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FURNISH, ENERGY AND SPEED OPTIMIZATION THROUGH LOW CONSISTENCY REFINING

Abstract

Paper Makers worldwide strive to provide superior quality paper at the lowest cost possible. The underlying cost structure for paper making is fundamentally different in different countries. With liberalized economies, and lower shipping costs, the barriers to trade are lower than ever before. This puts additional pressure on the Indian Paper Makers largely because the higher cost of furnish and the energy – two major cost items in the paper manufacturing.

Historically, a low focus has been placed on the optimization of the low consistency refining system specially in the context of the fundamental cost structure. This has resulted inlow hanging fruits in the Low Consistency Refining Optimization. Historical focus on these refiners has been largely on the plate cost reduction and to a lower extent on the energy reduction. This leaves out the potential bigger gains in terms of furnish cost reduction and speed optimization.

This paper is focused on a systematic approach on developing the right optimization goals for the low consistency refining system.

Context

The refining is the only equipment in the whole paper mill that mechanically alters the fiber structure at microscopic level to enhance properties for the final sheet of paper. All other equipmentscreen, separate, transport or press the fibers without altering its microscopic physical structure.

Therefore, the ultimate goal of the optimization for refining should be focused on getting the desired quality because that is where most of the unrealized value potential is. The secondary goal of the optimization should be focused on doing it most cost effective way – whether this be via energy reduction or plate cost reduction or a combination of both. This layered strategy for refining optimization works hand in hand with the overall cost structure of the paper mills as described later in this paper.

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Introduction

Paper making is a very complex process. The fibers largely come from trees (though other raw material such as straws, bagasse, etc. cannot be ignored). These fibers are then either chemically or mechanically separated to form pulp. The optical (such as brightness, opacity, color, etc.), physical (density/ bulk, porosity, smoothness, etc.) and mechanical properties (such as Tensile, Burst, Tear, CMT, Stiffness, Ring Crush, etc.) are then imparted through one of the three main mechanisms:

1. Chemicals – starts from the selection of the chemical process used for the pulping, and then progresses through bleaching for whitening the paper and then other chemicals such as wet or dry strength resins, retention aids, enzymes, etc.
2. Additives and Coatings – Fillers such as Clays can be added to impart the higher density, and opacity or to enhance brightness. Colors can be added to provide the desired shade.
3. Mechanical – the centri-cleaners take out the sand and other undesirable higher density materials, screens ensure that shives and bigger fiber flocs do not end up in the sheet, and the refiners impart the desired sheet properties by altering underlying fiber micro-structure.

Whereas, there are several processes that are specialists to a very narrow set of desired properties (such as bleaching targets at whitening the brown fiber into white paper), most processes have a significant overlap – such as:

1. Strength resins and Enzymes can increase the strength properties of the paper – so can the refining or selection of the right raw material (hardwood, softwood ratio, recycle paper ratio and the recycle paper quality, mechanical versus chemical pulping process, etc.)
2. Sheet porosity, smoothness and density can be changed by adding (or reducing) fillers and so the refining change can also cause these changes.
3. Addition of the retention aid can increase couch moisture (and hopefully press solids), and so the selection of raw material ratios and the refining (or lack of)

Because of overlaps, it creates an opportunity to reduce the overall cost of manufacturing of paper.

Understanding Cost Structure

In order to optimize, one needs to understand the underlying variable cost structure of the paper making.

In a large majority of cases, furnish (raw material) is the largest cost item for making paper. And yet, until only a few decades ago, very few paid any attention to this part beyond the negotiating process that carried with suppliers of raw material. It is only since last two decades or so, mills started paying attention to affecting the cost structure through changing furnish ratio or yield.

The cost of raw material is particularly high in India when compared to most North American and North European countries.

In processes where the chemical pulping is carried out on site and specially in processes where the whitening of the paper is desirable (such as fine papers) – chemicals generally compose of the second most highest cost item. Thedefinitions of various grades are much more based upon the final quality of

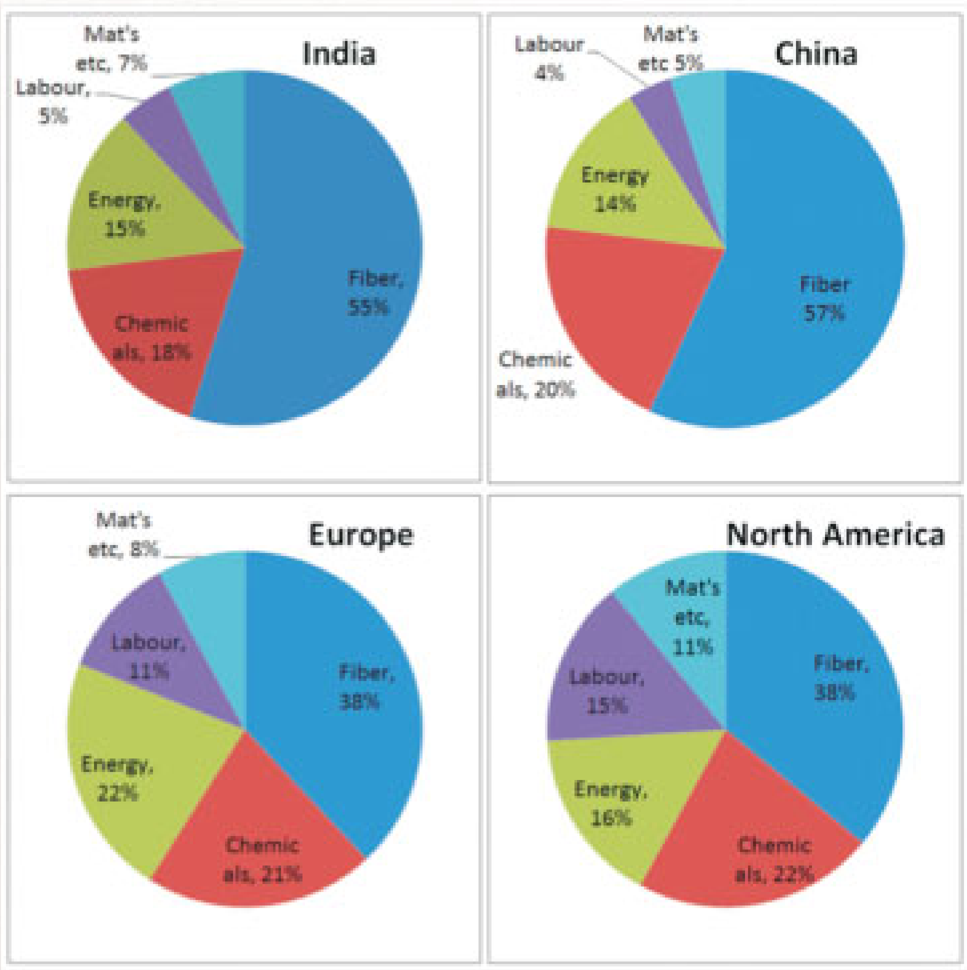

***Fig 1:** The Cost Structure at different part of the world for Grade –Coated recycled board*

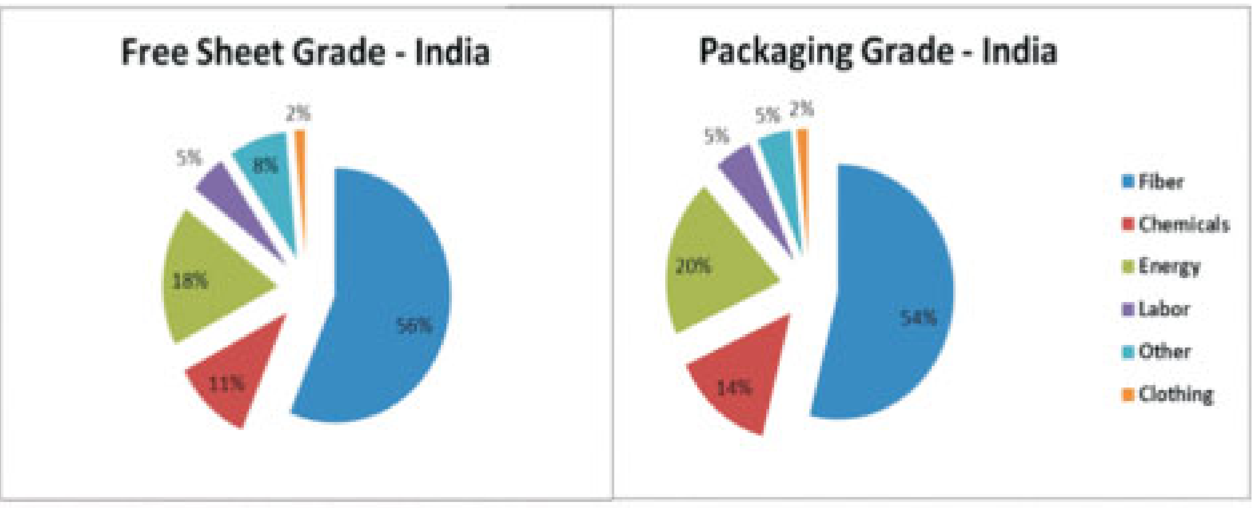

***Fig 2 :** The Cost Structure For Indian Free Sheet and Packaging Grade.*

the paper (such as Linerboard, Medium, Sack Kraft, Tissue, Writing/Printing etc.) and not the processes that are used to make that sheet. These flexibilities (or lack of) should be understood – as these can open the doors for optimization. Here too, the optimization efforts for containing the cost has been limited to stock prep chemicals only (such as retention aids, and strength additives, etc.) and these also have been limited to one dimension only (how much of these can be reduced before the performance drops). However, attention on changing the refining strategies to change the strength additives, etc. is warranted.

In processes where the paper is either made with recycled fiber or mechanical pulp is used instead of chemical pulp, the energy cost is generally second after the raw material. In processes where the chemical pulping is used, energy cost is generally the third largest item. Refining is energy intensive, and therefore it can consume a significant amount of energy. The cost of energy varies significantly from region to region. In the USA, the costs are particularly high in Northeast and are generally lower in Midwest and in some Western territories. As an average, the electricity costs are lower in Northern Europe than in the North American countries. Also as an average, the cost of electricity is significantly higher in India than either North American or Northern European countries.

Therefore out of three largest (variable) cost items in the paper industry, India is disadvantaged in furnish and energy cost, which must be overcome through technical expertise and implementation of the optimization strategies to keep ahead of cheaper imports from countries where the fundamental cost structure is lower.

The overall productivity (machine speed and uptime) also has a significant overall impact on the top and the bottom line. Whereas by looking at the distribution of the cost over the paper production (depreciation perspective) this cost may be not as high, if you look at the opportunity cost – in terms of the lost profit due to the lost production – this cost may rank among top contenders.

Picking Right Refining Optimization objectives

With so many inter-weaving effects, it is very difficult to pick a starting point. This paper is specially focused on a framework to be able to direct resources. The first point in this is to understand qualitatively what potential benefits and draw backs are inherent in any given approach for the refining.

Table 1 for Pros and Cons for Typical Refining Objectives

	Objective	Mechanism to achieve objective	Pros (improves overall profitability)	Cons (reduces the overall profitability)
Plate Cost Focus	Reduce Plate Cost	Find a cheaper supplier	Reduces the direct plate cost	May limit the potential for the technical expertise to optimize the system for overall cost structure
	Improve plate life	Use harder alloy	Reduces the direct plate cost	Limits the use of more advanced plate designs to improve the overall cost structure, and may increase the risk of plate breakage
TCO Focus	Reduce Energy Cost	Energy Efficient Plates	Reduced electricity bill. This can provide higher benefit than Plate Cost focus alone.	May increase plate consumption, and may limit the use of optimized plate
VDO Focus	Improve targeted quality	Optimized plate design	Quality target can be translated into better overall cost structure through machine speed, furnish substitution, chemicals substitution or basis weight reduction. This generally has the highest cost saving or profit generation opportunity.	Needs SOP development, re-training, focus – and therefore needs significant focus from the supplier. There are very few suppliers with technical resources to support this. It may also increase the cost of the plates and the energy usage.

TCO (Total Cost of Ownership) Perspective for Refiners

The refiners should be looked at the TCO perspective. In this perspective, you are using a piece of equipment that costs you X dollars to get Y set of properties. Therefore the focus should be on X – TCO and the Y – Value Driven Objectives or VDOs. Please note the table below shows the costs / refiner – not the total cost of all the refiners.

Table 2:Typical costs of operating a low consistency per refiner

Diameter in inches @ RPM	Typical (short) TPD	Typical net HPD/T Potential @ 90% load	Typical Plate Cost $/ Ton	Typical Maint. Cost $/ Ton	Energy $/ Ton @ $600 / hp / year) @ 90% load	TCO $/ Ton
20" @ 900	50 – 90	2.2 – 3.6	.30 - .55	.10 - .20	4.85 - 8.75	5.25 – 9.50
24" @ 720	80 – 125	2.5 – 4.0	.25 - .50	.10 - .20	5.25 – 8.25	5.60 – 8.95
30" @ 600	130 – 230	1.8 – 3.2	.20 - .40	.05 - .15	3.85 – 6.85	4.10 – 7.40
34" @ 514	165 – 290	2.0 – 3.5	.20 - .40	.05 - .10	4.00 – 7.05	4.25 – 7.55
38" @ 514	230 – 400	2.2 – 3.9	.20 - .40	.05 - .10	4.60 – 8.05	4.85 – 8.55
42" @ 450	275 – 490	2.3 – 4.1	.20 - .40	.05 - .10	4.50 – 8.00	4.75 – 8.50
46" @ 450	365 – 670	2.2 – 4.0	.20 - .40	.05 - .10	4.10 – 7.50	4.35 – 8.00

Table 3: Typical costs of operating a low consistency per refiner as % of TCO

Diameter in inches @ RPM	Typical (short) TPD	Typical net HPD/T	Typical Plate Cost % of TCO	Typical Maint. Cost % of TCO	Energy $/ Ton % of TCO
20" @ 900	50 – 90	2.2 – 3.6	6%	2%	92%
24" @ 720	80 – 125	2.5 – 4.0	5%	2%	93%
30" @ 600	130 – 230	1.8 – 3.2	5%	2%	93%
34" @ 514	165 – 290	2.0 – 3.5	5%	1%	94%
38" @ 514	230 – 400	2.2 – 3.9	4%	1%	95%
42" @ 450	275 – 490	2.3 – 4.1	5%	1%	94%
46" @ 450	365 – 670	2.2 – 4.0	5%	1%	94%

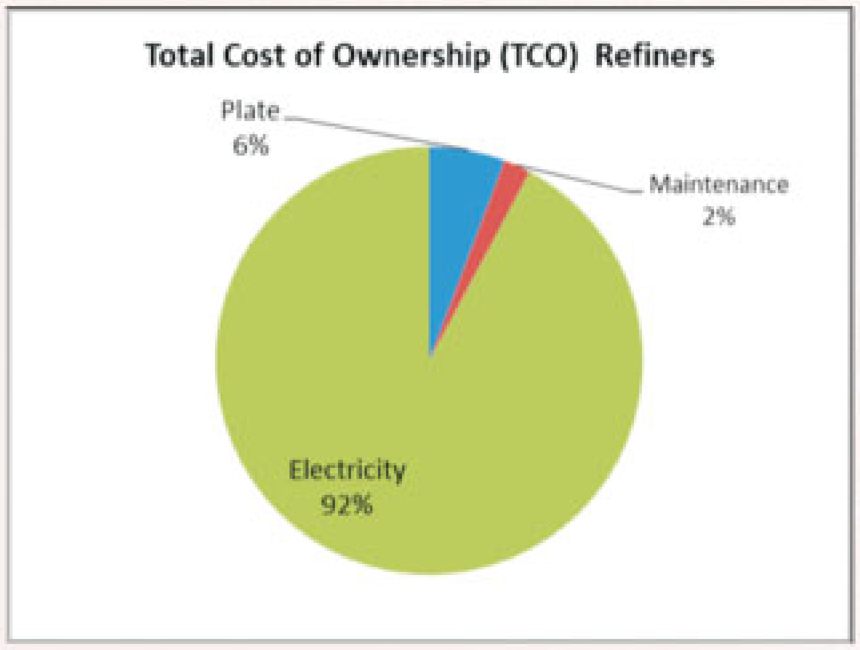

***Fig.3 :** A Typical PI distribution of the TCO*

The above tables and the adjacent chart shows that the majority of the cost of ownership of the refiners resides in the electricity cost, and yet, there are several companies who will devote countless hours of purchasing personnel in negotiations of the plate cost reduction or finding an alternative supplier, rather than focusing on the overall cost of ownership. This chart shows that a slight reduction of the electricity cost can easily pay for the higher cost of the plate – provided a right supplier is chosen for optimization.

VDO (Value Driven Objectives) Perspective

Whereas, the above TCO perspective shows the cost perspective, it omits a very important part of the equation – benefit side. This benefit side is called Value Driven Objective.

The underlying reason of the refining is to develop fiber properties. By developing them in the most optimal way, we can seek further optimization. This generally requires three phases:

1. Understanding of the key variables that can provide a defined set of leverage to reduce cost or improve productivity or grade structure, and understanding the constraints of system.
2. Development of the plate design that is optimized for your pulp and for a narrow set of objectives for the refiner plate performance.
3. Translating these benefits into opening the bottlenecks to enhance productivity or reduce cost or improve grade structure.

From the discussions earlier in the Introduction and Understanding the Cost Structure, it is clear that there are a lot of Variables to account for in a system optimization. Because of the interwoven nature of their variable effects it has been difficult to address. The focus on refining can provide that opening.

By targeting quality improvement through refining one can target one of the areas below:

1. Reduce cost of Furnish by substitution of the expensive furnish with cheaper furnish.
2. Reduce Basis weight.
3. Reduce Chemical cost
4. Improve machine speed

Furnish substitution

Furnish substitution may come in many forms. A few examples are:

1. Replacing lower yield pulp with higher yield pulp.
2. Substituting softwood pulp with hardwood or vice versa
3. Replacing chemical pulp with mechanical pulp.
4. Creating flexible grade recipe to accommodate varying level of virgin and recycle pulp
5. Ability to add Cheaper grade of recycle fiber

Pulp yield adjustment

This option is generally limited to the brown paper production (such as box boards, liner boards, corrugated medium, sack Kraft, etc.). Historically, the Kraft pulp for brown bag/ sack grades of paper was produced at very similar yield and Kappa number as for the Fine Papers, and for the linerboard at slightly higher Kappa number/ yield. It is only in last 2-3 decades, whereas a lot of progress has been made to the extent that the line between the chemical pulps and the semi-mechanical pulps has been blurred. It was common to see Kappa numbers in the 60-70 range for Sack grades, and in lower 80s range for Linerboard grades. It was also common to see the yield on the hardwood pulp for Corrugated Medium pulp in the upper 60s to lower 70s percent range. The race to improve yield started somewhere in 90s, and now a days, it is not uncommon to see upper 80s and lower 90s Kappa number for Softwood Kraft for sack grades, and over 100 Kappa numbers for Linerboard grades – with some testing grounds at over 110! The focus on the refining has opened this window very wide, and with the different plate designs and increased refining resources the pulp development has not seen any adverse effect. The economics work out in favor of improving the yield. For a 500 TPD plant, an improvement of yield by 2% results in 10 Tons of wood savings (on oven dry basis – or on the as the tree comes basis ~ 20-25 TPD). This translates to roughly $700-$1,500 per day savings – based on the mill location and its availability of the wood basket. This translates to $250,000 to $550,000 savings annually. A long term trend for the refining power needs show that it takes ~ 0.25-0.5 HPD/T additional per % improvement in yield for the same or even better quality of pulp than by the yield drop. This translates to 125 to 250 HP additional usage, which assuming $600 / hp / year electricity cost translates to $75,000 to $150,000 per year additional cost. Therefore an investment in the focus on the right objectives and right plate patterns can turn $75,000-$150,000 additional cost in the electricity to $250,000 to $550,000 savings.

Substitution of Softwood with Hardwood or vice versa

The common perception is that softwood gives better strength. This is generally true for the Tear and the stiffness, but generally you can develop tensile and burst with hardwood as good as with softwood pulp with the right refiner plate selection.

On the other hand, hardwoods generally lead to higher smoothness and better formation. However, with correct plate designs, you can also develop smoothness and formation with softwood pulps.

Depending on your wood basket availability, the cost of hardwood or softwood may be cheaper. It is not uncommon to see a difference of $15 to $50 per ton difference between the two (for the chips), and it is not uncommon to see softwood pulp at $50 to $100 per ton more expensive than hardwood pulp in the market place. A refining plate optimization should take this into account.

For a paper machine producing 500 TPD, a substitution of 2% furnish change would result in 10 TPD of furnish differential. At a $50 to $100 per ton differential, this translates to $500 to $1000 per day, or from $180,000 to $365,000 annual savings. In one case, on a machine producing 500 TPD, we were able to reduce the softwood by 3% by optimizing the fiber development through targeted strategies for softwood and hardwood both. This resulted in 0.3 HPD/T more power application overall. The economics worked out as below:

1. Increased variable cost due to additional energy: 150 HP ~ $90,000 / year
2. Increased variable cost due to working with know-how plate supplier - $25,000 per year
3. Decreased cost due to furnish substitution - $410,000 / year
4. Overall net impact = reduction of variable cost by $295,000 per year!

To be able to start this strategy, you must be able to define what exact properties you are seeking, and what are the bottlenecks from the paper quality perspective. Then, ask the question, what we can do to achieve these similar objectives with alternative and cheaper means.

Replacing Chemical pulp with Mechanical pulps

Except a few exceptions, chemical pulps are generally more expensive to produce than mechanical pulps. In some grades due to inherent market place requirements (such as for US # 1 & #2 Coated free sheet), it is mandated that there is no mechanical pulp in the furnish. In other grades, due to yellowing of the lignin carrying mechanical pulps, the use of mechanical pulp may be limited. However, there are a significant number of grades, where it not due to these constraints, rather – just because we have been making paper for long time with one furnish recipe – and there has not been a significant impetus to change that – there has been lower focus on the furnish substitution.

It is not common to see mechanical pulps to be $100-$200 cheaper per Ton than their counterpart in the chemical pulps. Therefore a small substitution of the chemical with mechanical pulp can produce a large cost savings. For example, a 500 TPD machine can make only 1% substitution can save $500 to $1,000 per day, which translates to $180,000 to $365,000 per year. Generally it does not take any more energy to develop the fibers better – it may take different plates and different refining strategy.

Flexible recipe for grades to vary ratio of virgin fiber to recycled:

The market prices for the virgin and the recycled fibers remain uncertain and can vary significantly. There are times, when producing virgin pulp is cheaper than buying recycled fibers and there are times when this relationship is opposite. A difference in the furnish cost per Ton may vary from $25/ Ton on the lower end to as much as $70 per Ton. Therefore in the example above of a machine producing 500 TPD, and being able to change the furnish ratio by 1% can result in $125 to $350 per day savings – or $45,000 to $125,000 per year savings.

Reducing Basis Weight

Most paper makers sell paper by weight, and therefore they do not consider reducing the basis weight as a viable and justified reason to reduce overall cost. However most user of that paper (be that printing press, or be that box plant) are not concerned with the weight of the paper, they are much more concerned with the surface area that it has provided them. Over time, mills develop grades with some understanding in the market place on their Tons translation to the area, and that places them in some particular basket for the pricing. The mills that can consistently deliver higher square meters for a given roll weight, can generally command higher prices per Ton for that paper.

Because the pricing can be sticky and it can take sometime to change marketplace perceptions, for the sake of this discussion, the basis weight is valued at the cost of furnish. There are generally three reasons for the basis weight addition:

1. Higher basis weight to meet some strength target specific to that grade
2. Higher basis weight to meet some bulk/ caliper target specific to that grade
3. Higher basis weight to get higher productivity (more tons) from the machine

The first two are very legitimate reasons for adding basis weight. The third reason simply shows a need for the sales department and the production department to communicate better with each other.

The refining can improve the strength, but it may require additional refining power, and depending on the current plate designs – may limit the drainage on the machine. Therefore the balancing act here is between the refining power, drainage and the basis weight target.

Basis weight reduction can be valued at the cost of furnish on the finished ton of paper to estimate the overall value generation. Assuming a 500 TPD production machine, and a drop in the basis weight by 1% will reduce furnish usage by 5 TPD. In a brown recycled paper plant, the cost of furnish may be ~$100-$200 per ton range, which leads to $500 to $1000 savings per day or $180,000 to $365,000 per year. In a white paper production plant, the cost of furnish is generally significantly higher (~$250-$400 per ton), and here the savings may be far greater ($450,000 to $730,000 per year).

Reducing Chemical Cost

Paper mill consumes chemicals in many areas. Some chemicals (such as bleaching, retention aids, pH control, etc.) have very little in common (in effects) with refining, and therefore those are not considered here. The chemical cost that is targeted at following two areas can be optimized by including refining into the overall picture:

1. Cooking chemicals in the brown paper production – reduction in these chemicals also increases yield, and that was covered in detail in section of yield adjustment.
2. Paper/ machine or stock prep strength additives – this is the focus area for below.

Enzymes, dry strength resins and wet strength resins are the examples of the chemicals that are generally added for the strength. Because the refining can also influence strength – the inter-relationship of these should be examined. In some of these chemicals additions, the drainage is not affected negatively, and therefore an argument can be made that refining (which affects drainage), and chemicals can not be thought of as a substitution of each other. One should draw the X-Y plot of various grades with varying degree of basis weight and the production rates to see if there is a flattening of the curve at the top end of the basis weight as shown in the section below for the improving paper machine speed section. If this plot suggests that the drainage is not a key factor for at least some of the grades, an optimization opportunity exists by improving the refining for the strength.

Improving machine speed

It is common to hear that the machine is drainage limited. But the data may or may not support this. In order for the machine to be truly drainage limited, their production rate should flatten out at the higher basis weight grades. Therefore, my first course of action is to plot basis weight of grades and the TPD of that machine on X-Y axis as below:

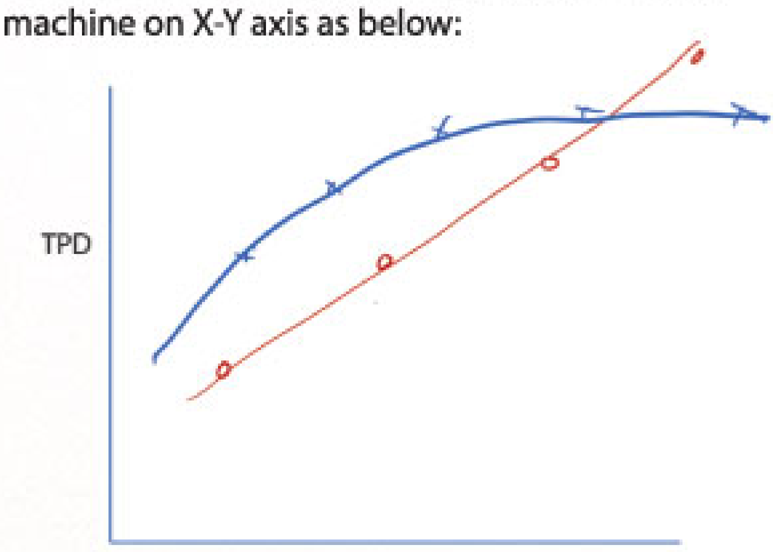

***Fig 4 :** The Basis weight of Grades of paper and TPD of Machine*

The machine that has flattening production rate for higher basis weight may have the drainage or steam limitation beyond the point where the flattening of the curve is seen. The mill that does not see this flattening does not have an indication that the machine is either drainage or steam limited.

Once you have developed this graph, this can provide you some indication of the machine is truly drainage or steam limited. Whereas, 80% of paper machines believe that their paper machine is drainage or steam limited, a large majority of the paper machines may have this limitation only for a handful of grades. Machine speed directly increases the productivity, so each additional ton produced gives you the full gross margin of for that grade. The gross margins (calculated as selling price – variable cost for the paper) can vary significantly from mill to mill and can vary anywhere from $100 to $600 per ton depending on the grade. Therefore in the example above with 500 TPD production rate, a 1% increase in the speed can result into 5 Tons of paper contributing towards gross margin valued at $500 to $3,000 per day in range or $180,000 to over $1,000,000 per year.

It is not uncommon to see that operators have to slow down machine because they are either seeing too many breaks (most likely due to mechanical condition of the machine), or due to inability to meet grade specs (most commonly Burst or CMT or RC). If the machine is kept at the lower speed due to inability to meet the strength tests, the fiber quality improvement through refining can provide significant value generation. In these cases, the value can be generated through more optimized refining.

VDO Valuation

Table 4 : Relative importance of the VDO discussed for a 500 TPD paper machine:

VDO Item	Annual savings potential in500 TPD Brown Paper production $/ year	Annual savings potential in 500 TPD White Paper production $/ year
2% Yield ?	$200,000 - $400,000	Generally not applicable
2% Furnish Substitution	$40,000 - $180,000	$100,000 - $365,000
1% Basis Weight ?	$180,000 - $365,000	$450,000 - $730,000
1% machine speed ?	$180,000 - $1,000,000	$180,000 - $1,000,000

The benchmarking info provides the following for the TCO. Fine paper (writing & printing paper) is considered for representing the White Paper production, and Linerboard (paper for the box production) is considered for the brown paper production. Please note that the table below do not match with the one shown in the TCO section; the table shown in the TCO section was based off per refiner, the table below is based off for a 500 TPD machine.

Table 5: Total Cost of Ownership (TCO) for Refiners for virgin pulp based machine

TCO Item	500 TPD LinerboardVirgin	500 TPD Fine Paper Virgin
Electricity usage	4 - 8 HPD / T + no load	4 – 7 HPD/ T + no load
Electricity usage	$1,000,000 - $3,000,000 per year	$1,000,000 - $2,800,000 per year
Plates Consumption	$100,000 - $400,000 per year	$50,000 - $200,000 per year
Maintenance	$20,000 - $50,000 per year	$20,000 - $50,000 per year

Table 6: Total Cost of Ownership (TCO) for Refiners for recylced pulp based machine

TCO Item	500 TPD LinerboardOCC based	500 TPD Fine Paper Recycled
Electricity usage	2.5- 5 HPD / T + no load	1.5 - 3 HPD/ T + no load
Electricity usage	$700,000 - $2,000,000 per year	$600,000 - $1,500,000 per year
Plates Consumption	$100,000 - $300,000 per year	$50,000 - $150,000 per year
Maintenance	$20,000 - $50,000 per year	$20,000 - $50,000 per year

Table 7: TCO Savings Potential based on assumed % Savings for Virgin Pulp based machines

TCO Item	500 TPD LinerboardVirgin	500 TPD Fine Paper Virgin
10% Electricity ?	$100,000 - $300,000 per year	$100,000 - $280,000 per year
10% Plates ?	$10,000 - $40,000 per year	$5,000 - $20,000 per year
20 % Maintenance ?	$4,000 - $10,000 per year	$4,000 - $10,000 per year

Table 8: TCO Savings Potential based on assumed % Savings for Recycled Pulp based machines

TCO Item	500 TPD LinerboardOCC based	500 TPD Fine Paper Recycled
10% Electricity ?	$70,000 - $200,000 per year	$60,000 - $150,000 per year
10% Plates ?	$10,000 - $30,000 per year	$5,000 - $15,000 per year
20 % Maintenance ?	$4,000 - $10,000 per year	$4,000 - $10,000 per year

It should be noted that these cost saving potentials are not additive; in fact, at many times, a savings in one area results in negative on the other.

Table 9:TCO/VDO Opportunities for Virgin Based mills *(Savings are not additives)*

TCO/ VDO Item	500 TPD LinerboardVirgin	500 TPD Fine Paper Virgin
10% Electricity ?	$100,000 - $300,000 per year	$100,000 - $280,000 per year
10% Plates ?	$10,000 - $40,000 per year	$5,000 - $20,000 per year
20 % Maintenance ?	$4,000 - $10,000 per year	$4,000 - $10,000 per year
2% Yield ?	$200,000 - $400,000	Generally not applicable
2% Furnish Substitution	$40,000 - $180,000	$100,000 - $365,000
1% Basis Weight ?	$180,000 - $365,000	$450,000 - $730,000
1% machine speed ?	$180,000 - $1,000,000	$180,000 - $1,000,000

Table 10: TCO/VDO Opportunities for Recycled Based mills *(Savings are not additives)*

TCO Item	500 TPD LinerboardOCC based	500 TPD Fine Paper Recycled
10% Electricity ?	$70,000 - $200,000 per year	$60,000 - $150,000 per year
10% Plates ?	$10,000 - $30,000 per year	$5,000 - $15,000 per year
20 % Maintenance ?	$4,000 - $10,000 per year	$4,000 - $10,000 per year
2% Yield ?	Generally not applicable	Generally not applicable
2% Furnish Substitution	$40,000 - $180,000	$100,000 - $365,000
1% Basis Weight ?	$180,000 - $365,000	$450,000 - $730,000
1% machine speed ?	$180,000 - $1,000,000	$180,000 - $1,000,000

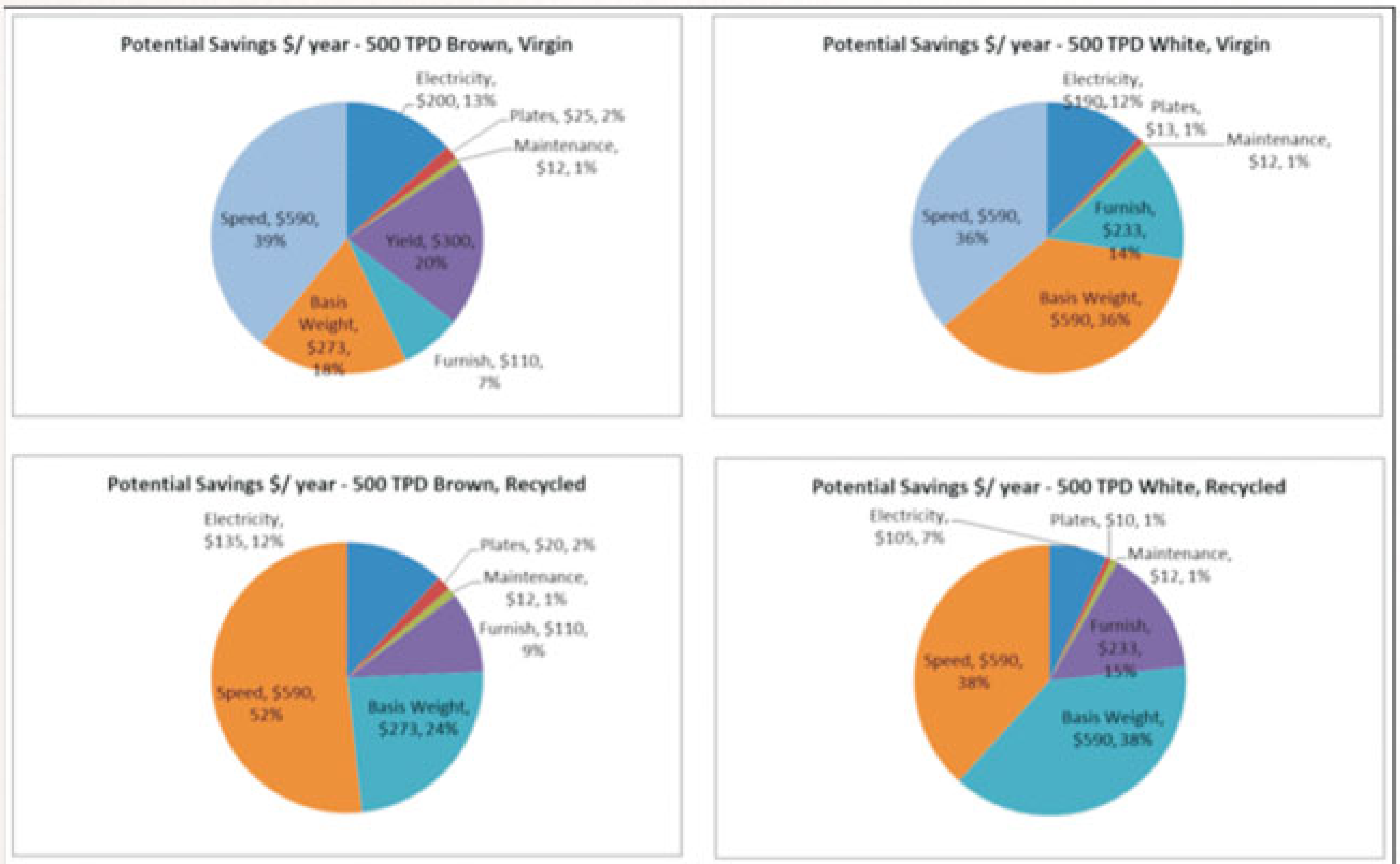

***Fig.5:** Following PI Charts are developed based on the midpoint values from above tables:*

This leads to a rule of priority for the optimization:

1. Focus on VDO – the items in VDO opportunity will generally yield the highest savings opportunities, and therefore this should be the 1st priority.
2. Focus on the Electricity – 2nd priority – this item is large enough that it should not be neglected. However be aware that focus on this should not take away from VDO. If you can gain something in VDO by sacrificing a little on the electricity – it is generally a net gain.
3. Focus on the plate cost – 3rd priority – this item most often can result in negative impact on TCO or VDO and therefore be aware with this focus. Generally the plates that cost less have one or both of these things present:
    a. A cost sensitive supplier – with little focus or understanding or the resources available for the overall optimization
    b. Plate designs that are focused on the plate life – and may cost more in terms of the TCO or VDO
4. Focus on the maintenance – as the above chart shows, the maintenance cost for the refiners is minimal. And therefore if anything – focus on increasing maintenance as this can provide far greater benefits.

Factors in selecting the right refiner plate supplier

Keeping in view the discussion so far, it is expected from right plate suppliers to fulfil the followings

1. Improving customer operating results– does the plate presentation from the supplier is limited to the plates and the corresponding costs, or does it take an approach of VDO/TCO?
2. Innovative products and technical solutions– has the supplier introduced new products to the market place in recent years?
3. Does the supplier have the technical resources available that have direct experience in the paper industry? If so, are these resources spread too thin?
4. Can the supplier provide necessary training to the Operating and the Technical personnel at the mill.

CONCLUSION

As this paper shows, there are significant opportunities to improve overall cost structure through LCR plates optimization. Many large and effective corporations have made significant investment in the resource allocations in recent years to gain full advantage through this. A Paper Mill should look at its own human capital to see what resources can be allocated to optimize refining, and what is the best way to train them, and then work with a technically competent supplier to take advantage of this opportunity.

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