to limit the temperature rise to 2^{o}C to mitigate effects of climate change. This requires changing the portfolio of energy basket from fossils to non-renewables, reduce energy use through energy efficiency and conservation and reduce GHG emissions.

The broad intent and its goals can only be achieved by coordinated actions at various level by society, business, industry and government. As part of its endeavour the Government of India is formulating policies, action plans to support and guide industry and entrusted National Productivity Council to prepare of Best Practices Manual for Reducing GHG Emissions in various sectors namely, **Thermal Power Plant, Chlor-Alkali, Cement, Pulp and Paper, and Sponge Iron.**.

This manual is expected to serve as reference manual for

- Identifying sources of GHG emissions
- Assess and quantify emissions.
- Evaluate and assess potential to improve energy efficiency and reduce GHG emissions.
- Propose a menu of options which industry can consider for assessment and implementation.

The scope of this manual covers GHG emissions in the plant boundary and does not include transportation of raw materials, products and wastes to secured landfills, emissions from domestic waste treatment and emissions from sales and other offices.

It is hoped the manual will be handy reference and guide for all levels of engineers and managers working in the sector.

STUDY TEAM

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1. INTRODUCTION

1.1 BACKGROUND

Energy is a major driver of economy and the per capita consumption of energy is a lead indicator of its development. The fossil fuels, constituting 72.4% of the energy basket as of 2013[1], is the major contributor of GHG emissions and consequently global warming. The wider consensus that the temperature rise is to be limited to 2°C requires reducing GHG emissions by changing the portfolio of energy mix from fossil fuels to non-renewable sources, and reducing energy use through energy efficiency and conservation.

India is a net energy importing country and its GDP growth is one of the highest in the world. To maintain its growth rate as well as to ensure energy security and meet its committed GHG emission target reduction (30-35%) by 2030 from 2005 levels, India has been taking measures to shift its energy consumption towards renewable energy, besides adopting energy conservation and management measures. Studies indicate potential to reduce GHG emissions as shown in Figure 1.1.

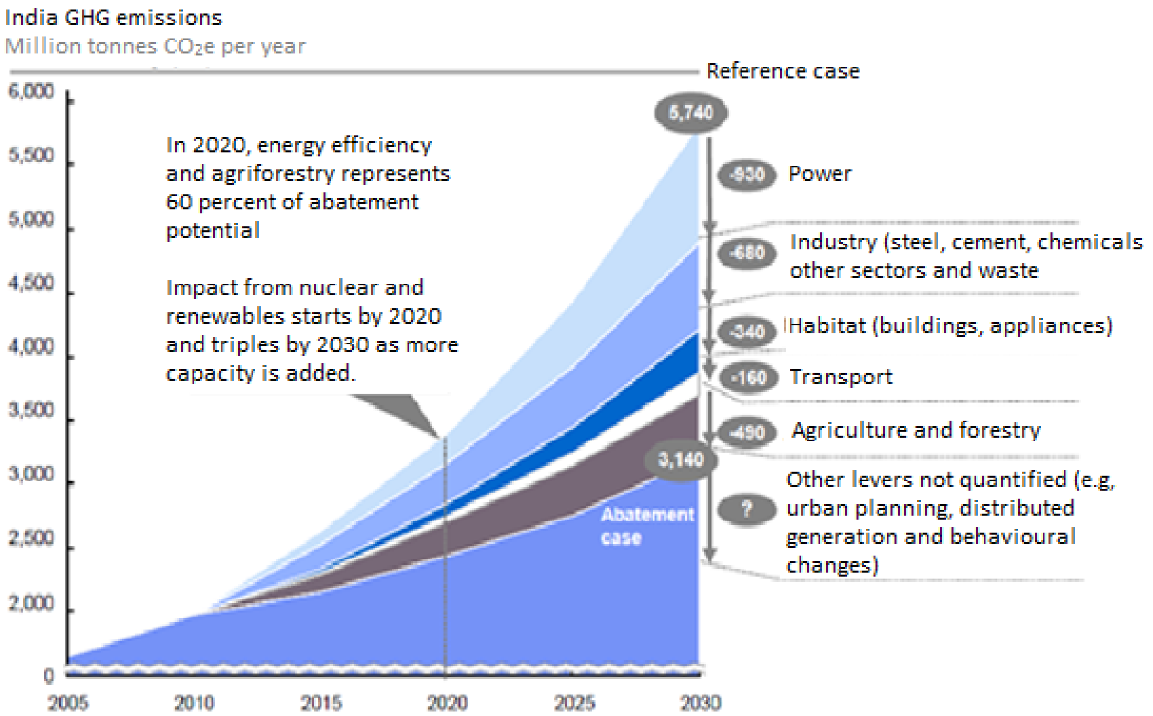

Figure 1.1 Indian GHG Emission Scenario (Past, Current & Projected)

Source: Pathways to lowcarbon_economy_Version2

[1]http://data.worldbank.org/indicator/EG.USE.COMM.FO.ZS

As can be seen, industrial sector's GHG reduction potential is about 680 million tonnes CO_2e per year. In line with these projections provided by various studies, Government of India has evolved policies, action plans and mission oriented programs to address the following objectives and issues.

- Energy security – to meet present and future needs
- Environmental impact-to address local emissions & global climate change
- Economic development – to create a sustainable development
- Ease of implementation

1.2 ABOUT THE PROJECT

To ensure effective translation of policy and implementation of action plans, Department of Industrial Policy & Promotion (DIPP), under Ministry of Commerce & Industry, Government of India has entrusted National Productivity Council of India (NPC) with the project titled "Preparation of Good Practices Manuals for Green House Gas Emission Reduction in Five Energy Intensive Industry Sectors in India" under the 12th Plan period (2012-2017).

The scope of the project is to conduct field and questionnaire survey in five selected energy intensive sectors (Thermal Power Plant, Chlor Alkali, Cement, Pulp and Paper and Iron and Steel) of Indian economy, and bringing out manuals on Good Practices for GHG Emission reduction in the selected energy intensive sectors. Out of these five energy intensive sectors, this manual highlights the best practices involved for reducing Green House Gases Emission Reduction in the Paper & Pulp sector.

This manual brings out sources and trends driving India's greenhouse gas emissions in the paper& Pulp sector, outlining present situation and technologies that offer potential for significant emission reductions through enhanced energy efficiency that will put India on a sustained low-carbon path without sacrificing economic growth. It also highlights the Government of India policies and interventions that spur energy efficiency and GHG reduction activities in the sector eventually leading to improving energy security.

1.3 METHODOLOGY

For preparing this manual, the following methodology was adopted:

- Sector reports were prepared with inputs from questionnaire survey, detailed field visits and audits, workshops and guidance from steering committee.

- The synopses of the reports were extracted to prepare this manual for comprehensive presentation of information and provide guidelines for implementation of GHG emission reduction options.
- Feedback on the manual contents and the material was sought and received from industries, sector association, and other stakeholders and the same was incorporated in the final manual

1.4 GREENHOUSE GASES AND ITS IMPACT

Over the last 100 years, it has been found out that the earth is getting warmer and warmer, unlike previous 8000 years when temperatures have been relatively constant. The present temperature is 0.3–0.6 $^{\circ}$C warmer than it was 100 years ago. The key greenhouse gas (GHG) causing global warming through human enhanced GHG effect is carbon dioxide.

The natural greenhouse effect is the process by which radiation from the earth's atmosphere warms its surface to a temperature above what it would be without its greenhouse gases naturally present in the atmosphere. The greenhouse gases naturally present in the atmosphere include carbon dioxide, water vapor, methane, nitrous oxide, and ozone.

Certain human activities add to the levels of most of the naturally occurring gases. For example, carbon dioxide is released to the atmosphere when fossil fuels such as oil, natural gas, coal, wood etc are burned. The enhanced greenhouse gas effect is the further rise in average earth’s temperature due to increase in the amount of carbon dioxide and other greenhouse gases in the earth's atmosphere due to human activities. Both these effects are depicted in Figure 1.2.

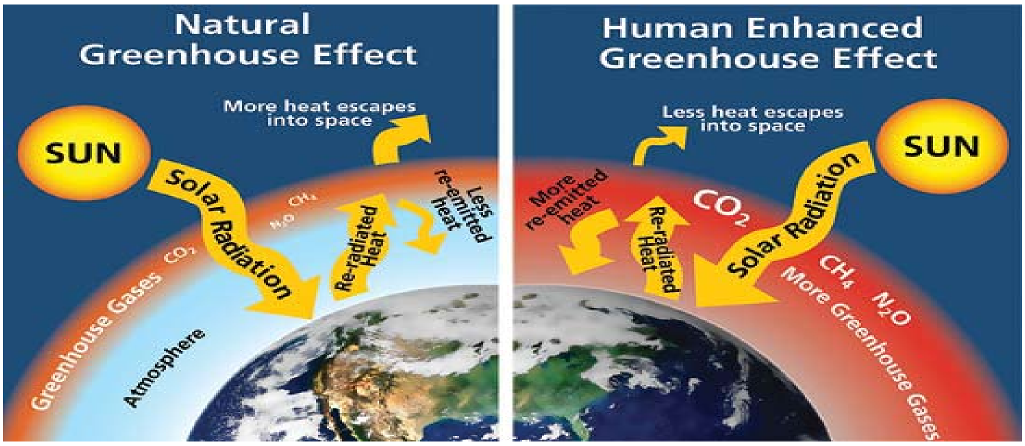

Figure 1.2 Natural and Human Enhanced Greenhouse Effect

Green House Gases (GHG) is of two types namely direct and indirect. Direct GHG contribute directly to the greenhouse effect in the atmosphere by trapping the infrared radiation near the earth's surface. The major GHG gases identified by Intergovernmental Panel on Climatic Change (IPCC) are carbon dioxide, methane, nitrous oxide, hydrogen fluorocarbons, per fluorocarbons, sulphur-hexafluoride.

Indirect GHG control the oxidizing capacity of the troposphere by reducing the hydroxyl radical distribution thereby increasing the residence time of direct greenhouse gases, such as methane and ozone. Although there are a number of ways of measuring the strength of different greenhouse gases in the atmosphere, the Global Warming Potential (GWP) is the most used indicator.

GWP depends upon the greenhouse gas ability to absorb heat in the atmosphere. HFCs and PFCs are the most heat-absorbent. Methane traps over 21 times more heat per molecule than carbon dioxide, and nitrous oxide absorbs 270 times more heat per molecule than carbon dioxide. The GWPs for different GHGs are presented in Table 1.1.

Table 1.1 Direct and Indirect Green House Gases and its GWP

GHG	Name	Common Sources	Atmospheric Lifetime (years)*	Global Warming Potential (GWP)
CO_2	Carbon Dioxide	Fossil fuel combustion, forest clearing, cement production etc.	50-200	1
CH_4	Methane	Landfills, production and distribution of natural gas and petroleum, fermentation from the digestive system of livestock, rice cultivation, fossil fuel combustion, etc.	12	21
N_2O	Nitrous Oxide	Fossil fuel combustion, fertilizers, nylon production, manure, etc.	150	310
HFC's	Hydro fluorocarbons	Refrigeration gases, aluminum smelting, semiconductor manufacturing, etc.	264	Up to 11,700
PFC's	Per fluorocarbons	Aluminum production, semiconductor industry, etc.	10,000	Up to 9200
H_2	Hydrogen	Chlor alkali production etc	100	5.8

The Figure 1.3 shows comparison of per capita CO_2 emission for the top five GHG emitting countries of the world and EU. India—owing to higher population—per capita

CO_2 emission is the least. However, in terms of absolute emissions India is the third largest CO_2 emitting country, behind the US and China (2015) and contributing about 6 % (2.3 Gt CO_2) of global emissions (WEO 2015).

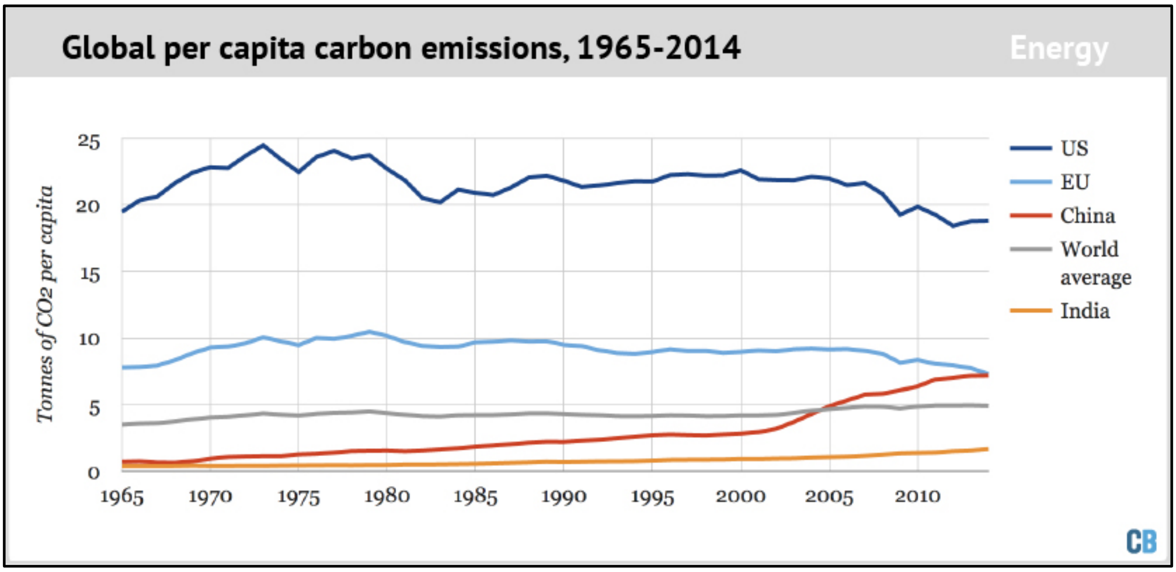

Figure 1.3 Per capita CO_2 Emissions

Impacts of Global Warming

Rise in Global Temperature

Observations show that global temperatures have risen by about 0.6 °C over the 20th century. There is strong evidence now that most of the observed warming over the last 50 years is caused by human activities. The various climate models predict that the global temperature will rise by about 6 °C by the year 2100.

Rise in Sea Level

In general, the faster the climatic change, the greater will be the risk of damage. The mean sea level is expected to rise 9–88 cm by the year 2100, causing flooding of low lying areas and other damages.

Food Shortages and Hunger

Water resources will be affected as precipitation and evaporation patterns change around the world. This will affect agricultural output. Food security is likely to be threatened and some regions are likely to experience severe food shortages and hunger.

Models also predict an average increase in temperature in India of 2.3–4.8°C for the benchmark doubling of carbon dioxide scenario. It is estimated that 7 million people would be displaced, 5700 km^2 of land and 4200 km of road would be lost, and wheat yields could decrease significantly.

Due to rising energy demand, India's CO_2emissions are expected to grow at the rate of 7%and surpass the present EU-28 emissions by 2020. As a part of mitigation effort, India is committed to increase its share of non-fossil energy sources from current 19% to 40% by 2030. However, combustion of fossil fuel will continue to be the single major contributor to the global warming in the coming years and hence the focus is on efforts to opt for renewable energy and enhance energy efficiency.

1.5 OUTLINE OF ENERGY SCENARIO IN INDIA

The energy mix of India for 2013 presented in the pie chart (Figure 1.4) indicates fossil fuel is the main stay of India's energy mix.

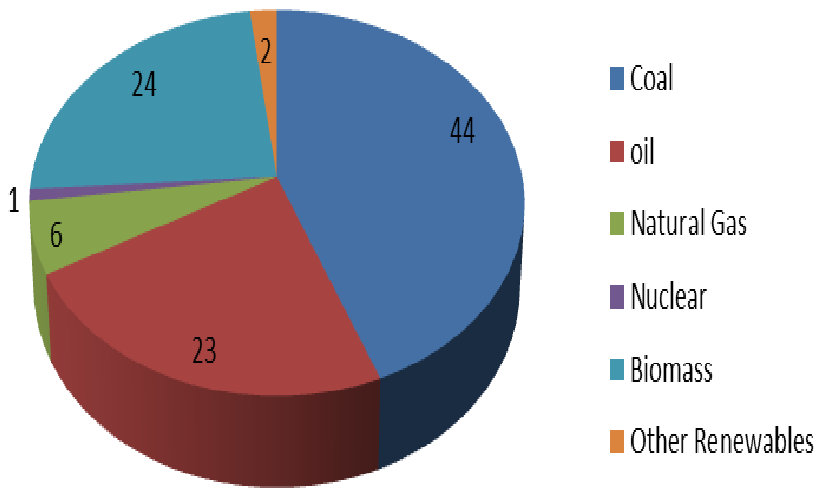

Figure 1.4 Primary Energy Demand in India for 775 MTOE
(Source : IEA, 2015)

Industrial energy demand has almost doubled over the 2000-2013 period, with strong growth from coal and electricity. Large expansion in the energy-intensive sectors is anticipated in the future. The present energy consumption in these energy intensive sectors in the country is high compared to the developed world. The major energy consuming sectors in the country are Iron & Steel, Chemicals, Textiles, Aluminium, Fertilizers, Cement & Paper. These sectors account for about 60% of the total energy consumption in industry. The energy consumption in manufacturing is relatively high in India which is reflected in the Specific Energy Consumption (SEC). This, therefore, provides an opportunity to reduce energy consumption and thereby GHG emissions. The typical SECs in different manufacturing sectors is presented in Table 1.2.

Table 1.2 Specific Energy consumption in Energy Intensive Industries

Sl. No.	Industrial Sector	Specific Energy Consumption (SEC)	
		India	World
1	Iron and Steel	6.5–7.0 GCal/Ton	4.5–5.5 GCal/Ton
2	Cement	80 kWh/T	110 kWh/T
3	Aluminium	4300 kWh/T (Refinery) 16500 kWh/T (Smelter)	3850 kWh/T (Refinery) 15250 kWh/T (Smelter)
4	Fertilizer	7.7 GCal/T of Urea	6.5 GCal/T of Urea
5	Paper and Pulp	8.4 Steam consumption/Ton	4.5 Steam consumption/Ton
6	Textile	7.1 GCal/Ton	3.1 GCal/Ton
7	Chlor Alkali	3.1 GCal/T (Soda ash) 2.1 GCal/T (Caustic Soda)	2.6 GCal/T (Soda ash) 1.8 GCal/T (Caustic Soda)

Source: BEE PAT Document

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1.6 ENERGY CONSERVATION AND GHG EMISSION REDUCTION INITIATIVES BY GOVERNMENT

The major policies that are currently promulgated and being implemented to meet the energy and climate challenge are summarized in Table 1.3.

Table 1.3 Government Policies and Initiatives for Energy Conservation

Policy /Initiative Statement	Key Features of the Policy
Energy Policies	
1. National Electricity Policy 2. National Rural Electrification Policy	• Access to Electricity - Available for all households in next five years • Availability of Power - Demand to be fully met by 2012. Energy and peaking shortages to be overcome and adequate spinning reserve to be available. • Supply of Reliable and Quality Power of specified standards in an efficient manner and at reasonable rates. • Per capita availability of electricity to be increased to over 1000 units.
3. National Tariff Policy	• Minimum lifeline consumption of 1 unit/household/day.

Policy /Initiative Statement	Key Features of the Policy
2006	• Financial turnaround and commercial viability of electricity Sector. • Protection of consumers' interests.
Industrial Energy Efficiency Programs	
1. National Mission for Enhanced Energy Efficiency (NMEEE) (a) Market Transformation for Energy Efficiency (MTEE) (b) Energy Efficiency Financing Platform (EEFP) (c) Perform, Achieve, and Trade (PAT) Mechanism for Energy Efficiency	• Market-based approaches to unlock energy efficiency opportunities, estimated to be about Rs. 74,000 crores (2014-15) • Annual fuel savings in excess of 23 million toe • Cumulative avoided electricity capacity addition of 19,000 MW • CO_2 emission mitigation of 98 million tons per year
2.National Mission on Sustainable Habitat (NMSH)	Works on Municipal Solid Wastes, urban storm water &water mgmt. & energy efficiency
3.Energy efficiency Standards and Labelling Program	• BIS: formulations and implementations of national standards/production, quality and EMS certifications BEE : key thrust of EC Act,2001
1. Capacity Building for Industrial Pollution Management	• Build capacity at the State and Central level, and develop a framework to address these issues in a comprehensive and systemic manner under an area-wide management approach. • The proposed project is aligned with the endeavour of the GoI to establish a National Program for Rehabilitation of Polluted Sites (NPRPS) as a framework for scaling up clean-up and rehabilitation of polluted sites and facilitate the reduction of environmental and health risks associated with legacy polluted sites.
Capping, Trading and Taxing	
1. Tax on Coal to Fund Clean Energy	All means to instil price signals to spur energy efficiency and using cleaner fuels

Policy /Initiative Statement	Key Features of the Policy
2.Renewable portfolio standards/obligation • Renewable Purchase Obligation (RPO) under the Electricity Act 2003 is mandated at the state level (discussed below in "National Policies Implemented at the State Level")	• States can choose to apply the RPS requirement to all its utilities or only the investor owned utilities. • States can also define what technologies are eligible to count towards the RPS requirements.
3. RECS (Renewable Energy certificate System)	• Aimed at addressing the mismatch between availability of RE resources in state and the requirement of the obligated entities to meet the renewable purchase obligation (RPO) • Cost of electricity generation from renewable energy sources is classified as cost of electricity generation equivalent to conventional energy sources and the cost for environmental attributes. • Two categories of certificates, viz., solar certificates issued to eligible entities for generation of electricity based on solar as renewable Cost of Electricity Generation by Renewable Sources Cost Equivalent to Conventional Source Cost for Environmental Attributes energy source, and non-solar certificates issued to eligible entities for generation of electricity based on renewable energy sources other than solar
Subsidies for Energy Conservation	
1. Financial incentives through the Jawaharlal Nehru National Solar Mission 2. Financial incentives by the Ministry of New and Renewable Energy through the Indian Renewable Energy Development Agency	• Creating capacity in the area of solar, wind, bio-mass and other forms of renewal energy generation • Supports financially as well as technically to promote solar heater other solar applications widely in the country and particularly in the areas where conventional energy is not possible to supply • Long term energy security • Ecologically sustainable growth • Set target-20,000MW
Energy Conservation in Buildings and Municipalities	
Energy Conservation Building Code	• Provide technical support to BEE to implement the ECBC in a rigorous manner • Develop reference material and documentation to support

Policy /Initiative Statement	Key Features of the Policy
	the Code • Develop ECBC Training material for workshops and training programs • Develop a road map for ECBC implementation
1. Municipal Demand-Side Management 2. State Energy Conservation Fund	Municipal Demand Side Management (MuDSM) is devised to take care of the most common and other issues which are seen as a hurdle by the Municipality to shift itself towards the energy efficient zone from the existing situation of high amount of energy consumption.
Energy Conservation in Agriculture and Forestry Activities	
Agriculture, forestry, and other land use policies 1.Agricultural Demand-Side Management (AgDSM) 2.National Mission for Sustainable Agriculture 3. National Mission for a Green India	• Consists of those activities, methodologies, awareness, policy and technologies that influence consumer (farmers) behaviour and changes their (farmers) consumption patterns. • The objective of the AgDSM programme is to reduce peak demand, shift the time during which electricity is consumed to off-peak hours and to reduce the total quantum of consumption.

1.7 GHG EMISSION FACTORS

The emission factors considered for calculations in this manual are tabulated in Table 1.4 (CEA, 2014).

Table 1.4 Typical GHG Emission Factors

No.	Parameter		Units	Factor
1	Grid Electricity		Kg CO_2/kWh	0.82
2	CPP Electricity			
	a.	Coal Fired	Kg CO_2/kWh	1.03
	b.	Diesel Fired	kg CO_2/kWh	0.62
	c.	Gas Fired	kg CO_2/kWh	0.49
3	Coal (Sub-bituminous)		kg CO_2/kg	1.1
4	Diesel/Furnace oil		kg CO2/kg	3.12

2.0 PULP AND PAPER SECTOR PROFILE

2.1 INTRODUCTION

There are about 825 number of paper mills in India producing about 15.3 million tonnes of Paper, Paper board & Newsprint per annum and accounting for about 3 percent of the world's production of paper. The estimated turnover of the industry is approximately Rs.50000 crores. The sector provides employment to more than 0.5 million people directly and 1.5 million people indirectly.

Most of the paper mills are in existence for a long time and hence the technologies adopted fall in a wide spectrum ranging from rather obsolete to the most modern. The paper industry is highly fragmented with varying sizes ranging from 10 TPD to 1500 TPD. There are thirty one large mills based on woody raw materials (Eucalyptus, Casuarinas, Subabul etc.) having capacities ranging from 300 to 1500 TPD contributing to 26% of the total production. The remaining 74% of the production comes from recycled waste paper and agro residues based mills. India is one of the fastest growing markets for paper and paper consumption in the country and is estimated to touch 20 million tons by 2020.

The large scale mills (>100,000 TPA) though only5% of the total number of mills in the Indian paper industry contribute to 28% of the installed capacity. Medium scale mills (10,000–100,000 TPA) contribute63 percent of the total installed capacity, while small scale mills(< 10,000 TPA) contributes to only 9 percent of the industry's capacity.

Although present per capita consumption of paper (10 kg) is significantly low compared to the global per capita paper consumption (58 kg), it is expected to rise in coming years due to increasing demand. It is estimated that India's paper demand will rise by 53% by 2020. Even the increase in per capita consumption by one kilogram will lead to increase in production by one million tonnes.

The raw materials in the pulp and paper industry are waste paper, agro-residues and wood. The share of wood in the total raw material mix is 31 percent in 2011. The pulp and paper sector is increasingly adopting sustainable wood sourcing.

2.2 PERFORMANCE AND PRODUCTIVITY INDICATORS

Specific Energy Consumption

The pulp and paper industry is energy intensive, with energy costs accounting for nearly 25 percent of the paper manufacturing costs. Energy performance, in terms of primary energy consumption, in Indian paper mills is reported to be much lower than that of European paper mills. The primary energy consumption of European mills at 22 GJ/tone of product is half the average energy consumption of mills in India. The specific energy consumption of some of the major mills in India is given in Table 2.1.

Table 2.1 Specific Energy Consumption of Major Mills in India

Some Major Mills in India	**Specific Energy Consumption (GJ/BD/MT)** **2012 – 13**
BILT – Shree Gopal Unit	58
BILT – Ballarpur	42
BILT – Sewa	61
TNPL	45
JK Paper Ltd. – CPM	34
ITC Ltd.	31
Seshasayee Paper & Board	51
Orient Paper	91
Star	45
Century	55
West Coast Paper	45
JK Paper	49
Weighted average	**45**

The specific electricity and thermal energy consumption is shown in Table 2.2.

Table 2.2 Typical Specific Energy (Electrical and Thermal) Consumption

No.	**Type of Mill Electrical Energy**	**Specific Electricity Consumption kWh/T**	**Specific Thermal Energy Consumption, GJ/T**
1	Integrated Wood / Bamboo based	1500 – 1800	35.0
2	Agro based mill without recovery	1300 – 1500	29.5
3	Waste Paper based	800 – 950	13.2

Specific Coal Consumption

The main source of energy in Indian pulp and paper industry is coal which contributes to more than 50 percent of the total energy consumed. The specific coal consumption of some major mills in India is given in Table 2.3.

Table 2.3 Specific Coal Consumption Major Mills in India

Some Major Mills in India	**Specific Coal Consumption (MT/BDMT)** **2012 – 13**
BILT – Shree Gopal Unit	2.1
BILT – Ballarpur	1.7
BILT – Sewa	1.8
TNPL	1.1
JK Paper Ltd. – CPM	1.0
ITC Ltd.	1.0
Seshasayee Paper & Board	1.3
Orient Paper	3.5
Star	0.5
Century	1.6
West Coast Paper	1.0
JK Paper	1.6
Weighted average	1.3

Specific Water Consumption

With rising water scarcity, mills are increasingly adopting various water conservation measures to reduce the water consumption levels. In terms of total quantum of water consumed, the mills are using 30 percent lesser water today to produce 170 percent more pulp and paper. Although the reduction in water consumption is impressive, there is enough scope for further reduction considering that the average fresh water consumption of Indian mills is 68 m^3/MT compared to 35m^3/MT of European mills.

The Table 2.4 shows specific water consumption of major paper mills in India.

Table 2.4 Specific Water Consumption of Major Mills in India

Some Major Mills in India	**Specific Water Consumption (m^3/BDMT)** **2012 – 13**
BILT – Shree Gopal Unit	127
BILT – Ballarpur	59
BILT – Sewa	105
TNPL	58
JK Paper Ltd. – CPM	42
ITC Ltd.	42
Seshasayee Paper & Board	74
Orient Paper	135
Star	109
Century	77
West Coast Paper	91
JK Paper	58
Weighted average	**68**

Productivity Indicators

Ratio of output to particular inputs may be termed as "partial productivity" measures. There are as many indices of partial productivity as there are factors of production. The most important and most often used are the partial productivity indices of labour and capital respective1y. These indices are:

$$AP_L = \frac{Q}{L}$$

$$AP_K = \frac{Q}{K}$$

Where,

AP_L and AP_K are average productivity of labour and capital

Q is the total output/value added

L is the labour

K is the capital.

While the partial productivity indices of labour and capital are simply the average product of labour and capital, the total factor productivity, often referred to as the index of “technical progress", is defined as output per unit of all factors of production combined. It is the composite measure of productivity which relates output to all the conventional inputs simultaneously. The concept of total factor productivity defined as the ratio between real product or output and real factor input (a weighted sum of the different inputs).

Labour and Capital Productivity

The term ‘Labour Productivity’ is generally defined as “the ratio of physical amount of output achieved in a given period to the corresponding amount of labour expended”. In any business organization wage payments are directly or indirectly based on the skill and productivity of the workers, therefore labour productivity is considered as the most important factors in productivity computations.

There are many methods to determine labour productivity. One simple method using the above definition is input in terms of cost/expenses and capacity and utilization and input in terms of man-hours.

Determinants of Labour Productivity Growth

Factors such as economies of scale, increasing capital labour ratio and increase in wage rate have considerable influence on labour productivity growth. Generally, more capital-intensive industries are more productive and efficient than the less capital intensive ones.

The productivity growth function is expressed as:

ln (APLG) = á + ln (CAPG) + ln (EMOLG) + ln (GVAG) + u (1)

Where,

APLG = growth of labour productivity

CAPG = growth of capital intensity

EMOLG = growth of emoluments per employee

GVAG = growth of gross value added

u = error term

Labour productivity growth is regressed on growth of value added, capital labour ratio and emoluments per worker. A positive and significant relationship is expected between growth of labour productivity and value added. Growth in labour productivity can also be due to increase in capital intensity through the substitution of capital for labour or the availability of more machines per worker. Increase in growth of emoluments per worker could positively influence the productivity of labour, particularly where emoluments paid are very low.

Some suggestions for cost reduction and performance improvement and improving business effectiveness include,

- Control over operating expenses and cost of goods sold.
- Maximize capacity utilization to reduce overheads.
- Reduce interest burden and increasing own funds
- Use long-term funds to finance core current assets.
- Prefer plant location close to raw materials

3.0 PULP AND PAPER PROCESS DESCRIPTION

3.1 OVERVIEW OF PULPING AND PAPER PRODUCTION

Pulping and paper production comprises six major processes before finished product is rolled out.

a) Raw Material Preparation
b) Pulping
c) Washing
d) Bleaching
e) Pressing and Drying
f) Packing

The schematic of a paper production for different type of plant is shown in Figure 3.1

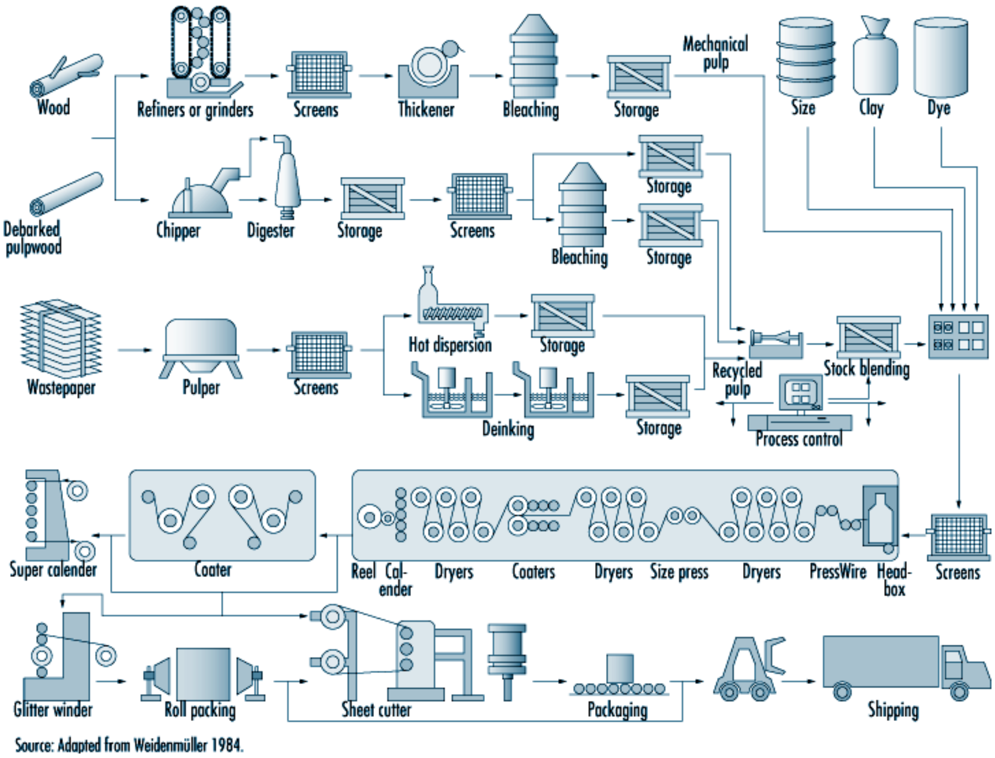


Figure 3.1 Process Flow Diagram of Paper Manufacturing

3.2 RAW MATERIAL SELECTION

The selection of raw material for any paper and pulp industry depends upon the structure of the raw material and the desired product output. The following parameters influence the selection of the material.

- Moisture content – Percentage of water reported relative to dry or wet wood weight.
- Specific gravity – Density of material relative to the density of water.
- Tension &compression strength properties.
- Bark content.
- Chemical composition – cellulose, hemi-cellulose, lignin, and extractives.
- Length of storage – Amount of Decay & Extractives Content.
- Dimensions.
- Species (Wood, agro-based, recycled, etc.)

Types of raw materials

Paper mills are classified into three categories based the raw material usage such as wood based, recycle based, and agro based.

Wood-based

Tissue	Function
Outer Bark	Physical and Biological Protection. Not preferred. Usual tolerance is between 0.3-0.5percent.
Inner Bark (Phloem)	Conduction of food up and down the stem
Vascular Cambium	Thin layer of cells giving rise to all the wood and inner bark fibers. The tree stem grows outwards.
Rays	Storage and lateral food movement from the phloem to the living cells of the cambium and sapwood.
Pith	The center of the tree; from the apical meristem.
Growth Ring	One year's growth of wood
Early wood	Low density wood designed for conduction of water
Latewood	High density wood designed for strength to support the tree.
Sapwood	Conduction of Sap (water, soil nutrients) up to the leaves.
Heartwood	Provides strength to support the crown. Often relatively low moisture content in softwoods.
Juvenile Wood	The first ten growth rings surrounding the pith. Usually low density and relatively short fibers.

Recycled Paper–based

The various materials that can be recycled based on their fiber content and impurities are as follows:

- Mixed Waste Paper
- Newspaper
- Corrugated Containers
- Clean, Hard, White Paper Clippings
- Brown Paper

The recycled paper has to be cleaned before being mixed with major pulp ingredients. Cleaning removes impurities such as hot melt adhesives, wax and polyethylene from coated boxes, contact adhesives, pressure sensitive adhesives, polystyrene, wood extractives, etc.

Bagasse / Agro Waste–based

Bagasse is the fibrous residue remaining after sugarcane is crushed to extract its juice and requires less bleaching chemicals e.g., chlorine than wood pulp to achieve a bright, white sheet of paper. The fibers are well suited for tissue, corrugating medium, newsprint and writing paper. Bagasse contains 65- 68% fibers, 25-30% pith, 2% sugar and 1-2% minerals.

3.3 PREPARATION OF RAW MATERIAL

Raw materials are prepared for pulping. For wood, the log is cut into smaller size of ~2.5m for easy handling followed by removal of bark from wood. Finally wood is broken into chips. The chips are sorted into various sizes and thickness for uniform pulping.

3.4 PULPING PROCESS

The pulping process can be any one of the following:

- Mechanical pulping
- Chemi-Mechanical Pulping
- Chemi-Thermo-Mechanical Pulping (CTMP)

Mechanical Pulping

This involves mechanical destruction of lignocellulosic materials using only water and steam. The total yield is between 90-98%. Since mechanical pulps cannot be brightened using chemicals, chip quality has to be very good. Also, the age of chips should be less than 2 weeks old as older chips decay due to oxidation resulting in decolourization. The chips are washed to remove sands, pebbles, tramp metal, and other gritty materials before further processing so that refiners are not damaged.

Chemi-Mechanical Pulping

This process involves pre-treatment of the wood material before grinding. The woods are treated in large digesters using aqueous Na_2SO_3 and Na_2Co_3 under vacuum. The temperature and pressure are maintained at 130-155˚C and 10.34 bar respectively. The yield is between 85-95%.

Chemical Pre-treatment

Cold Soda Process: Chips are soaked in 5-15% caustic soda (sodium hydroxide solution) which acts as swelling agent and retains only the lignin. The yield here is typically between 80-95%.

Hot Sulphite Process: This involves use of hot pressurized sulphite liquor before fibration. This leads to higher brightness (82%) than cold soda process.

Alkaline Peroxide Pre-treatment: This is a four stage process before refining process. Compression of chips using screw press, chemical addition and bleaching takes place simultaneously. Energy consumption is 30-40% lower compared to sulphite treatment.

Chemi-Thermo-Mechanical Pulp (CTMP)

The chips are pre-treated using solution of sodium sulphite and sodium hydroxide at elevated pressure and temperature. Liquid penetration is done using compression of chips and subsequent impregnation is carried out in impregnator vessel.

The Table 3.1 summarises different types of pulping process.

Table 3.1 Different Types of Pulping Process

Process	Chemicals	Species	Pulp Properties	Uses	Yield, %
Mechanical Pulping	None Grind Stones for Logs Disk Refiners for Chips	Hardwoods like Poplar or Light Coloured Softwoods like Spruce, Balsam Fir, Hemlock, True Firs	High Opacity, Softness, Bulk, Low Strength and Brightness.	Newsprint, Books, Magazines	92-96%
Chemi-Mechanical Pulping	Chemi-Thermo-Mechanical Pulping (CTMP), Mild action; NaOH or $NaHSO_3$		Moderate Strength		88-95%
Kraft Process, pH 13-14	$NaOH + Na_2S$ (15-25% on wood); Unlined Digester; High recovery of pulping chemicals, Sulphur Odor	All Woods	High Strength, Brown Pulps unless Bleached	Bag, Wrapping, Linerboard, Bleached Pulps for White Papers	65-70% for Brown Papers, 47-50% for Bleachable Pulp; 43-45% after Bleaching
Sulphite, Acid or Bisulphite, pH 1.5-5	$H_2SO_3 + HSO_3$ with Ca^{2+}, Mg^{2+}, Na^{+}, or NH_4^{+} Base; Ca^{2+} is traditional but outdated since no recovery process; Lined Digesters.	Hardwoods Poplar and Birch and Non Resinous Softwoods, Douglas Fir is unsuitable	Light Brown Pulp is Unbleached, Easily bleached to high brightness, weaker than Kraft Pulp, but higher yield	Fine Paper, Tissue, Glassine, Strength Reinforcement in Newsprint	48-51% for bleachable pulp; 46-48% after bleaching
	Mg^{2+} Base	Almost all Species – Spruce and True Firs preferred	Same as above but lighter colour and slightly Stronger	Newsprint, Fine Papers, Etc.	50-51% for bleachable pulp; 48-50% after bleaching
Neutral Sulphite Semi-Chemical (NSSC) pH 7-10	$Na_2SO_3 + Na_2CO_3$ about 50% of the chemical recovered as Na_2SO_4	Hardwoods (preferred) Aspen, Oak, Alder Elm, Birch, Softwoods, Douglas Fir Sawdust and Chips	Good Stiffness and Moldability	Corrugating Medium	70-80%

3.5 PULP BLEACHING

Pulp bleaching is carried out to enhance the brightness of the pulp using chemical dosing. Brightness defines the whiteness of the pulp or the paper, on a scale from 0% –absolute black to 100%– absolute brightness of 96% by reflectance of blue light (457nm) from the paper. The typical brightness of some of the pulps is listed as follows:

a) Unbleached Kraft – 20%
b) Unbleached Sulphite – 35%
c) Newsprint – 60%
d) Groundwood – 65%
e) White Tablet Paper – 75%
f) High Grade Bond – 85%
g) Dissolving Pulp – 90%

Apart from brightness, colour reversion and consistency places a major part during bleaching. Colour reversion is yellowing of pulps when exposed to air, heat, certain metallic ions, and fungi, due to modification of residual lignin content present in the pulp. Consistency on other part plays the role of increasing the reaction rate of oxygen, peroxide, and hypochlorite with lignin for a given chemical loading during bleaching. Normally consistencies range from 3-20%.

Bleaching Mechanical Pulp

In bleaching of mechanical pulp, the lignin present is masked, unlike bleaching in chemical pulp where the lignin is removed altogether. The whole process of bleaching mechanical pulp is referred to as 'Brightening'.

Brightening is carried out in a single stage or two-stage depending upon the brightness required and the wood pulp species used. Usually brightness requirement ranges from minimum of 6-12% to maximum of 60-70% in single stage, and 70-75% in two-stage process.

Bleaching Chemical Pulp

For bleaching of chemical pulp, the amount of lignin present in the pulp helps to monitor the extent of delignification during cooking process. Monitoring of residual lignin after cooking and between various stages of bleaching and pulp brightness is used to attain the required degree of bleaching. Measurement of lignin is carried by indirectly measuring the amount of oxidant consumed by the lignin present in a known mass of pulp sample; the term used is known as "kappa number and K-number".

3.6 PULP REFINING

Pulp refining is the mechanical treatment process of pulp fibers to optimize paper making properties. Increased surface area of the fibers results in denser sheet. The fibre bonding and strength is increased, but strength of individual fibers is decreased. The individual fiber strength provides tear strength to the paper. The factors governing the refining process are as follows:

a) Fiberbrushing
b) Fibercutting
c) Drainage
d) Fibrillation
e) Average fiber length

Variables Affecting Refining

Lignin is high in hemicelluloses and low in low yield pulps. In refining process, high temperature and high pH reduces the refining energy requirements.

Refining at high pH leads to increase, in the rate of hydration due to fiber swelling, improves ultimate strength of the paper, increases sheet bulk, produces a lower stock freeness, reduces equipment corrosion, and produces a softer sheet.

Refining at low pH leads to hardness of the fibers, denser sheets that is hard and snappy, and runs better on the paper machine. Some of other important variables are plate speed, plate clearance, and type of tackle.

The Table 2.5 shows the GHG emission from various process activities in a typical paper mill.

Table 3.2 GHG Emissions from Various Process Activities

Emission Source	**Types of Pulp & Paper Mills where emissions sources typically are located**	**Type of GHG Emissions**
Fossil Fuel / Biomass Fired Boilers	All types of Pulp and Paper Mills	Fossil CO_2, CH_4, N_2O; Biogenic CO_2, CH_4, N_2O
Direct Fired Dryers	Gas Fired Dryers at some Pulp & Paper Mills	Fossil CO_2, CH_4, N_2O
Combustion Turbines	All types of Pulp & Paper	Fossil CO_2, CH_4, N_2O

Emission Source	Types of Pulp & Paper Mills where emissions sources typically are located	Type of GHG Emissions
	Mills	
Chemical Recovery Furnaces – Kraft & Soda	Kraft & Soda Pulp Mills	Fossil CO_2, CH_4, N_2O; Biogenic CO_2, CH_4, N_2O
Chemical Recovery Furnaces – Sulfite	Sulfite Pulp Mils	Fossil CO_2, CH_4, N_2O; Biogenic CO_2, CH_4, N_2O
Chemical Recovery Combustion Units – Standalone Semi-Chemical	Standalone Semi-Chemical Pulp Mills	Fossil CO_2, CH_4, N_2O; Biogenic CO_2, CH_4, N_2O
Kraft & Soda Lime Kilns	Kraft & Soda Pulp Mills	Fossil CO_2, CH_4, N_2O; Process Biogenic CO_2
Makeup Chemicals ($CaCO_3$, Na_2CO_3)	Kraft & Soda Pulp Mills	Process CO_2
Flue Gas Desulphurization Systems	Mills that operate Coal Fired Boilers that required to limit SO_2 Emissions.	Process CO_2
Anaerobic Wastewater Treatment	Chemical Pulp Mills (Kraft mostly)	Biogenic CO_2, CH_4
Onsite Landfills	All types of Pulp & Paper Mills	Biogenic CO_2, CH_4

4.0 BEST PRACTICES

4.1 RAW MATERIAL HANDLING

Automatic Chip Handling and Thickness Screen

Uniform chipping size reduces the quantity of cooking chemicals required. Variations in chip thickness adversely impact product quality and yield. Pulp made from fines has lower yield and strength due to shorter fibre lengths. Screening of chip thickness is carried out to ensure pulp quality and consistency in thickness.

Wood chips lose 1percent of its usable fibre content every month in storage. Ideally, specific chips should not be stored more than one month. A key to efficient storage of chips is the adoption of FIFO inventory method for chip handling. Generally, bulldozers and pneumatic conveying system produce 3 to 4percent of dust and damage up to 3 percent of chips. Automatic Reclaimer system prevents this damage from occurring and it also reduces operating costs.

Automation of chip handling and thickness screening includes accurate metering of chips. Accurate and frequent data online enable control over pulping process. In the automation of chip handling, the chip size distribution system is used to optimize and control cooking. The measured data can be used to document the quality of chips purchased and for payment disbursal. It replaces the labour intensive chip sampling and laboratory test. The other benefits include,

Higher yield

By screening and controlling the chip thickness, reduced pulp reject losses improve pulp uniformity, and ensures higher yield from cooking.

Pulp quality

Any fluctuation on chip quality has negative effect on Kappa number. The proper screening techniques avoid fluctuations in chips quality.

Lower chemical consumption

Chips discolour with age. Adoption of First In, First out (FIFO) inventory control measure ensures timely use of chips, and prevents discoloration. Bleaching chemical consumption is also reduced.

Energy /GHG reductions

Chip thickness screening system helps recovery and recycle of usable fibres. For example, 3percent recovery of usable fibre in the screening system in a 2000 TPD mill saves approximately Rs. 370 Lakhs per year (assuming chip cost of 2000 per ton)

Belt Conveyor Instead Of Pneumatic Conveyor for Conveying Wood Chips

In many paper mills, part of material i.e. chips are transported using pneumatic conveying system which is not as energy efficient as mechanical conveying system Fully-enclosed pneumatic conveyor reduces possible loss of material while conveying. The pneumatic conveyor also consumes more power than the equivalent capacity of mechanical conveying system because of use of pressurized air. For the same conveying distance and same material transfer rate, the pneumatic conveying system requires almost 10 times the power of mechanical conveying system. Dust collection system of pneumatic conveying system is much larger than that of mechanical conveying system.

In contrast, the drive motor of a mechanical conveyor is directly connected to roller or sprocket through the gear/chain. The motor energy is directly transferred to conveyor, which is in direct contact with the material. The mechanical conveying system generates more dust as it not fully enclosed. More moving parts mean more maintenance. Also, such system runs in straight line and any change in direction require additional motor. Still, mechanical system is more energy efficient than pneumatic system.

Overall, the replacement of pneumatic system with mechanical conveying system will reduce power consumption. In a mill processing 1000 tonne of pulp per day capacity, replacing the pneumatic conveyor from the chip pile to screening with mechanical conveyor reduced energy consumption by 17.2 kWh/tones (NCASI report).

Energy /GHG Reductions

For a pneumatic system with blower capacity: 300 m^3/hr of chips and motor capacity:1000 HP and connected power: 18.2 kWh/T of pulp. Equivalent mechanical conveyor motor size would be about 50 HP and about 1 kWh/T pulp. Thus, replacement of the pneumatic conveyor would save about 17.2 kWh/T of pulp.

For calculation of GHG emissions from grid electricity consumption, the following formula can be used:

GHG emission in t_{CO2} = Electricity consumption (MWh) X GHG emission factor (tCO_2/MWh)
= 0.0172 MWh X 0.93 tCO_2/MWh (as per CEA data base)
= 0.015996 tCO_2.

Considering 1000 tonnes/day mill capacity,
= 1000 (Tonnes/day) X 365 (days/year) X0.0172 (MWh/tonnes)

Electricity saving = 6278 MWh/yr

GHG emissions reduction = 6278(MWh/yr) X0.93 (tCO2/MWh
= 5838.54 tCO_2/yr

Auto Slip Power Recovery Systems (ASPR) for Chipper Motor

As high starting torque requirements in many applications in paper mill cannot be achieved by squirrel cage motor, slip motor is being used to start and operate large machines. Slip ring motor handles high starting torque with relatively low starting current making operations safe.

The chipping equipment uses slip-ring motor as it handles large quantity of raw materials for chipping. The chipper motor may require change in speed based on load and the speed control of motor is achieved by varying the rotor resistance, which leads to heat and power loss.

If the drive application calls for variable speed, Auto slip power recovery system (ASPR) can be adopted. ASPR is an external system connected to the rotor circuit providing excellent torque and speed control. It recovers power from the rotor and feed it back to the power system, avoiding any wastage of energy. The benefits of ASPR are:

- Lower operating costs by reducing the energy cost
- Reduced vibrations, in turn enhancing lifetime of equipment
- Good process control

Energy / GHG Reductions

For a 1000 kW fan, the energy saving with ASPR would be about 200 kW or 4800 kWh per day, equivalent to a saving of Rs. 20,000 @ Rs. 4.20 per unit (one kWh) of energy.

GHG emissions reduction with this measure is determined as follows:

GHG emission in t_{CO2} = Electricity consumption (MWh) X GHG emission factor (tCO_2/MWh)
=0.200 MWh X 0.93 tCO_2/MWh (As per CEA data base)
= 0.186 tCO_2

Considering 24 hrs of operation in a year
= 365 (days/year) X4.8 (MWh/day)

Total electricity saving = 1752 MWh/yr

GHG emissions reduction = 1752 (MWh/yr) X0.93 (tCO2/MWh

= 1629.36 tCO_2/yr

4.2 COOKING, DIGESTER, PULPING AND BLEACHING

Installation of Extended De-Lignifications System for Cooking Wood

The removal of lignin is normally carried out with high alkali charge in cooking process which can affect pulp yield. By adding oxygen, and maintaining temperature, pressure and alkali charges, lignin removal is higher and pulp quality is improved.

The content of lignin in pulp is represented by *kappa number* in pulp mills. This kappa number is normally reduced in modern mills by including de-lignification system before bleaching system. Incorporation of de-lignification system reduces the lignin without affecting the yield.

Figure 4.1 Oxygen De-lignification **Tower**

With the latest technology, the kappa number can be further decreased with introduction of extended de-lignification system. These results in higher degree of de-lignification compared to conventional system. In addition to the pulp quality, this technology significantly reduces the chemical consumption in bleaching system. It can produce pulp with 30 to 50 % lesser chemicals than the conventional Kraft cooking methods without significant yield loss. The reduction in kappa number will result in considerable savings in chlorine dioxide, soda and chlorine and consequently effluent load is also reduced.

The adaption of this technology lowers the delignification degree to the extent of 40% to 60% with no adverse impact on pulp quality. The extended de-lignification reduces the cooking liquor by about 5–10 %.

Energy /GHG Reductions

Steam consumption before delignification = 1.42 tons/ton of pulp
Steam consumption after delignification = 0.7 tons/ton of pulp
Difference in steam consumption = 0.72 tons/ ton of pulp
For a plant of 200 TPD capacity, LP steam consumption difference = 144 TPD

Typically the HP steam generates 220 kWh/ton in fully condensing mode and LP steam generates only 110 kWh/ton. Accordingly, for the same power to be generated from turbine, reducing one ton of LP steam would reduce one ton of HP steam at inlet to turbine in turn reducing the power generation. So in order to maintain the same power output from turbine 0.5 ton of HP steam needs to be fully condensed without LP steam extraction.

Thus, saving 1 ton of LP steam would result in saving 0.5 ton reduction of HP steam. Assuming HP steam reduction as 50% of LP steam consumption reduction in a cogeneration system, the HP steam consumption will be 72 TPD. So if HP steam conditions are 44 bar, 400^oC and boiler efficiency as 80%, the savings in fuel would be 2520 MTOE. Table 4.1 shows comparison of Conventional Cooking vs Delignification:

Table 4.1 Comparison of Conventional Cooking and Delignification

Operating Parameter	Conventional Cooking	Extended Delignification
Steam consumption (tons/ton of pulp)	1.42	0.7
Average batch time (hrs)	6	4
Kappa number	21 – 22	12 – 13
Yield (%)	45.3	46
Washing loss (kg/ton of pulp as sodium sulphate)	16	10
Black liquor concentration (%)	14.2	16
Ash retention (%)	7	10
Paper breakage (%)	3.3	1.5

Considering the fuel savings of 2520 MTOE,
One ton of oil equivalent= 10 x 10^6kcal = 11630kWh
For 2520 MTOE of fuel=11630 x 2520 = 29,307,600 kWh.

Assuming the electricity generated from fossil fuel based generation system,
GHG emission in t_{CO2} = Electricity consumption (MWh) x GHG emission factor (tCO_2/MWh)
= 29,307.6 MWh X 0.93 tCO_2/MWh (As per CEA data base)
= 27256.068 tCO_2.

Elemental Chlorine Free (ECF) Bleaching System

The lignin content in the raw material is responsible brown color in the pulp. During pulping, the lignin content is reduced to 5%. For producing high quality paper, lignin content should be reduced to 1%.

During bleaching, elemental chlorine removes the remaining lignin in the pulp and brightens pulp from brown to white to a desired brightness level. The chlorine and hypochlorite (hypo) used in bleaching system react with lignin and forms pollutants such as chloroform, dioxins and furans in the effluent stream.

Elemental Chlorine Free (ECF) bleaching which uses chlorine dioxide instead of elemental chlorine as the bleaching agent reduces chlorinated pollutants in wastewater stream. This technology prevents pollution as well as conserves resource without affecting production quality.

Recovery of Chemicals from Spent Liquor Obtained from Counter Current Washing of Unbleached Pulp in a Medium Size Paper Mill

Chemical recovery is the process in which chemicals used in pulping section is recovered for reuse in pulping process. Pulp washing is required before bleaching to recover pulping chemicals. Conventional washers use more water for washing unbleached pulp.

Steam cycle washer has being recently adopted in most of the pulp mills to wash unbleached pulp. The principle uses counter current washing to wash unbleached pulp which is energy-efficient. This technology also uses 75% less water than conventional washers, as it allows the pulp mat to be washed at a high consistency of 28–32 %.

Installation of Down Flow Lo-Solids Cooking System

In pulping process, the cooking involves chips preheating, impregnation, and digestion. During cooking, the fibres are separated by dissolving lignin using white liquor. During impregnation, chemical are added which are absorbed by the chips. Subsequently, these chips are heated to reaction temperature in digester along with pulping chemicals which is a mix of sodium hydroxide and sodium sulfide.

Traditionally, batch digester is used for cooking wood chips to separate and dissolve the lignin from the cellulosic raw material and considerable quantity of steam and electricity is consumed. The yield which comes out of digester will be brown in color and it will be sent to bleaching process for further removal of lignin and lighten the pulp.

The conventional batch type digester system is being replaced with continuous type, down flow Lo–Solids cooking system. During the process, the chips are passed through the top separator sheet to impregnation zone and steam is added to top of the digester to heat chips to 120 ^{0}C before impregnation. The top section of the digester has enough retention time to ensure good impregnation with liquor before cooking process of wood chips. In the cooking zone, the chips are heated up to 150^{0}C. The next zone of the digester is the co-current cooking zone after which the rest of the liquor is extracted from the digester at all the low extraction screens. Washing in the digester is done by passing the white liquor in the counter current direction through the pulp in the digester bottom wash zone. Pulp from the digester is blown to the blow tank. The benefits include,

- Up to 60% saving in steam consumption per ton of pulp production
- Uniform pulp quality and properties.
- Improved digester yield.
- Reduced bleaching chemicals
- Saving in steam

Energy /GHG Reductions

Baseline	
Representative production (unbleached pulp) for the day	314
Representative steam consumption for the day	465
Benchmarking of process specific steam consumption ratio, T/T	1.48
Emission Reduction	
Representative production (unbleached pulp) for the day in project scenario	537
Representative steam consumption for the day in project scenario	295
Specific steam consumption ratio for the project activity, T/T	0.55
Difference in SSCR of baseline and project scenarios, T/T	0.93
Actual value of output on the day, T	537
Net reduction in steam consumption per day (kg/day) or additional steam required per day	499148
Total enthalpy of steam at the boiler outlet, kCal/kg	782.4
Heat content of feed water, kCal/kg	105
Net enthalpy of steam being supplied in boiler, kCal/kg	677.4
Net reduction in steam energy consumption per day, kCal/day	338097836
Efficiency of the boiler, %	80
Daily reduction in input energy to the boiler, kcal/day	422622295
Daily reduction in input energy to the boiler, TJ/day	1.767
Carbon emission factor for fuel – 1 (Coal), TC/TJ	26.2
Carbon emission factor for fuel – 2 (Black Liquor)	0

% usage of coal per day	63
% usage of black liquor per day	37
CO_2 emission reductions in the boiler per annum	35282

Oxygen-Delignification in Cooking Process

In cooking pulp, the removal of lignin is carried out with alkali charge with subsequent effect on pulp quality and further removal of lignin is done in bleaching system, which brightens the colour of pulp for high quality paper product. Initially, the sodium hypochlorite is used for bleaching chemical pulps and later, the same was replaced with chlorine. However, due to the environmental concerns, the chlorine bleaching is replaced with Elemental chlorine free (ECF) and Totally Chlorine Free (TCF) bleaching process.

By adding Oxygen De-lignification system in between cooking and bleaching system, chlorine consumption in bleaching system is reduced and use of technology such as Elemental Chlorine Free (ECF) and Total Chlorine Free (TCF) pulp production is enabled.

Oxygen De-lignification also improves yield in bleaching system. The oxygen de-lignifications reduce the absorbable organic halogens (AOX), bio-chemical oxygen demand (BOD), chemical oxygen demand (COD) and colour in the effluent. The different types of oxygen de-lignification are,

- High consistency oxygen de-lignification(HCOD)
- Medium consistency oxygen de-lignification(MCOD)
  a) Double stage
  b) Single stage
  c) Mini stage

Depending on the type of mill, operating and installation cost, appropriate delignification system is chosen for the pulp mill. Single stage MCOD, is the most common technology adopted in the industry. The benefits include,

- Reduction of bleaching chemicals
- Reduction of AOX production
- Lesser COD/BOD content in effluent
- Reduced operating cost
- Lesser Environmental Impact
- Good Yield compared to extended cooking

Optimizing the Dilution Factor in Brown Washing

The pulp is pumped to washers after cooking. In washers, pulp is washed with fresh and back water in different stages. Generally, washing takes from 4 to 6 hours. Brownstock washers are used to recover the pulping chemicals from pulp end product. During washing some carryover takes place, which results in excess bleaching chemicals in bleaching system and organic materials in the effluent. Brownstock washing efficiency is generally measured by COD carryover into the bleaching system. The cost of bleaching chemicals per tonne of pulp varies with dilution.

Optimizing the dilution factor will help recover the organic solids and spent cooking chemicals from the pulp and avoids the dilution of black liquor. It also reduces the organic load in the effluent system. Optimizing the dilution factor lowers the average amount of water evaporated from black liquor, thereby reducing steam consumption in evaporator section. Increasing dilution factor decreases the black liquor solid losses as these solids are recovered and used as fuel in recovery boiler to generate steam. Utilizing black liquor solids in recovery boiler reduces fossil fuel consumption and hence GHG emissions.

The brown stock washing efficiency has significant impact on chemical cost, evaporation load, and organic load on effluent treatment system. It reduces bleach plant chemical consumption and load in the chemical recovery area.

Pressure Screens Instead of Centrifugal Screens in Pulping Section

Pulp product from cooking should be cleaned properly as it will be processed subsequently through many machines. The pulp should not contain any visible contamination and has to be cleaned adequately by cleaners and screens before sending it to process machines. Some machines like press, paper machines can be damaged by contaminants in the pulp. The main objective of screening is to remove the acceptable fiber (accepts), fiber clumps, knots, and other non fibrous material (rejects).

Two types of screens presently used in screening pulp product are i) Pressure screen ii) Centrifugal screen. Pressure screen uses pressure to force stock through the screen and most of screens use a blade to scrap clogs from screen. In centrifugal screening, material is fed into inlet feed and redirected to cylindrical sifting chamber by means of feed screw. Rotating chamber continuously propels the material against screen and resultant centrifugal force on the particles accelerates them through the aperture.

Centrifugal screen has hole diameter of 2mm, whereas pressure screen has hole diameter of 0.3mm. The quality of screened pulp with pressure screen is better and also less electricity is consumed.

Energy/GHG Reduction

GHG emission in tCO2 = Electricity consumption (MWh) X GHG emission factor (tCO_2/MWh)

= 0.016(MWh) X 0.93 tCO_2/MWh (As per CEA data base)

= 0.01488tCO_2

Heat Recovery from Bleach Plant Effluent

In bleaching section of pulp mills, considerable hot water is discharged as effluent. This heat can be recovered to generate warm water for paper machines using a heat exchanger.

Energy /GHG Reduction

Energy savings potential is 939,000 GJ/year

Preheat Chlorine Dioxide Before It Enters the Mixer

Chlorine dioxide (ClO_2) is used in bleaching section for bleaching pulp product. Generally, it is chilled to maximize its concentration, before it enters the mixer. As an energy conservation measure, chlorine is preheated using secondary heat such as alkaline stage effluent before entering the mixer to reduce steam consumption in bleach plant.

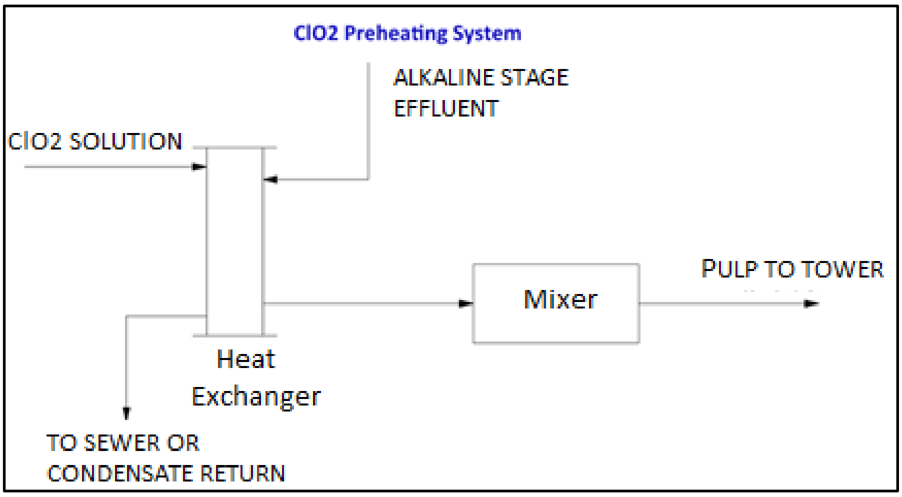


Figure 4.2 CLO_2 Preheating System

Energy/GHG Reduction

In one study, for a mill producing 1000 ADT of bleached pulp, where kappa value to bleaching is 30, and ClO_2 concentration of 9.5 g/l. By heatingClO_2 from 2.8 to 43.3°C using secondary heat, 0.59 GJ/ADT of energy was reduced and net CO_2 reduction is 12,625 t-CO_2/year.

Use of Flash Steam from Batch Digester Blow or Black Liquor Flash (For Use in Evaporator or Chip Pre-Steaming)

During cooking process, flash steam is produced when pulp and cooking chemicals are brought from higher pressure to atmosphere at the end of the cycle. In batch digester, the produced steam is stored as hot water in an accumulator, whereas in continuous digester, extracted black liquor is allowed to flow into tank and steam is flashed. The flash steam can be recovered and used in other applications such as chip pre-steaming, water heating and evaporative section (black liquor evaporation).

In continuous digester, black liquor is flashed in different stages. This flash steam can be used for thermal energy in multi stage evaporator and can offset steam generation in recovery boiler.

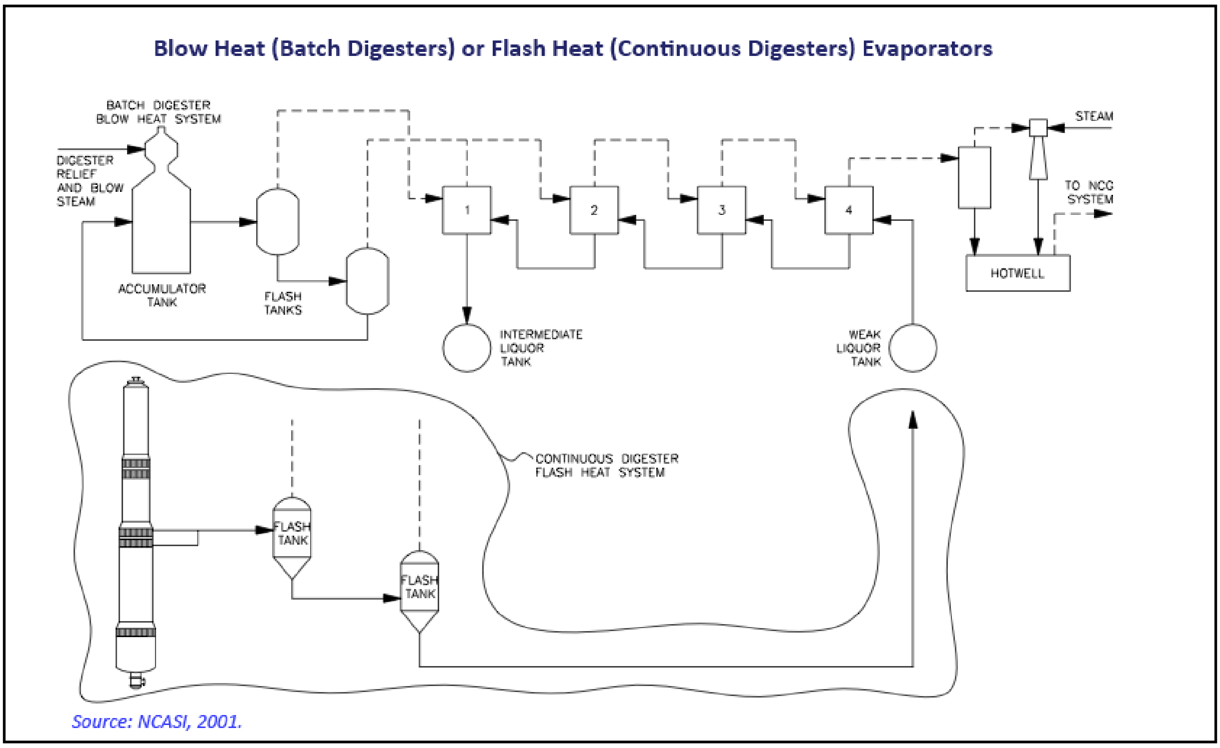


Figure 4.3 Blow Heat or Flash Heat Evaporator

Energy/GHG Reduction

In one study, for a plant producing more than 650 000 tons of paper, improved heat recovery reduced 991,700 GJ of fuel and 743,775 GJ of steam, annually.

4.3 RECOVERY PLANT

Seven Effects Free Flow Falling Film Evaporator Instead Of Conventional Triple-Effect Evaporator to Improve Steam Economy

The concentration of black liquor consumes more steam than any other process. Black liquor, generated during the pulping process has dissolved lignin, cooking chemicals and large quantities of process water. The black liquor is concentrated in evaporation process and raised to 45–65% in solids concentration, and combusted in boiler to generate the steam. In conventional evaporation system, the five effect rising film evaporator is used to concentrate the black liquor in the evaporation process. This process uses the considerable amount of steam during the evaporation process. Black liquor with 45% concentration in solids will generate steam of 3.0 ton/tons of black liquor. With higher concentration —65 % and 85% of black liquor, steam generation will be in the range 3.4–3.8 tons /tons of black liquor respectively.

The conventional rising film evaporator can be replaced with seven effects, free flow falling evaporator (FFE). Steam consumption will be reduced due to increased processed stages and improved heat transfer co-efficient.

In falling film evaporators, the liquor is introduced from the top of the tubes and flows down by gravity as thin film. Due to the gravity, the flow is fast and thin film is formed during the process thus improving the heat transfer coefficient and specific steam consumption. Fossil fuels used for steam generation is also reduced. The concentrated black liquor used for steam consumption leads to further reduction of fossil fuel consumption.

This technology optimizes steam consumption and it uses more effects for the efficient concentration of solids in liquor. In multiple effects, the steam of first effect is reused in the subsequent effects in which boiling takes place at a lower temperature and pressure. This improves heat availability and maximizes evaporation. The installation of seven effect, free flow falling evaporator in ITC, lead to the following benefits,

- Reduction in specific consumption to 50% annually.
- Reduction in coal consumption
- Reduction in GHG emissions

Energy /GHG Reduction

Total estimated reduction in 10 years of crediting period is 522471 T CO_{2e}

Annual average over the crediting period of estimated reduction is 52247 T CO_{2e}

Installation of Black Liquor Gasification

Black liquor is the by-product of pulping process containing lignin fragments, cooking chemicals and other inorganic salts. Black liquor, accounting for majority of fuel used in Kraft mills, is combusted in recovery boiler to produce thermal and electrical energy. Recovered chemicals are formed as smelt and collected in bed at the bottom of furnace. It is dissolved in weak wash water in smelt dissolving tank (SDT) to form a solution of carbonate salts called green liquor. The efficiency of recovery boiler is only 65 to 70%.

Alternatively black liquor can be gasified to produce synthesis gas. The gas is cleaned for power generation. Also, pulping chemicals are recovered during gas cleaning.

Energy /GHG Reduction

Theoretical balance calculations show that a black-liquor-based integrated gasification with combined cycle (IGCC) technology can achieve a power efficiency of about 30 % compared with 12-13 % for conventional recovery boiler. Thus, IGCC can increase power production by about 900 kWh/ADT, while at the same time reducing heat production by 4 GJ/ADT, which is more than a typical surplus in a Kraft mill. Fuel savings of 1.6 GJ/t pulp is estimated for a complete gasification and combined cycle. It is also expected that black liquor gasification will reduce emissions of SOx, NOx,CO, volatile organic compounds, particulate matter, CH4, etc.

4.4 PAPER MACHINE

Replacement of Suction Couch Roll by Solid Couch Roll in the Paper Machine

Suction couch roll is used in paper machine, which requires vacuum system to maintain suction in paper machine to maintain dryness between 0.7 to 1.5%.

With installation of solid couch roll in place of suction couch roll, dryness is improved without use of vacuum system in paper machine. The vacuum pump can thus be removed.

Energy/GHG Reduction

About 225 kW of electrical power can be reduced by replacing suction couch by solid couch and by avoiding operation of holding zone vacuum pump. The annual monetary savings is estimated to be Rs. 81 Lakhs without substantial investment.

Use of Bamboo Dust along with Coal Firing in the Coal Fired Boilers

In most of the pulp mills, bamboo and other hard woods are used as raw material for manufacturing paper product. During pulping of these materials, considerable waste is generated. A bamboo based paper mill with capacity of 300 MTPD generates around 25 to 30 MTPD of dust. The bamboo dust is normally sold to nearby areas for domestic use or it is transported and dumped in open places or openly burned. The calorific value of briquette made from bamboo waste is 4160kcal/kg and can be potentially tapped as a source of energy. The bamboo dust can be used along with coal in coal-fired boiler for the thermal and power generation.

Installation of Variable Frequency Drives on Motors with Varying Loads

In industry, higher capacity motors than required are used to run rotary equipments such as pumps, compressors and agitators leading to higher power consumption. Selecting appropriate and right capacity motor during design and commissioning will reduce electrical energy. During operational stage, such excess capacities can be corrected by fitting variable frequency drive (VFD).

The variable frequency drives alter the speed of the motor to meet the load requirements. They can be used to replace throttling operation in pumps and inlet/outlet van damper on fans. This technology is applicable for rotating equipments such as agitators, pumps, fans and blower for variable speed.

Installation of Multiport Dryers to Reduce Steam Consumption in Paper Machines

The purpose of drying is to remove the moisture in pulp before making final end product. Drying section has many cylindrical, rotating steam drum dryers. The pulp passing over the heated drums releases moisture and gets dried. The dryer section is the largest thermal energy consumer in paper machine section. The various factors influencing drying are:

- Steam pressure and temperature
- Temperature and humidity of air
- Energy content of steam
- Heat and mass transfer co-efficient

Installation of multi port steam dryer is an efficient method for drying the pulp compared to conventional steam dryer. High heat transfer as well as uniform temperature distribution along the cylinder walls increases the rate of drying compared with conventional drying machine. The increased drying efficiency can lead to reduction in number of dryers in the section or increased production with the same number of dryers. This can be easily retrofitted to existing dryers.

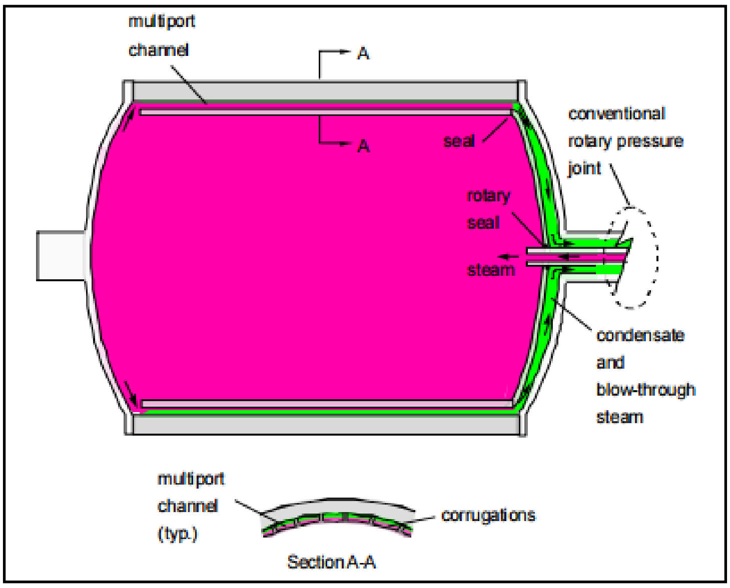


Figure 4.4 Multiport Dryer

Installation of Low Intensity Refiners for Wood Fibres

Refining uses mechanical force to pulp fibers and alter their cell structure. Refining influences the quality of final product in paper mill. By optimizing refining process, high quality products can be produced using less expensive fiber with reduced chemical and energy use.

The refining mechanism based on Specific Edge Load (SEL) is widely used to characterize low consistency refiners. Specific energy is calculated based on the net applied power (motor load minus no-load power) divided by the throughput. This variable is typically controlled via a power or specific energy set point, which in turn controls the plate gap and the total power applied to the fiber. By adopting low intensity refiners, quality and energy efficiency will be improved. The benefits include,

- Improved tensile strength and porosity
- Increased bulk at smoothness or drainage
- Improved pick resistance of hardwood vessel segments
- Reduced energy requirements

Energy /GHG Reduction

A typical mill had three 38" (965 mm) hardwood refiners operating in parallel. Cast plates with a bar-groove-depth of 2.4, 2.4, 6.4 mm were being used to refine the hardwood furnish. This was one of the finest available 38" cast patterns, with a bar edge length of approx. 88 km/rev.

The mill conducted a trial using a set of 38" 1.6, 2.0, 8.7 mm fabricated plates (FB) with a bar edge length of 132 km/rev. With 50% more edge length than the cast pattern, the operating intensity range was reduced from 0.8-1.0 Ws/m to 0.5-0.6 Ws/m. The trial objective was to compare pulp quality and plate life in a side-by-side plate comparison. Pulp quality results are shown in Figures 1 – 4 and summarized below.

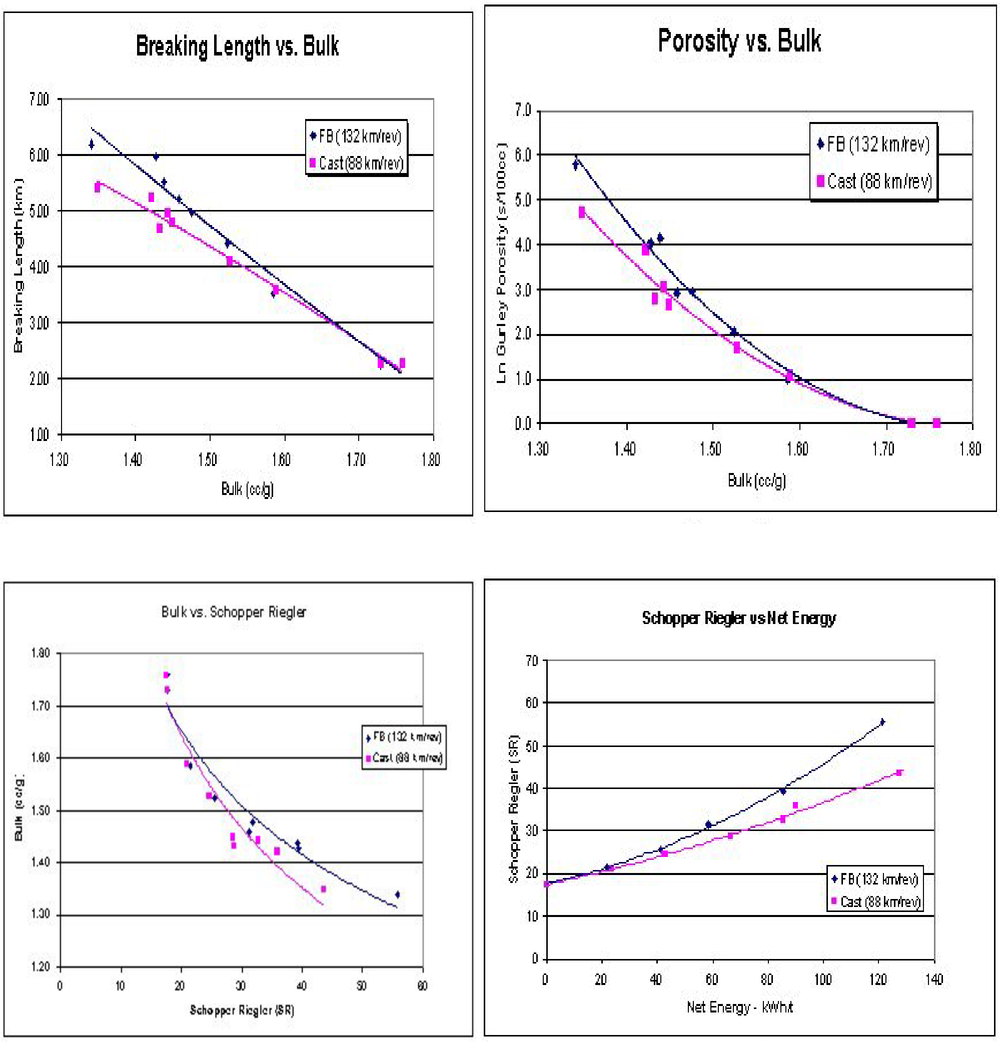


Figure 4.5 Pulp Quality Results

Compared to the mill's target freeness of 300 CSF (40 SR), the lower intensity plates resulted in 2% more bulk, a 5% increase in tear strength and a 9% greater tensile strength.

In addition to gains in pulp properties, the mill realized a 13% reduction in applied energy and found that their plate life had doubled with lower intensity refining. All of these factors contributed to improved operations and cost savings for the mill.

Installation of Shoe Press in Paper Machine

In paper machine, the paper is dewatered and dryness is improved. Higher the dryness in the press section, lesser the energy requirement in dry section of paper mill. In addition to dewatering the paper, press also has the higher influence on paper quality. It impacts thickness, volume and surface characteristics of paper product. Conventional paper machine has roll presses in press section.

In recent years, shoe presses are being used in paper machine. Shoe press has many advantages over conventional roll press such as energy efficiency, higher de-watering efficiency and improved paper quality.

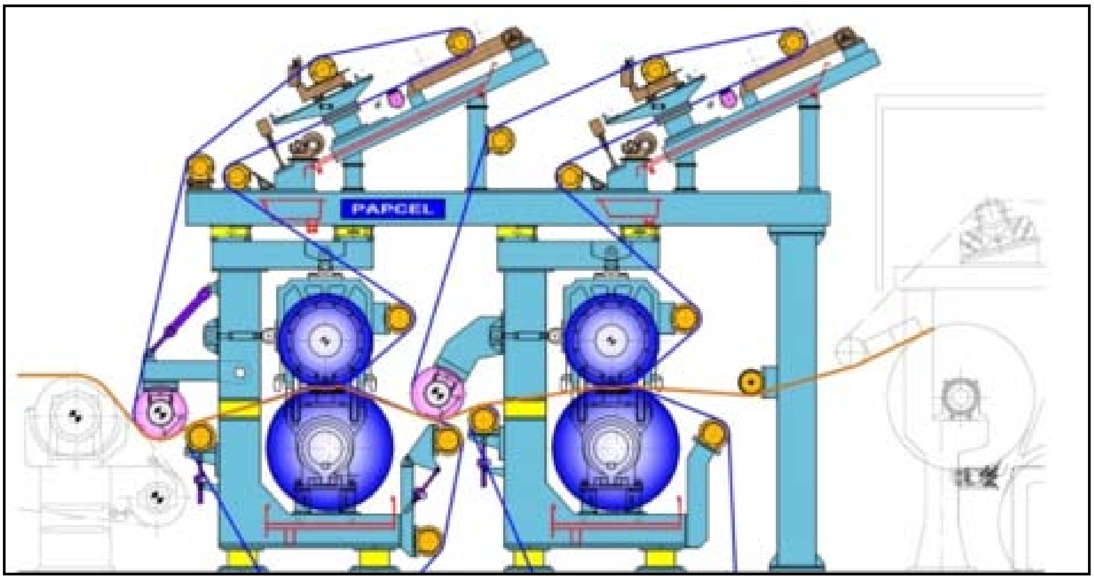


Figure 4.6 Shoe Press

4.5 OTHER GOOD PRACTICES

Chipping, Pulping and Soda Recovery

- Avoid idle running of chippers, conveyors, etc. by installing simple interlocks.
- Ensure optimum loading of chippers
- Avoid fresh water for pulpers and beaters and use back water
- Interlock agitators with pumps at storage chests
- Providing timer control for agitators for sequential operation

- Optimize fresh water consumption in pulp mill washers e.g., alkali washer back water in chlorine washer and chlorine washer back water in brown stock washed pulp.
- Install belt conveyor for conveying wood chips instead of pneumatic conveyors.
- Install VSD for cutters and chippers
- Install two stage preheating in digesters (combination of MP steam and LP steam)
- Install water ring vacuum pumps instead of steam ejectors in evaporators, depending on the cost of steam.
- Install high capacity chippers with mechanized feeding
- Install oxygen delignification
- Installation of TDR's in place of beaters
- Install medium consistency pumping
- Replace brown stock washing with double wire press system
- Install high efficiency washing system such as, Flat belt/wire washer, Double wire press, Twin roll press
- Install VSD for primary, secondary and tertiary centri-cleaners, pumps of unbleached and bleached pulp.
- Install pressure screens in pulp mill and avoid centri-cleaners
- Install 7-effect evaporator instead of conventional triple-effect evaporator
- Installation of falling film evaporator
- Install 2-stage steam heating in black liquor pre-heater
- Install soda recovery plant in medium sized paper plants
- Install causticiser and rotary lime kiln
- Increase in TAA to get higher solids concentration in black liquor
- Installation of plate heat exchanger in evaporator section
- Optimizing of hydraulic system operation in calendar
- Installation of two stage steam heating in black liquor pre-heating
- Energy Savings by stopping broke deflaker when broke refines is in operation
- Improved brown stock washing (conventional brown stock washing with pressure diffusion or wash press.
- Installation of Blind Drilled Rolls (Dri-Press Rolls) Instead of Conventional Press Rolls in Press Section of Paper Machine

Stock Preparation and Paper Machine

- Optimize loading of refiners and beaters
- Interlock agitators with pumps at storage chests
- Minimise recirculation in receiving chest and machine chest
- Optimizing excess capacity/ head in pump by change of impeller or trimming of impeller size
- Avoiding pump operation by utilization of gravity head

- Optimise capacity of vacuum pumps by RPM reduction
- Install level indicating controllers for couch pit pumps
- Optimising pressure of high pressure pump used for wire cleaning and deck showers
- Stopping broke deflaker when broke refiner is in operation
- Install new correct size high efficiency pumps
- Install new high efficiency fans & blowers in boiler
- VSD for displacement pump, discharge pump, hot fill pump and warm fill pump of washing and screening plant
- Replace eddy current drive with VFD for washing and bleaching
- Install suspension type agitators to keep the pulp in suspension during pumping
- Optimizing the capacity of vacuum pumps by RPM reduction or bleed-in control
- Optimize the suction line size of water ring vacuum pumps
- Install pre-separators for water ring vacuum pumps
- Install mixing type agitators to mix different types of pulp
- Introduce double dilution system
- Install double disc refiners instead of conical refiners
- Install VSD for paper machine fan pumps
- Install VSD for tanks dilution pumps
- Install VSD for mould fan pumps
- Install VSD for flat box vacuum pump to avoid bleeding or throttling
- Avoid interconnection of high and low vacuum sections
- Optimize suction pipe line size for water ring vacuum pumps
- Install pre-separators and extraction pumps for water ring vacuum pumps
- Install dual speed motors for couch pit agitator and press pit agitator
- Install VSD for MG machine/MF machine hood fans
- Replace steam ejector with water ring vacuum pump in evaporator section
- Install cascade condensate system in paper machine area
- Install flash steam recovery system for paper machines
- Reel pulper operation optimized by effective utilization of winder pulper
- Optimizing operation of hydraulic system of calendar
- Automatic operation of hood and ventilation system
- Replace conical refiners with double disc refiners
- Install conical port high efficiency vacuum pumps in place of flat port vacuum pumps
- Replace centrifugal screens with pressure screen
- Segregate high-vacuum & low-vacuum sections of the paper machine and connect to dedicated systems
- Segregation of high-head and low head users in cooling towers and process areas
- Install tri-nip press section in paper machine to reduce drying load
- Install computerized automatic moisture control system for paper machines

- Install paper machine hood heat recovery system
- Convert small steam turbines in paper machine area to DC or AC drive so as to enhance cogeneration.

5. CASE STUDIES

Selected case studies related good practices for reducing GHG emissions as observed in various paper mills are presented in this chapter.

5.1 ENHANCING POWER GENERATION IN HIGH PRESSURE COGENERATION BATTERY

Captive Cogeneration Plant

Although most paper mills in India have adopted boilers with steam pressure of 64 bar, Seshasayee Paper & Boards Limited (SPB) as early as in 2005, had installed the state of the art high pressure boiler with steaming conditions of 105 bar and 510°C. This selection was primarily aimed at achieving low specific steam consumption through integrated double extraction condensing steam turbine.

The cogeneration battery comprises two cogeneration stations – CPP & HP Chemical Recovery Cogeneration. The CPP is basically coal–fired FBC boiler generating very high pressure steam with associated double extraction condensing steam turbine. The HP chemical recovery cogeneration is Chemical Recovery Boiler (CRB) generating high pressure steam with associated extraction back pressure steam turbine. This is shown in Figure 5.1.

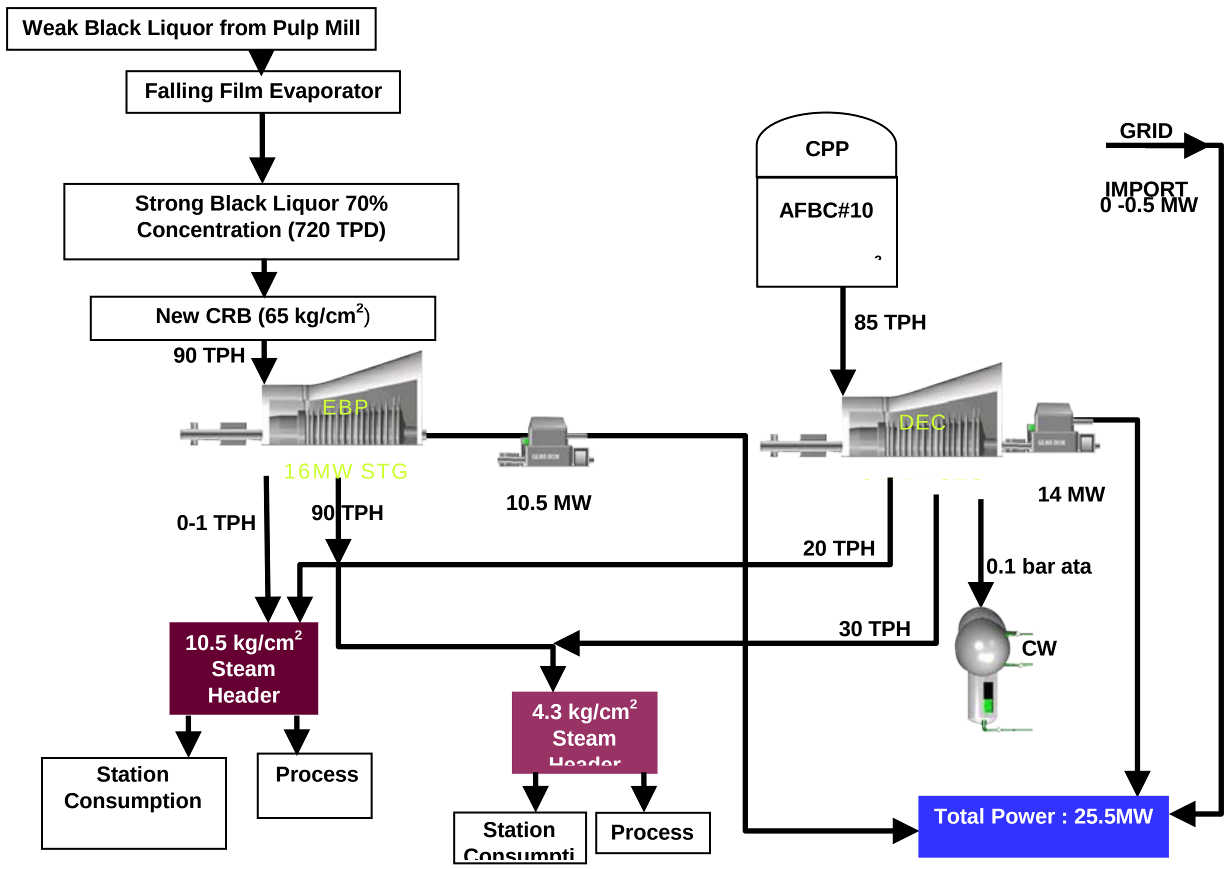


Figure 5.1 High Pressure Co-gen Battery Schematic

Green Power Enhancement through MP to LP Steam Switch in 16 MW STG – Cogeneration Unit

The power is termed Green, because of use of black liquor solids (biomass) as fuel in Recovery Boiler. In order to enhance power generation, flow rate of extraction of MP steam (10.5 kg/cm^{2}g) is minimized thereby maximizing LP exhaust steam.

With reduction in E1 steam extraction flows (as related to design flow), the temperature at turbine nozzle increases relating to lower electrical power conversion and higher de-superheating. The reduction in the back pressure steam drawn had to be offset with increased extraction of same quantity from the coal- fired cogeneration system.

The project was implemented in 2 phases. Extraction steam was reduced from 18 TPH to 7-8 TPH in the first phase. The increased power gain was further augmented in the second phase through minimal steam extraction (< 1 TPH) and maximizing exhaust steam drawn from STG. The power net output had increased by ~0.9 MW. This included a small gain of ~ 0.1 MW due to lowered exhaust steam temperature at turbine nozzle. However, there would be drop in 21 MW STG Power output. No investment was required for implementing the scheme. This innovative scheme can be implemented by all paper mills having cogeneration battery (fossil & non-fossil units inclusive).

Additional Power of 0.9 MW is generated through the successful implementation of the scheme. The overall net gain is 0.2 MW for the entire cogen-battery. REC gain is about 600 units/month. In terms of PAT, SEC reduction is 1000 TPA of coal equivalent.

Advanced Re-insulation State of the Art Scheme of High Pressure Boiler Main Steam Pipeline

Boiler system is inclusive of main steam pipe-line from high pressure boiler outlet to steam turbine inlet. Existing insulation mattress was removed from the main steam pipeline and advanced insulation redesign of the hot steam pipe-section of high thickness (210mm) and high density (150kg/m^3) had ensured ~ 5 °C drop (as against the original figure of 10 to 12°C) from boiler steam outlet to turbine inlet.

Energy gain of 3 kcal/kg due to reduction in radiation and convection heat losses from steam pipeline had been achieved resulting in additional power generation of 0.3 MW. The gains in terms of REC credit is about 200 units/month. SEC reduction related to PAT scheme is 1500 TPA coal equivalent.

Power Conversion in 21 MW DEC Steam Turbo-Generators

In cogeneration plants, steam and power for process use are made available from a single source. Power generation in steam turbine is primarily a function of the steam enthalpy entering and leaving the turbine nozzles. The goal is to keep the inlet steam enthalpy at maximum value and lowering the enthalpy of steam leaving the turbine nozzles. Based on this concept, a scheme had been developed for attaining maximum power at all points of time.

Double Extraction Condensing Steam turbine

In any captive power plant, the focus is on maintaining good exhaust (condenser) vacuum. However, based on study of heat and balance diagram, it was found that exhaust steam wetness has more influence over specific steam consumption than condenser vacuum.

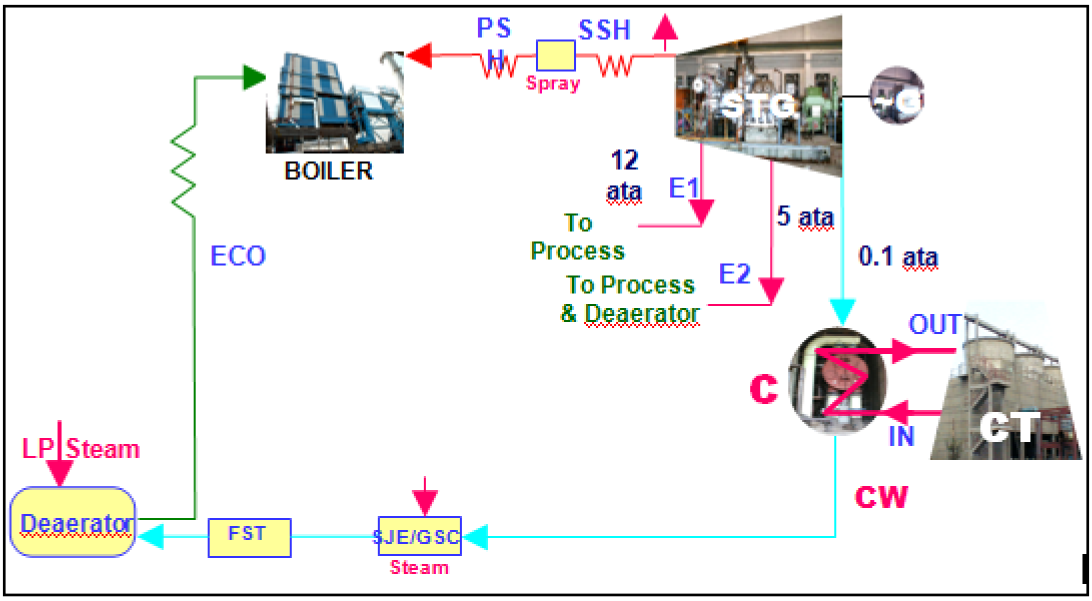


Figure 5.2 CPP Unit Process Flow-sheet

To maximize the differential steam enthalpies between steam at turbine inlet & outlet steam, either the inlet HP steam entry conditions (i.e., enthalpy) should be kept at the highest possible figure or the exhaust steam enthalpy figure should be aimed at lowest practicable steaming conditions (enthalpy). As the inlet steam enthalpy is related to HP steam pressure and temperature (latter having more impact), the aim was to achieve low exhaust steam enthalpy practicable at all points of time.

Maximizing Steam Turbine Cycle Efficiency through Exhaust Steam Vacuum – Dryness Fraction Integration in 21 Mw Extraction Condensing Steam Turbo-Generator

Exhaust steam leaving the double extraction condensing turbine is at high vacuum and the waste low grade steam is condensed on the shell side with cooling water flowing through the tubes in 2–pass arrangement. The warm cooling water is sent to the cooling tower and the cooled water is returned to the condenser to continue the cooling cycle..

The cooling water flow rate was increased by about 25 % (through release of cooling water flow valve throttling) allowing lower cooling water temperature differential across the condenser as well as enhanced condenser heat exchange due to increased velocity. The condenser vacuum also improved marginally.

In–Depth Analysis of Condensing loads on Operational Factors

The 21 MW Double Extraction cum Condensing (DEC) steam turbine is designed by BHEL for economic continuous rating with exhaust condensing steam flow at 37 TPH.

Maximum allowing condensing load is 50 TPH. Three phases of operation of STG are considered:

- High [50 TPH] &design loads/ECR [37 TPH]
- Medium load [22 to 34 TPH]
- Low load [10 to 22 TPH]

Generally in condensing steam turbines, all the designed units are with wet steam at steam turbine exhaust to the condenser. The dryness fraction of exhaust steam leaving the steam turbine can be as low as 88 to 89 % and as high as 96 to 100%

Since electrical power generation is directly proportional to enthalpy differential between inlet steam at turbine and exhaust steam leaving the turbine, the water /condensate component contribute to electrical power besides the major power generation through the steam component.

Cycle Efficiency

Turbine cycle efficiency is defined as the ratio of electrical power generated to the thermal energy available in inlet steam entering the steam turbine. It is a good practice to enhance condenser vacuum, primarily through further expansion of exhaust steam before it leaves the steam turbine to condenser. This lowers exhaust steam dryness (DF) and maximizes the enthalpy differential across the turbine inlet and outlet nozzles. The resulting increase in power generation is quite significant.

Challenges in Implementation

The steam turbine had already been efficiently designed by BHEL for high vacuum (0.9 - 0.91 at) and low dryness fraction (88%) at rated load which gives very little room for manoeuvring. Hence one has to make sure that the turbine is not operated on a continuous basis at lower exhaust steam dryness. This problem had been successfully circumvented with the indigenous scheme development for continuous monitoring of dryness fraction of exhaust steam (indirect measurement through algorithm relating the cooling water side measurements as well as Condensing steaming conditions).

Performance Analysis

Operating the 21 MW double extraction condensing steam turbo-generator with low condensing loads, had resulted in very high cycle efficiency, as can be seen from the results stated in Table 5.2

Table 5.1 STG (21 MW) Performance at High and Low Condensing Loads

Parameter	High	Low	Units
Condensing Load	42	10	TPH
HP Steam in	80	82	TPH
E1	0	19	TPH
E2	38	53	TPH
Co-gen Cycle efficiency	60	87	%
Elec. Power	21.5	15.5	%
Thermal Energy	38.5	71.5	%
Input Energy	77	79	MWt
Electrical Power Gen.	16 .4	11.2	MWe
Thermal energy dissipated	26.5	6.3	MWt

Through in–house developed condensing steam dryness fraction monitoring scheme, the dryness fraction was maintained at a low value on a sustained basis without any fear of over performance related to wetness related erosion (refer Figure 5.3).

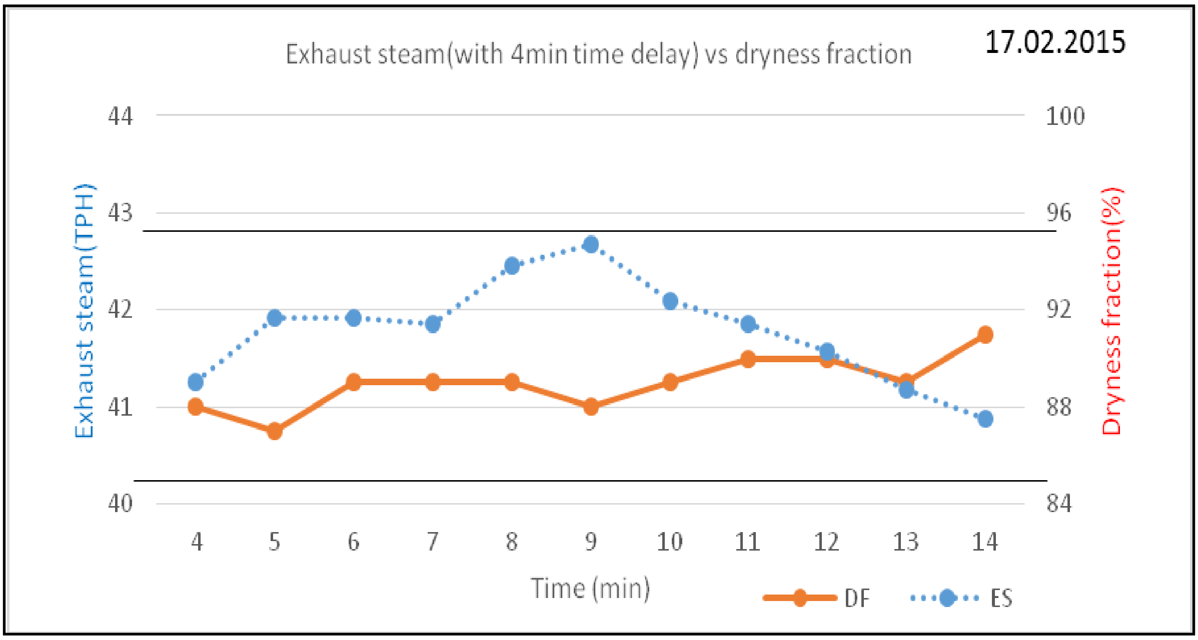


Figure 5.3 Steam Turbine (21 MW) -High Condensing Load Operation

5.2 STEAM SAVING AND ITS ASSOCIATED GHG EMISSION REDUCTION WITH IMPLEMENTATION OF SHOE PRESS IN PAPER MACHINE

In normal tri-nip press in the paper machine, the contact area of the nip sheet web is very short. The improved design and technology in shoe press increased the contact area of nip with paper web. This improved the dryness of the paper web by 5- 6% entering the drier section. This also increased paper machine speed and reduced steam consumption and power consumption and associated GHG emission as presented in Table 5.3.

Table 5.2 Steam Savings and Production Improvement with Shoe Press

Particulars	Units	PM1*	PM 2
Steam consumption / MT of after shoe press	MT	2.14	1.651
Steam consumption / MT of paper before shoe press	MT	2.08	1.76
Steam saving / MT of paper before shoe press	MT	-0.06	0.11
Avg. Production per annum after shoe press	MT	121725	135491
Avg. production per annum before shoe press	MT	91876	104134
Production increase due to shoe press per annum	MT	29849	31357
Steam saving per annum	MT	-7266*	14938
GHG emission reduction per annum	MT CO2e	-3114	6402

* Steam consumption increase due to the production of more surface sized paper after installation of shoe press.

Power Saving and associated GHG emission reduction with implementation of shoe press in the paper machine is given in Table 5.4

Table 5.3 Power Savings and Production Improvement with Shoe Press

Particulars	Units	PM 1	PM 2	
		PWP	PWP	NP
Power consumption / MT of paper after shoe press	KWh	536	589	540
Power consumption / MT of paper before shoe press	KWh	594	620	624
Power saving / MT of paper	KWh	58	31	84
Avg. Production per annum after shoe press	KWh	121725	132382	3109
Avg. Production per annum before shoe press	KWh	91876	52871	51263
Production increase due to shoe press per annum	KWh	29849	31357	
Power saving per annum	MWh	7015	4113	
GHG emission reduction per annum	MT CO2e	6539	3834	

Use of Renewable fuel in Power Boiler

TNPL generates its power and steam from captive power plant. The fossil fuel such as coal is partly substituted by renewable fuels like bagasse pith, agro fuels and in-house wastes like secondary sludge which are all carbon neutral and thus contributing to GHG emission reduction.

5.3 INSTALLATION OF VFD ON WEAK BLACK LIQUOR FEED PUMP IN NEW EVAPORATOR PLANT

The flow rate of WBL feed pump was being controlled through isolation control valve at an average manual valve opening of 30-40%, offering significant potential for energy savings. After installing VFD, power consumption reduced by 50 kW. The details are shown in Table 5.5

Table 5.4 Energy Savings with VFD on WBL Feed Pump

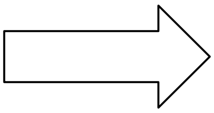
WBL feed pump capacity	90	kW
Earlier running KW with DOL(at 30-40 % Valve Open)	71	kW
Present Running load with VFD(at controlled speed)	21	kW
Reduction in KW after VFD control	50	kW
Cost Savings	Rs.16.80	Lacs/annum

Fuel Switch in Lime Kiln

Energy cost had been reduced significantly by switching over from furnace oil to producer gas and pet coke as shown in Table 5.6.

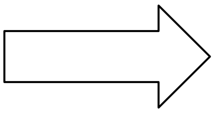
Table 5.5 Energy Savings with Fuel Switching in Lime Kiln

Input	Basic Price	GCV, kCal/kg	Cost, Rs. Basis 1 kL/FO	
Furnace oil	Rs. 40000 / kL	10200	30000	
Producer gas		1300	26000	
Annual Energy Saving Rs 363 Lakhs				
Pet Coke	Rs. 15000 / Ton	8200 – 8400	18000	Pet coke price Rs. 15000 / MT
Annual Energy Saving Rs. 660 Lakhs				



PG plant

Rotary Lime Kiln



PET COKE

Rotary Lime Kiln

Figure 5.4 Replacement of DC Drives with AC Drives in Paper Machine (PM-3)

The sectional DC drives of PM-3 wet part is replaced with AC drives.

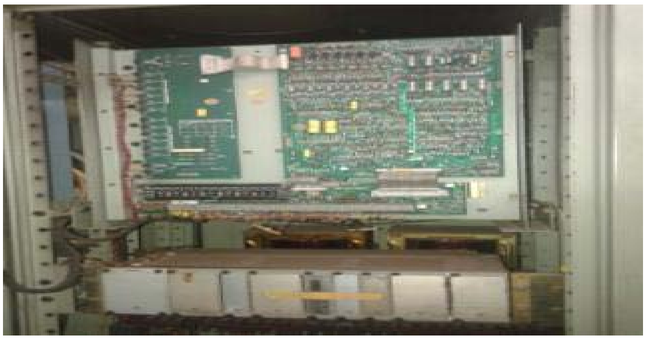


Figure 5.5 Analog AC drive

Figure 5.6 Digital AC drive

The energy savings and cost savings are 60kW and Rs. 18 lakhs respectively. The other benefits include easy fault diagnostic and online trends of faults/alarms.

Energy Efficiency in Steam & Condensate System

Existing System

- Old steam & condensate system was designed for 125 TPD productions while machine production capacity was increased to 190 TPD by increasing speed
- Higher steam consumption in the range of 3.1 T/MT of paper
- Condensate recovery was only 35-40% due to condensate evacuation problem/leakages.
- Higher DP required in rotary siphons to evacuate condensate from dryers means higher load on drive motors
- Frequent breakdowns of rotary siphons.

Improved System

- New siphons with lower siphon clearances (8 mm to 5 mm) in post dryers
- Spoiler bars installed in April -15 to improve heat transfer
- New separator added for 1stgroup having low steam pressure

Benefits

Reduction in steam consumption

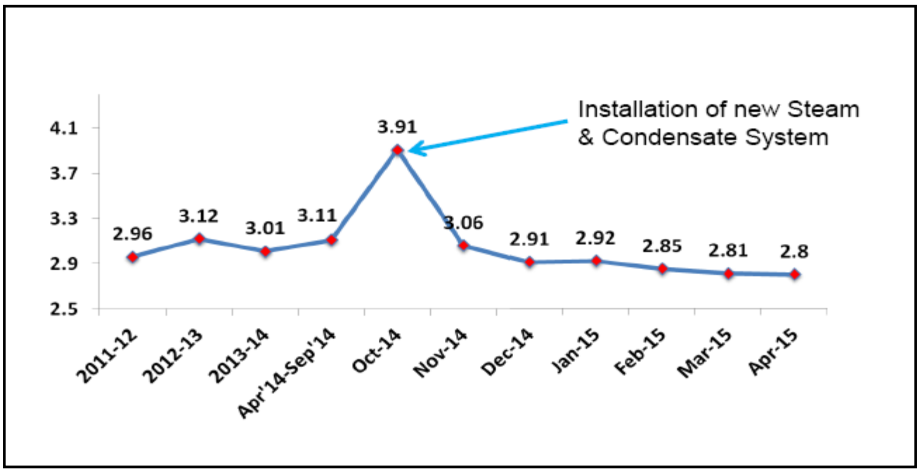


Figure 5.7 Reductions in Steam Consumption

Increase in Condensate Recovery

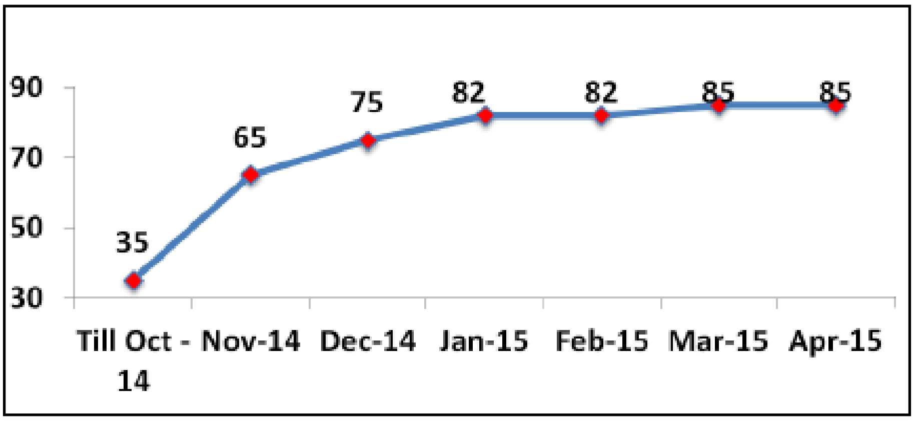


Figure 5.8 Increases in Condensate Recovery in Percentage

Reduction in Drive Loads

Table 5.6 Reduction in Drive Loads

No.	**Running Load, kW**		
	Drive Name	**(old Drive) Dated : 7th Oct. 2014**	**New VFD as on 7th Jan 2015**
1	Dryer – 1	38	25
2	Dryer – 2	48	32
3	Dryer – 3	75	54
4	Dryer – 4	32	35
5	Dryer – 6	74	58
Total		**259**	**204**

6. INTERNET OF THINGS (IOT)

As the world's expendable energy resources deplete and the industrial sector is being asked to deliver more to a growing population, energy efficiency has taken center stage to ensure the longevity of these energy resources, and the Internet of Things can play a crucial role. The emergence of the Internet of Things (IoT) almost certainly is the most important single development in the long evolution of energy management. The insight derived from data collected from new Internet-connected devices can be used to develop new services, enhance productivity and efficiency, improve real-time decision making, solve critical problems, and create new and innovative experiences.

Traditionally, many plants do not have the technology in place to track and measure energy use. On top of that, information on a plant's energy production and consumption is not consolidated into a single place. Energy production and consumption data is often not visible in real time and is not presented at a level granular enough to reflect how changes in behaviour affect energy use. With limited information at their disposal, energy managers can have a difficult time finding the places where energy use could improve. To develop a clear energy-saving strategy and drive energy-saving behaviour, managers need to boost monitoring capabilities and this data needs to be coordinated into a single system.

The Internet of Things (IoT) captures information seamlessly from the sensors and machines that monitor all aspects of the manufacturing process. The information it returns offer greater visibility into actionable data that can result in significant energy savings. Network sensors track energy performance, monitor for leaks and flag any subpar operating situations. Adding Internet of Things sensor technology to a plant allows for real-time alerts that notify energy managers about wasteful situations. Energy managers can then take timely action before their operation loses large amounts of money. Further, the Internet of Things gets the right information to the right expert– whether that person is an onsite manager, an off-site facility specialist, or a third party expert—when they need it, so they can make the best decisions to improve energy performance.

ABBREVIATIONS

GHG – Green House Gases

GDP – Gross Domestic Product

IPCC – Intergovernmental Panel on Climate Change

GWP – Global Warming Potential

Gt.CO_2 – Giga Tonne Carbon dioxide

MTOE – Metric Tonne Oil Equivalent

RPS – Renewable Portfolio Standards

BDMT – Bone Dry Metric Tonne

ASPR – Auto Slip Power Recovery

TPD – Tonnes per Day

AOX – Absorbable Organic Demand

BOD –Biological Oxygen Demand

COD – Chemical Oxygen Demand

ADT – Air Dried Tonne

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