Technologies That Promote Economic Growth Within The Bounds Of Pollution Control And GHG Reduction For Indian Pulp And Paper Industry

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ABSTRACT

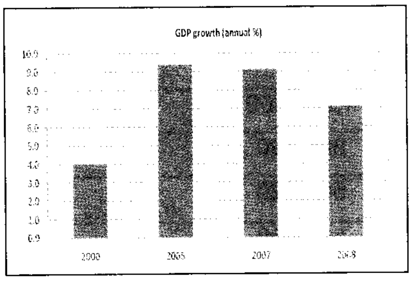
With GDP growth for India projected to be 7%-9% annually for the next several years, the demand for growth in every sector including the Indian pulp and paper is inevitable. However, with ever increasing demand on pollution controls, the paper industry in India has been looking to grow within the bounds on environmental compliance. Gone are the days when Pulp Mills could discard black liquor or spent lime mud into landfills. Another looming environmental aspect is the generation of green house gases (GHG) in the manufacturing process. The Copenhagen summit in 2009 has put the focus on green house gases or GHG, and has asked all nations to curb its emissions of these gases especially CO_2, Methane and NO_x.

In this paper we examine technologies that address all these aspects - increased pulp production, stringent environment regulations on black liquor and lime mud as well as GHG mitigation. Some of these technologies were developed for large pulp mills and for virgin wood pulping, and cannot be directly adopted for Indian industry where the capacities are much smaller and the feed stock is varied (Bagasse, wheat & rice straw, etc). Along with technology discussions, we would be illustrating the impact using complex computer models and simulations of these systems that compute mass, heat and chemical balances along with return of investment or ROI impacts. Our aim is to highlight the process changes and improved technology that Indian paper industry could adopt to address the need for increased pulp production within the bounds of environmental compliance and reduced GHG emissions, and yet do all of this in an economic fashion that benefits both the industry and environment.

Introduction:

Economic growth in the developing nations continues to remain strong and is expected to grow at impressive rates for the near future. While the GDP for developed nations is projected to be below 4%, many of the developing nations, including India are projected to be in the 7% -9% rate. Chart 1 shows the GDP growth rate for India since the year 2000. (1) The global recession in

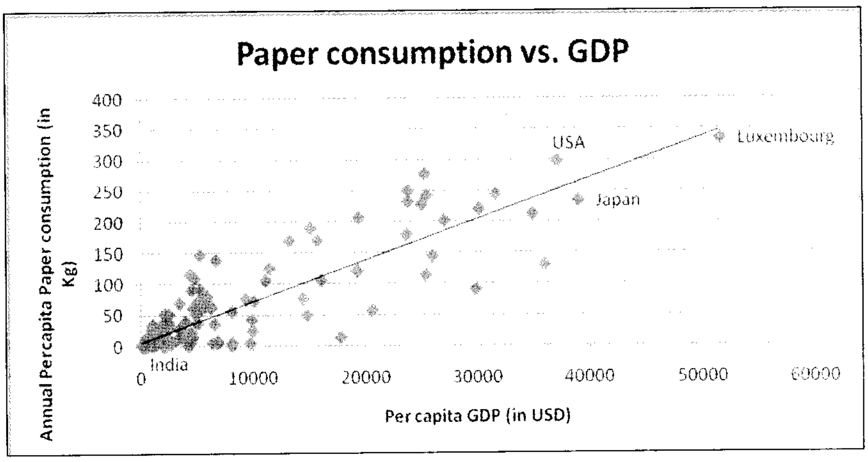
CHART 1



the past two years has certainly affected the growth, however, during the recovery phase, developing nations continue to grow faster than the developed nations. From the perspective of pulp and paper industry, strong GDP growth indicates increased consumption for paper and paper board products. While the per capita paper consumption in developed nations is above 200 kg per year, it is below 5 Kgs. for India (Chart 2). In fact, the data suggests that there is almost a linear correlation between the per capita GDP versus per capita paper consumption.

As can be seen from the numerous mill closures and capacity reduction announcements, especially in North America, pulp and paper industry in developed countries is declining. On the other hand, new paper machines are being installed in developing countries indicating the growth potential (2). Some of the key hurdles for the industry's growth in many developing countries have been the accessibility to resources, technology and infrastructure. In the context of India, much progress has been achieved on sourcing key raw materials. Apart from the importing pulp and other pulp sources, Indian industry has been working on sustainable forestry and also utilizing agro-based pulp sources.

CHART 2



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Currently, pulp used in Indian paper industry is evenly divided between these three sources: wood pulp, recycled paper and agriculture based sources such as Bagasse, wheat and rice straw. Indian paper and paperboard industry is comprised of more than 600 paper machines with a majority producing below 20,000 tons per year. The annual capacity is around 9 million tons/year (3). Although a majority of the grades are produced within India, a portion of the specialty grades are being imported (4).

A significant aspect of pulp and paper industry is its environmental impact from logging to paper production. The use of large quantities of chemicals during all the major steps in the paper making process demands recovery or implementation of efficient environmental controls. These issues are quite different for large mills versus smaller mills. In general, most large paper mills recover chemicals, not only due to the environmental compliance requirements but also due to the economical advantages. However, chemical recovery may not necessarily be economical for smaller mills due to the capital required to install these systems. Furthermore, in the mills that are based on agro pulp sources, there is a need for modifying or re-designing existing technologies. As an artifact of not having chemical recovery systems, many small and medium paper mills dispose the black liquor, lime and sludge. It is estimated that due to these practices, a 30 TPD (Tons/Day) capacity paper mill can be as polluting as a 200 TPD integrated Paper Mill (5).

In March 2003, the Ministry of Environment & Forest - Government of India, has launched a charter on "Corporate Responsibility for Environmental Protection (CREP)". The purpose of this charter is to achieve regulatory compliance *via* waste minimization, improved process controls and adoption of clean technologies (6). Many of the large paper mills have begun adopting these new guidelines to reduce emissions (7). In this paper we discuss some of the relevant technologies for chemical recovery, causticizing, lime recovery and reducing green house gases.

TABLE 1

Relative CO_2 emission from various fuels ("Voluntary Reporting of Greenhouse Gases Program" Energy Information Administration)

Fuel Name	CO_2 Emitted ($lbs/10^6$ Btu) *	CO_2 Emitted ($g/10^6$ J) *
Natural gas	117	50.3
Liquefied petroleum gas	139	59.76
Propane	139	59.76
Aviation gasoline	153	65.78
Automobile gasoline	156	67.07
Kerosene	159	68.36
Fuel oil	161	69.22
Tires/tire derived fuel	189	81.26
Wood and wood waste	195	83.83
Coal (bituminous)	205	88.13
Coal (sub bituminous)	213	91.57
Coal (lignite)	215	92.43
Petroleum coke	225	96.73
Coal (anthracite)	227	97.59

*Pounds of carbon dioxide emitted per million British thermal units of energy for various fuels

TABLE 2

List of countries and their ranks by 2006 emissions (8),(9)

Rank	Country	Annual CO_2 Emissions (in Thousands of Metric Tons),	% of Global Total
-	World	28,431,741	100.0
1	China	6,103,493	21.5
2	United States	5,752,289	20.2
-	European Union	3,914,359	13.8
3	Russia	1,564,669	5.5
4	India	1,510,351	5.3
5	Japan	1,293,409	4.6
6	Germany	805,090	2.8
7	United Kingdom	568,520	2.0
8	Canada	544,680	1.9
9	South Korea	475,248	1.7
10	Italy	474,148	1.7

Greenhouse Gases:

Like any other manufacturing facility where fossil fuels are used, paper industry is no exception about generating greenhouse gases. In Table 1, we provide some emission data from different fuel sources (8). Paper industry typically uses wood waste, coal and fuel oil as their major fuel choices. The black liquor that is burnt is also from wood resources, and therefore produces carbon dioxide and NO_x. Greenhouse gases are defined as

- Water Vapor
- Carbon Dioxide
- Methane
- Nitrous Oxide or NO_x
- Ozone
- Chlorofluorocarbons

Table 2 shows the top ten GHG emitting

CHART 3

Average % of silica and ash present in agro based feed stock compared to hardwood and softwood chips

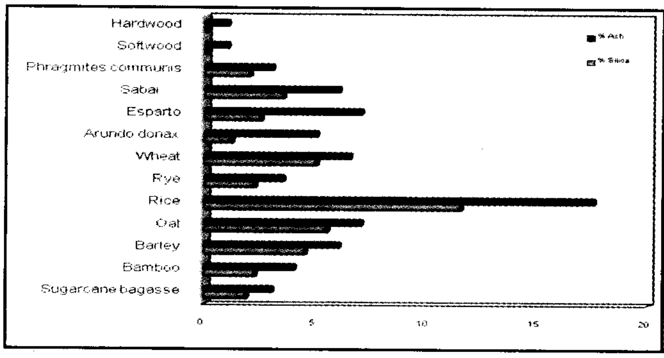
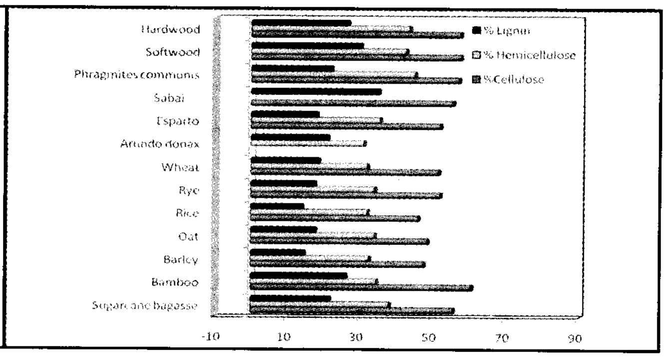


CHART 4

Lignin, cellulose and hemicellulose content in various agro feedstock compared to hardwood and softwood



countries. The prominence of developing nations such as China and India in this list is certainly driving the dialog for reducing GHGs at the Copenhagen summit (9). Furthermore, USA and India are working bilaterally to develop and implement technologies that reduce greenhouse gas or GHG emissions. We will look at an approach that is suitable for paper industry in this paper.

Agro Based Pulp And Paper Mills:

A lot of the mills in India use agro-based feed in their pulping and paper making processes. In charts 3 and 4 we show the differences in silica, ash, lignin, cellulose and hemi cellulose content (10, 11). Typically the agro feedstock has 30% less lignin than wood and hence the cooking conditions need to be different. The major differences between the pulping agro feedstock like Bagasse, wheat or rice straw, is that batch digesting process though effective, is more economical only for large Pulp Mills. For small and medium size ones, continuous digesters like a M&D digester (13) is more economical and uses less chemicals. Figures 1 and 2 illustrate the alkali and calcium cycles for wood based and agro-based pulping.

Here we compare two systems using computer models and simulations to show the similarities and differences. Along with this comparison we also provide the new system to mitigate green house gases. The GHG gases that are major concern in Pulp Mill are CO_2, methane and NO_x. Methane can be

FIGURE 1

Typical Kraft process for wood based pulps

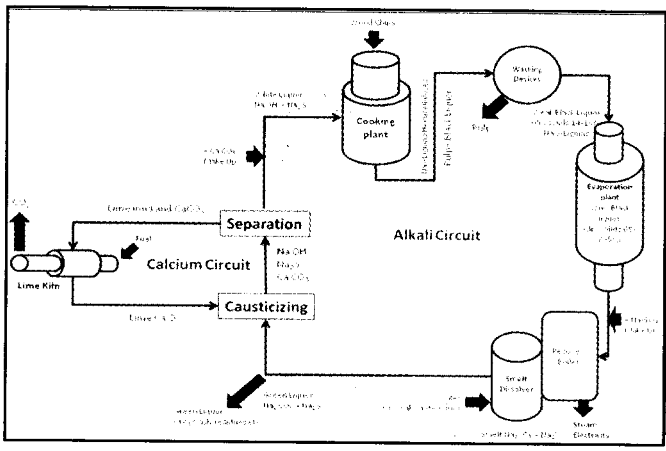


FIGURE 2

Typical pulping process for agro based feed stocks

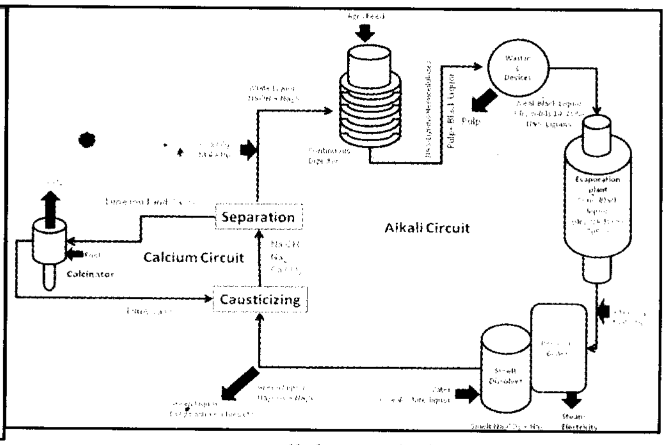


FIGURE 3

GHG mitigating system for agro based Pulp Mill

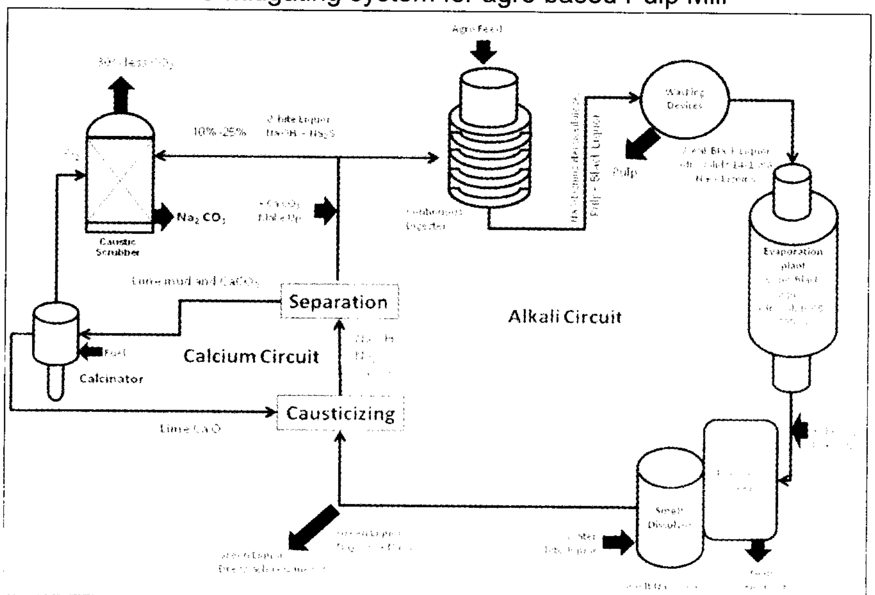


TABLE 3

Comparison of Agro based feed stock Pulp Mill and Wood based Pulp Mill

Wood Feed stock	Agro based feedstock	Comments
Fiber Preparation		
Debarker, chipper, steam impregnator	Cutter, Fiber Washing	Fiber washing is necessary for agro feed to remove silica, stones and chlorides that come with the feed
Cooking		
Batch or Continuous (Kamyr) Digesters – residence time typically over 3-4 hrs	Batch or horizontal / inclined Continuous Digester	Batch cooking is not efficient for agro feedstock as there is very less lignin to digest. A continuous Digester uses less chemicals and less energy
Chemical Recovery		
Typically Multiple effect Evaporator System and Recovery Boiler to burn the black liquor	Multiple effect Evaporator System and Recovery Boiler to burn the black liquor. Low Temperature Incinerator (LTI)is better alternative for small and medium mills	LTI offers better flexibility as the product of the system is soda ash pellets that could be recaustized or sold in the open market. Recovery Boiler on the other hand allows for steam and power generation that is not economical in LTI process. The smelt from the recovery boiler needs to be recaustizied, and reused within the Pulp Mill. Recovery boiler systems typically require an electrostatic precipitator or ESP to capture the entrained particles from the flue gas.
Recaustizing System		
Smelt tank, Green Liquor Clarifier, Slackers, White liquor Clarifiers	If LTI is used , we only need Green liquor dissolving tank, Slackers and White Liquor clarifier	The advantage LTI brings to the recaustizing process is fact that the temperature is not high as compared to the smelt dissolving tank that is employed with a recovery boiler.
Lime Recovery System		
Lime Kiln is the predominant system used here. Fluidized Bed Calcinator is not very popular	Lime kiln and Calcinator are both suitable. The footprint of Calcinator is 1/3rd smaller compared to kiln.	Although both kiln and FB Calcinator, the latter is much more cost effective compared to lime kiln in implementation and operating cost. The fluidized bed in Calcinator produces higher lime availability and lower energy usage. The footprint of FB Calcinator is roughly 1/3rd of lime kiln.
Green House Gas Mitigation		
SO_x, Methane and NO_x control systems are available by collecting the flue gases to burn it in the lime kiln. However, these systems do not address CO_2 emissions.	Typically, GHG controls are very limited.	LTI generates less NO_x as the temperature is low and black liquor to air ratio can be controlled to reduce NO_x emissions. The CO_2 generated in LTI and Calcinator or kiln can be scrubbed with caustic available in the system. The Na_2CO_3 generated can be partially recycled into the system. The rest could be spray dried and sold to outside parties.

FIGURE 4A

Pulping and recovery portion of the model for wood based Kraft Pulping

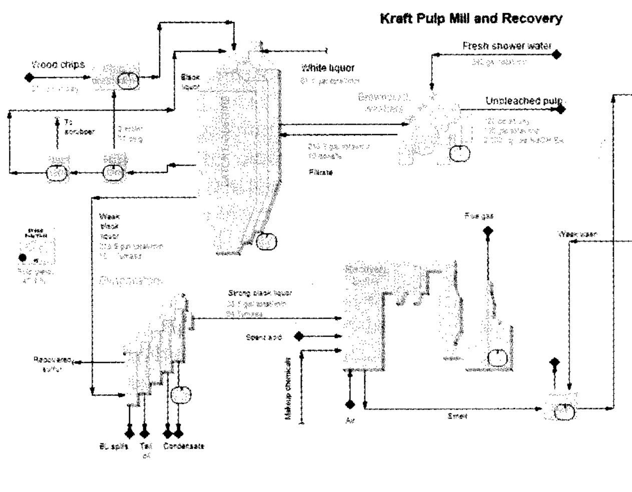
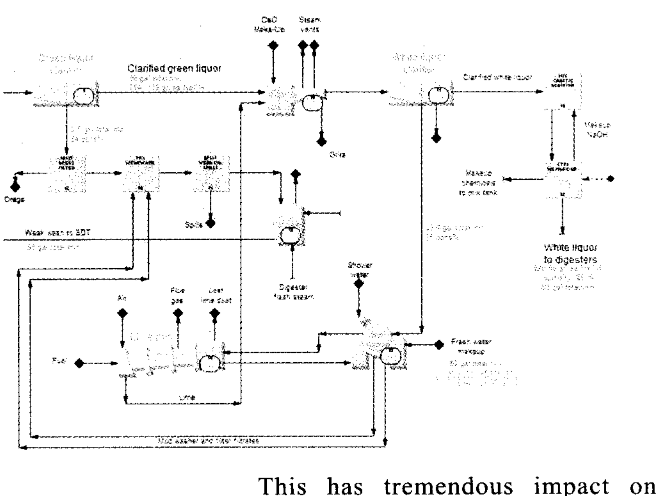


FIGURE 4B

Recaustisizing and Lime Cycle portion of the model for wood based Kraft Pulping



oxidized to CO_2 by burning it in the lime kiln, LTI or Calcinator. Therefore, the main issue for mitigation of GHG is NO_x and CO_2. We also have SO_x that is produced in chemical recovery system and is typically scrubbed with steam. Other gases are reactive with caustic and therefore can be scrubbed with it. The main concern for the scrubber system is the high temperature of the flue gases. This temperature can be reduced by using a heat exchanger and the resulting gas can be scrubbed through a packed column. Table 4 shows various experimental setups that have been tried successfully using NaOH to capture CO_2 (12). NO_x is controlled by lower temperature and fuelair ratios in the lime kiln, LTI or Calcinator. Other technologies include utilizing selective catalytic reduction and are generally more expensive.

Results From The Simulation Of Agro-Based Feedstock Versus Wood Based Feed stock:

For the sake of comparison we looked at a Kraft Mill with wood feedstock (figures 4a,4b) and compared it with a Pulp Mill that uses Agro-based feedstock (figures 5a,5b) and the results are outlined in Table 5. Figure 2 illustrates a closed loop Pulp Mill system for an agro-based feedstock, and shows the distinct differences between pulping and chemical recovery for wood based and agro-based feedstock pulping.

Since the lignin content is roughly 30% lower in agro feedstock, the sulfidity required for cooking is also lower. Typical Kraft mill with a wood feed stock operates at sulfidity 35-45% but if the throughput is less, this value drops to approximately 30%. Agro feed stock mill can operate at 20-25% sulfidity. This has tremendous impact on emissions, makeup chemicals without degradation of the cellulose or fiber. Furthermore, small and mid size Pulp Mills will benefit from lower usage of steam and chemicals using a continuous digester similar to M&D one. This digester employs a low residence time, and low pressure steam in the range of 7-10 psi.

We also used these models to investigate Greenhouse Gas Mitigation technology that employs caustic which is readily available in the system. The equipment that is being used is a caustic scrubber to scrub the CO_2 in the flue gases from the recovery boiler and calcinator. The results for the simulations for both the scenarios agro-based feedstock with and without GHG controls, are listed in Table 6. A schematic for this model is depicted in In Figure 3. The model indicates a reduction up to 30% in CO_2 emissions is feasible. The cost of the scrubber is recovered from the selling of the soda ash that is produced as a byproduct. (Figure 6)

Conclusions:

In this paper, we highlighted the impact of technologies like continuous digester, wet washing, low temperature incinerator, and fluidized Calcinator that could help agro-based feedstock develop better quality pulp and recover a majority of the chemicals used in the process. This has significant environmental impact and will help the mills expand their capacity in a gradual ramp. We also highlight the use of caustic scrubber to reduce the carbon dioxide produced in the system. This approach allows the mill to recover the sodium carbonate for internal use as well as sell the excess as soda ash to other industries. This technology can reduce CO_2 emissions by as much as 30% and is done within the context of

TABLE 4

Experimental methods used for CO_2 capture using NaOH

Solution	Experimental Setup	Experimental conditions
NaOH	Column, structured packings	gas load, p_{CO2}, liq. Load, packing type
Na OH	Column, 1.5 in Rasching Rings	Liq. Flow 0.4-1.7cm/s, ai=.5-1.5 cm-1
Water, NaOH	Column, 0.5 in Rasching Rings	Flow rate 11.8 ml/min
NaOH	Fine particle fluidized bed	Gas flow rate .1-.5 m/s
NaOH	Hollow Fiber Membrane Modules	2.5 M NaOH, liq. Vel. 0.005-0.02m/s

TABLE 5

		Wood Based Pulp Mill	Agro Based Pulp Mill
Throughput	Tons / Day	270	270
Pulp Yield	%	47.00	44.00
Sulfidity	%	28.00	18.00
Make Chemicals (Mainly NaOH)	Mt. / Hr.	0.10	0.3
TTA	as NaOH	118 GPL	124 GPL
Fiber to Liquor Ratio		3	3

TABLE 6

Agro based Pulp Mill with GHG Mitigation

	Without Mitigation Mt. / Hr.	With GHG Mitigation Mt. / Hr.
Make Chemicals (Mainly NaOH)	0.3	0.5
CO_2 produced in the Recovery Boiler and Calcinator	12.1	12.1
CO_2 finally emitted	12.1	7.9
Na_2CO_3 produced for outside sales	0	6.6

FIGURE 5A

Pulping and recovery portion of the model for agro based pulping

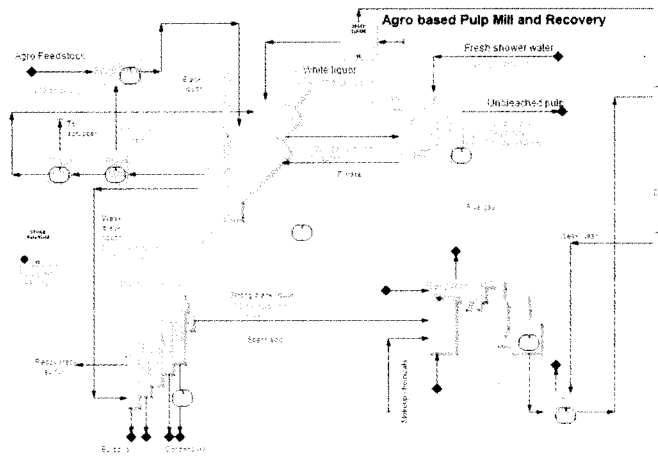


FIGURE 5B

Recausticizing and Lime Cycle portion of the model for agro based pulping

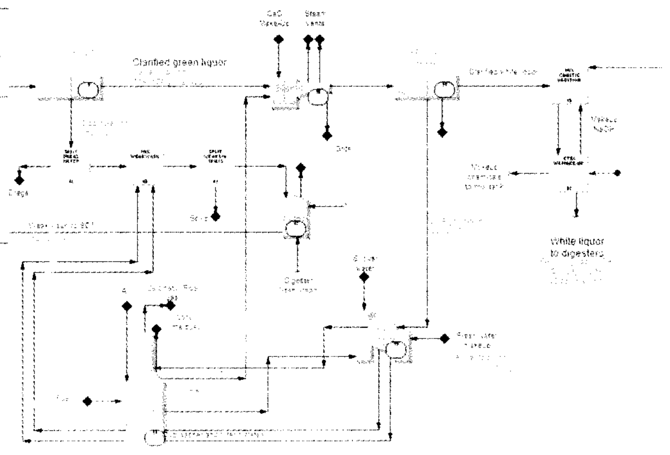
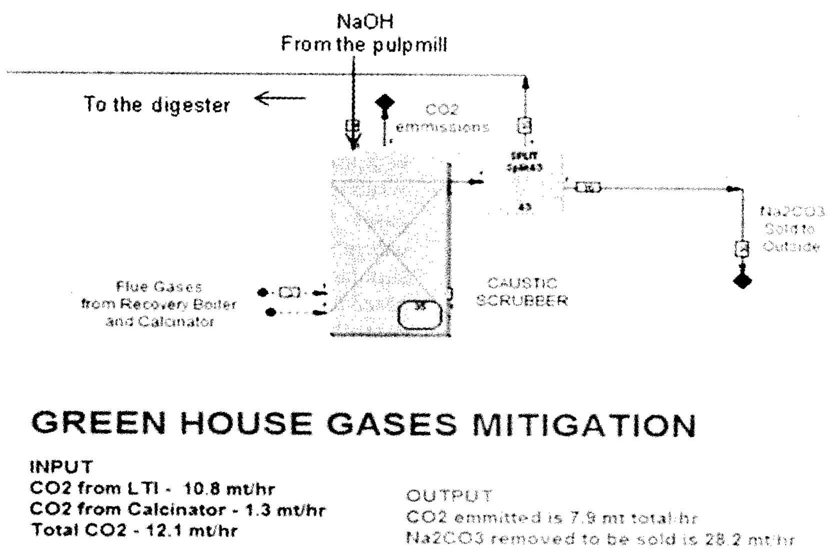


FIGURE 6

Simulation results for green house gas mitigation in agro based Pulp Mill



the pulping process as opposed to added expense.

All of these technologies have an underlying theme Sustainability. Agro-based feedstock are sustainable due its source, and are much easier to manage than forests that are source for wood. The concept of sustainability can be extended to the pulping process through a closed Pulp Mill system that can recover over 90% of the chemicals used. In addition, the GHG mitigation system that works in concert with the Pulp Mill takes sustainability and environmental responsibility to the next level where the manufacturing process is actually reducing the CO_2 produced in an economical fashion. Lastly, the authors would encourage mills to use various tools like the models and simulations employed in this paper to investigate the benefits for their companies.

References:

(1). "www.worldbank.org"; Accessed December 2009

(2) www.risiinfo.com/technologyarchives/papermaking/Unique-in-India-Ballarpur-Industries-Limited-BILT-in-Bhigwan.html Accessed December 2009

(3). "*Monthly Economic Analysis*", Ministry of External Affairs, Government of India, (January 2009)

(4). http://dipp.nic.in/industry/ind_plcy_03/paper.htm

(5). Srivastava, P.K., J. Sathaye, A. Gadgil, M. Mukhopadhyay, *Energy Efficiency and Environmental Management Options in the Indian Pulp and Paper Industry*, ADB Technical Assistance Project (TA:2403-IND), Forest Knolls, Calif.: ERI., (1998)

(6). http://www.cpcb.nic.in/crep.php

(7). Mathur, R. M., Thaplial, B. P. and Singh, K., IPPTA J. vol 21(3) pp 95-99, (2009)

(8). http://www.eia.doe.gov/oiaf/1605/coefficients.html. Accessed December 2009.

(9). *United Nations Statistics Division, Millennium Development Goals indicators: Carbon dioxide emissions (CO_2), thousand metric tons of CO_2* (collected by CDIAC)

(10). Hurter, Robert W., "*Agricultural Residues*", Nonwood Fibers Short Course, TAPPI (1997)

(11). Hurter, A.M., "*Utilization of Annual Plants and Agricultural Residues for the Production of Pulp and Paper*", Nonwood Plant Fiber Pulping Progress Report #19, TAPPI Press, pp. 49-70.

(12). Jung, Kyung Sook, Ph. D thesis "*CO_2 Separation and Regeneration Study from Power Plant Flue Gases with Reclaimed $Mg(OH)_2$*," University of Cincinnati, (2005)

(13). Biermann, C. J. "*Handbook of pulping and Paper Making*"; second edition, , Academic Press, (1996)