# Strategic Energy Management in Energy intensive enterprises: SWOT-AHP analysis of Indian recycled Paper and Pulp Industry

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**ABSTRACT**

For energy intensive industries, such as Paper and Pulp industry, energy costs form a significant part of the overall costs and hence economizing on energy isone of the targets towards enhancing profits. One important aspect of strategic energy management is to improve energy efficiency (EE) of the plant. Out of the multiple factors that affect the energy performance of a plant, the managements can concentrate on select few only on account of limitation of resources. Such a prioritization has been attempted in this work, using a hybrid method combining strengths, weaknesses, opportunities and threats (SWOT) analysis with Analytic hierarchy process (AHP). This has been applied to Indian recycled Paper and Pulp Industry. Sixteen factors that influence implementation of energy efficiency measures (EEMs) were identified and then prioritized quantitatively based on industry expert'sopinion. The analysis brings out that the industry values profitability the most. High energy cost, competition, management support and capital availability emerge as the top four factors. It is also seen that environmental policies and sectoral policies for paper and pulp industry, even though mandatory, do not influence the implementation of EEMs in a significant way. Community pressure, emerging technologies, renewable energy, production inefficiencies, qualified human resource are other factors identified. Sourcing of energy, scarcity of coal and waste paper collection deal with important factors of paper production but the experts have prioritized them lower down in the list. In comparison of the overall SWOT groups, external threats emerge to be the most important SWOT group followed by internal strengths.The work provides an insight into factors that influence EE in recycled paper and pulp industry.

**Key words**: Analytic hierarchy process, Energy costs, Recycled Paper and pulp industry, Strategic energy management, SWOT analysis

## 1. Introduction:

Quest for better productivity and profitability in energy intensive industries, such as paper and pulp (P&P) industry, hasled to increasing awareness regarding need for reducing energy costs. Researchers have shown that, in spite of the progress made in the field of energy efficiency (EE), there is still a significant potential for further improvement,known as energy efficiency gap [1]. This gap is attributed to existence of barriers to EE [2]; characteristics of many EE technologies [3]; complexity of energy systems [4] and uniqueness of each paper production plant [5].One method for reducing this gap in a paper mill is by adopting a systematic, wholistic and long-term approach to energy management by implementing a strategic energy management (SEM) plan [6].

SEMincludes top management commitment towards EE, performance assessment by energy audit, defining objectives and targets, making and implementation of action plan, iterative evaluation of progress and corrective action. Important research contributions on these components include studies on energy audit [7]; barriers and drivers to energy efficiency[8],[9];energy end use policy measures [10]; EE bench-marking [11]; SEM [12],[13],[14],[15],[16],[17]). There are studies available regarding factors that have influence on SEM in different industries and in different geographies. However, no study could be located that brings out factors influencing the SEM in recycled P&P industry in India in a structured and quantified way. This paper attempts to bridge this gap.

Objective of this paper is to identify and prioritize the factors that affect the SEM. A hybrid methodology has been used by combining study of strengths, weaknesses, opportunities and threats (SWOTanalysis) with analytic hierarchy process (AHP). The methodology is similar to that applied by [13] for analysis of Austrian P&P industry.

Section 2 of this paper presents a literature review on SEM in manufacturing. Section 3 presents an overview of Indian P&P industry. Sections4& 5 present the research design and methodology.In Section 6, factorsinfluencing SEM are identified by SWOT analysis and then quantified using AHP. Thereafter a discussion on the results obtained is presented. Section 7 brings out the Conclusions.

## 2. Literature Review

Need to adopt SEM in energy intensive industries was realized worldwideafter the energy crises of 1973[18]& 1979[19]. For India, the liberalization of 1991 was a watershed event that enhanced competitiveness[20]. Companies realized that SEM can act as a lever for enhancing efficiency and reducing costs [6]. The release of ISO-50001 standard in 2011 by the International Organization of Standardization (ISO) strengthened SEM initiatives by providing practical guidance and specifications. 18227 sites worldwidehad achieved ISO-50001 certificationtill 2019.[21].
[22] have provided definitions related to SEM. At strategic, operational and tactical level of a company, energy management has different objectives and different methodologies for implementation. At a company level, a promulgated Energy Management System (EMS) is very helpful. As per [6], an EMS is a “set of interrelated or interacting elements to establish an energy policy and energy objectives and processes and procedures to achieve those objectives.” It includes organizational structure, information system and technical tools (including hardware and software). They have presented a systematic review and developed a conceptual framework of energy management. The same is presented at Fig 2.1. This framework has been used for describing the SEM process and research works under each of its steps. SEM is an iterative process forcontinuous improvement.

The SEM process starts with the decision of the top management. A cross functional energy management team under an Energy manager is set up as. [23],[24],[25]. Initial energy Audit is the next step. [26] have defined energy audit as a “formal, systematic procedure that analyzes the current energy flows of the company.” The aim is to identify energy processes and consumers, to quantify their current energy use and potential to improve energy EE. [27] classified energy audit in three categories. Simple audit, general audit and detailed audit with gradually increasing interaction with staff and examination of energy data.

The next step is the Strategy/ Planning process. The energy team examines the resultsof initial energy audit and makes an energy policy, laying down targets and submits to the top management for approval. Energy policy, has beenstudied by[28],[29] and[15] amongst others. They observed 20 to 60 % of industries not having a documentedlong-term energy policy. One of the reasons is the perception that energy is not "core" of the business. [30]have said that the energy planning targets should be specific, measurable, appropriate, realistic and timed (acronym SMART). [31] have advocated for Strategic energy risk management (SERM) to be included. Energy intensive Paper industry is vulnerable to energy price volatility and supply shortages.

After strategic level approval of the action plan by the top management, EEMs are decided and implemented. Many of these are technology-based. Technologies specific to paper industry have been studied by [32] and[33]. Cross cutting technologies (applicable acrossdifferent industries)have been studied by [27] and[34]. The EEMs also include operation and maintenance (O & M) measures. [35],[36].[37] observed that technologies to reduce electricity consumption have higher adoption rate as compared to those providing energy efficient lighting. [38] and [39]brought out that specific characteristics of EEMs affect their understanding and adoption. They suggested a classification scheme for EEMs giving 12 characteristics. [34] expanded this classification to 17 attributes under six categories namely -production related, interaction with other systems, energy, economic, environmental and implementation related. The EEMs can also be of organizational and management nature [39]. The implementation also includes investment and operational decisions. Often the decision makers put very stringent payback criterion for allocation of funds.[28] determined this payback period to be three years or less. [40] found this be from 0.9 to 2.9 years. [63]argued that use of such short payback period results in bypassing of many profitable investment options. [41] identified factors affecting the investment decisions to be transparent and easy to understand calculations, access to correct information, better follow up, improvement of working methods and related tools. [42]postulated that, at times, organizations not having adequate capability to identify, evaluate and execute a particular EEM results in denial of investment. They also identified the factors that lead to successful implementation of a particular project to be reliable baseline data, clearly allocated responsibilities, availability of proven technology, financial resources and competence. [43] have argued that, while making investment decisions, both energy and non-energy benefits need to be considered. [44]suggested inclusion of productivity benefits in the calculations.

After implementation, follow up energy audits are undertaken to assess the impact of the steps taken and to enable course corrections, if required.[45],[27]

An essential part of the SEM is the controlling of the processfor performance management. This includes energy accounting, performance measurement and benchmarking. The role of information and communication technologies (ICT) for collection and monitoring of data is immense. An appropriate Energy Information System (EIS) needs to be implemented to facilitate real time collection of energy data, both financial and non-financial. With advances in Industry 4.0 technologies and AI and ML applications, these monitoring requirements could be built in ab-initio in case offuture green-field projects or during modernization[46].

[35] have brought out the importance of regular monitoring and analysis of energy consumption to enable oversight and corrective action. They also recommended that in large factories, sub metering and energy cost allocation at sub unit level will support the energy management. [47] have explained EE indicators (EEIs) (which can be adopted as Key Performance Indicators (KPIs) for performance measurements at company, factory and at process level. These Indicators can be economic, physical, thermodynamic and hybrid variety. [48] brought out that the system should be so designed that the operators are able to understand and correct the energy performance in real

time. [49]have suggested subcontracting the task of monitoring efficiency of energy usage to energy service companies (ESCOs) for better feedback with verified results, better accountability and understanding of further improvement potential.

Internal and external benchmarking is essential for realistic target-setting. [50] have classified EE benchmarking in three categories- industry benchmark (compared to other companies in the same sector), historical benchmark (compared with data of the same facility from an earlier time) and companywide benchmark (comparison of plants and processes within the same company with targets set to top quartile). [51] have recommended a process-based benchmarking for its usefulness in identifying EE potential. However, this is difficult to implement due todifficulty in sourcing data, complex interconnections between sub processes and uniqueness of each plant and process. [52] advocate use of EEI and Specific Energy Consumption (SEC) as the KPIs. [53] have suggested energy intensity (EI) as the KPI. [54] have recommended the data envelopment analysis (DEA) for benchmarking. [55] have used a statistical approach using a single matrix equation.

Organization: Energy management needs an administrative structure, a defined set of procedures and an internal reporting system. [56] determined that management practices supporting EE and the organizational set up are linked.[15] stipulated that independence of the energy manager is critical. [57] suggest that the energy manager needs to be supported by a cross functional team and needs to have free access to all relevant data. The effectiveness of energy manager increases with his closeness to the top management. However, if the CEO is in charge of EEM implementation personally, they do not get implemented well.[29] have defined the duties of energy manager to have entire responsibility for the energy management plan including its creation, funding process, functioning of energy department, execution of EEMs, communications and course correction. [47]advocated combining production and energy management into one structure, use of ICT and standardization. [58] suggested a combined energy and environment management system for optimum resource utilization. [38] opined that for implementation of EEMs the organization needs to be strong in energy aspects, organizationally and needs high motivation.

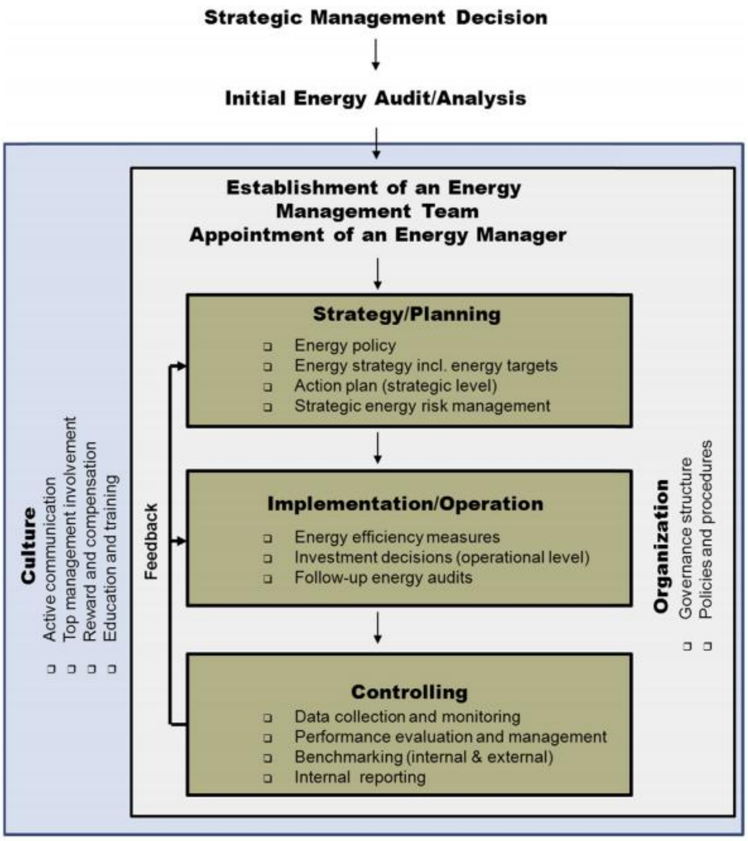


**Fig 2.1 Framework of an integrative energy management (adopted from[6]**

Organizational culture comprising of education, training, motivation and communication systems plays an important part in success of Energy plan. [59] brought out the need of energy related education. [35] highlighted the importance of support from top management and willingness for energy saving. [60] reiterated the importance of support from top management in operational vertical. [61] highlighted importance of award and recognition system towards motivation. [62] also brought out the importance of staff awareness and motivational measures.

An active communication culture horizontally and vertically is necessary. [25] highlighted importance of good communication practices. Different methods can be used for this, such as periodic reports and letters bringing out status of various projects and review meetings. [35] brought out the prevalence of passive information sharing with staff e.g. by means of bulletin boards.

## 3. The Indian paper and pulp industry

Indian paper industry ranks 5$^{th}$ among paper producers in the world [64]. Demand for paper is approximately 18 million metric tons per annum (PA), nearly 4.4 % of the world's consumption. The demand has gone up from 9.3 million tons in FY 08 at a CAGR of 6.3%. [65].India accounts for nearly 4 % of global production [66]. The per capita paper consumption in India is about 13 Kg PA against global average of 57 Kg and Asian average of 40 kg [65].

The Indian paper industry is fragmented. Top 5 companies make up approximately 30% of the industry capacity [67]. There are over 715 mills[68] with less than 100 of them having a capacity of 50000 TPA or more [65].

The industry can be classified in terms of raw material - virgin fiber (such as wood) agro fibers (such as wheat straw) and recycled fiber (waste paper). The segmentation based on raw material is 30-35 % wood based, 45-50 % recycled and 20-22 % agro[65].

Another classification can be on product segments-writing& printing (W&P); news print, packaging paper (e.g. carton board) and Speciality paper. The W & P segment constitutes nearly 30 % of industry [65] and is growing at the rate of 3-3.5 %. Here India is the second largest in Asia with consumption of 5.4 Mt after China at nearly 16 Mt [67].Packaging paper and board share is nearly 52 % (in 2019). This segment has grown at a CAGR of 7.8 % from 4.3 Mntons in FY 08 to 9.7 Mntons in FY 19. [65]. The news print segment accounts for 13 % and has grown at CAGR of 2.5 % during FY 08-19 to 2.5 Mntons. Speciality paper and others is the smallest segment and accounts for a miniscule 0.45 % share [65].

The size of Indian paper industry was estimated at Rs 70000 Cr in 2019-20. Contributing Rs 5000 Cr to the national exchequer. The industry provides direct employment to 5 lac people and indirect employment to 15 lac individuals[66]. India is one of the fastest growing paper markets. In first half of 2019-20 the paper imports were worth Rs 4941 Cr (up 19.69 % from Rs 4128 Cr for the corresponding period in the previous year [66].

Long term outlook for Indian paper industry is positive [67]. Paper demand is expected to grow at a CAGR of 6-7 % and is likely to reach approximately 22 million tons in 2021-22. Per capita consumption is expected to touch about 17 kg by 2024-25. [65].

The paper industry is ranked amongst the top six energy intensive industries in India. The energy consumption varies from 16-25 % of total costs. The energy consumption levels are expected to increase to 730 PJ and 1702 PJ by 2020 and 2030 respectively. [69].

## 4. Research Design

Literature review indicates that there is significant work on the factors that support adoption of EEMs.One way to determine the influencing factors is SWOT analysis, wherein the factors internal to an organization lead to strengths and weaknesses and those external lead to opportunities and threats. However, since SWOT analysis only leads to qualitative results, researchers have used a combined SWOT-AHP method to obtain quantitative and relative gradings to the ascertained factors. It is seen that; such analysis has been done in multiple industries &geographies.However, no work could be located that classifies SWOT factors affecting Indian recycled P&P industry quantitatively. This research gap has led the present work.

Accordingly, the first aim of the present research is to identify SWOT factors that influence implementation of EEMs in recycled P&P industry in India. Secondly to obtain the relative importance of these factors using AHP both within each group and also globally.

The study was undertaken in two stages as per [13]. First was the analysis to determine SWOT factors. In second stage the relative importance of each factor (within its own category and globally) was calculated using AHP.

Stage 1 was accomplished by literature survey, secondary data and industry reports. Researchers have indicated factors that influence the implementation of EEMs in P&P industry[23]. In addition,listed p&p companiespublish their annual reportscontaining a section on EEMs and the management appreciation of business environment [70]. Using these resources, 4 most important factors under each of the SWOT groupswere identified. These were then submitted to a panel of experts to decide the inter se priority of each of the factors with reference to others in the same group.

The factor that was rated to be of highest importance within a group was also taken to be representative of that group for the purpose of deciding weightage of thatgroup and all its elements. For selecting the panel of industry experts, a list of 40 manufacturers in recycled P&P industrywas drawn up from data bases of Central Paper and pulp research institute (CPPRI), Indian Newsprint Manufacturers Association (INMA), Indian Paper and Pulp Technical association (IPPTA) and Indian Agro and Recycled Paper Mills Association (IARPMA). After ascertaining qualifications, availability and willingness, a panel of 36experts was shortlisted. The panel was requested to make pairwise comparison of factors within each group and allot them marking as per 9-point scale of [71].

The pairwise relationship and markings were analysed by means of a video conference call (VCC) employing brainstorming and nominal group technique. This enabled the panel to arrive at a consensus classification and marking for each of the factors.

**Table 3.2:** Research process

| Stage | Step | Technique | Output |
|---|---|---|---|
| 1. Identifying SWOT factors influencing the EEM in recycled paper industry in India | Literature review | Review of earlier research and reports available in open domain | 16 SWOT factors (4 under each group) identified. |
| 2. Applying AHP to classify the SWOT factors in order of their importance within each SWOT group and on overall basis. | 1. Survey of industry experts | Written responses, brain storming, nominal group technique. | Pairwise contextual relationship among the SWOT factors |
| | 2. Calculation of weightage of factors intra group and globally. | AHP | Hierarchy of SWOT factors in order of their importance. |

## 5. Methodology

The methodology adopted in the present work is a combined SWOT/AHP analysis similar to that used in [13]. The AHP is based on industry expert survey. Initially the status of P&P industry in India was examined using secondary data, published literature and reports. This study led us to the most important internal and external factors that influence the SEM decisions in Indian P&P industry. The internal factors enabled us to identify the strengths and weaknesses while the external factors led us to opportunities and threats. TheseSWOT factors assist in development of successful strategy [72]. However, SWOT analysis gives only qualitative results without allocating anyrelative/quantitative prioritization or weightage to the factors to be considered. This results in ambiguity for the corporate decision makers when they are selecting EEMs for implementation and allocating organizational resources. To resolve this, [13]have recommended an integrated AHP/SWOT analysis which was employed in the next step.

The expert panel weresent an online questionnaire regarding the identified SWOT factors. They could also indicate any additional factors that they considered more important. Theywere to indicate pairwise comparison of all factors within the same SWOT group both in a relative sense (which factor is more important?) and also quantitatively (how much more important?).The quantitative assessment was on the nine-step scale as per [71]. This scale ranges from 9:1 (factor a is much more important as compared to factor b) to 1:9 (factor b is much more important as compared to factor a). The scale has only odd numbers. The center of the scale is 1:1 implying equal weight status of both a and b. After regular follow up, we received 23 filled up questionnaires achieving a response rate of 63.89 %. Out of these 23 experts, 18 attended the VCC for brain-storming.

The logic of pairwise comparison is given by equation 1 below:

To understand the logic of pairwise comparison, let us assume that a respondent i is comparing the factors a and b and decides that factor a is more important than factor b , then the weightage of factor a with respect to factor b by the respondent i , denoted as $w(a)_i/w(b)_I$ will be any odd number between 3 and 9 as assigned by i. If factors a and b are considered to be of the same importance as factor b, the value $w(a)_i/w(b)_I$ will be equal to 1. If the factor a is judged to be less important relative to factor b, then the value $w(a)_i/w(b)_I$ will be the reciprocal value of the odd numbers between 3 and 9. Putting this mathematically

$$w(a)_i/w(b)_i = \begin{cases} a_i > b_i, \; w(a)_i/w(b)_I \in \{3/1, 5/1, 9/1\} \\ a_i \approx b_i, \; w(a)_i/w(b)_I = 1 \\ a_i < b_i, \; w(a)_i/w(b)_I \in \{1/3, 1/5, 1/7, 1/9\} \end{cases} \quad (1)$$

Then the average figure for results of all pairwise comparisons were calculated. The average scores were then normalized such that the less important factor always gets a score of unity. The more important factor would get proportionately changed to appropriate value between 1 to 9. The process for ascertaining the scores by summation of results of comparisons between factor a and factor b by all n respondents is given in equation 2 below:

$$w_a/w_b = \begin{cases} \sum_{i=1}^{n} w(a)_i > \sum_{i=1}^{n} w(b)_i, \; \frac{w_a}{w_b} = \frac{\sum_{i=1}^{n} w(a)_i}{\sum_{i=1}^{n} w(b)_i} \\ \sum_{i=1}^{n} w(a)_i = \sum_{i=1}^{n} w(b)_i, \; \frac{w_a}{w_b} = 1 \\ \sum_{i=1}^{n} w(a)_i < \sum_{i=1}^{n} w(b)_i, \; \frac{w_a}{w_b} = \left[\frac{\sum_{i=1}^{n} w(a)_i}{\sum_{i=1}^{n} w(b)_i}\right]^{-1} \end{cases} \quad (2)$$

It is to be noted that $w_b/w_a$ is the reciprocal value of $w_a/w_b$

$$w_b/w_a = \frac{1}{w_a/w_b} \quad (3)$$

These calculations lead to five judgment matrices. The elements of these matrices are obtained from the calculated values and their reciprocal values. Out of these five matrices, one matrix is for each SWOT factor groups and one matrix for the overall pairwise comparisons across the groups. Each of these matrices are [4X4] matrices for the respective four factors a,b,c,d.

$$A = \begin{bmatrix} 1 & \cdots & w_a/w_d \\ \vdots & \ddots & \vdots \\ \frac{1}{w_a/w_d} & \cdots & 1 \end{bmatrix} \quad (4)$$

To obtain the relative priorities of the factors, eigen value method is applied. It is the scalar quantity λ linked to the eigen vector v. The eigenvector of a square matrix A is a vector v suchthat:

$$A \times v = \lambda v \quad (5)$$

In a realistic case the matrix A might contain inconsistencies. In such a scenario the priorities can be obtained by using the matrix A as input in the equation (6) as indicated below:

$$(A - \lambda_{max} I)\, v = 0 \quad (6)$$

In equation (6),$\lambda_{max}$ is the principal eigen value of matrix A, v is the correct eigen factor; and I is the identity matrix. To obtain the principal eigenvalue, each column of the judgement matrix is summed, multiplying the sums by their corresponding eigen factor, and adding up the products (as per eigenvalue method described by [71]. For calculating the eigenvector v, which indicates an estimate of the relative weightage of each factor, the judgement matrices are squared, the sums of each row are calculated and then normalized to get the principal eigenvectors of the matrices. This procedure is to be repeated until the calculated eigenvectors of each matrix result in nearly identical value. In this work, the first iteration itself sufficed to arrive at a maximum difference with an absolute value smaller than 0.001.

The next step involves calculation of the consistency index (CI) and consistency ratio (CR) for each judgement matrix as per equations (7) and (8) below:

$$CI = (\lambda_{max} - n)/(n - 1) \quad (7)$$

$$CR = 100(CI/ACI) \quad (8)$$

Here, n is the number of factors (same as the number of columns and rows of the matrix) and $\lambda_{max}$ is the principal eigenvalue. For calculating $\lambda_{max}$ each column of the judgement matrix is added, the sum so obtained is multiplied by its corresponding eigenvector and then the products are added up [71]. To obtain index values that are independent of matrix size, the CI values will need to be converted into CR values. This is done by using the average consistency index (ACI) of randomly generated comparisons. As per [73] theACI for a 4-order judgement matrix with the scale as described earlier is 0.89. They have also indicated a rule of thumb that the value of CR should be 10 percent or less. Higher values would be indicative of inconsistent judgement and hence may need to be reviewed.

[74] have indicated methodology for calculation of overall weighting factors (global priorities). For this the weighting factor of each factor within a SWOT group (localpriority) is multiplied by the value of the corresponding weighting factor for the whole SWOT group. The sum of all overall weighting factors is one.

## 6. Results and discussion

As per the process discussed in section 5, the most relevant SWOT factors for the P&P industry in India were selected. The same are listed at **Table 6.1**. These factors have been discussed in section 6.1. The same have been analyzed quantitatively as per the expert's opinion in section 6.2 thereafter.

**Table6.1. Summary of strengths, weaknesses, opportunities and threats as regards strategic energy management in the paper and pulp industry in India**

| | Positive | Negative |
|---|---|---|
| Internal | **Strengths** | **Weaknesses** |
| | $S_a$: Management support | $W_a$: Lack of economies of scale |
| | $S_b$: Capital availability | $W_b$: Sourcing of Energy |
| | $S_c$: Qualified Human Resource | $W_c$: Waste heat recovery |
| | Sd: R&D facilities and innovation culture | $W_d$: Production inefficiencies |
| External | **Opportunities** | **Threats** |
| | Oa: Emerging technologies | Ta : High energy costs |
| | Ob: Sectoral policies | Tb: Scarcity of coal |
| | Oc: Collection of waste paper | Tc: Competition |
| | Od: Renewable energy | Td: Environmental policies & Community pressure |

*6.1. SWOT Factors*

Indian recycled P&P industry is benefitted by identified strengths ($s_a$- $s_d$). It was seen that the managements of the mills were supportive of the need and benefits of EE in their plants. Especially those plants that have professional managements in place as opposed to family owned businesses were seen to be taking active interest in this aspect. ($S_a$ – Management support).
The well run and profitable plants management were also seen to be making the requisite capital available for modernization to install state of the art energy efficient equipment ($S_b$ – Capital availability)
With excellent training and educational establishments being available in the country, manufacturing industries being encouraged and the economy of the country on the growth path, there is adequate availability of high-quality trained manpower for execution of mill development projects and also for O&M of new technology equipment after installation. ($S_c$: Qualified Human Resource)

The Indian P&P industry has good Research and Development (R&D) facilities and innovation culture that encourages regular upgradation of production processes and operation practices to ensure energy efficient exploitation. ($S_d$: R&D facilities and innovation culture)

Now coming to the identified weaknesses that need to be overcome towards enhancing EE, it is seen that the P&P industry is highly fragmented. There are over 715 mills with the capacity varying from 660 to250000 tons per Annum (TPA)[68] This does not allow them the leverage of economies of scale ($W_a$: Lack of economies of scale)

The sourcing of energy in Indian conditions is mostly state owned and monopolistic both for the grid power and for coal (required for captive power plants) ($W_b$: Sourcing of Energy)

The plant designs are such that there is excess heat generated as compared to that required for the production process and for drying. This results in loss of a significant quantity of flue gases and results in poor EE to that extent. ($W_c$: Waste heat recovery).

On account of various inefficiencies, such as old machinery, old technology, breakdowns, excessive turnaround time when changing over the product line from one grade of paper to another etc. results in sub optimal capacity utilization. Since the fixed costs remain the same, any shortfall in the capacity utilization affects the performance of the plant adversely. ($W_d$: Production inefficiencies)

Coming to the opportunities for better EE, the first one is in terms of the emerging technologies. These could be both cross cutting technologies such as those related to motors or to heat recovery technologies [34] and P&P industry specific such as those detailed by [32]and [33].. The progressive and forward-looking segment of the paper industry can achieve better EE and corresponding better economic performance if they implement these new and emerging technologies. ($O_a$: Emerging technologies)

As paper industry is one of the major energy intensive industries and also one of the highly polluting industry, it has always been on the radar of the policymakers, regulators, and various government authorities for various policy led schemes and mandates. These include a mix of regulatory and price-based incentives such as Perform Achieve and Trade (PAT) Scheme and ESCERTS [75],[76]). ($O_b$:

Sectoral policies). Electricity conservation act 2001, resulted in mandatory reports and monitoring of energy use in energy intensive industries including P&P industry to curtail energy crisis in the country. This,in turn resulted in reduction in energy consumption in P&P mills through production process improvements by use of Energy Efficiency technologies (EETs).[77].

For the recycled fiber-based segment availability of waste paper is a major issue since collection efficiency of the same has been historically sub optimal compared to international bench marks. However, with better environmental awareness and actions taken by different organizations this collection has been improving, resulting in better raw material availability. ($O_c$: Collection of waste paper) India also is one of the fastest growing paper market growing @ 6.3 % CAGR as per[65].

Fortunately, the geographic location of India has bestowed upon it, abundance of sunlight in most of the areas where the paper mills are located. With the concentrated solar energytechnologies availability improving, there is opportunity for the industry to utilize these technologies for process heat as well as drying requirements and to realize economic gains. In areas where wind, tidal or any other form of renewable energy is available, the mills can explore them also. Availability of SCT technologies and subsidies also are supportive in this direction. ($O_d$: Renewable energy)

Coming to the potential threats, the higher costs of energy affects the economies of this industry. Prices of coal and electricity have historically been going up. ($T_a$: High energy costs). As per [68]and [78] high energy costs present both business environment risk and also business development risk. As per [76] high or potentially high energy prices would be incentive for better EE. The energy price rise leads to technology improvement in the industry and declining EI. Rising prices have historically also led to installation of captive cogeneration plants. [77]

In Indian conditions, most of the thermal power is from coal based thermal plants. Further, Coal India and its subsidiaries have near monopoly as far as industrial requirement of coal goes. They do have an alternative of import but in most cases that would turn out costlier on account of transportation costs and foreign exchange fluctuations. ($T_b$: Scarcity of coal)

International competition in this industry is intense. In general, the foreign producers have got mills that are many times bigger in comparison and hence are able to achieve very high economies of scale. (Tc: Competition) The low competitive prices of finished product are a major incentive for better EE to reduce energy costs [76]

Ever tightening environmental policies, regulatory requirements as regards pollution, environmental audit reports, mandatory disclosures at stock exchanges etc. create a pressure on the company management to be seen as environment friendly and also affects the organizations' brand value. ($T_d$: Environmental policies & Community pressure). [79] talks about policy led creation of environment policy, community pressure and capital market disclosures (both by the company and the regulator). They have also discussed the effect of pollution levy and emissions tradingin this direction. [80] have brought out as to how the stock markets reward or penalize environmental ratings of companies.

*6.2. AHP analysis*

By its inherent characteristic the SWOT analysis indicates the factors to be considered under each category without bringing out their relative importance as compared to other factors in the same category. It also does not provide the importance that needs to be accorded to each of the categories as compared to other categories. Therefore, an AHP analysis was attempted on the factors and categories that resulted from the SWOT analysis presented earlier. This enabled us to allot an inter se priority to each of the categories and to the factors within each category as perceived by the decision makers in the P&P industry. The methodology for calculations under AHP is indicated in [82]. Sample calculations are indicated in Table 6.2.

**Table 6.2: Sample calculations**

| Strengths | Sa | Sb | Sc | Sd | Product of values | nth root of product of values | eigen vector (ev) |
|---|---|---|---|---|---|---|---|
| Column | [1] | [2] | [3] | [4] | [5]=1*2*3*4 | [6]= $\sqrt[4]{[5]}$ | [7]=[6]/∑[6] |
| **Sa** | 1 | 3 | 5 | 9 | 135.00000 | 3.4087 | 0.55741 |
| **Sb** | 1/3 | 1 | 5 | 7 | 11.66667 | 1.8482 | 0.30223 |
| **Sc** | 1/5 | 1/5 | 1 | 3 | 0.12000 | 0.5886 | 0.09625 |
| **Sd** | 1/9 | 1/7 | 1/3 | 1 | 0.00529 | 0.2697 | 0.0441 |
| **sum** | 1.6444 | 4.3429 | 11.3333 | 20.0000 | | ∑[6]=6.1152 | 1 |
| **sum*ev** | 0.917 | 1.313 | 1.091 | 0.882 | Lambdamax = ∑sum*ev | | =4.202 |
| **CI** | Consistency index | | | =(Lambda max -n)/(n-1) | | **=0.202/3** | =0.067 |
| **CR** | Consistency Ratio | =CI/ Random Index (RI) | | | | =0.067/ 0.9 | =0.074 |
| Random Index (RI) for n= 4 is 0.9 as per the table of random indices [82] | | | | | | | |
| **Since CR <= 0.1 Hence the pairwise comparisons are consistent. No corrective action is necessary.** | | | | | | | |

Similar calculations for the other SWOT groups, that is Weaknesses, Opportunities and Threats lead to group priorities as shown in table 6.3 below. For determining the overall priorities, the top priority factor from each group is taken to represent the group and weightage of each group is calculated exactly as per table 6.2. This weightage when multiplied to each of the factors results in their overall priority as shown in Table 6.3. This table indicates the results of combined SWOT -AHP analysis. The SWOT factors arranged in the order of priority are presented in table 6.4. The results are presented graphically in Fig. 6.1. The SWOT factors appear on the straight lines in their respective SWOT sectors. The relative importance of the factor is determined by the length of the line representing it. The longer distance from the origin implies higher importance.

**Table 6.3: SWOT factors with group priority and overall priority**

| | SWOT Factors | Group priority | Group rank | Group weightage | Overall priority | Overall Rank |
|---|---|---|---|---|---|---|
| Column Number | [1] | [2] | [3] | [4] | [5] | [6] |
| Strengths | $S_a$: Management support | 0.55741 | 1 | 0.2634 | 0.1468 | 3 |
| | $S_b$: Capital availability | 0.30223 | 2 | 0.2634 | 0.0796 | 4 |
| | $S_c$: Qualified Human Resource | 0.09625 | 3 | 0.2634 | 0.0254 | 9 |
| | $S_d$: R&D facilities and innovation culture | 0.0441 | 4 | 0.2634 | 0.0116 | 12 |
| Weaknesses | $W_a$: Lack of economies of scale | 0.11778 | 3 | 0.0550 | 0.0065 | 14 |
| | $W_b$: Sourcing of Energy | 0.05502 | 4 | 0.0550 | 0.0030 | 16 |
| | $W_C$: Waste heat recovery | 0.26337 | 2 | 0.0550 | 0.0145 | 11 |
| | $W_d$: Production inefficiencies | 0.56382 | 1 | 0.0550 | 0.0310 | 8 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Opportunities | $O_a$: Emerging technologies | 0.58238 | 1 | 0.1178 | 0.0686 | 6 |
| | $O_b$: Sectoral policies | 0.08497 | 3 | 0.1178 | 0.0100 | 13 |
| | $O_c$: Collection of waste paper | 0.04241 | 4 | 0.1178 | 0.0050 | 15 |
| | $O_d$: Renewable energy | 0.29025 | 2 | 0.1178 | 0.0342 | 7 |
| Threats | $T_a$ : High energy costs | 0.56506 | 1 | 0.5638 | 0.3186 | 1 |
| | $T_b$: Scarcity of coal | 0.03928 | 4 | 0.5638 | 0.0221 | 10 |
| | $T_c$: Competition | 0.26968 | 2 | 0.5638 | 0.1521 | 2 |
| | $T_d$: Environmental policies & Community pressure | 0.12597 | 3 | 0.5638 | 0.0710 | 5 |

**Table 6.4: Overall priority in descending order**

| Factor | Group priority | Group weightage | Overall Priority | Overall Rank |
|---|---|---|---|---|
| Column Number | [1] | [2] | [3]=[1]*[2] | [4] |
| $T_a$ : High energy costs | 0.5651 | 0.5638 | 0.3186 | (1) |
| $T_c$: Competition | 0.2697 | 0.5638 | 0.1521 | (2) |
| $S_a$: Management support | 0.5574 | 0.2634 | 0.1468 | (3) |
| $S_b$: Capital availability | 0.3022 | 0.2634 | 0.0796 | (4) |
| $T_d$: Environmental policies & Community pressure | 0.1260 | 0.5638 | 0.0710 | (5) |
| $O_a$: Emerging technologies | 0.5824 | 0.1178 | 0.0686 | (6) |
| $O_d$: Renewable energy | 0.2902 | 0.1178 | 0.0342 | (7) |
| $W_d$: Production inefficiencies | 0.5638 | 0.0550 | 0.0310 | (8) |
| $S_c$: Qualified Human Resource | 0.0963 | 0.2634 | 0.0254 | (9) |
| $T_b$: Scarcity of coal | 0.0393 | 0.5638 | 0.0221 | (10) |
| $W_C$: Waste heat recovery | 0.2634 | 0.0550 | 0.0145 | (11) |
| Sd: R&D facilities and innovation culture | 0.0441 | 0.2634 | 0.0116 | (12) |
| $O_b$: Sectoral policies | 0.0850 | 0.1178 | 0.0100 | (13) |
| $W_a$: Lack of economies of scale | 0.1178 | 0.0550 | 0.0065 | (14) |
| $O_c$: Collection of waste paper | 0.0424 | 0.1178 | 0.0050 | (15) |
| $W_b$: Sourcing of Energy | 0.0550 | 0.0550 | 0.0030 | (16) |

It is seen that High energy costs emerges as the most important factor by the analysis. This appears logical since the energy cost has continuously been rising and this uptrend is expected to continue. Being an energy intensive industry, since the energy cost comprises a significant proportion of the overall cost of the paper industry, every rise in energy prices affects the profits of the company. [81].

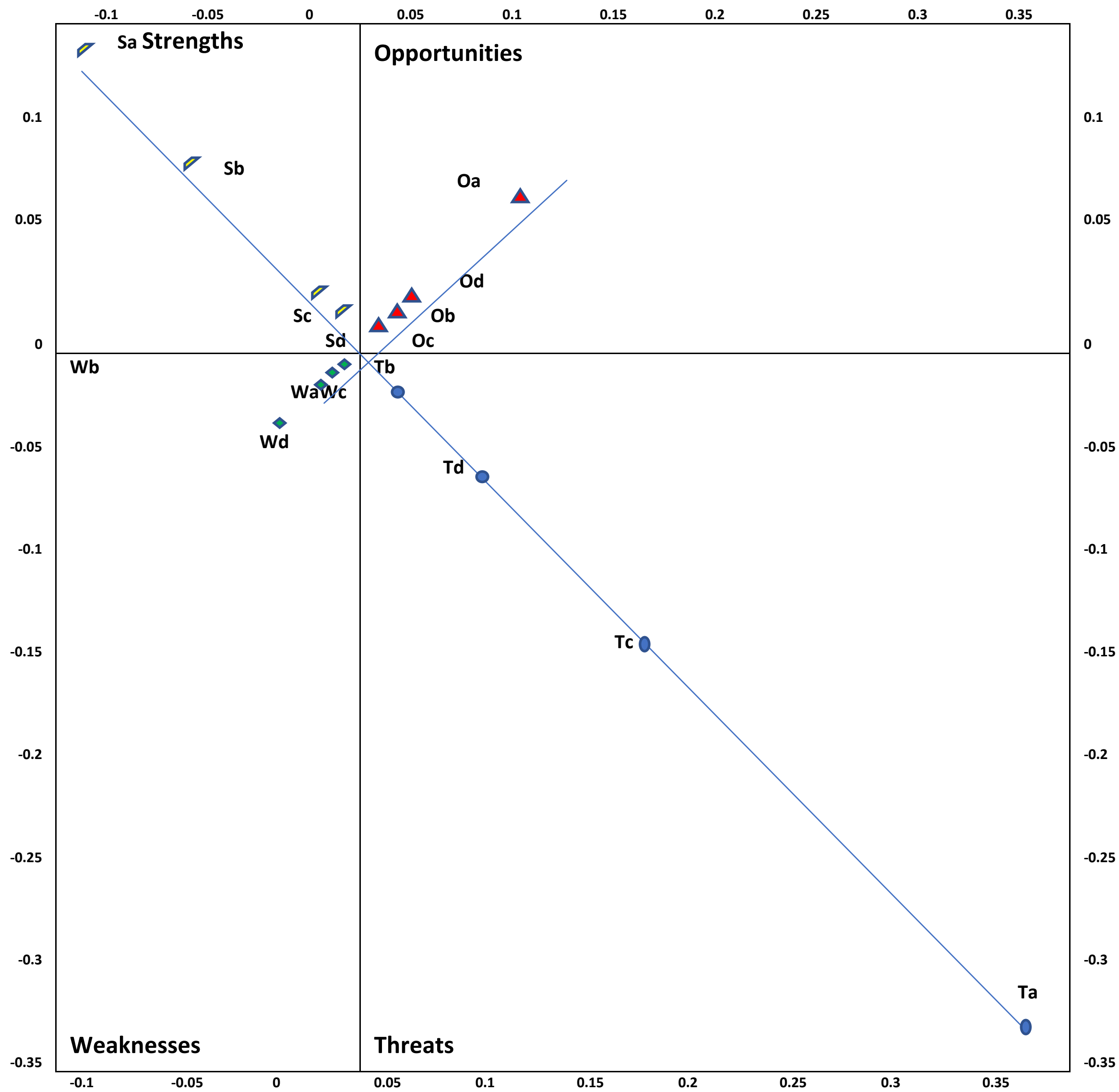


**Fig 6.1: Overall SWOT factor weightages**

Second in the overall order of importance is competition. This being a very competitive industry, every participant strives to perform better than the competition. The cost of production per ton of paper is the parameter that all managements monitor. This factor also incentivizes companies to implement EEMs as a way of cost reduction.

The third most important factor that decides the quantum of EEMs implementation is management support. The management support singularly affects the organizational resources, priority and funding that is made available towards achieving better EE.

The fourth important factor that emerged in this study is capital availability. Out of the perpetually scarce budget provisions, that are available for modernization or capital investment, what proportion can be spared for EE enhancement. This factor also has a close linkage with the previous factor of management support. If the top management feels strongly about energy efficiency, a larger budget is likely to be allocated for the same.

The fifth factor in the order of importance is the threat of environmental policies and community pressure. The governmental policies, that are in support of environmental protection and therefore favoring EE,act to work in two ways. They can be in the nature of incentives such as subsidies for adoption of renewable energy sources orPAT scheme by the Bureau of Energy Efficiency (BEE). On the other extreme there can be penalties such as energy taxes or compulsion to buy energy certificates for extra carbon foot prints [75]. Community pressure from environmental groups and social media acts as incentive since environment friendly image is important for the companies. It affects their brand image and stock prices. Increasingly stricter environmental disclosures and EE performance are being mandated by the authorities.

Opportunities by way of emerging technologies at affordable costs and renewable energy are at 6$^{th}$ and 7$^{th}$ priorities.
The first weakness finds its place only at 8$^{th}$ place and that is production inefficiencies leading tolow capacity utilization. There is, perhaps, a natural reluctance from the experts to highlight weakness in their own organization.

Thus, in the top half of prioritization, most factors are economic in nature having a direct bearing on the profits. They are also incidentally supportive of EE.
Having qualified, trained and motivated human resource is essential for implementation,O & M of new technology projects, but that does not seem to be important for decision making as it has emerged at priority 9.
Scarcity of coal appears at priority 10 and not a major decision variable since it affects all the manufacturers equally.
Weakness in terms of waste heat recovery has been rated at priority 11. By the nature of process of paper-making, additional waste heat recovery beyond the existing provisions becomes less viable and hence mostly not attempted.
R&D facilities and innovation culture is rated at priority 12. Most units use these facilities for quality-control activities and for product design for various grades of paper. For EE related research, they mostly depend on external agencies.

Government Sectoral policies have been rated at priority 13 and do not affect the EE decisions much. Mandatory provisions are implemented being unavoidable.

Lack of economies of scale has been rated at rank 14. Majority of plants do suffer due to their small size that is linked to lack of capital. These companies have low priority for EE.

Better collection of waste paper should be supportive of EE but has been rated low at priority 15 since the mills largely depend on external suppliers of waste paper and to a small extent on imported paper.
Sourcing of energy is rated at the lowest priority of 16$^{th}$being an uncontrolled variable and equally affecting all manufacturers.

While comparing the overall SWOT groups, threats emerge to be the overall most important group.Second priority are strengths. This is in agreement with the findings of[13].Experts consider that, the internal strengths are to beemployed against the external threats to achieve the objectives better EE. Three of the four weaknesses falling in the lower half of the priority list also supports this finding. One of the likely sources of error in the present research is the possible reluctance of the experts to accept the weaknesses in their organizations as of importance.

## 7. Conclusions

The SWOT-AHP analysis has afforded an insight to the factors influencing EE in Indian P&P Industryin a structured and quantified manner. It emerges that managements have a focused approach on profitability. The top two factors,that is high energy cost and competition directly have economic implications. The next factor, that is management support depends on the personal preferences of the CEO and the Board of Directors. If they are supportive, the EE initiatives have a better chance of getting implemented. Making capital available forEEMs again depends upon the top management and thus factors three and four are linked. Environmental policies of government are mandatory and hence get implemented by force. Community pressure, especiallyfrom social media, affects the brand image and hence has commercial implications. Use of emerging technologies and renewable energy for achieving better EE also seem to be implemented only when they are leading to better profitability and have shorter payback periods. Production inefficiencies leading to suboptimal capacity utilization and availability of qualified human resource though important,are seen to have a limited impact on decision making regarding implementation of EEMs.Scarcity of energy sources, mainly coal in case of Indian Paper industry, is accepted as a universal constraint and worked around by importing coal if required. There has been upgradation of old design coal fired boilers to higher EE Atmospheric Fluidized Bed Combustion (AFBC)boilers, but such upgradations have been for reasons of better energy efficiency and not linked to coal shortage. Waste heat recovery has already been deployed in most of the mills to some extent. The balance potential for residual waste heat recovery does not appear to be adequately cost effective and hence was assessed lower down in the priority list. Availability of R & D facilities and innovation culture is mostly restricted to paper manufacturing issues (process control for quality and variety of products) rather than EE improvement in plant and machinery. Sectoral policies for P&P industry are mandatory and as such the industry follows the directives. But beyond the mandates, these do not provide much incentive or motivation for adoption of EEMs. Lack of economies of scale are on account of limitation of funding in the 2$^{nd}$ and 3$^{rd}$ level companies. This group of companies are not in a position to spare financial and other resources specifically for EEMs and hence this factor is not considered very important towards enhancing energy efficiency. At the national level there is significant scope for better collection of waste paper. However, since the supply chain of waste paper is a separate industry in itself, it does-not impacts the EE implementation in paper industry to any significant level. For the Indian P&P industry the sourcing of energy is mostly state controlled (both electricity and coal) and hence has been assessed as the least important factor by the experts. In comparison of the overall SWOT groups, external threats emerge to be the most important SWOT group followed by internal strengths. These are followed by opportunities and weaknesses at 3$^{rd}$ and 4$^{th}$ priorities overall.

This research project has thus identified SWOT factors and prioritized them mathematically. The findings can therefore be used by decision makers in P&P industry to address the appropriate SWOT factors to achieve optimum level of EE for their plant and machinery.

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