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Barriers to Energy Efficiency Measures in Recycled Paper and Pulp Industry in India: An Interpretive Structural Modelling- Based Framework

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ABSTRACT: Paper and pulp industry is one of the top six energy intensive industriesin India. Even then available energy efficiency measuresface certain barriers to their implementation in paper and pulp industry. This study examines barriers to energy efficiency in the context ofrecycled fibre-based Paper and Pulp industry in India. The objective of this study is to pinpoint the barriers that are significantly important using interpretive structural modelling and develop a hierarchy to investigate the contextual relationship among these barriers. Results of this study show that Poor Information Quality regarding Energy Conservation Measures and Technical Risks emerge as the most important barriers that would drive all other barriers. The study has also performed "cross impact matrix multiplication applied to a classification" (MICMAC) analysis of the barriers to classify them based on the dispersal of their driving power and dependence power. It brings out Poor Information Quality regarding Energy Conservation Measures, Uncertainty about future energy prices and fiscal policies, Uncertainties regarding hidden costs and Technical risks as independent barriers having strong driving power but weak dependence power. Addressing these barriers would be the key to success for implementation of energy efficiency measures by any organization.

Key words – Energy efficiency, Interpretive structural modelling, Paper and pulp industry,Barriers, MICMAC analysis

1. **Introduction**

Paper and pulp industry is one of the top six energy intensive industriesin India[1].Typically, around 30 % of the input cost in this industry is towards Energy. Therefore, betterenergy efficiency (EE)would help in making this industry more competitive and environment friendly. However, certain Energy efficiency measures (EEMs) and Energy efficiency technologies (EETs) are not implemented because of certain barriers. [2-4]. This study attempts to identify the barriers relevant for Indian recycled fibre-based paper industry and to prioritize them in a structured way considering their interrelationships.

A literature survey was undertaken to identify the known barriers. Of these, 15 barriers were shortlisted with the help of expert opinion as most relevant. Contextual relationship amongst these barriers was established using interpretive structural modelling (ISM). Thereafter impact matrix cross reference multiplication applied to a classification (MICMAC) analysis is performed to classify the barriers based on their driving power and dependence power that brings out their effect of other barriers. The ISM technique in conjunction with MICMAC analysis separates the dominating barriers that need to be addressed by the industries. This soft computing technique integrates the experience and knowledge of industry experts with the mathematical and modelling theory to determine causative relationships among variables of a complex system. Anumber of researchers have utilized this technique. [5]have listed the recent contributions using ISM technique in Indian context.

This paper is structured as follows: After a brief introduction in section 1, Section 2 reviews the literature in the area of barriers to EE. Section 3 presents the research design. Section 4 generates the hierarchical model using the ISM technique. Section 5 details the MICMAC analysis and classifies the barriers based on their driving power and dependence power. Sections 6 and 7 bring out summary results and discuss the potential applications of the same.

2. Literature Review.

Existence of barriers to Energy Efficiency (EEBs) , resulting in non-implementation of many EEMs, even though they are theoretically profitable has been researched by many [3] ,[6-**10**]. Sorrel divided these barriers into six classes: risk, imperfect information, hidden costs, access to capital, split incentives and bounded rationality. Another categorization added three categories viz Economic, Organizational and Behavioral barriers. Combining these classes and categories and extending this thought process,[6] presented a taxonomy that became the foundation of work by many of the future researchers. This taxonomy further divides the economic category into market and non-market failures. It also includes additional classes under each category namely heterogeneity (under the economic non-market category); adverse selection and principal - agent relationships (economic market); form of information, credibility and trust, inertia and values (behavioral) and lastly power and culture (**organizational** barriers). Depending on the technology, sectors and region, the effect and nature of these barriers may vary. This important work known as Sorrels taxonomy is summarized at table 2.1.

Table 2.1. Barriers to Energy efficiency: The Sorelltaxonomy (Adopted from [6]

Theoretical framework	Theoretical barrier	Comment
Economic non-market failure	Heterogeneity	A technology or measure may be cost-efficient in general, but not in all cases.
	Hidden costs	Examples of hidden costs are overhead costs, cost of collecting and analysing information, production disruptions, inconvenience, etc.
	Access to capital	Limited access to capital may prevent energy efficiency measures from being implemented.
	Risk	Risk aversion may be the reason why energy efficiency measures are constrained by short payback criteria.
Economic market failure.	Imperfect Information	Lack of information may lead to cost-effective energy efficiency opportunities being missed.
	Split incentives	If a person or department cannot gain from energy efficiency investments it is likely that implementation will be of less interest.
	Adverse selection	If suppliers know more about the energy performance of goods than purchasers, the purchasers may select goods on the basis of visible aspects such as price.
	Principal-agent relationships	Strict monitoring and control by the principal, since he or she cannot see that what the agent is doing, may result in energy efficiency measures being ignored.
Behavioural	Bounded rationality	Instead of being based on perfect information, decisions are made by rule of thumb.
	Form of information	Research has shown that the form of information is critical. Information should be specific, vivid, simple, and personal to increase its chances of being accepted.
	Credibility and trust	The information source should be credible and trustworthy in order to successfully deliver information regarding energy efficiency measures. If these factors are lacking this will result in inefficient choices.
	Inertia	Individuals who are opponents to change within an organization may result in overlooking energy efficiency measures that are cost-efficient.

	Values	Efficiency improvements are most likely to be successful if there are individuals with real ambition, preferably represented by a key individual within the top management.
Organizational	Power	Low status of energy management may lead to lower priority of energy issues within organizations.
	Culture	Organizations may encourage energy efficiency investments by developing a culture characterized by environmental values.

[4]added to Sorrel's taxonomy by including origin of the barrier in relation to the organization (internal or external). They also give importance to the actor or area that is affected by the barrier (such as, market, government/politics, behavioural, economic). Their taxonomyis shown in Table 2.2 below.

Table 2.2:The New taxonomy (Adopted from [4])

Origin	**Actor/ Area**	**Barriers**
External	Market	Energy prices distortion
		Low diffusion of technologies
		Low diffusion of information
		Market risks
		Difficulty in Gathering External Skills
	Government/ Politics	Lack of proper regulation
		Distortion in fiscal policies
	Technology/ services suppliers	Lack of interest in energy efficiency
		Technology Suppliers not updated
		Scarce communication skills
	Designers and manufacturers	Technical Characteristics not adequate
		High initial costs
	Energy suppliers	Scarce communication skills
		Distortion in energy policies
		Lack of interest in energy efficiency
	Capital suppliers	Cost for investing capital availability
		Difficulty in identifying the quality of the investments
Internal	Economic	Low capital availability
		Hidden costs
		Intervention-related risks
	Behavioral	Lack of interest in energy efficiency interventions
		Other priorities
		Inertia
		Imperfect evaluation criteria
		Lack of sharing the objectives
	Organizational	Low status of energy efficiency
		Divergent interests
		Complex decision chain
		Lack of time
		Lack of internal control
	Barriers related to competences	Identifying the inefficiencies
		Implementing the interventions
	Awareness	Lack of awareness or Ignorance

At times a factor may act as drivers and at other times as barrier and these terminology may overlap. Hence,[11] used a unified term diffusion factors to indicate both drivers and barriers.

Ref [4]in the new taxonomy brought in a major change in the way the barriers are addressed by their classification into external and internal barriers. The barriers pertaining to external environment (comprising of market participants, Government agencies, political forces, technology and service suppliers, designers and manufacturers of equipment and systems, suppliers of energy and financiers) are essentially uncontrolled variables. The industry has no direct control on them and hence they need to be managed, complied with or adjusted to. On the other hand, the internal barriers that pertain to the inside of the industry, such as on account of economic factors, behavioral characteristics of the management and employees, organizational structure and its peculiarities, competences available inhouse and the awareness regarding energy efficiency issues are amenable to change management initiatives. They can therefore be regarded as controlled variables. The management can therefore pay more attention towards addressing and mitigating them. Subsequent paragraphs discuss these barriers.

A multitude of market forces continuously affect the techno- commercial decisions by companies that may act as barrier and obstruct implementation of Energy efficiency supporting actions. The energy prices variation amounting to different generation costs during the day may acts as a barrier [12]. In most economies the official pricing policies result in lower energy rates for higher energy used by industries[13].At many places, the energy rates are kept low on policy or legislation mandates[14]. Liberalization and mandated price structures have often worked at cross purposes and reduced the incentive for manufacturing industries to invest in EEMs[15-19]. Innovative character of new EETs often leads to their low diffusion[20].Incomplete or delayed information about energy performance, potential savings, execution methodology, valuation, definition of any EET may act as a barrier[21]. Energy audits by qualified professionals is one of the ways to overcome this barrier.Ref [12] indicated market risks resulting in uncertainties regarding future energy prices as another barrier. Ref [22] brought out barrier on account of difficulty in gathering external skills. The availability of experts in this area is limited and their charges often on the higher side. EETs fall under the category of credence goods (where consumers have difficulties to ascertain the quality/effectiveness prior to purchase) and hence vulnerable to adverse selection. Purchasers might be reluctant to pay the premium for high-efficiencyproducts[64].

Governments exercise significant influence as controller/influencer of fiscal/monetary/regulatory and environmental policies and procedureson the implementation of EEMs. The bureaucratic procedures for financial support often act as a barrier[67]. Lack of proper regulation and lack of standards for energy performance for new equipment might represent a barrier[75]. Distortion in fiscal policies and resulting taxes,subsidies or policy interventions affect the market driven costs and often act as barrier[12],[48].

The technology or services suppliers may be reluctant to promote high EETs if they get better returns from lower EETs[47].If the marketing staff of manufacturers/ service providers themselves are not well trained and lack communication skills to convey the performance potential of new technologies, they would be ill equipped to incentivize potential customers [12].

Designers andmanufacturers are another set of stakeholders. If the technical characteristics of EETs are perceived by the customers as inadequate on some count, they may not get adopted [44].High initial costs of new EETs including design and manufacturing costs also act as a barrier [45-46].

Lack of communicationskills in energy suppliers resulting in unclear/ambiguous presentation regarding options in energy contracts will deter the customers.Energy prices distortion caused by variable pricing during the day might act as disincentive for user to invest in EETs[6].Energy suppliers may lack interest in EE and hence be reluctant to promote EETs since lower energy use will mean lower returns for them[46].

Capitalsuppliers have their role as investors for EETs.The costs to evaluate debt carrying capability and to service a large number of small and medium-sized projects act as barriers for investors[59].Difficulty to identify the quality of investments may further act as a barrier. New and innovative EETs often do not get selected in comparison to well-known solutions during evaluation by capital suppliers[48].

Every function within an organization has its own characteristic, competence and behavior. Some of these result in creation of internal barriers. Economic barriers are most prominent among these and have been topic of study by many researchers. These include low capital availability [67], inadequacy of capital to invest or its availability at rates much above the average rate of return (ROR)[22]. Access to capital has emerged as another important barrier. Multiple case studies by [19], [23-26]have indicated various limits of payback period for a specific EEM to be acceptable to the investment decision makers. The range varies from 0.9 to 4 years depending on the country, time horizon, type, size, sector and subsector of industry.

An EEM may in reality be unviable economically on account of hidden costs involved in its implementation. Various categories of hiddencostsinclude general overheads for energy-management,costs specific to a technology investmentandloss of benefits associated with an efficienttechnology.Another classification is based on project stage that is Pre interventions, those during implementation and post intervention. Pre-intervention costs include costs towards research of energy inefficiencies and opportunities, energy audits, preliminaryevaluationoftheinvestment,evaluation of debt carrying capability,time and efforts from decision makers and implementors, information on EETs and training.Costs during implementation include cost of plant modifications and those due to production disruptions/hassle/inconvenience. A stop in the continuous paper production process entails losses. Post-intervention costs include those required for training and also towards development of new maintenance practices[27-29]. Risk associated with implementation of new technologies can be under three categories: (i) External Risk, (ii) Business Risk, and (iii) Technical Risk. Risk aversion by decision makers results in requirement of high ROR for acceptance of any EEM[30-35].

Enterprises often rationally discard investments with a ROR lower than their internal ROR. Hence anintervention not being sufficiently profitable may act as a barrier[36].

The phenomenon of heterogeneity implies that even if a technology is cost-effective on average for a class of users, some firms may find the new level of efficiency not cost-effective on account of certain specific parameters of production [25][36].

One important set of barriers emerges from behavioral traits of humanbeings. There may be lackofinterestinenergyefficiency due to a perception that energy issues are not important, say due to production process not being energy intensive or the firm perceives itself as already efficient[37].

Primacy of other priorities over EE may act as a barrier. EE projects may not be adopted if they do not have a strong link to the strategic vision or core activity of the organization. Decision-makers might be focused on few core business activities[6], [22]; [38-40].

Inertia as a barrier represents the resistance to change and risk. It can result in preferring interventions with quick and low investments and returns, thus slightly modifying the production system. Human beings are naturally averse to change and risk. This tendency results in the decision makers not considering EEMs thatcall for change from the accepted norms or in the habits of the end user. Lack of transparency and difficult to understand calculations may also lead to inertia[41].

Imperfect evaluation criteriais another barrier. The decision-makers might lack proper knowledge or criteria for evaluation. At times they might adopt criteriasuch as ROR, without any relationship with the uncertainty associated to the consideredalternatives[42-43].

Lack of sharing the objectives may result in misalignment between the behavior of personnel and energy management targets. This might result in low implementationof energy management practice[49].

The phenomenon of bounded rationality means that the organizations and individuals, usually do not consider the complete information but instead make decisions by intuition or hunch, resulting in avoidance of some of the worthy EEMs[50].

Form of information may also act as a barrier. The decision makers may rely on information that comes from a known person and if presented in a vivid, personalized and specificmanner [6].Reliability, credibility and trustworthiness of the information provider may be more important as compared to mere profitability of the investmentproposalfor its acceptance[41].

Organizational values are an important deciding factor towards acceptance of an EEM for implementation[6].

Another set of barriers arises out of interaction of roles within an organization and contextual factors such as energy culture, power relationships, managers' interest, and the characteristics of the investment itself having a bearing on acceptance of an EEM. [51-52].The status of EE is an important factor. The functionaries responsible for EE not having sufficient power acts as a barrier[53]. Phenomenon of split incentives inhibits implementation of EEMs. It means that the benefits of EEMs may not accrue to the entity implementingit.Suchas when departments are not accountable for energy consumed and there is no sub metering[54]. Complex decision chain within organization acts as a barrier. If thedecision-makingprocess involves several functions, the information flow might not be straight and smooth[55].The decision makers may not have enough time for EE. [56]Improper/ inadequate implementation may be a consequence of lack of internal control and monitoring systems[6]."Principal agent relationship"is another barrier. Here a lack of trust between owner and the management of a company may result in the owner selecting an investment with higher ROR over an EEI that may be more economical in long term[42].The organizational culture also plays an important role. An organization may encourage EEIs by developing a culturethat promotes environmentalawareness[6].

Another set of barriers relate to competences. These include competences to identify inefficiencies, opportunities and those essential towards implementing the interventions. Lack of specific competences on methods and tools to identify energy waste and other inefficiencies may act as a barrier[57]. Competences for identifying the opportunities by acquiring qualifications to understand the new technologies in the marketare also considered essential. Contract and project management abilities to implement the approved EEMs are also equally important [4]).

Lack of Awarenessof decision makers on EEmay lead to their forfeiting a worthwhile EEMs.[44]
A tabular summary of important researchworks with correlation to specific barrier examined therein is indicated in table 2.3.

Table 2.3- Contribution by researchers on barriers to Energy Efficiency

Origin	Actor/	Barriers	[23]	[30]	[58]	[50]	[55]	[59]	[60]	[4]	[31]	[44]	[42-]	[53]	[20]	[24]	[63]	[12]	[64]	[45]	[48]	[36]	[65]	[14]	[56]	[16]	[27]	[25]	[2]	[17]	[47]	[46]	[38-]	[13]	[33]	[39]	[41]	[67]	[34]	[68]	[21]	[3]	[28-]	[69]	[19]	[26]	[9]	[22]	[35]	[40]	[75]	[37]	[18]
External		Energy prices distortion																√						√		√				√				√										√									√
		Low diffusion of technologies													√																																						
		Low diffusion of information																																							√												
		Market risks																√																																			
		Difficulty in Gathering Ext Skills																																													√					
	M	Adverse Selection																	√																																		
	G	Lack of proper regulation																																				√												√		
		Distortion in fiscal policies				√												√			√																								√								
	T	Lack of interest in EE																													√																						
		Tech Suppliers not updated																√																																			
		Scarce communication skills																																																			
	D	Technical Characteristics not adequate										√																																									
		High initial costs																		√												√																					
	E	Scarce communication skills																																								√											
		Distortion in energy policies																																								√											
		Lack of interest in EE																														√																					
	C S	Cost for investing capital availability						√																																													
		Difficulty in identifying quality of investments																			√																																
	Ec	Low capital availability			√				√	√													√						√				√					√		√		√			√		√	√					
Internal		Access to Capital	√													√												√																	√	√							
		Hidden costs							√													√					√	√	√				√							√		√	√		√			√					
		Intervention-related risks		√					√		√																		√	√			√		√				√	√			√		√				√				

	Intervention not sufficiently profitable																				√																															
	Heterogeneity																				√						√																									
B	Lack of interest in EE interventions																																																		√	
	Other priorities																														√			√						√						√		√			
	Inertia																																		√																
	Imperfect evaluation criteria											√																																							
	Lack of sharing the objectives							√				√																																	√							
	Bounded Rationality				√																																															
	Form of information																																							√											
	Credibility & Trust																																		√																
	Values																																							√											
O	Low status of energy efficiency							√					√																											√											
	Divergent interests															√																																			
	Split Incentives																														√																				
	Complex decision chain					√																																													
	Lack of time																						√																												
	Lack of internal control																																							√											
	Principal Agent Relationship											√																																							
	Power																																							√											
	Culture																																							√											
C	Identifying the inefficiencies								√																																						√					
	Identifying the opportunities								√																																											
	Implementing the interventions				√			√	√													√						√				√												√			√					
A	Lack of awareness or Ignorance			√				√	√		√																	√				√												√			√					

Legend for the table : A= awareness; B= behavioural ;C= Barriers related to competences, CS= Capital Suppliers; D= Designers and Manufacturers; E= external ; Ec= Economic ; EE=Energy Efficiency; En=Energy Suppliers G= Government ; I = Internal ; M= Market ; O= Organizational; T= Technology/ services suppliers

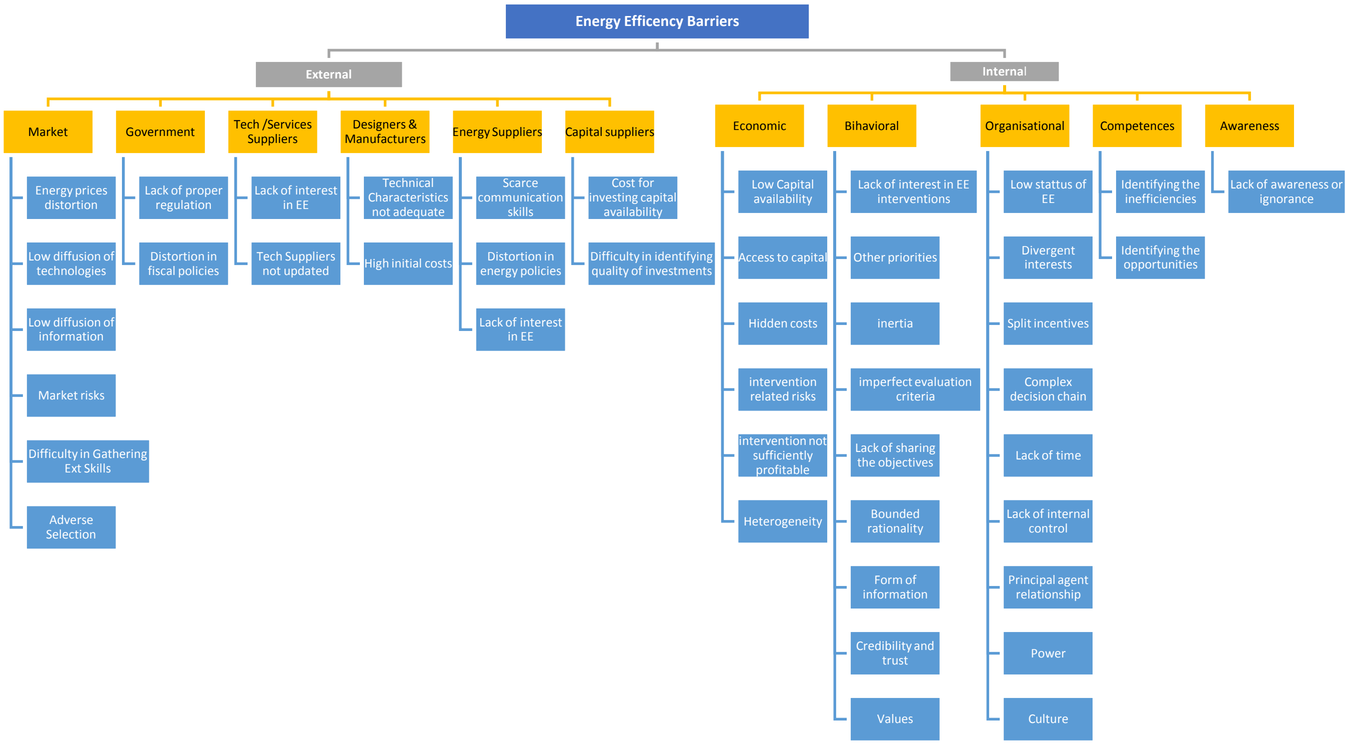
A unified classification framework of barriers has been created by combining the different taxonomies discussed earlier. Cagno's taxonomy has been employed as the base to integrate clusters of multiple barriers. The same is presented in tabular format in table 2.4 below. The same is depicted in a graphical format at Fig 2.1.

Table 2.4 – Unified framework of Barriers to Energy efficiency

Barriers to Energy Efficiency			
Origin -External		**Origin -Internal**	
Actor/Area	**Barrier /Diffusion Factor**	**Actor /Area**	**Barrier / Diffusion Factor**
Market	Energy prices distortion	Economic	Low capital availability
	Low diffusion of technologies		Access to Capital
			Hidden costs
	Low diffusion of information		Intervention-related risks
			Intervention not sufficiently profitable
	Market risks		Heterogeneity
	Difficulty in Gathering Ext Skills	Behavioral	Lack of interest in EE interventions
			Other priorities
	Adverse Selection		Inertia
Government	Lack of proper regulation		Imperfect evaluation criteria
	Distortion in fiscal policies		Lack of sharing the objectives
Technology /Services Suppliers	Lack of interest in EE		Bounded Rationality
	Tech Suppliers not updated		Form of information
			Credibility & Trust
	Scarce communication skills		Values
		Organizational	Low status of energy efficiency
Designers & Manufacturers	Technical Characteristics not adequate		Divergent interests
			Split Incentives
	High initial costs		Complex decision chain
Energy Suppliers	Scarce communication skills		Lack of time
			Lack of internal control
	Distortion in energy policies		Principal Agent Relationship
			Power

	Lack of interest in EE		Culture
Capital Suppliers	Cost for investing capital availability	Barriers related to Competences	Identifying the inefficiencies
			Identifying the opportunities
	Difficulty in identifying quality of investments		Implementing the interventions
		Awareness	Lack of awareness or Ignorance

Fig 2.1 – Unified framework of barriers to Energy efficiency



3. Research Design

As shown earlier, there is significant research available on barriers that have an impact on the implementation of EETs and EEMs in the industry. There have also been many surveys to bring out the relative importance of various factors as perceived by different stakeholders. However, no work could be located that determines the relationship and relative impact of various barriers on each other in a structured way, thereby resulting in a significant research gap. Towards bridging this gap, the present work was taken up.

The aims of this research project are three folds. Firstly the Identification of important barriers to implementation of EEMs in recycled fiber-basedpaper industry inIndia. Next would be to ascertain the interrelationship of these barriers by developing a structured hierarchical model using ISM technique. And thirdly to study the dispersal of impacts of each of the barriers and to classify them based on their driving power and dependence power using MICMACanalysis.

Towards development of hierarchical model, a structured two stageapproach was followed as per [5]. Firstly the relevant and important barriers were shortlisted. Then they wererankedandmeaningfulrelationshipsamongthemwereobtained.

For shortlisting of barriers,literature was reviewedextensively which led to an initial list of 108 barriers. After preliminary screening this list was rationalized by clubbing together similar barriers with different nomenclatures having only minordifferences.This rationalized list comprising 76 barriers was thensubmitted to a panel of experts to identify the barriers that have significant impact on implementation of EEMs in paper industry.

For selecting a panel of experts, a list of recycled paper manufacturers was drawn up from the data bases obtained from Central paper and Pulp Research Institute(CPPRI),Saharanpur,Indiannewsprintmanufacturersassociation(INMA),IndianPaperandPulpTechnical Association (IPPTA) and Indian Agro and recycled Paper mills association(IARPMA). Atotal of 40 manufacturers were selected. From the websites of these selected industries/from CPPRI/ INMA/IPPTA/ IARPMA, the contact details of key stakeholders dealing with EE such as Chief Executive OfficerCEO), General Manager(GM), Energy manager(EM) wereobtained.An email was sent to these 40 units explaining the background of the research. Extracts of documents regarding barriers to EEMs were attached with the mail.After rigorous follow-up, 23 industries indicated their willingnessto participate. Afterdeliberations, 18 industries were shortlisted based on their profile, availability and willingness of their experts. A tabular profile of shortlisted industries is shown in **Table 3.1**.

As the decision making involved both technical and strategic issues, the short-listed entities were requested to nominate one specialist from technical side and one dealing with strategic decision making and funds allocation. This nomination resulted in a panel strength of 36 for participation in the next stage of research.

Table 3.1– Profile of respondent industries from recycled paper and pulp sector in India

Parameter	Description	Total	%
Product	Writing Printing Paper	6	20
	News print	7	23.33
	Packaging & Kraft paper	14	46.67
	Speciality Paper	3	10
No of employees	100-1000	12	66.67
	>1000	6	33.33
Capacity(Tons per Annum)	<100000	8	44.44
	100000-300000	6	33.33
	>300000	4	22.22
Location	West (Gujarat, Maharashtra)	5	27.78
	South (Tamilnadu, Karnataka)	5	27.78
	North (Punjab, UK, UP)	5	27.78
	East (West Bengal)	2	11.11
	Central (MP)	1	5.56

In the second stage a survey was mailed to the panelwith a request to rate the importance of therationalized list of 76 barriers on a 5 point Likert scale (1–Not important at all, 2-Notveryimportant,3-Somewhatimportant,4-Moderatelyimportantand5-Extremely important). 15 dominant barriers emerged with average scores above 4.The participants were then asked to give contextual pairwise relationship among the 15 dominant barriers. After receipt of responses, avideo conference call(VCC) was organized in view of the ongoing pandemic. 33 Out of the 36 panelists attended the VCC and collectively analyzed the data using brainstorming and nominal grouptechnique.The analysis determined the contextual relationship as to which of the barrier leads to another in each pair. A Structured self-interaction matrix(SSIM) was developed which in turn used to obtain the underlying structure using ISM.MICMAC was then used to classify barriers, depending on their driver power and dependence power. A tabular summary of research process employed is indicated at Table3.2

Table 3.2: Research Process

Stage	Step	Technique adopted	Output
1. Identifying barriers to implementation of EE measures in paper&pulp industry	1.Literature Review	Review of earlier research	Identified 108 Barriers to energy efficiency. Rationalized to 76 barriers by clubbing together similar barriers with minor differences.
2. Developing barriers for EEinterrelationshipmodel	1.Survey ofindustry experts	Written responses followed by brain-stormingandnominal grouptechnique.	a. Short listed 15 barriers considered most relevant for Indian conditions of recycled Paper and pulpindustry. b. Developed a contextual pairwise relationship among the barriers.
	2. Developing Barriers hierarchical framework	ISM	Generated 8 level relationship model
	3. Identifying driven – dependencerelationship of barriers to EE	MICMAC	Barriers classified into four clusters

4. ISM Methodology

ISM methodologyis used for identifying and categorizing factors that may affect a given issue [71-72]. The steps in the formulation of ISM Model [73]are described belowand a flow chart for the same is presented at Fig 4.1:

Step 1: Listthe relevant barriers
Step 2: Develop an SSIM in consultation with experts using contextual relations between pairs ofbarriers
Step 3: Develop Initial reachability matrix (IRM) using appropriate relationships from SSIM.
Step 4: Develop Final Reachability Matrix (FRM) considering transitive property between variables. (Transitivity means that if a variable A is related to B and B is related to C, then A is necessarily related to C)
Step 5: The FRM is partitioned into different levels. The partition table is developed consisting of reachability set and antecedent set consisting of a set of variables driving the variables in question.
Step 6: Levels in the hierarchical framework are obtained by followingsteps:

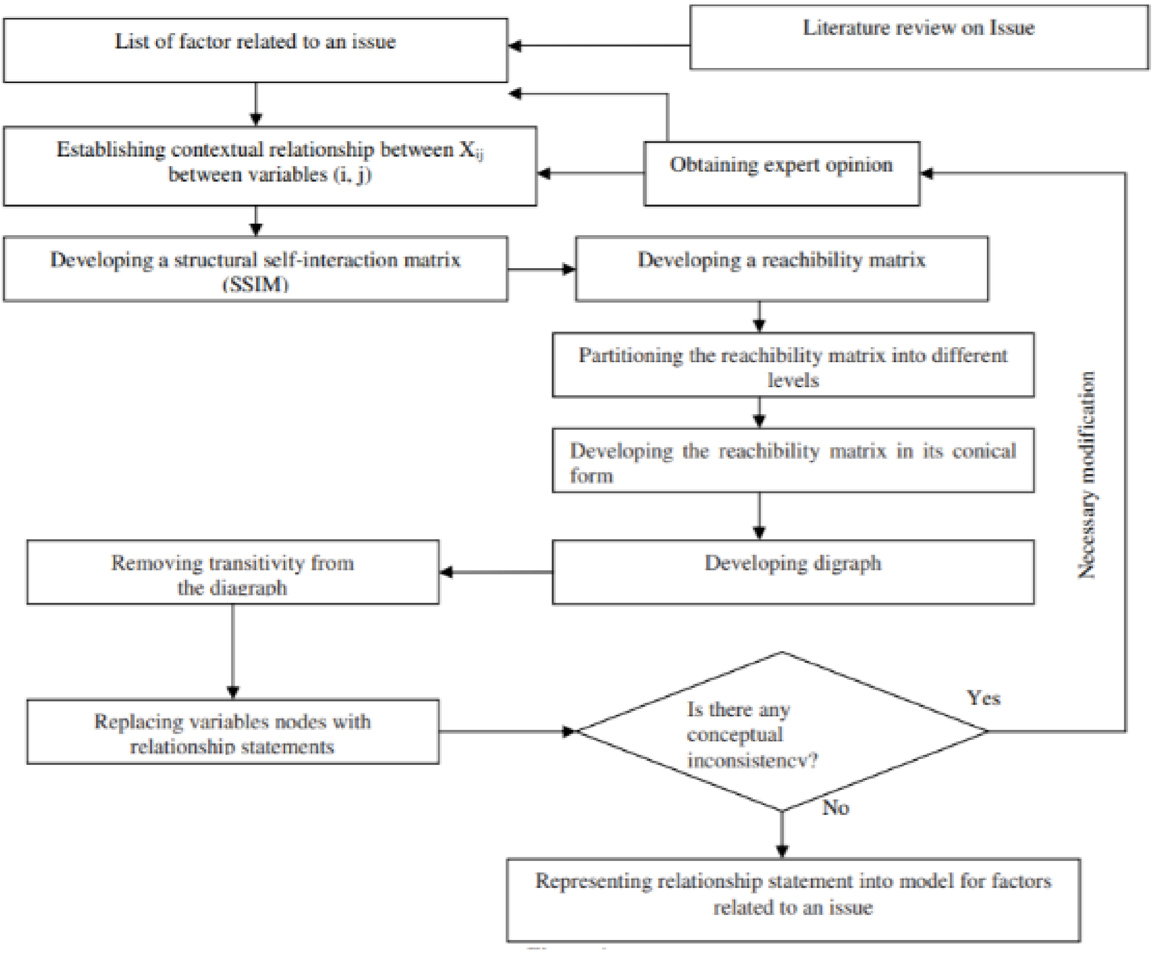
6.1 Identify variables at level I for which the reachability and intersection set are thesame.

6.2 Remove all the level one variables from the reachability and the antecedent set and determine level two variables following the same process as in 6.1.

6.3 Repeat 6.2 till the level of all the variables isdecided.

Step 7: Based on the above a directed graph is drawn and transitive links removed.
Step 8: The resultant digraph is converted into an ISM, by replacing variable nodes with statements.
Step9: In the last step the expert opinion is once again used to review the ISM based model developed in step 7 to remove any inconsistency and appropriate modifications are carriedout.

Fig 4.1 – Flow chart for developing an ISM model (adapted from [73])



4.1 ISM Based model for Barriers to Energy Efficiency in recycled Paper and PulpIndustry

The details of application of ISM methodology are as below:

4.1.1 Identification of Dominant barriers for Indian recycled paper and pulp industry:

Stage 2a as per the research process at Table 3.2 yielded 15 barriers that were considered most relevant by the experts. They have been serial numbered from B1 to B15. Each of these barriers have been designated with a barrier code by creation of a 3-letter acronym using the initial letters of important words of the respective barriers. These barriers are discussed in succeeding paragraphs.

B1- Poor Information Quality regarding ECM(PIQ)- Personnel making investment decisions need to have timely access to good Quality of information regarding ECMs. Imperfect information is a case of market failure. Insufficient information about the energy performance of different technologies and their potential savings may lead to decisions based on uncertain information, and may result in less investment in EEMs or avoidance of a technology which may actually be worthy of induction[6]. The time needed to refine and disseminate information on energy-efficient technologies, acts as abarrier[36].

B2- No cost-effective Technological ECM available (CET)- This barrier pertains to the available technologies for ECMs not being cost effective or affordable viz a viz the cost of funding and potential economic benefits that are likely to accrue.**.** In the initial stages, new technologies are relatively costly as the design and development costs need to be amortized amongst a low number of customers. Further there are hidden costs linked to implementation of a new technology that may render it non cost effective[65], [68],[19], [2],[54].

B3- Uncertainty about future energy prices and fiscal policies (EPP)- Profitability of any investment in EEMs is directly linked to anticipated direction of energy prices. However, in addition to demand and supply based price variations, there are artificial interventions and controls by government authorities and regulators on energy pricing that act as barriers. Intraday variable costs of energy are, in-fact a disincentive for investments towards EEMs[12]. Mandated prices for fuels are often designed to subsidize the industry to promote employment generation & economic activity but they also mean lower rates for higher consumption of energy and hence are non-supportive for EEMs[19].

B4- Lack of staff awareness or motivation (LSM)- It pertains to the ignorance of the staff members regarding importance of energy efficiency. It is more a status than a behaviour. In case of decision makers, it would result in their not considering EEMs for implementation and in case of other staff, it would amount to them not following energy efficiency supporting practices[2][4][19][44],[54][57-58],[60], [70].

B5- Insufficient top management support (TMS)- In most organizations no significant financial decisions or commitment of any resources may be made unless actively supported by the top management. Hence insufficient top management support becomes a significant barrier [60]. This has a negative effect in two ways. Firstly, it restricts implementation of EEMs with associated financial resources. Secondly, it also affects developmentand sustenance of an organizational culture that supports energy efficient behaviour and practices adversely. Organisational will and motivation can only be created by top management since significant resources and efforts are required towards such a change management.

B6-Lack of time or other priorities (OTP)- This pertains to a phenomenon wherein most top executives and decision makers are bogged down by multiple urgent actions and their immediate targets to the detriment of long- term objectives / good to do things. EEMs fall in the latter category and need adequate thought, planning and mental resources to be invested prior implementation. This also leads to a linked phenomenon, called bounded rationality, where individuals may not consider full information, but instead make decisions based on intuition or hunch. This may often result in some worthwhile EEM being left out of consideration. [2],[19],[57-58], [70]and [60].

B7-Lack of information about allocation of energy costs (AEC)-This internal barrier pertains to lack of accountability of energy costs incurred by each sub-unit or department within an organization [60].This is also linked to lack of adequate internal controls by way of sub-metering. In literature, this has at times been addressed as a case of split incentives, meaning thereby that, the department responsible for energy efficiency have no control on energy consumption by the production or service departments. These energy consuming departments in turn have no incentives to consume less energy, nor a budgeting system that links their performance to energy efficiency.

B8- Lack of technical skills (TSK)-Typically, in a production organization, the skill sets available pertain to operation and maintenance of the plant and machinery. They may not have inhouse talent with skills and qualifications required for identification of deficiencies, identification of opportunities available by way of suitable energy efficient technologies and then for implementing new EEMs. These may include capabilities for contract and project management. These shortcomings constitute a significant barrier. [2],[19],[54],[57-58],[60], [65].

B9- Limited access to Capital (CAP)-In an economic environment, capital is a scarce resource. Even when funds are available, there are competing proposals and options available for deploying the same. Further the managements would always like to deploy the funds in an activity or project that would give the best financial returns. At times the decision makers only allow funds to be deployed for projects that promise returns at a rate better than the organizations' internal rate of return. All these conflicting conditions make the limited access to capital a very important barrier. Rightly so, this has been one of the most researched topics also. [2-4],[9],[12][19][54][58][60],[65],[68],[70].

B10- Uncertainties regarding hidden costs (UHC)-Every EEM has certain hidden costs associated with it[25]. Hidden costs are those that are not reflected in normal investment calculation by payback method. An EEM may actually be unviable, if the hidden costs are taken into account[28].In many cases a management's decision to reject a potential investment in a EEM may be rationally justified from a business perspective (Nicholas, 1994). Hidden costs are classified into general overheads, technology specific expenditure and loss of benefits associated with an efficient technology [58]. Ref [57] presented a classification based on the project stage, that is pre-intervention, during implementation and post intervention. The pre-intervention costs are those incurred on the research of energy inefficiencies and opportunities [68], cost of energy audits [36], preliminary evaluation of the investment and to understand the debt carrying capability. Unaccounted costs during implementation include those due to disruption of production, hassle, inconvenience [6] and modifications to the existing layout. The post implementation expenses include those on training and towards development of new operation and maintenance practices [54]).

B11- Other priorities for financial investments (FIN)-Given the scarcity of financial resourcesand since there are multiple competing projects and departments vying for them, the capital usually gets allocated to those activities that are perceived by the decision makers as in the best interest of the business, preferably linked to the core business of the company. EEMs get funds allotted, only when the top management is convinced of their importance. In other situations, this scarcity acts as a barrier[2], [19], [53-54], [57-58],[60],[70].

B12- Technical risks (e.g. production failure) (RPF)-[6] taxonomy has considered risk as an important factor. They have indicated risk to be of three types – external risk, business risk and technical risk. Out of these, technical risks such as production interruptions and production failure is one of the critical barriers[60]. This becomes all the more important, if thedecision is about strategically important part of the core business activity. The decision maker may decide to forgo implementation of an EEM if the perceived risk of loss on account of potential production loss is significant[2], [6], [19],[54] and [68].

B13- No options to improve energy management practices (IEM)-In a hierarchical organization, the status of a person heading a particular function determines the importance accorded to the function[6]. More often than not, the functions dedicated to energy management are placed in position of less importance and as such they are unable to exercise power or take independent initiatives to improve energy efficiency. In most cases it is observed that the top management commitment and support is essentially required to achieve worthwhile results in the area of energy efficiency[60].

B14- Difficulty to cooperate interdivisional (DCI)-This barrier arises on account of the departments focusing on their core functions in preference to the energy objectives of the organization[60]. This may result in certain misalignment between the behaviour of personnel and that expected to achieve energy efficiency targets (De Canio, 1993). Departmental tendency to pursue their functional priorities in preference to energy objectives may act as a barrier for implementation of EEMs[49].

B15- Limited authority of energy manager (EMG)-The energy manager not having adequate authority and status is detrimental for implementation of EEMs. The senior management is preoccupied by the core business and production activities of the organization to the neglect of energy management actions and implementations. During budget allocation again, the Energy manager lacks weight to influence the decision makers and the fund allotment authorities to make capital allocations in favour of EEMs. Research has indicated that best results are obtained in those companies where the top management support and commitment towards the cause of EE, enables and empowers the energy manager to act as a change management agent to alter and improve the energy behaviour culture, as well as to implement good energy management projects. [60]

The barriers considered most relevant are summarised at Table 4.1 below.

Table 4.1- Barriers considered most relevant by the experts

S No	Selected Dominant Barrier	Barrier code	Parameter as per Cagno et al, 2013 [4] taxonomy			References
			Origin	Actor /Area	Barrier	
B1	Poor Information Quality regarding ECM	PIQ	E	M	Low diffusion of information	[54],[60]
B2	No cost-effective Technological ECM available	CET	E	M	Low diffusion of technologies	[2], [19], [54], [65], [68]
B3	Uncertainty about future energy prices and fiscal policies	EPP	E	G	Distortion in fiscal policies	[12], [19],[50]
B4	Lack of staff awareness or motivation	LSM	I	A	Lack of awareness or ignorance	[2], [4], [19],[54], [57-58], [60] ,[70]
B5	Insufficient top management support	TMS	I	O	Low status of energy efficiency	[60]
B6	Lack of time or other priorities	OTP	I	O	Other priorities	[2], [19] [57-58],[70], [60]
B7	Lack of information about allocation of energy costs	AEC	I	O	Lack of internal control	[60]
B8	Lack of technical skills	TSK	I	B	Lack of competency for implementing	[2],[19] [54] [57-58] [60]; [65].
B9	Limited access to Capital	CAP	I	E	Low capital availability	[2-4], [8-9],[12],[19],[54],[58], [60-61], [65],[68], [70]
B10	Uncertainties regarding hidden costs	UHC	I	E	Hidden costs	[2-3], [8], [25], [28-29], [54], [57], [60],[66], [68], [70].
B11	Other priorities for financial investments	FIN	I	E	Low capital availability	[2], [19], [53-54],[57-58], [60],[70].
B12	Technical risks (e.g. production failure)	RPF	I	E	Intervention related risk	[2],[19],[54], [68].
B13	No options to improve energy management practices	IEM	I	O	Low status of energy efficiency	[6], [60].
B14	Difficulty to cooperate interdivisional	DCI	I	B	Lack of sharing objectives	[42], [49], [60].
B15	Limited authority of energy manager	EMG	I	O	Low status of energy efficiency	[60].
Legend for the table: E= external; I = Internal; M= Market; G= Government; A= awareness; O= Organizational; C= Barriers related to competences; Eco= Economic; B= behavioural						

4.1.2 Structural Self Interaction Matrix(SSIM)

A SSIM brings out the contextual relations among the barriers. Subsequently the SSIM is converted to reachability matrix by converting the symbols to their binary equivalents. Table 4.2 indicates the symbols and the rules for their conversion.

Table 4.2 – Symbols in SSIM and Rules for conversion to binary equivalents

Symbol in Cell (i,j)	Contextual relation	Rule for conversion to binary equivalent	
		Entry in Cell (i,j)	Entry in cell (j, i)
V	Barrier i leads to Barrier j	1	0
A	Barrier j leads to barrier i	0	1
X	Barriers i and j	1	1

	lead to each other		
O	Barrier i and j are unconnected	0	0
Note: index i is for barrier in row and j is for barrier in column.			

Table 4.3: Structural Self Interaction Matrix for Barriers to Energy Efficiency

		B15	B14	B13	B12	B11	B10	B9	B8	B7	B6	B5	B4	B3	B2	B1
		EMG	DCI	IEM	RPF	FIN	UHC	CAP	TSK	AEC	OTP	TMS	LSM	EPP	CET	PIQ
B1	PIQ	O	V	V	O	O	O	O	V	V	V	O	V	O	O	X
B2	CET	V	V	V	O	O	O	A	O	O	O	A	A	O	X	
B3	EPP	V	V	V	O	V	V	V	V	V	V	X	O	X		
B4	LSM	X	X	X	0	X	V	X	V	X	X	A	X			
B5	TMS	V	V	V	A	V	V	V	V	V	V	X				
B6	OTP	X	V	V	0	X	O	A	V	A	X					
B7	AEC	V	V	V	A	V	V	A	V	X						
B8	TSK	O	V	V	A	A	O	A	X							
B9	CAP	V	V	V	A	X	V	X								
B10	UHC	O	V	V	A	V	X									
B11	FIN	O	V	V	O	X										
B12	RPF	V	V	V	X											
B13	IEM	A	A	X												
B14	DCI	A	X													
B15	EMG	X														

4.1.3 Reachability Matrix (RM)

Firstly an IRM is developed from the SSIM using the rules in table 4.3. The same is shown in Table 4.4. Thereafter the FRM is generated using the transitive property as per step 4 of the ISM methodology. The FRM is depicted at Table4.5.

Table 4.4: Initial Reachability Matrix

		B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12	B13	B14	B15
		PIQ	CET	EPP	LSM	TMS	OTP	AEC	TSK	CAP	UHC	FIN	RPF	IEM	DCI	EMG
B1	PIQ	1	0	0	1	0	1	1	1	0	0	0	0	1	1	0
B2	CET	0	1	0	0	0	0	0	0	0	0	0	0	1	1	1
B3	EPP	0	0	1	0	1	1	1	1	1	1	1	0	1	1	1
B4	LSM	0	1	0	1	0	1	1	1	1	1	1	0	1	1	1
B5	TMS	0	1	1	1	1	1	1	1	1	1	1	0	1	1	1
B6	OTP	0	0	0	1	0	1	0	1	0	O	1	0	1	1	1
B7	AEC	0	0	0	1	0	1	1	1	0	1	1	0	1	1	1
B8	TSK	0	0	0	0	0	0	0	1	0	0	0	0	1	1	0
B9	CAP	0	1	0	1	0	1	1	1	1	1	1	0	1	1	1
B10	UHC	0	0	0	0	0	0	0	0	0	1	o	0	1	1	0
B11	FIN	0	0	0	1	0	1	0	1	1	0	1	0	1	1	0
B12	RPF	0	0	0	0	1	0	1	1	1	1	0	1	1	1	1
B13	IEM	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0
B14	DCI	0	0	0	1	0	0	0	0	0	0	0	0	1	1	0
B15	EMG	0	0	0	1	0	1	0	0	0	0	0	0	1	1	1

Table 4.5: Final Reachability Matrix

		B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12	B13	B14	B15	Driving Power
		PIQ	CET	EPP	LSM	TMS	OTP	AEC	TSK	CAP	UHC	FIN	RPF	IEM	DCI	EMG	
B1	PIQ	1	0	0	1	1*	1	1	1	0	0	0	0	1	1	0	8
B2	CET	0	1	0	0	0	0	0	0	0	0	0	0	1	1	1	4
B3	EPP	0	0	1	0	1	1	1	1	1	1	1	0	1	1	1	11
B4	LSM	0	1	0	1	0	1	1	1	1	1	1	0	1	1	1	11
B5	TMS	0	1	1	1	1	1	1	1	1	1	1	0	1	1	1	13
B6	OTP	0	0	0	1	0	1	0	1	0	O	1	0	1	1	1	7
B7	AEC	0	0	0	1	0	1	1	1	0	1	1	0	1	1	1	9
B8	TSK	0	0	0	0	0	0	0	1	0	0	0	0	1	1	0	3
B9	CAP	0	1	0	1	0	1	1	1	1	1	1	0	1	1	1	11
B10	UHC	0	0	0	0	0	0	0	0	0	1	o	0	1	1	0	3
B11	FIN	0	0	0	1	0	1	0	1	1	0	1	0	1	1	0	7
B12	RPF	0	0	0	1*	1	0	1	1	1	1	0	1	1	1	1	10
B13	IEM	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	2
B14	DCI	0	0	0	1	0	0	0	0	0	0	0	0	1	1	0	3
B15	EMG	0	0	0	1	0	1	0	0	0	0	0	0	1	1	1	5
Dependence Power		1	4	2	11	4	9	7	10	6	7	9	1	15	14	9	

4.1.4 LevelPartition

As per steps 5 and 6 of the ISM methodology, levels of variables are decided by partitioning. (Table 4.6). The results of partitioning after 8 iterations, the summary results and the sequential summary results are indicated in Tables4.6, 4.7 and 4.8 respectively.

Table 4.6–Results of partitioning (Iteration I to VIII)

Iterations	Barrier code	Reachability set	Antecedent Set	Intersection Set	Rank
I	B1	1,4,5,6,7,8,13,14	1	1	
	B2	2,13,14,15	2,4,5,9	2	
	B3	3,5,6,7,8,9,10,11, 13,14,15	3,5	3,5	
	B4	2,4,6,7,8,9,10, 11,13,14,15	1,4,5,6,7,9,11,12,13,14,15	4,6,7,9,11,13,14,15	
	B5	2,3,4,5,6,7,8,9,10,11,13,14,15	1,3,5,12	3,5	
	B6	4,6,8,11,13,14,15	1,3,4,5,6,7,9,11,15	4,6,11,15	
	B7	4,6,7,8,10,11,13,14,15	1,3,4,5,7,9,12	4,7	
	B8	8,13,14	1,3,4,5,6,7,8,9,11,12	8	
	B9	2,4,6,7,8,9,10,11,13,14,15	3,4,5,9,11.12	4,9,11	
	B10	10,13,14	3,4,5,6,7,9,10,12	10	
	B11	4,6,8,9, 11,13,14	3,4,5,6,7,9,11	4,6,9,11	
	B12	4,5,7,8,9,10,12,13,14,15	3,12	12	
	B13	4,13	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15	4.13	I
	B14	4,13,14	1,2,3,4,5,6,7,8,9,10,11,12,14,15	4,14	
	B15	4,6,13,14,15	2,3,4,5,6,7,9,12,15	4,6,15	
II	B1	1,4,5,6,7,8,14	1	1	
	B2	2,14,15	2,4,5,9	2	
	B3	3,5,6,7,8,9,10,11, 14,15	3,5	3,5	
	B4	2,4,6,7,8,9,10, 11,14,15	1,4,5,6,7,9,11,12,14,15	4,6,7,9,11,14,15	
	B5	2,3,4,5,6,7,8,9,10,11,14,15	1,3,5,12	3,5	
	B6	4,6,8,11,14,15	1,3,4,5,6,7,9,11,15	4,6,11,15	
	B7	4,6,7,8,10,11,14,15	1,3,4,5,7,9,12	4,7	
	B8	8,14	1,3,4,5,6,7,8,9,11,12	8	
	B9	2,4,6,7,8,9,10,11,14,15	3,4,5,9,11.12	4,9,11	
	B10	10,14	3,4,5,6,7,9,10,12	10	

	B11	4,6,8,9, 11,14	3,4,5,6,7,9,11	4,6,9,11	
	B12	4,5,7,8,9,10,12,14,15	3,12	12	
	B14	4,14	1,2,3,4,5,6,7,8,9,10,11,12,14,15	4,14	II
	B15	4,6,14,15	2,3,4,5,6,7,9,12,15	4,6,15	
III	B1	1,4,5,6,7,8	1	1	
	B2	2,15	2,4,5,9	2	
	B3	3,5,6,7,8,9,10,11, 15	3,5	3,5	
	B4	2,4,6,7,8,9,10, 11,15	1,4,5,6,7,9,11,12,15	4,6,7,9,11,15	
	B5	2,3,4,5,6,7,8,9,10,11,15	1,3,5,12	3,5	
	B6	4,6,8,11,15	1,3,4,5,6,7,9,11,15	4,6,11,15	
	B7	4,6,7,8,10,11,15	1,3,4,5,7,9,12	4,7	
	B8	8	1,3,4,5,6,7,8,9,11,12	8	III
	B9	2,4,6,7,8,9,10,11,15	3,4,5,9,11.12	4,9,11	
	B10	10	3,4,5,6,7,9,10,12	10	III
	B11	4,6,8,9, 11	3,4,5,6,7,9,11	4,6,9,11	
	B12	4,5,7,8,9,10,12,15	3,12	12	
	B15	4,6,15	2,3,4,5,6,7,9,12,15	4,6,15	III
Iterations	Barrier code	Reachability set	Antecedent Set	Intersection Set	Rank
IV	B1	1,4,5,6,7	1	1	
	B2	2	2,4,5,9	2	IV
	B3	3,5,6,7,9,11,	3,5	3,5	
	B4	2,4,6,7,9, 11	1,4,5,6,7,9,11,12,	4,6,7,9,11	
	B5	2,3,4,5,6,7,9,11	1,3,5,12	3,5	
	B6	4,6,11	1,3,4,5,6,7,9,11	4,6,11	IV
	B7	4,6,7,11	1,3,4,5,7,9,12	4,7	
	B9	2,4,6,7,9,11,	3,4,5,9,11.12	4,9,11	
	B11	4,6,9, 11	3,4,5,6,7,9,11	4,6,9,11	IV
	B12	4,5,7,9,12	3,12	12	
V	B1	1,4,5,7	1	1	
	B3	3,5,7,9,	3,5	3,5	
	B4	4,7,9,	1,4,5,7,9,12,	4,7,9	V
	B5	3,4,5,7,9,	1,3,5,12	3,5	
	B7	4,7	1,3,4,5,7,9,12	4,7	V
	B9	4,7,9,	3,4,5,9,12	4,9	
	B12	4,5,7,9,12	3,12	12	
VI	B1	1,5	1	1	
	B3	3,5,9,	3,5	3,5	
	B5	3,5,9,	1,3,5,12	3,5	
	B9	9,	3,5,9,12	9	VI
	B12	5,9,12	3,12	12	
VII	B1	1,5	1	1	
	B3	3,5,	3,5	3,5	VII
	B5	3,5,	1,3,5,12	3,5	VII
	B12	5,12	3,12	12	
VIII	B1	1	1	1	VIII
	B12	12	3,12	12	VIII

Table 4.7- Summary Results of partitioning

Barrier code	Reachability set	Antecedent Set	Intersection Set	Iteration no and Level
B1	1,4,5,6,7,8,13,14	1	1	VIII
B2	2,13,14,15	2,4,5,9	2	IV
B3	3,5,6,7,8,9,10,11, 13,14,15	3,5	3,5	VII
B4	2,4,6,7,8,9,10, 11,13,14,15	1,4,5,6,7,9,11,12,13,14,15	4,6,7,9,11,13,14,15	V
B5	2,3,4,5,6,7,8,9,10,11,13,14,15	1,3,5,12	3,5	VII
B6	4,6,8,11,13,14,15	1,3,4,5,6,7,9,11,15	4,6,11,15	IV
B7	4,6,7,8,10,11,13,14,15	1,3,4,5,7,9,12	4,7	V
B8	8,13,14	1,3,4,5,6,7,8,9,11,12	8	III
B9	2,4,6,7,8,9,10,11,13,14,15	3,4,5,9,11.12	4,9,11	VI
B10	10,13,14	3,4,5,6,7,9,10,12	10	III
B11	4,6,8,9, 11,13,14	3,4,5,6,7,9,11	4,6,9,11	IV
B12	4,5,7,8,9,10,12,13,14,15	3,12	12	VIII
B13	4,13	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15	4.13	I
B14	4,13,14	1,2,3,4,5,6,7,8,9,10,11,12,14,15	4,14	II
B15	4,6,13,14,15	2,3,4,5,6,7,9,12,15	4,6,15	III

Table 4.8 - Sequential Summary Results of partitioning

Barrier code	Reachability set	Antecedent Set	Intersection Set	Iteration no and Level
B13	4,13	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15	4.13	I
B14	4,13,14	1,2,3,4,5,6,7,8,9,10,11,12,14,15	4,14	II
B8	8,13,14	1,3,4,5,6,7,8,9,11,12	8	III
B10	10,13,14	3,4,5,6,7,9,10,12	10	III
B15	4,6,13,14,15	2,3,4,5,6,7,9,12,15	4,6,15	III
B2	2,13,14,15	2,4,5,9	2	IV
B6	4,6,8,11,13,14,15	1,3,4,5,6,7,9,11,15	4,6,11,15	IV
B11	4,6,8,9, 11,13,14	3,4,5,6,7,9,11	4,6,9,11	IV
B4	2,4,6,7,8,9,10, 11,13,14,15	1,4,5,6,7,9,11,12,13,14,15	4,6,7,9,11,13,14,15	V
B7	4,6,7,8,10,11,13,14,15	1,3,4,5,7,9,12	4,7	V
B9	2,4,6,7,8,9,10,11,13,14,15	3,4,5,9,11.12	4,9,11	VI
B3	3,5,6,7,8,9,10,11, 13,14,15	3,5	3,5	VII
B5	2,3,4,5,6,7,8,9,10,11,13,14,15	1,3,5,12	3,5	VII
B1	1,4,5,6,7,8,13,14	1	1	VIII
B12	4,5,7,8,9,10,12,13,14,15	3,12	12	VIII

4.1.5 The ISMModel

The barriers have been classified into eight levels after partitioning. These levels indicate the antecedent-precedent relationship between the barriers. Level VIII barriers are antecedents of level VII barriers. Level VII barriers are antecedents of level VI barriers, and so on…. The finalISMmodelisshownin figure4.2. PIQ and RPF emerge to be the most important barriers at lowest level VIII, that would drive other barriers. EPP and TMS are placed at level VII. CAP is at Level VI. Next in the order of importance at Level V, we have two barriers, LSM and AEC. Thereafter at Level IV, we have three barriers, CET, OTP and FIN. Next at level III again we have three barriers, TSK, UHC and EMG. Below that at level II we have one barrier, DCI and the highest level I again there is one barrier IEM.

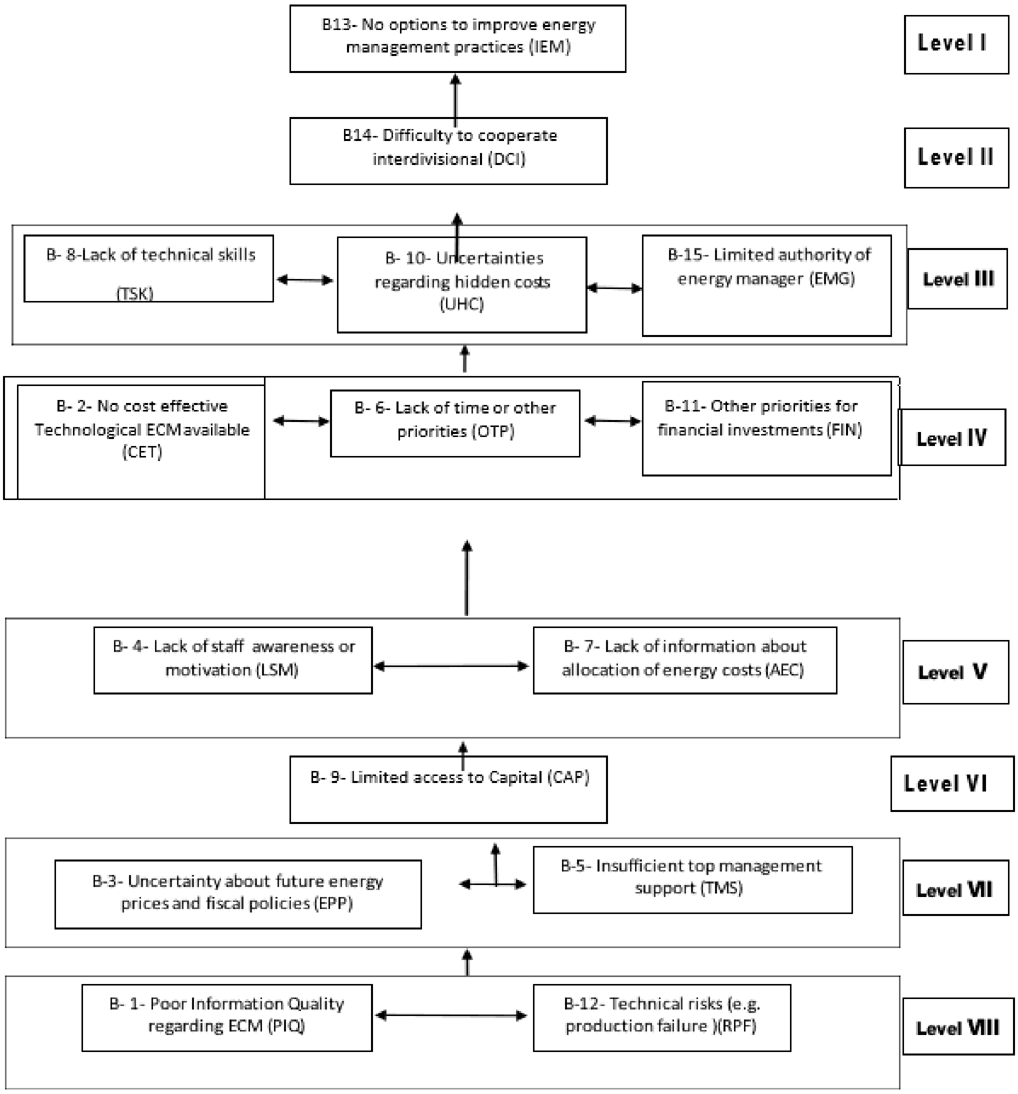


Figure 4.2- ISM based model for barriers to energy efficiency in recycled paper and pulp industry

5. Cross impact MICMAC analysis:

MICMAC analysis is used to classify the elements of a complex system utilizing multiplication attributes of matrices, and the dispersal of impacts based on their driving power and dependency power [62], [74].HereMICMAC analysis is utilized to classify the EE barriers into four clusters namely autonomous, dependent, linkage and independent. The driving and dependent power is obtained from the FRM (Table 4.5). The resulting Driver Dependence diagram is presented in **Figure 5.1** Features of different clusters have been indicated in **Table 5.1**. Higher driving power of a barrier means that a large number of barriers could be overcome by overcoming such a barrier. Autonomous cluster comprises of barriers that have weak driving power and weak dependence and are relatively disconnected from the system. Four barriers form a part of this cluster, namely CET, TMS,AEC and CAP. The “dependent” cluster has weak driving power but strong dependence. Fivebarriers namelyOTP,FIN, IEM,DCI and EMG are located here.Linkage cluster is the third one having strong driving power and strong dependence. These barriers are unstable since any change to them will have an effect on others and also a feedback on themselves. Two barriers fall under this cluster namely LSM and TSK. The fourth “independent” cluster has strong driving power but weak dependence. Four barriers form part of this cluster namely PIQ, EPP, UHC and RPF.The classification into the above four clusters helps identify the potential difficulty in removal of the barriers.Ingeneral,higherdriverpowerofabarriermeans that a large number of barriers could be removed by its removal. Higher dependence values for barriers require a large set of barriers to be addressed before its removal and a more likely success in the implementation of energy efficiency measure [75].

Table 5.1: Cluster classification of barriers

Driving Power	Cluster IV- Independent Barriers								Cluster III- Linkage Barriers							
15																
14																
13																
12							B10				B8	B4				
11		B3														
10	B12															
9																
8	B1															
8																
7							B7			B6 B11						
6																
5						B9				B15						
4				B2												
3				B5											B14	
2																B13
1																
	Cluster I- Autonomous Barriers								Cluster II- Dependent Barriers							
	1	2	3	4	5	6	7	8	8	9	10	11	12	13	14	15
	Dependence Power															

Cluster No	Cluster Name	Cluster features	Driving Power	Dependence Power	Barriers to Energy Efficiency
I	Autonomous Barriers	Relatively disconnected from the system, with which they have only few links , which may not be strong	Weak	Weak	B2- No cost effective Technological ECM available (CET) B5- Insufficient top management support (TMS) B7- Lack of information about allocation of energy costs (AEC) B9- Limited access to Capital (CAP)
II	Dependent Barrier	These barriers are the automatic followers of other barriers	Weak	Strong	B6- Lack of time or other priorities (OTP) B11- Other priorities for financial investments (FIN) B13- No options to improve energy management practices (IEM) B14- Difficulty to cooperate interdivisional (DCI) B15- Limited authority of energy manager (EMG)
III	Linkage Barriers	These barriers are unstable in the fact that any action on these barriers will have an effect on others and also a feedback on themselves.	Strong (Key barriers)	Strong	B4- Lack of staff awareness or motivation (LSM) B8- Lack of technical skills (TSK)
IV	Independent Barriers	These barriers are the key factors that would impact the implementation of energy management practices.	Strong (Key barriers)	Weak	B1- Poor Information Quality regarding ECM (PIQ) B3- Uncertainty about future energy prices and fiscal policies (EPP) B10- Uncertainties regarding hidden costs (UHC) B12- Technical risks (e.g. production failure)(RPF)

Fig 5.1: Driver Dependence Diagram

6. Discussion

As can be seen from figure 4.2 An eight-level hierarchical model was developed using ISM technique. It indicates PIQ and RPF to be the most important barriers at level VIII. They drive other barriers being the antecedents of level VII barriers which are TMS and EPP. They thus emerge as next in the order or priority. CAP is at Level VI. Next in the order of importance at Level V, we have two barriers, LSM and AEC. Thereafter at Level IV, we have three barriers, CET, OTP and FIN. Next at level III again we have three barriers, TSK, UHC and EMG. Below that at level II we have one barrier, DCI and the highest level I again there is one barrier IEM. We can therefore consider level VII and VIII barriers as most important, Levels IV, V and VI as having intermediate importance and those at level I,II and III as those least important in the hierarchy. This hierarchical model thus helps us to understand and classify the barriers in the order of their importance and management can accordingly formulate their strategy to address each of the barriers to achieve best results.

The observations from driver dependence diagram at figure 5.1 indicate the relative driving power and dependence power of various barriers. Higher driving power of a barrier means that a large number of barriers could be overcome by overcoming such a barrier. Higher dependence values for barriers require a large set of barriers to be addressed before its removal.

Autonomous cluster comprises of barriers that have weak driving power and weak dependence and are relatively disconnected from the system. Four barriers form a part of this cluster, namely CET, TMS, AEC and CAP.

The “dependent” cluster has weak driving power but strong dependence. Five barriers namely OTP, FIN, IEM, DCI and EMG are located here.

Linkage cluster is the third one having strong driving power and strong dependence. These barriers are unstable since any change to them will have an effect on others and also a feedback on themselves. Two barriers fall under this cluster namely LSM and TSK.

The fourth “independent” cluster has strong driving power but weak dependence. Four barriers form part of this cluster namely PIQ, EPP, UHC and RPF.

The classification into the above four clusters helps identify the potential difficulty in removal of the barriers. This can be utilized by management tasked with implementation of energy efficiency measures appropriately.

7. Conclusions

The aims of this research project were to identify important barriers to implementation of Energy Efficiency Measures in recycled fiber-based paper industry in India and to ascertain the interrelationship of these barriers. The same was achieved by developing a structured hierarchical model using ISM technique. Another aim was to study the dispersal of impacts of these barriers and to classify them based on their driving power and dependence power using MICMAC analysis. These two studies would enable us to ascertain the relative importance of each of the barriers and indicate the optimum direction for tackling them by managements. The important contributions of this project have been as follows:

- An extensive literature review was undertaken in the area of barriers to energy efficiency that inhibit implementation of EEMs. Taxonomies generated by various researchers were studied and a unified framework of barriers to energy efficiency has been presented.
- The review resulted in listing of one hundred and eight barriers to EEMs. After preliminary screening and rationalizing a list of 76 barriers remained. After consulting a panel of 36 experts selected out of industry professionals, 15 dominant barriers considered most relevant and important to the recycled based paper and pulp industry in India were identified. These barriers were codified as PIQ, CET, EPP, LSM, TMS, OTP, AEC, TSK, CAP, UHC, FIN, RPF, IEM, DCI and EMG.
- It is observed that all the fifteen barriers identified are important and any industry aiming to implement Energy efficiency measures would need to address them.
- The contextual pairwise relationship between each pair of barriers was arrived at by this expert panel using a written survey, brain storming and nominal group technique. The identified fifteen barriers were subjected to ISM technique that resulted in an eight-level hierarchical model. It indicates “Poor information Quality regarding available ECMs” and “Technical risks such as risk of production failure” to be the most important barriers at level VIII. “Top management support” and “Uncertainty about energy prices and fiscal policies” emerge as next in the order or priority at Level VII.
- The barriers were also categorized based on their driving and dependence power using MICMAC analysis into four clusters known as autonomous, dependent, Linkage and independent barriers. This categorization brought out “Poor information Quality regarding available ECMs”, “Uncertainty about energy prices and fiscal policies”, “Uncertainty about Hidden Costs” and “Technical Risks (e.g. production failure)” as independent barriers that deserve most attention while implementing any ECM.
- The MICMAC analysis also underscored the importance of company employees in effort towards EE.

"Lack of staff awareness or motivation" and "Lack of technical skills" emerged as linkage barriers having strong driving and dependence powers.

- The results can be leveraged by managements of different stakeholders to promote a culture of EE and to implement the ECMs. Market participants and technology suppliers can work to make good quality information available and to minimize the technical risks pertaining to their product and services.
- The top managements of companies need to support and prioritize the EE projects. They also need to invest in training, motivation and skill upgradation of their employees. Government agencies responsible for this sector need to take appropriate policy initiatives to make ECMs commercially attractive to the companies.

The work was carried out under certain limitations. In view of ongoing Covid-19 pandemic and on account of wide geographic dispersion of the paper mills under sample, digital media was used for expert's interaction. This limited the scope and depth of discussion to some extent. The number of experts was also relatively small. Performing empirical study coupled with use of appropriate multivariate analysis tools may further help in achieving better appreciation and understanding of causal relationships between the barriers to Energy efficiency.

Paper industry has a singular characteristic and limitation that each paper mill is a custom designed unique set-up in terms of location, size, plant configuration, products, work culture and process. As such there are bound to be local biases of the experts from the panel. This precludes standardisation and each technology upgrade or equipment needs to be custom built / installed.

The present study was restricted to paper mills employing recycled fibre as raw material. It would be appropriate to extend this study to mills using agro-fibres and virgin pulp as raw material, especially considering that the energy consumption in agro- based and virgin pulp-based paper mills is significantly higher and hence Energy efficiency is of even more importance for them.

The methodology adopted in this paper can be used in other process industries for modelling the hierarchical structure and ascertaining relative importance of factors affecting production. As a further work in this area it is planned to take up a similar study for driving factors that lead to better implementation of ECMs in paper industry.

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