Exploring the business case for Utilisation of Agro-residue as raw material for Composite Panel in India

(Stubble Up Project)

White Paper

CRB CENTRE for RESPONSIBLE BUSINESS
Enabling Change for Impact

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Contents

1. EXECUTIVE SUMMARY

In India, more than 500 million metric tons of crop residues are produced each year. Large parts of this, especially rice straw, but also wheat straw are burnt each year for quick removal, leading to very serious health hazards for the whole North Indian region. Yet, with globally increasing environmental awareness and developing interest in circular economy models, innovators are exploring the options to use crop residues productively. One emerging option is the production of composite panel, or MDF out of stubble or straw cut very shortly above ground. The National Policy for Management of Crop Residues, 2014 (India) for example mentioned the production of board out of crop residues as one possible solution to reduce crop burning. This option looks especially interesting, as wood shortage is all set to increase. The industry thus starts discussing the substitution of wood by faster growing natural resources, and most importantly by resources perceived as waste in other industries, such as bagasse, crop residues, and other forms of cellulose waste.

The plywood industry in India is approximately 100 years old; the MDF industry only 30 years. While the plywood industry is dominated by the informal sector, MDF is produced by large corporations, as the capital expenditure is extremely high. MDF especially is a market in full expansion, as economic growth, real estate and the demand for modular furniture all drive its growth.

Despite shortage of wood, the pressure on the industry to innovate has therefore been rather limited, so that the available technology in India to produce panel out of crop residues has not been commercialised at large scale. Bagasse-based products exist on the market, but are not very successful yet. In contrast, companies in countries like Thailand, The Netherlands, USA, and Germany, have in recent years developed products made from straw and husk and are very successful on the global market. In India, too, customer preferences start changing and a niche market exists in Tier I cities for ecological products such as organic food, and sustainable fashion. Thus, offering sustainable furniture options could be a great business opportunity in India as well. Challenges on the way to realise the potential of this opportunity, however, include especially the management of a complex supply chain in terms of seasonality, geography and raw material susceptibility to rot, as well as the marketing to end-customers.

In this situation, two vastly different business models appear as possibilities to exploit this market: (i) the interest of large players could push for rapid scaling up of supply chain management, production and marketing as substitute for regular board; (ii) rather small, decentral units could be used to pilot the product labelled as

ecological board, and identify its market value. Such small units could for example be created as CSR initiatives of larger companies as well.

Which of these two options is applicable, chould be decided after a detailed techno-economical feasibility study, as also suggested by the NITI-Aayog (2018), in a geographical setting that satisfies a few criteria, as has been provided in this *White Paper*.

2. BACKGROUND AND RATIONALE

2.1 CROP RESIDUE – WASTE OR RESOURCE?

Crop residue is the left-over organic material after harvesting. It is the non edible part of crops grown for food production, e.g. the straw of wheat plants, the stalks of lentil plants; or traditionally non used parts of the plant, e.g. stalks of cotton or jute plants. Crop residue is usually further divided into the stubble (the roots and short stem attached to it which remains on the field), and the straw/stalk that are harvested but not the primary produce.In India, more than 500 million metric tons (MT) of such residual biomass is produced annually.[1] A large part of this biomass is produced through grain production.

2.1.1 Wheat and rice crop residue - quantities, seasonality and geography

In 2017, India produced 92 MT of wheat on approximately 30 mnhectare land.[2] India is thus the second producer of wheat in the world. Estimates for the grain:straw ratio vary, but roughly speaking for every tonneof wheat grain 1.5 tonnesof straw are produced.[3] Based on these figures, one can calculate that **wheat straw production in India in 2017 has been of 138 MT**.[4]

Regarding rice, production in 2017 has been of 109 MT on approximately 43 mnhectare land.[5] This makes India the second largest producer of rice worldwide. The grain:straw ratio in rice again varies between 1:0.7 to 1:1.5.[6] **Estimates for the year 2010 put rice straw production in India at 284.99 MT.**[7]

Availability of both rice and wheat straw show a marked seasonality - wheat is harvested in April, while rice is harvested in October/November in North India. However, a study of IIT Kanpur 2007 shows that if one uses a variety of plants, availability of crop residue can be almost year round.[8]

Crop residues are also a resource that is marked by great geographical variability. Two third of the wheat production in India are concentrated in the three Northern states UP, Punjab and Haryana.[9] Over one third of the rice production is found in

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[1] www.nicra.iari.res.in/Data/FinalCRM.doc
[2] Department of Agriculture Cooperation and Farmers Welfare (2017a)
[3] Yasina et al. (2010)
[4] Agarwal (2007) estimated 159.98 mio t for the year 2010
[5] Department of Agriculture Cooperation and Farmers Welfare (2017b)
[6] NL Agency 2013
[7] Agarwal (2007)
[8] Agarwal (2007)
[9] Directorate of Wheat Development (no date)

West Bengal, UP, and Odisha.[10] Figures of 2009 indicate the following production of grain straw:[11]

State	Quantities of cereal crop residue
UP	72 MT
Punjab	45.6 MT
West Bengal	37.3 MT
AP	33 MT
Haryana	24.7 MT

Table 1: Indian states with highest crop residue production in 2009

[10] 2014 Data of Community.data.gov.in (2017)
[11] Jain et al. (2014)

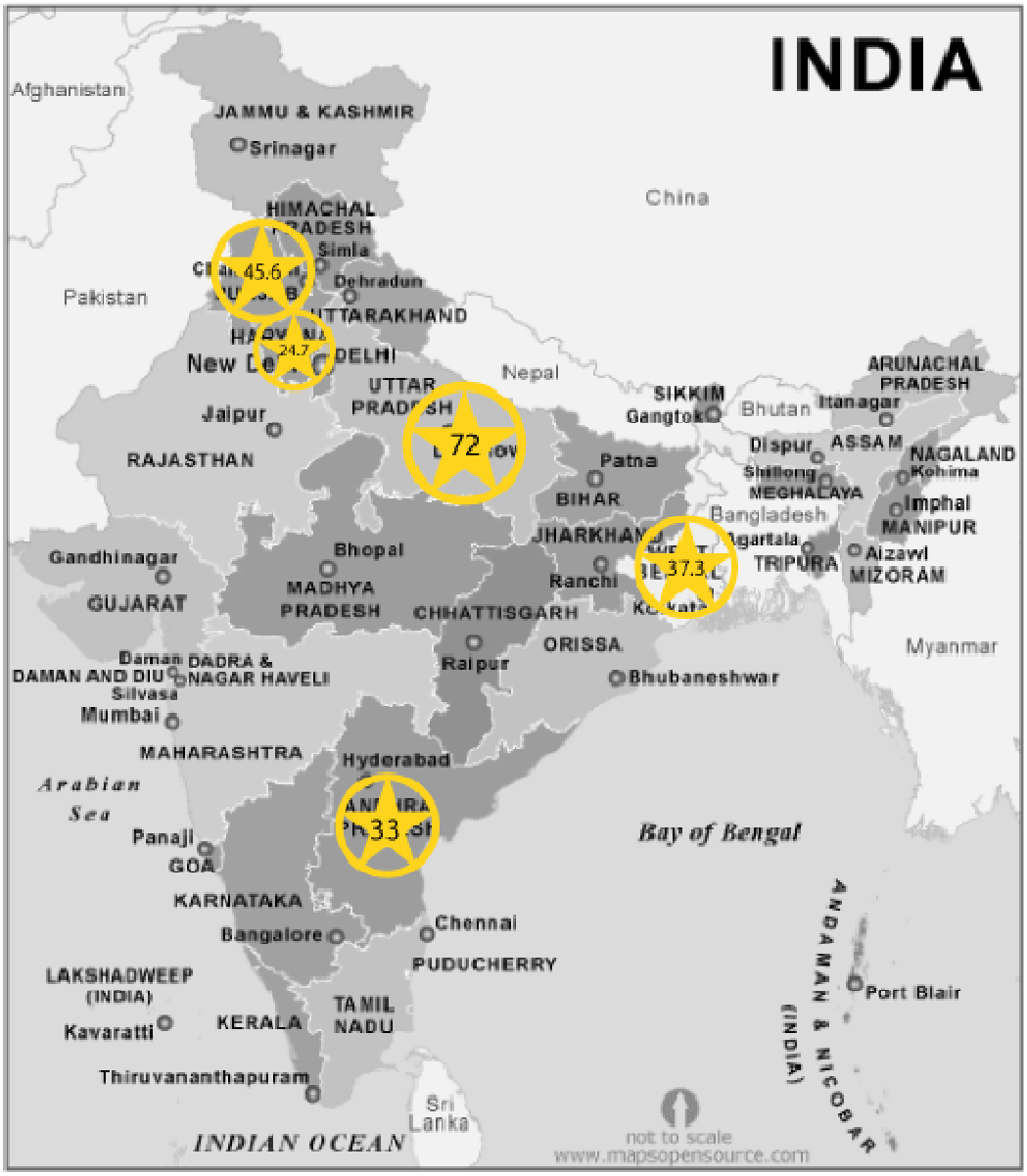

Fig. 1: States with highest crop residue production. Numbers indicate million tons per year.

2.1.2 Crop residue uses

Crop residues have traditionally had a variety of uses in rural areas. Rice straw, for example, is used especially in South India as feed for ruminants despite its rather low calorific value; wheat straw is used as fodder extensively throughout the country. Apart from this, straw is used as manure, in the production of mats, as poultry litter, for animal bedding, and for mushroom production.[12] Both wheat and rice straw have been used as fuel for cooking, thatching, or as traditional building material (part of mud bricks).[13] With the advent of industrialisation, straw has been used for packaging of glass and fruit, and for firing brick kilns. Apart from these uses, new uses have been introduced in recent years, namely the use of straw for biofuel

[12] Singh et al.1995
[13] NL Agency 2013

production and energy generation.[14] As both of these lead to the combustion of straw, these uses are however not CO2 neutral. Thermal insulation is another use of straw in the construction industry.[15] Finally, both crop residues are partly composted and /or incorporated into the fields to maintain soil fertility. Composting and incorporation, if managed properly, can lead to carbon accumulation in the soil.

Caveat

Despite the focus of this report, it should be noted that from an environmental point of view, and as has been agreed across the Indian agriculture/scientific community, by far best option of usage of crop residue is in-situ incorporation or mulching of agriculture residue into the agricultural land. This practice combats soil degradation, preserved the soil nutrients and biotic community and reduces the need of fertilisers tremendously. It helps in building up top soil that acts as CO2 sink, that has much improved water absorption/retention capacities as compared to degraded soils, and that benefits the plant-microbial bridge and flow of liquid carbon into the soil, thus leading to a higher nutrient content in food items. Experiments in Ukraine have also shown that soil carbon content only increased if the entire available straw was ploughed back into the soil after harvest.[16] Burning of straw is calculated to lead to the loss of an equivalent to US $18 million worth of urea.[17]

Despite these existing uses, every year, around 90% of paddy straw and 25% of wheat straw is currently burnt in open air by the farmers in India.[18] Rice straw is burned to a larger extent especially due to the short time window of 10-15 days between harvest of rice and sowing of wheat.[19] The amount of straw burned has increased tremendously with the introduction of combine harvesters as these machines leave a large stalk in the field as compared to manual harvesting where the plant is cut shortly above the ground.[20] Shortage of manual labour on farms is also a contributing factor,[21] as this further pushes for mechanical harvesting. From a farmer's perspective, burning of crop residue is cost-effective,[22] allows quick reutilisation of the agricultural field, and is said to prevent the spread of phyto-diseases.

[14] Teri & Yes Bank (2018)
[15] Ellen Macarthur Foundation (2016)
[16] NL Agency 2013
[17] http://www.downtoearth.org.in/coverage/not-a-waste-until-wasted-40051
[18] Refer https://www.hindustantimes.com/delhi-news/delhi-s-pollution-nightmare-crop-burning-in-nearby-states-begins/story-djXJY8W0Ugzm8dgsxmbN0K.html and other sources (Jain et al. 2014) that indicate a great variation between 8-80% of straw that is burnt
[19] CII & NITI-Ayog (2018)
[20] Jain et al. (2014); Interview Mr. Chitlangia 18.05.18
[21] GoI (2014)
[22] NL Agency 2013

This way of disposing off crop residue represents a major health hazard in the whole region, and contributes around 50% of the fine particulate matter in Delhi's air in the months of October/November.[23]

Table 2 shows the air pollution generated through straw burning in Egypt.

Pollutant	g/kg straw burnt
CO2	1460
CH4	0.74
N2O	0.79
CO	72.4
NOx	3.52
SO2	0.15
PM2.5	12.95

Table 2: Pollutants produced through straw burning. (Source: NL Agency 2013)

Over the year 2009, figures for India indicate that in UP alone, 3.37 MT of CO2, 2 MT of CO, 55600 tonnesof NOx, 899 tonnesof SOx and 86800 tonnesof PM2.5 have been emitted through crop residue burning.[24]It has been established beyond doubt that health hazards associated with air pollution range from respiratory problems to cancer. Moreover, CO2 is a known agent contributing to climate change.

However, even from an economic point of view, open field burning is seen increasingly as inefficient. It leads to nutrient loss, loss of soil fauna and microbes, [25] and the resource straw constitutes is not utilised. As CII & NITI-Ayog (2018) note, it is time "to assign a real economic and commercial value to the agricultural residue". Crop residue has in fact come into the focus as one of the agricultural "wastes" that could and should be recovered and utilised productively in the context of a more circular economy.[26]

[23] The Indian Express 2018; a study done by IIT Kanpur indicates a contribution of 26% of PM 2.5, and 17% of PM 10 (Sharma &Dikshit 2016).
[24] Jain et al. (2014)
[25]GoI (2014)
[26] Teri & Yes Bank 2018

2.2 CIRCULAR ECONOMY – CONTEXT AND RATIONALE

In recent years, the global economic debate has started shifting towards the concept of "Circular Economy".[27]

Circular Economy (CE) is defined as an economic system in which material and energy are recycled and reused as much as possible. It rests on three core principles: design out waste and pollution; keep products and materials in use; regenerate natural systems.[28] CE is seen as an alternative to a linear economic model of "make, use, dispose"[29] and proposes to significantly reduce natural resource use and waste disposal while at the same time maintaining economic growth and consumption oriented lifestyles.[30]

The concept has received much attention since a 2012 report by McKinsey & Co. has calculated the potential economic benefits of a circular economic model for the EU to be 1.8 trillion Euro by 2030. The concept also fits into the larger developmental discourse: In 2015, the Sustainable Development Goals included sustainable consumption and production patterns in the list of international goals to be achieved by 2030.

At the same time, the EU ratified a Circular Economy Action Plan[31], whereas Indiaestablished the Indian Resource Panel in order to promote the use of recycled materials and resource efficiency.[32]In 2016, the EllenMcArthur Foundation calculated that **a circular economy trajectory in India could lead to annual benefits of ₹40 lakh crore (US$ 624 billion) in 2050**, while reducing greenhouse gas emissions and other environmental externalities.[33] Following these developments, India and the EU decided to collaborate on matters of the circular economy in 2017.[34]

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[27] This concept has its roots in the 1966 model of the "closed economy" coined by Kenneth Boulding and has been further developed by several economists over the last decades. It has been influenced by a number of theoretical discussions, namely cradle to cradle, laws of ecology, looped and performance economy, regenerative design, industrial ecology, biomimicry, Permaculture and blue economy (Wikipedia, no date).

[28] Ellen Macarthur Foundation 2017

[29] "A circular economy is an alternative to a traditional linear economy (make, use, dispose) in which we keep resources in use for as long as possible, extract the maximum value from them whilst in use, then recover and regenerate products and materials at the end of each service life." (Wrap 2018)

[30] "A circular economy aims for a global economic system that can thrive in the long-term by decoupling economic growth from resource use and environmental impacts. It has the potential to give rise to much more resilient economies with more abundant resources and a healthier environment. " BSI Group (2017)

[31] European Commission et al. (2015)

[32]Matthan (2018)

[33] Ellen MacArthur Foundation (2016)

[34]FirstPost (2017)

In 2018, TERI and YES Bank have prepared a report on the Circular Economy[35] which wants to address the resource usage of India's fast growing economy.
The report identifies 5 Rs as crucial for designing a Circular Economy: reduce, reuse, recycle, re-manufacture (create new products by utilising waste streams), and repair/refurbish. The initiative discussed in this Whitepaper fits most importantly into the 4th of these R.

The concept of CE is, of course, nothing new to India. In a way, *jugaad*[36]is practiced circularity and reuse and recycling have always been normality in this country,[37] though these have partly been practices of the lower classes and are associated with certain amount of stigma. Newer aspirations of the growing middle class might therefore run counter to the concept of circular economy, in some cases.[38]

For the context of this study, it is important to note that **all so-called waste products of agricultural production can be incorporated in a circular economic model**. Straw being one agricultural 'waste' produced in huge quantities in India, its use as resource for innovative product lines will have social, environmental as well as economic benefits elaborated on below. However, to take advantage of this situation requires specific harvesting techniques - either the manual harvesting that cuts the grain stalk shortly above the ground, harvesting with combine harvesters whose cutting height can be adjusted to leave less stalk on the field (e.g. twin cutter bar harvesters)[39], or stubble removal from the field.[40]

3. STUBBLE UP PROJECT

3.1 AIMS AND OBJECTIVES

This study aims at exploring the possibility of converting rice/wheat straw into composite board in India, by assessing global experiences and having discussions with key stakeholders. Though the use of rice/wheat straw for the production of composite boards/panels has been considered in India[41]and the technology is available,[42]commercialisation hasn't taken off. Industry experts believe this has been due to a combination of techno-economic and logistical factors. Identifying and creating the market for such products also seem to emerge as a primary constraint.

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[35] Teri & Yes Bank (2018)
36 As per Oxford Dictionary, the expression *Jugaad*(word in Hindi language) is defined as, "a flexible approach to problem-solving that uses limited resources in an innovative way". Countries around the world are beginning to adopt jugaad in order to maximize resources
[37] Teri & YES Bank (2018)
[38]Matthan (2018)
[39]GoI (2014)
[40] Interview Mr. Chitlangia 18.05.18
[41] Pandey & Sujatha D. (no date)
[42] IPIRTI (2018a)

This study therefore sets out to review past experiences in India and current global best practices to identify opportunities as well as challenges linked to the production and marketing of this product in India.

3.2 Stakeholders

The stakeholders of this study are first and foremost the inhabitants of North India who are until date obliged to frequently breathe air that is hazardous to human health. As those responsible to promote and increase the people's health and well-being, naturally the Indian government and the governments of the relevant states are stakeholders in any process that can mitigate air pollution. Moreover, the farmers are significant stakeholders, as a valuable resource they produce is in many cases not fetching its actual market value. Finally, all those actively involved in manufacturing MDF or in using it for producing consumer goods etc. are stakeholders in that panel made from crop residue could be a competitor to their traditional products, but also a chance to innovate and branch into the production of a more sustainable and environmentally friendly product.

3.3 Approach and Methodology

This study is based on a desk study as well as qualitative interviews conducted with three representatives of the plyboard manufacturer industry, two senior scientists, and two representatives of plyboard buying companies.
Care has been taken to collate academic and business research with first-hand information from the sector, as this study covers cutting edge issues which have not all been documented at this stage in the literature. A stakeholder meeting has been organised by Centre for Responsible Business and MVO Netherlands that brought together actors form the United Nations, Scientists, NGOs and innovators. The discussions of this meeting have further enriched this report.

3.4 Limitations

This study is constrained in time as research has been carried out over two months in May and June 2018. Therefore, it concentrates on one sector, the composite panel industry, and does not look into other useful products which could be made out of crop residues in the logic of circular economy. Both time and financial means have not permitted travelling to gather more extensive or face to face primary data, so that interviews were conducted over the phone. Geographically, the research has concentrated on the Northern Indian states; partly because these are the centre of grain crop production in India as well as of hazardous air pollution in parts of the year; partly to allow more in-depth analysis for a smaller area rather than a superficial analysis over a larger area.

4. COMPOSITE PANEL INDUSTRY IN INDIA

4.1 PRODUCT TYPES AND MARKET IN INDIA

Traditional plywood is manufactured from layers of wood veneers that are bonded by different, mostly formaldehyde based, adhesives. A variety of wood qualities and sizes can be used to make boards of different hardness and water resistance, depending on usages.[43]

Besides plywood, newer products in the industry are

- particle board (made from wood waste chips, sawdust etc.)[44]
- fibre boards/ composite panel/ medium density fibre board (MDF, made from wood fibres)[45]

Plywood has different usages according to its hardness. Softwood plywood is used for floors, walls and roofs in home constructions, for packages or fencing. Hardwood plywood is used among other for heavy wear flooring in containers, buildings or factories.

MDF is used mostly for furniture and other indoor applications like cabinetry, flooring, loudspeaker boxes and more. PB is used for similar uses as well as sound insulation. Density and strength of PB is lesser than that of MDF; its advantage is that it is light in weight and its cost is also reduced.

Particle board qualities cannot compete with plywood. MDF, however, has very good qualities in terms of screw holding, bonding, edge cutting, and moisture resistance. MDF allows raw material utilization to the extent of 95%, against 65-70% as is the case with plywood. MDF is therefore seen as a more environmentally friendly alternative especially to cheaper (i.e. softer) plywood qualities.[46]

In 2016, the Indian wood panel industry[47] has reached a value of INR 250 billion. [48][49]Plyboard accounts for 67% of this market, while the MDF market is estimated to

[43] Ken Research (2015)
[44] Displays2Go (2015)
[45] Composite Panel Association (no date)
[46] Business Standard (2013)
[47] This includes laminates.
[48] Shah & Shah 2015; other sources estimate its value to be of 4 billion USD (Imarc, no date)
[49] NPCS (no date)

be worth INR 13 billion (5%), and the Particle board market has reached INR 27 billion (10%).[50]

4.2 History and Context

The Indian plywood industry is almost 100 years old. The first factory opened in 1924-5 in Assam.[51] The Indian government supported the budding industry after independence through establishing various research organisations, like the Indian Plywood Manufacturers Research Association, IPIRA (1962; today IPIRTI), and the Indian Paper and Pulp Research Institute (1980).[52] By 1968, 74 plywood factories existed in India.[53] Initially, the industry was driven by the demand of tea-chest plywood, but by the 1960s this changed and more than 50% of demand was for other uses such as decorative plywoods, marine and aircraft plywoods, doors etc.[54] Today, In India, more than 50% of plywood is consumed in the residential sector; in fact, 66% of the plywood consumption is for manufacturing of furniture alone.[55]

During the decadesupto 1996, the Indian plywood industry was almost exclusively located in the North-Eastern states. In 1996, however, a landmark judgement in the TN GodavarmanVersus Union of India case banned felling of all trees in forest areas. Two years later, the government cancelled the licenses of all plywood manufacturers in the North-East to force relocation to designated industrial zones for better state control. These two developments totally changed the landscape of the Indian plywood industry, in terms of location as well as the mix of formal and informal actors in the field.

Manufacturers started relocating to areas in proximity to ports for timber import, as well as proximity to plantations. A cluster emerged in West Bengal. Formal sector players also started outsourcing to informal units, and large informal clusters emerged in Haryana, Punjab, UP, Kerala and Karnataka as well as Gujarat and West Bengal. While before the judgement approximately 60% of the market was in the hands of the formal sector, now the balance shifted to 90% informal manufacturers. Only more recently, the emergence of formal players in the agro-forestry sector has lead to a partial re-formalisation. Big players like Greenply, Centuryply for example, are backward integrated with timber operations in Laos and Myanmar, and planto

[50] Shah & Shah (2015)
[51] Chitlangia (1968)
[52] Chitlangia (1968); IPIRTI (2018b); CPPRI (2018)
[53] Chitlangia (1968)
[54] Chitlangia (1968)
[55] Imarc (no date)

expand further to Indonesia and Vietnam[56] for in-house procurement of timber. Due to these developments, the market share of informal units has declined to approximately 60-70%.[57]

Today, government regulations represent a large entry barrier. Pursuant to the Supreme Court's order, opening of a new saw mill, veneer or plywood industry requires prior approval from the Central Empowered Committee (CEC).[58] Entrance of new players into the market is therefore not easy.

MDF has been developed in the 1960s in the USA. Since then the industry has globally grown to a production capacity of 54 bio m3.[59] In India, MDF was introduced in 1987, with a manufacturing unit of Mangalam Timber Products in Odisha. Nuchem opened a unit in 1992. Only from 2006 onwards, however, big players entered the market and made MDF much more visible, and in the following also more accepted in the market. In the 2000's six more units opened in the country. The country's biggest MDF factory belongs to Greenply and opened in 2010; the company has signed the contract for a 2nd unit in 2016 that will have the capacity of the whole current domestic MDF market (see section 4.4).[60]

4.3 Main Players

As mentioned in chapter 4.2, the plywood industry in India is dominated by the informal sector to as much as 70-80%. This sector mostly caters to the medium and low-end range of the market. The remaining 20-30% of the market consists of over 500 different manufacturing companies.[61] However, 5-6 companies are the dominant players. Greenply alone has a 26% market share in the organised plywood market,[62] or 4.1% share in the total market. It is closely followed by Century Plywood (3.4%), Kitply Industries (3.2%) Worthy Plywood (2.3%), Sarda Plywood Industries (1.8%) and Uniply Industries (1.4%).[63] Other important manufacturers are National Plywood, Merino, Westernply, Jollyboard and more.

[56] Global Wood Markets Info (2016)
[57] Shah & Shah 2015
[58] Shah & Shah (2015)
[59] Business Standard (2013)
[60] Greenply Industries Ltd. (2016)
[61] Sawmill Owners & Plywood Manufacturers Association (no date)
[62] Greenply Industries Ltd. (2016)
[63] NPCS (no date)

Though not all manufacturers of plywood have entered the MDF and PB market, there is a large overlap of players, as the following table shows.

Company Name	Headquarters	Plywood	Fibre board/particle board
Centuryply	Kolkata	x	x
Greenply	Kolkata	x	x
National Plywood Industries	Kolkata	x	-
Sarda Ply	Kolkata	x	-
Mayur Plywood	Kolkata	x	-
Western Ply	Kerala	x	-
Jollyboard	Mumbai	-	x (softboards)
Kitply	Kolkata	x	x
Uniply	Chennai	x	x

Table 3: Main plywood manufacturers in India.

In contrast to plywood, the MDF segment has no significant involvement of the unorganised sector.[64]Greenply holds a 30% share in the MDF market as the following table indicates.[65] In the PB segment, approximately 70% of the market is informal.[66]

Company Name	Volume (CBM)	Market Size (million INR)	Market Share (%)[67]
Mangalam Timber	17,000	400	3
Shirdi Industries	12,000	280	2
Action Group	115,000	2,750	21
Greenply Industries	161,000	4,080	31

[64]Greenply Industries Ltd. (2016); Shah & Shah (2015)
[65]Greenply Industries Ltd. (2016)
[66] Shah & Shah (2015)
[67] Market Share data is from before the Centuryply production unit was opened.

Company Name	Volume (CBM)	Market Size (million INR)	Market Share (%)[67]
RushilDécor	60,000	1,050	8
Nuchem	64,000	848[68]	8.5
Centuryply	198,000	no data	no data
Domestic production total	**627,000**	**9900**	**66**[69]
Planned production			
Greenply	360,000		

Table 4: Main MDF manufacturers in India

4.4 Location of the Industry

The developments mentioned in section 4.2 have led to a concentration of plywood industries in Kolkata with 6 out of the 9 leading companies located here. In terms of manufacturing units, however, Yamuna Nagar in Haryana is considered to be the plywood hub having more than 250 units.[70] The plywood manufacturing units of the two biggest players in the industry are distributed strategically in the country.

Company	Unit Location	Benefit
Greenply	Nagaland	proximity of timber
	West Bengal	proximity to port and East Indian market
	Uttarakhand	proximity to timber and North Indian market
	Gujarat	proximity to port and West Indian market
Centuryply	Chennai	proximity to port and South Indian market
	Assam	proximity to timber resources

[68] Crisil Research (no date). This includes other business branches of Nuchem.
[69] Shah & Shah (2015)
[70] Shah & Shah (2015)

Company	Unit Location	Benefit
	West Bengal	proximity to port and East indian market
	Haryana	proximity to North indian market
	Kachch	proximity to port

Table 5: Location of the main plywood production units. (Sources: Greenply Industries Ltd. (2014); MoneyControl (no date)).

The MDF industry shows a more diverse geography.

Name	Headquarter	Number of manufacturing Units (Composite Board)	Location
Mangalam Timber Products	Kolkata	1	Odisha
Nuchem	Jaipur	1	Haryana
Shirdi Industries	Mumbai	1	UK
Action Tesa	Delhi	1	UK
Greenply	Kolkata	1 (2nd opening in 2018)	UK, (AP)
RushilDécor	Ahmedabad	1	Karnataka
Centuryply	Kolkata	1	Punjab

Table 6: Location of the main MDF production units. (Source: Shah & Shah (2015)

Fig. 2: Location of the main MDF production units in India.

While manufacturing is mostly based in North India, 50% of the MDF market is located in South India.

4.5 Growth of the Sector

With rising incomes, economic growth and a flourishing real estate market, the plywood and composite panel market is in full expansion.[71]

The plywood market has grown at a CAGR of nearly 5% in 2009-2016.[72] After introduction of GST in 2017, demand for plywood had plummeted by 50% within a

[71] Greenply Industries Ltd. (2016)
[72] Research & Markets (2017) based on IMARC (2017)

month.[73] In November of the same year the GST rate was reduced from 28% to 18%. Following this, industrial actors expect strong growth of 25% year on year in the coming years.[74]

The MDF industry has already been growing at 20% CAGR between 2010 and 2015 due to the above named drivers plus an increased demand in readymade furniture. It is the fastest growing segment in the wood panel industry.[75] The PB industry has also grown strongly at 15% CAGR in the same time.[76] As GST has levelled the price differences between cheap plywood and composite board, it is expected that the low price plywood segment might get flushed out to some extent by MDF or particle board.

Moreover, India's MDF market is considered to be still underexploited, especially since consumption of MDF is much lower than in neighbouring China. As a result of this, China produces around 44 million m3 (44% of the global volume produced), while India produced only 517,000 m3 of MDF in 2015.[77]

In 2008, India still imported more than 50% of its MDF demand. This declined significantly with the entry in the market of Greenply, who built a manufacturing unit with a capacity of approximately 50% of the country's demand at the time. This unit used a new technology (continuous press technology) that was cheaper and allowed for more differentiated products.[78] In 2016, imports were down to 30% of the MDF consumed in the country, and imports continue to decline. The market is therefore considered to be in full expansion, and strong growth drivers lead analysts to expect a doubling of the market value by 2020 to 30 billion Rs.. Based on this outlook, manufacturers like Greenply and Rushil Decor are planning to triple their capacity in the coming years, as mentioned above.[79] The new Greenply manufacturing unit is located in Andra Pradesh, chosen for easy availability of plantation wood[80] as well as to get a foothold in the large South Indian MDF market.[81]

[73] Plyreporter.com (2017)
[74] The Times of India (2014)
[75] MoneyControl (2018)
[76] Shah & Shah (2015)
[77] Greenply Industries Ltd. (2016)
[78] Shah & Shah (2015)
[79] MoneyControl (2018)
[80] Greenply Industries Ltd. (2017)
[81] Shah & Shah (2015)

4.6 CHALLENGES AND OPPORTUNITIES

Both, the plywood and the MDF industry benefit from an increased popularity of wood based construction material.[82] However, the industry is in a restructuring process that benefits bigger companies, as well as the formal sector. This latter development is understood to be caused by an increasing demand for branded plywood, as well as the GST regime which has lead to a decrease of the price difference between branded and non-branded plywood.[83][84]

MDF in particular appears to be a market in full expansion, especially due to changing customer preferences that drive a fast growing demand for modular furniture / ready-to-move-in apartments and offices.[85] Moreover, cheap category plywood has been witnessing stiff competition from the MDF and particle board (PB) segment, as plywood prices have increased.[86] This has led to a decline in price difference.

As MDF generally experiences an increase in acceptance in the market, it is therefore estimated that MDF might capture a portion of the INR 40 billion cheap plywood market segment. Also, MDF imports are still at 30% of demand, so that opportunities to increase domestic sales is high for the industry, though imported MDF is cheaper at least in coastal areas.[87] Substituting imports by domestic production is helped by recent political developments. In July 2016, the Finance Ministry, Government of India has imposed definitive anti-dumping duty on Plain Medium Density Fibre Board (MDF) imports from Vietnam and Indonesia. Anti-dumping duty on Plain MDF Board is levied on boards having a thickness of 6mm or above and will be valid for a period of five years. The petition seeking an anti-dumping probe on MDF had been jointly filed by Greenply Industries and Mangalam Timber Products. Rushil Decor Ltd, which accounts for 20 per cent of production, had supported the petition.[88] This decision will thus further benefit the industry.

In general, the government is perceived to propagate MDF and PB over plywood by restricting capacity expansions for the latter.[89] This is partly due to higher awareness for the importance of forest cover.

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[82] Dahiya (2015)
[83] Shah & Shah (2015)
[84] The Times of India (2014)
[85] Shah & Shah (2015)
[86] Shah & Shah (2015)
[87] Shah & Shah (2015)
[88] Srivats (2015)
[89] Business Standard (2013)

Despite the situation presenting rather limited incentives for manufacturers of MDF and PB to innovate, the ***scarcity of wood and changing environmental sensibilities pose a serious challenge to the industry and might provide an opportunity for the industry to venture into the new products that are the subject of this report***. Plywood and panel manufacturing uses approximately 8.3 million m3 of wood per year in India.[90] A large part of this wood is imported. In 2017, India imported 1.7 million m3 of wood in the first two quarters alone.[91]

Rather than relying on this slow growing, externally procured natural resource, crop residues have come into the focus of the industry at least in other parts of the world as fast growing, cheap, and locally available resources for the panel industry.

5. Crop Residue – Innovations and Possibilities, as raw material for Composite Panel Industry

5.1 History and Case Studies of Global Best Practices

China, US, The Netherlands, Germany, Thailand and other countries have developed or are currently developing alternative fibre board and particle board technologies that use crop residues as raw material with the aim to produce quality products that can substitute for wood as input material.

Though first technologies to produce rice husk particle board had been developed in India in 1985,[92] manufacturers and research organisations worldwide long struggled with the new input. The different composition of straw - containing less fibre, and being high in silica content - proved to be challenging. In the late 1990s, the EU funded a research project on "Innovative Technology for Panel Manufacture from FiberisedAgriwaste".[93]

Around 2008, IPIRTI and the CPPRI in India worked on producing MDF using rice straw and the technology developed allowed producing a board with a quality similar to that of wood based boards.[94] IPIRTI has since developed various boards out of agricultural residue, such as rice husk MDF boards, bagasse particle boards, wheat particles board, wheat straw board, rice straw MDF boards, coconut husk board and pine needle boards.

[90] NCCF (2017)
[91] Plyreporter.com (2017)
[92] Pandey & Sujatha D (2009)
[93] European Commission CORDIS (2002)
[94] Interview Mr. Chitlangia 18.05.18

First attempts at commercialisation in India, however, have been problematic and unsuccessful. Production trials using sugarcane bagasse (a Unit promoted by Bajaj Industries Ltd, started around 2000, closed down in 2012) failed commercially. Due to higher costs and lower quality of the product as compared with wood based board, acceptance in the market was very poor.[95] A pilot project using rice straw, having been anchored by a representative from the industry who also used rice straw to produce paper, had solved the logistical issues of seasonality, storage and transportation. Nevertheless, due to internal business reasons this pilot project was never commercialised.[96]

In the last ten years however, things have started moving fast in this segment and a number of companies have globally started to commercially produce straw based panel. There are perhaps lessons for India to draw from these experiences, especially given the scarcity of wood and changing consumer preferences. The following table gives an overview of some existing companies who produce board out of crop residues, globally.

Company Name	Product	Input	Year of Launch
Dow Pipeline, Canada	Composite Board	Wheat Straw	2001
Kirei, USA	Board	Sorghum stalks	2004
Oryzatech, USA	stak Blocks	Rice Straw	2009
Novofibre, China	Oriented Structural Straw Board	Wheat Straw	2009
Kokoboard, Thailand	Board	Rice Straw, Rice Husk	2009
Resysta, Germany	Board	Husks	2010
Avery Dennison & NOBLE Environmental Technologies, USA	ECOR Panels	Any form of cellulose	2017
CalAg LLC, USA	Medium Density Fibreboard	Rice Straw	2018

[95] Interview Dr. Pandey 17.05.18
[96] Interview Mr. Chitlangia 18.05.18

Table 7: Producers of crop residue based board. (Sources: Sardar, Z. (2009), Treehugger (2004), Han, G. et al. (2012), Esler, B. (2016))

The following boxes summarise some of the global success stories:

Company: Resysta International GmbH
Country: Germany
Product: Panel made from rice husk, salt and oil

Details: Resysta has developed a building material for outdoor use and all uses where water creates a problem that replaces tropical hardwood. The material looks like tropical hardwood, but has certain advantages:

- it cannot absorb water, which causes wood to swell, warp and splinter
- rice husks are poor in lignin, thus the material maintains its original appearance unlike wood that greys

Recognition: Can help projects gain LEED Green Building credits. Has won several design awards.

Portland, USA, 2016

Company: Kirei
Country: USA
Product: Panel made from sorghum stalks

Details: Material designed for its aesthetic appeal; interior uses. Currently, Kirei uses a no-added-urea formaldehyde adhesive, with bio-based binding agents in the pipeline.

Recognition: Customers globally including Starbucks, McDonald's, Hilton and Google. Can help projects gain LEED Green Building credit.

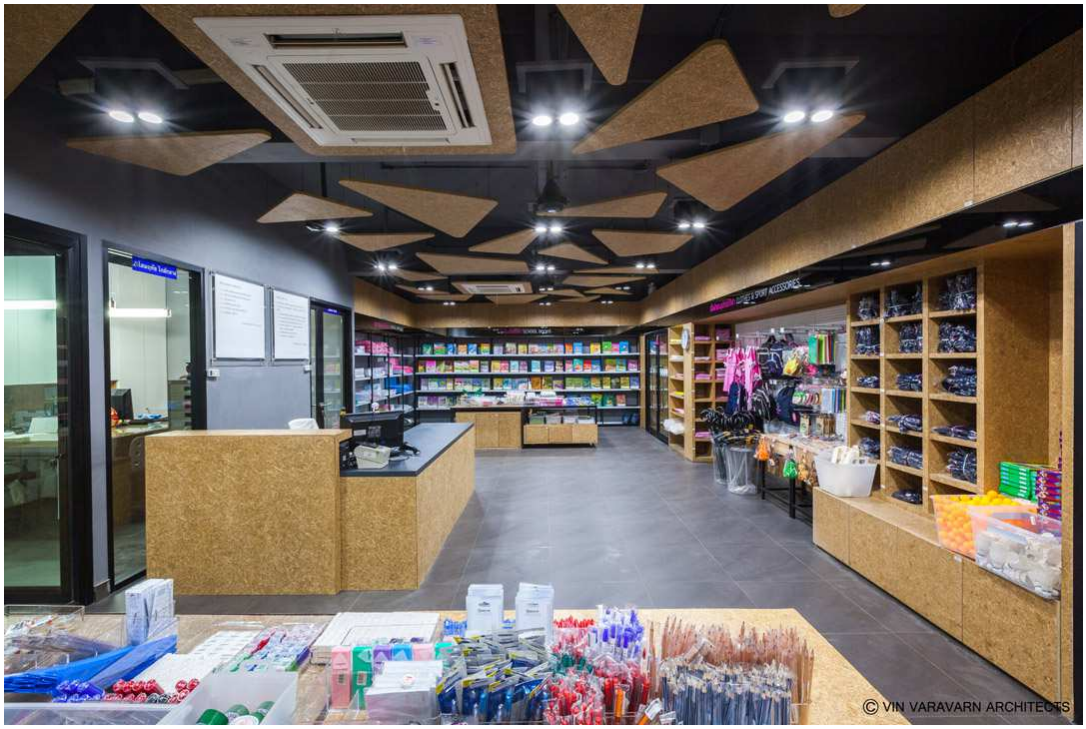
Price range: comparable to mid-range hardwood

Company: Kokoboard
Country: Thailand
Product: Panel made from rice straw, rice husk (and other material)

Details: Panels for flooring, ceiling, decoration, furniture. The boards are moisture resistant and can be used in bathrooms and kitchens. No formaldehyde is used.

Recognition: British Council Climate Champion 2010, Finalist, Sankalp Award, india 201, Finalist, Postcode Lottery Green Challenge, Netherland, 2011, Thai SOCIAL ENTERPRISE Award 2014, Finalist, The Venture, Thailand, 2015

Opportunities for SMEs: Kokoboard has developed a low cost manual rice straw board production line that makes panels of 60x60 cm



5.2 TECHNOLOGY

Today, the technology to produce high quality composite board out of crop residues exists in India. This was confirmed by a number of industry stalwarts interviewed during the process of undertaking this study. Dr. Pandey, former Director of IPIRTI, confirmed that the technology is mature and had been commercialised in the late 1980s already (though commercialisation failed due to logistical and price problems).[97] Similarly, Jaydeep Chitlangia of Sardaply, and Mr. Bhajanka of Centuryply stated that technological issues are minimal.[98] Yet, Dr. Roy, former Director of the CPPRI, suggested that further screening of existing technologies would be beneficial to identify best practices.

One of the problems the industry originally had struggled with was the question of the adhesive. Straw having different chemical and physical characteristics than wood, the traditional formaldehyde based adhesives are not able to penetrate the raw material without prior treatment. Some researchers have identified a chemical-thermo-mechanical treatment that allows usage of traditional adhesives. This said, formaldehyde based resins are a health hazard for workers and even end users as plywood continues to emit formaldehyde. The development of formaldehyde free adhesives is therefore a need of the hour, for the industry.

[97] Interview Dr. Pandey, 17.05.2017
[98] Interview Mr. Chitlandiga, 18.05.18

Other researchers seem to have successfully experimented with different, non-formaldehyde based adhesives such as PMDI (polymethylene diphenyl diiscyanate), though these are upto ten times more expensive[99] and therefore not used in India so far.[100] Finally, companies like Ecor and Resysta produce hardboard without the usage of any adhesive. Water, heat and pressure, or water, salt and oil are used to produce these boards that don't require any chemical additive.

Another technological means to overcome the different chemical composition of straw as compared to wood has been developed by innovators such as Kriya Labs, New Delhi. This company has developed a technology of separating lignin from cellulose in decentralised(mobile) units. This could facilitate the utilisation of cellulose for making boards or paper, while pushing for new usages of lignin. Dr. Roy, former Director of the CPPIR also encouraged raw material upgradation of straw at the site of harvest to remove silica, the debris of the resource, in order to bring down transportation costs and increase the quality. High silica contents are especially problematic in the production of particle board, while not posing major issues in the production of MDF.[101].

5.3 Business Lens analysis

5.3.1 An emerging market for eco-friendly products

On the Indian market, a crop residue based MDF or PB does not exist at this point of time. However, corporates that use readymade furniture in their shop setups, or sell readymade furniture to customers seem to have interest in such innovative products, as has been confirmed from their discussions with the research team.

Globally, it is the discourse around a more sustainable use of natural resources that is driving the development of the market for agro-waste board. Entrepreneurs everywhere realise that using what is considered a waste product not only brings environmental benefits but even makes sense from an economic point of view. The commitment to sustainability increasingly becomes a selling point at least in the upscale market, where awareness is high, and Indian clients have started embracing global values of ethical consumption. As is seen in the growing market for organic food products (projected to grow at a CAGR of over 23% by 2023)[102] and sustainable fashion, niche markets for such products exist especially in Tier I cities. Bringing the sustainability discourse into the home furniture market could be an innovative and advantageous move for manufacturers. Finally, one interviewed manufacturer

[99] Halvarsson 2010
[100] Dr. Sujata D.'s presentation at the stakeholder meeting
[101] Dr. Sujata D.'s presentation at the stakeholder meeting.
[102] TechSci Research (2018)

pointed out that this product would find global acceptance due to its environmental benefits, so that a market analysis should not restrict itself to the Indian market alone.[103]

In India, companies like ITC already work on ways to use post-consumer plastics for producing polymers. Such polymers could be fused with agri-residue to develop panels and representatives of the company showed interested in exploring this possibility. However, one could argue that growing demand for such products could have implications on supply of plastics.[104] Godrej Interio as well showed interest in case such board is offered at a competitive price and has similar qualities as regular MDF. Representatives noted how using such a panel could act as a unique selling point on the market.[105] Creating a niche product as the one that is being presented in this report, could also be augmented through application of sustainability standards and certificates. One such standard, Forest Stewardship Council has shown interest in such possibilities, especially when the product is produced strictly using agro-residue.

5.3.2 Production costs

In other parts of the world, calculations have shown that production of composite board promises to be around 20% cheaper than the production of traditional plywood. One contributing factor in this is that it requires less energy use as processing and drying is easier than for wood.[106] Another factor is that straw is comparatively cheap.

Rice and wheat straw are the cheapest of the plant fibres available for composite board production.[107] However, the price for straw will vary geographically and seasonally, and competing uses will determine the final market price. The following tables collect costs that farmers have to incur to harvest stubble and transport the material to the factory as well as prices for straw purchased for different uses.

Harvesting of stubble	425 INR/t - 900 INR/t
Transportation cost	150 INR/t
Total cost to farmer	575 INR/t

[103] Interview Mr. Chitlangia 17.05.18
[104] A couple of rounds of discussions with representative of ITC, June 2018
[105] Exchange of email with representative of Godrej Interio, June 2018
[106] Mantanis, G. et al. (no date)
[107] Pandey & Sujatha D (no date)

Table 8: Costs to farmers for supply of crop residue.[108] The distance covered by transport was not mentioned in the source used. Alternative estimates indicated a much higher cost, namely 3000-4000 INR/Tonne[109]

Sale to brick kilns	600-700 INR/t
Past sale to power companies	500-700 INR/t
Sale to paper & packaging industry	1700 INR/t
Planned sale for energy production	5500 INR (for pellets!)[110]

Table 9: Straw prices.[111]

The table indicates that straw prices seem to vary greatly. When IPIRTI developed the technology for composite board out of agro residues, straw prices were below 3000 INR/tonnes. Dr. Sujata D (Scientist, IPIRTI) indicated that the economic viability of the technology would not be possible if prices increased to 7000 INR/tonnes.[112] The future price of straw will depend to a very large extent on government plans to increase straw-to-energy uses (as part of the Biofuel Policy, 2018 of India) - plans that are likely to develop as power is one of the priority sectors of the Indian government.

The Biomass Management report by CII & NITI-Ayog for example suggests that 10% of biomass is to be reserved for energy production.[113] In such a scenario, production of MDF out of crop residue might be viable only if government support is available in the form of subsidies or other financial incentives such as capital and interest subvention, excise duty wavers, insurance schemes, accelerated depreciation on equipment or market development assistance.[114]

[108] Sood, J. (2014); presentation by Rene van Berkel (29.05.2018)
[109] As reported during a meeting hosted by the Dutch Embassy, India in Delhi under the INDUS-Forum banner on 24th May 2018 (as part of the Dutch Trade Mission to India, led by Prime Minister, Mark Rutte)
[110] Dr. Roy's information on NTPC (February 12, 2018) invitation for bidding.
[111] Sood (2014)
[112] Dr. Sujata D's presentation at the 'Stubble Up' stakeholder meeting, 29th May 2018 (Delhi)
[113] CII & NITI-Ayog (2018)
[114] Mr Roy's presentation at the 'Stubble Up' stakeholder meeting, 29th May 2018 (Delhi). Mr Roy also recalled how fiscal incentives by the Government have increased the usage of agricultural residues in paper production to ⅓ by 2005.

5.3.3 Triple Bottomline(Business Sustainability)

Given earlier efforts to get such initiatives (composite panels produced from agro-residue) off the ground, it is important that a detailed assessment is undertaken to establish the 'feasibility' of such businesses. Further, a certain element of newness needs to be instilled into such plans, and a bouquet of options should be considered than limiting them to the traditional ways of running such businesses (akin to how plyboard, MDF, PB units are established and run).

In this regards, emphasising on a strong 'triple bottomline'(sustainability) comprising economic, social and environmental costs and benefits of the proposed initiativewould be critical, and provide better visibility of such initiatives – especially from the demand side. These elements have been examined in this section (below):

- **Economic:**At this point, the economic feasibility of production of composite panel out of wheat and rice straw is yet to be established. The cost analysis in the context of this would need to include "costs or benefits to the farmer, related to avoided costs for straw incorporation, costs for (additional) nutrient replacement, and timeliness cost (i.e., cost associated to potential delays in other farming operations due to straw collection)"[115]; straw costs; logistics costs; as well as production costs.

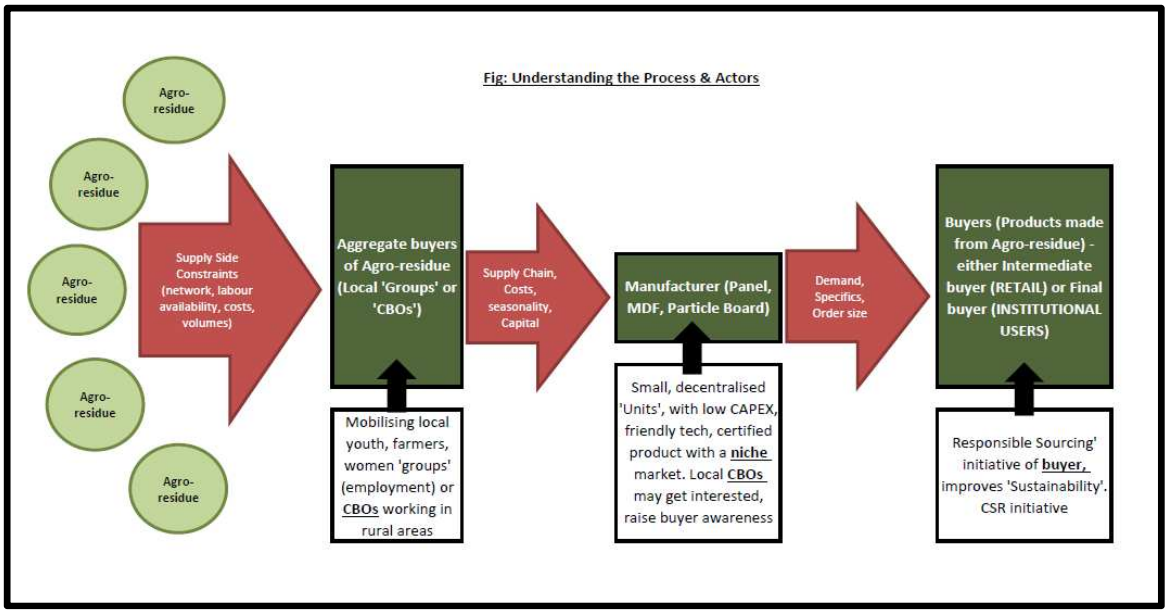
- **Social:** social benefits of the product include improved income for farmers as straw gets re-valued as industrial input material; potential improved income generation/job creation in rural areas if manufacturing units are located decentrally to reduce transportation costs. This could include formation of local 'groups' (youth, farmers, women) to collect and aggregate stubble and also small, low-tech low-CAPEX processing units that can be owned by Community Based Organisations (CRBOs), *Panchayats*. There would also be potential improved public health (cost savings) through reduction of air pollution if the innovation is coupled with different harvesting techniques

- **Environmental**: environmental benefits of the product include potential reduced air pollution if the straw procurement leads to changed harvesting practices (incentive to farmers to cut shortly above the ground), and reduced strain on forest resources (wood). Environmental costs may include reduced soil fertility if straw is diverted to the industry instead of being incorporated into the soil.

[115] NL Agency (2013)

Below is a graphic that highlights how a decentralized, agro-residue based composite panel business could be envisaged, together with the various supply and demand side dynamics – which would have to be kept into consideration. It is evident that there isn't much problem with availabeility/application of technologies – it is the business model/product development/niche market development – which are areas that need to be emphasized on.

Fig: Flow Chart of decentralized, agro-residue based composite panel business model



5.4 Challenges and Roadblocks

While the technological questions seem to have been resolved in a number of cases, several challenges persist to scale up the production in the Indian context. These include:

- ***Awareness related challenges***:

- low awareness in the manufacturing community about the technological application and costs (especially if the tech could be raw material agnostic or does it have to be different for different stocks – paddy straw and wheat straw)
- no awareness in the commercial and individual consumer community about the availability of products made from agro-residue (and associated issues pertaining to quality and costs)

- ***Production related challenges***

- geographically scattered availability: crop residue needs to be collected from every farm separately[116]
- small and scattered landholdings: With typically small landholdings, and scattered plots of even one owner, the supply chain management becomes a challenge as several hundreds or even thousands of farmers and areas could be involved.
- seasonality of the availability of the raw material and supply uncertainties
- lack of data on quantities of surplus straw[117] and its location
- exorbitant transportation costs: as straw has very low bulk density, transportation costs rise tremendously.[118] This can be improved through creating straw bales/pellets before transport. However, baling/pelletisationraises costs and is also subject to technology.[119]
- quick need to replant: The rice harvest in November is followed immediately by wheat sowing, so that time for incorporation or removal of stubble is very limited.
- storage problem: Because of the temporal availability just mentioned, crop residue needs to be stored for longer periods of time. This not only creates costs to farmers (and therefore to manufacturers) in terms of storage space, but also means that the resource needs to be protected against insects, rodents, mold, and rot and fire.[120] One factor that needs to be taken into account is that moisture content has to be below 18% to prevent rot.[121]
- treatment of finished product: as the industry experience in treatment to make the board resistant to mold, decay, fungus and termites is much lower than for plywood, more research is required here[122]
- lack of domestic backward integration as the largest machinery companies are European and Chinese[123]
- existing production machinery is typically designed to produce 7.5 million square meters of board, 19mm thick basis per year. Such high volumes might not be the right choice for the product.

[116] NL Agency(2013). The representative of MVO Netherlands, for example, stated that a unit of ECOR requires 4000t of straw/a, i.e. the produce of 2000 acres of land.
[117] GoI (2014) mentions an approximate quantity of 140.84t annually as crop residue surplus in India, based on estimates of the MNRE 2009.
[118] Agarwal (2007)
[119] NL Agency (2013)
[120] Agarwal (2007)
[121] Halvarsson, S. (2010)
[122] Han et al. (2012)
[123] Interview Mr. Chitlangia 18.05.18

- high capital expenditure: due to the large volumes processed in typical machines, and the fact that machinery is imported, the capital expenditure for making MDF is very high (approx. 250 crore INR)[124]

Risk perception related challenges

- perception of risk is high amongst those manufacturers who are aware of the technology due to the failed Bajaj experiment with board made from bagasse
- due to the very high capital expenditure, and as the machinery involved does not work economically below a certain capacity (while wood and straw are available in geographically different areas so that one production unit cannot easily switch products as per demand) the initial risk of investment appears to be high
- Biofuel policy highlights the possibility of deploying of agro-residue towards biofuel production centres/businesses. This could be perceived as a business risk for entrepreneurs, even when they are interested

Several of the production related challenges listed here appear to have been solved by the paper industry, however, so that cross-industry learning would be beneficial for the project proposed in this report.

6. WAY FORWARD

Available review of secondary data and limited collection and analysis of primary data has led to an understanding that several options needs to be explored to arrive at a tangible business response to the existing agricultural residue and its impact on air quality due to burning. There has been a consensus amongst all stakeholders that a long-term and sustainable solution needs to be explored, within the traditional market framework as well as in the non-traditional innovation space.

Several stakeholders have suggested that it is critical to work with market leaders of the MDF so as to bring this solution to scale and influence a shift of the mainstream towards the principles of circular economy. Indeed this needs to be explored and concerted effort needs to be made to understand the challenges faced by the large manufacturers in supply chain management, production of boards as well as marketing and financial viability. This needs further sector/industry specific focussed study to arrive at a feasibility report.

Quite a few stakeholders and industry experts have suggested a more local alternative, closer to the areas of raw material production, economically viable and engaging the local population in terms of livelihood and employment. Several

[124] Dr. Sujata D.'s presentation at the stakeholder meeting

innovation and incubation hubs can play a critical role in exploring these solutions, including running an innovation challenge in prominent Universities and Institutes to find a viable and long terms solution for straw burning, aimed at setting up Small and Medium Enterprises in rural areas.

Corporate Social Responsibility Funds (CSR Funds) can be of great assistance for setting up Small and Medium size enterprises in rural areas, addressing issues of ecology (crop burning) as well as livelihood and migration. Several companies have a mandate to work on sustainable development and therefore their help could be sought in piloting and scaling some community based innovations.

For these emerging options, the next step would be to undertake a detailed techno-economic feasibility assessment, which should take into consideration the following:

- Calculation of collection and production cost
- Volume assessment raw material - availability of paddy/wheat stubble, and other agro-residue that can be used as supplement (top-up)
- Cost of baling or pelletisation
- Cost and feasibility of storage and transportation
- Market analysis to assess the endprice consumers are ready to pay for such a 'niche' product (especially if the same is certified as a sustainable product)
- Identification of possible policy gaps (part of the enabling environment for promoting rural enterprises)
- analysis of demand (thinking 'out-of-the-box' assessment of potential buyers/users)
- Communication/branding of such a 'niche' product

Once such ***feasibility studies*** have been conducted, ***piloting*** the most feasible option in practical terms will be crucial as only then actors will be able to invest in market development without which this project cannot be successful. Such pilots could be considered in locations, which satisfy some or all of the following criteria:

- Volume of available raw materials (paddy straw, wheat straw, other supplements)
- Possibility of diversion of raw materials for other uses
- Existence of local 'groups' (youth, farmers, women)
- Existence of credible community based organisations with good understanding of the ground
- Prevalence of government (State Govt) support for youth etrepreneurship, women's enterprises, farm-based enterprises
- Access to technology providers (technology should be low-tech, low-cost)
- Access and visibility of potential users/consumers (intermediate or final)

ANNEXURE I

INTERVIEW GUIDELINES - PRODUCERS

Product (composite board, wood based vs. rice or wheat straw/husk)

- What raw material do you use traditionally to make PB/FB?
- What are the most important quality criteria for you when you consider composite boards?
- If you compare the quality of composite board made from wood and made from straw, what are the differences?
- If you compare the usages, what are the differences
- Are there different grades of Composite Boards?

Production process

- Can you briefly describe the challenges in the production process of wheat or rice husk/straw based MDF?
- For the producer, what does this mean?
- Is there difference in cost of production?
- Is there a difference in technology?
- Does he have to invest in new machinery?
- Are the other materials required (adhesives…) readily available?
- Do the workers need to be retrained to produce composite board?
- What other factors in the production process itself could be an impediment for someone who wants to switch to / start producing straw based composite board?
- Can a producer run both productions parallel / slowly increase the share of straw based MDF in his production?
- Are you aware of existing production facilities of straw based MDF? Are these in pilot stage, or fully operational and selling?

Supply chain

- What's the availability cycle of the raw material you currently use?
- Is there is a geographical limitation to the availability of this material?
- What is the procurement process and protocol for these raw materials (for eg company owned, supplier dependant, pre production purchase contracts etc)?
- What are the vulnerabilities in the current supply chain (quality, quantity, climate, price, storage etc)?
- From your point of view, what are problems that could arise in the supply of raw material for the production of straw based composite board?

        - Cost?
        - Transportation?
        - Seasonality/ storage?
        - Price?
        - Localisation?
        - Any other?

Distribution/Market

- Do you see a readily available market for straw based composite board?
    - If so - specify (which distributors/users/user groups)
    - If not - why not?
    - If not - how do you think such a market can be encouraged?
- What are crucial factors for a slow pick-up? Is it lack of awareness? Is it resistance from carpenters/architects/designers/builders? Is it resistance from end customers? Is it actual deficiencies in the product that need to be improved on through innovation?

Switching to composite board

- Have you explored using crop residue as he raw material?
    - If not, why not.
    - If yes, have you decided to give it a try?
        - If not, why not?
        - What would have to happen for you to venture into it?
        -
        - If so: what was your experience?
            - If it was a success:
                - Market
                - Supply
                - How long did it take to become profitable
                - Volume of production
                - Problems they are facing
                - …
            - If it was a failure,
                - How long did the experiment last/year of opening & shutting
                - Reasons for failure
                - Would they be willing to try again? Under which conditions?

- What is the biggest risk when doing such a switch?
- What could be factors that push a producer to make such a switch?

- What kind of enterprise, according to you, is most likely to start producing composite board (established or not? Which size? location?)

ANNEXURE II

INTERVIEW GUIDELINES – POTENTIAL USERS

- How do you use plywood in your enterprise?
- What is the most important factor for you when deciding which material to use? Which qualities? Price? Ready availability? Stability of supply? Design qualities/beauty? …
- How important are health related factors for you in your procurement / product design / material choice? (discuss formaldehyde emissions of MDF)
- How important is sustainability for you in your procurement and marketing strategy? How do you mainstream sustainability in your operations?
- As a manufacturer of [xxx], how do you think you can contribute to halt deforestation/improve forest cover in India?

- Are you aware of the existence of composite panel / MDF made from wheat and rice husk/straw?
- Have you ever worked with composite panel instead of plywood? (if global company - ask if this was in India or other operations)
    - If so: what was your experience?
    - If not: what information would you need to be willing to try it out? Is there anything else you would need to be willing to try this out?
- Do you think the market is open to trying out straw based MDF?
- Do you think customers make a choice based on sustainability criteria in the Indian market?

ANNEXURE III

ACRONYMS

Bn	billion
BS	British Standard
CBM	cubic meter
CE	Circular Economy
CII	Confederation of Indian Industry
CPPRI	Central Paper and Pulp Research Institute
CSR	Corporate Social Responsibility
EU	European Union
GoI	Government of India
IIT	Indian Institute of Technology
IPIRTI	Indian Plywood Industry Research and Training Institute
MDF	Medium Density Fibre Board
NCCF	Goi
NITI-Ayog	National Institution for Transforming India
NPCS	NIIR Project Consultancy Services
PB	Particle Board
To	tonne

REFERENCES

Agarwal, A.K. (2007): Bioenergy options and rural India. In: IIT-Kanpur: Electrification and Bio-energy Options in Rural India. https://www.iitk.ac.in/erl/Index_files/Popular%20Publication/06-Electrification_Final%20IIR.pdf

BSI Group (2017): Executive Briefing: BS 8001 – a Guide. https://www.bsigroup.com/Sustainability/BS8001_Executive_Briefing.pdf

Business Standard (2013): GIL lays foundation of its Medium Density Fibre (MDF) factory. https://www.business-standard.com/article/press-releases/gil-lays-foundation-of-its-medium-density-fibre-mdf-factory-108091001125_1.html

Chitlangia, P.D. (1968): The Plywood Industry in India. Welcome Speech at the Exhibition of Plywood and Wood-based panel products, New Delhi 1968.https://www.jstor.org/stable/42603673?read-now=1&seq=1#page_scan_tab_contents

CII & NITI-Ayog (2018): Action Plan for Biomass Management. http://www.niti.gov.in/writereaddata/files/document_publication/ReportOfTheTaskForceOnBiomassManagement.pdf

Community.data.gov.in (2017): Production of Rice from 2013-14 to 2014-15. https://community.data.gov.in/production-of-rice-from-2013-14-to-2014-15/

Composite Panel Association (no date): Medium Density Fiberboard (MDF). https://www.compositepanel.org/products/medium-density-fiberboard.html/details/

CPPRI (2018): Overview. http://www.cppri.org.in/home-overview

Crisil Research (no date): Nuchem Ltd. https://www.nseindia.com/content/corporate/eq_NUCHEM_base.pdf

Dahiya, V. (2015): Plywood Industry in India. https://www.slideshare.net/vikram_dahiya/plywood-industry-a-deep-insight

Department of Agriculture Cooperation and Farmers Welfare (2017a): Commodity Profile of Wheat for June 2017. http://agricoop.nic.in/sites/default/files/Wheat%20Profile%2023-06-2017.pdf

Department of Agriculture Cooperation and Farmers Welfare (2017b): Commodity Profile for Rice- July, 2017 http://www.agricoop.gov.in/sites/default/files/Rice%20profile%20July-%202017.pdf

Displays2Go (2015): Particle Board vs. MDF vs. Plywood. A Comparison.https://www.displays2go.com/Guide/Comparing-Building-Materials-Particle-Board-MDF-Plywood-1

Directorate of Wheat Development (no date): Wheat production. http://dwd.dacnet.nic.in/wheat_prod1/area_prod.htm

Ellen MacArthur Foundation (2016): Circular Economy in India: Rethinking growth for Long-term Prosperity. https://www.ellenmacarthurfoundation.org/assets/downloads/publications/Circular-economy-in-India_5-Dec_2016.pdf

Ellen MacArthur Foundation (2017): Circular Economy Overview. https://www.ellenmacarthurfoundation.org/circular-economy/overview/concept

Esler, B. (2016): Rice husk and polymer composite wood alternative makes its way into laminates. https://www.woodworkingnetwork.com/news/woodworking-industry-news/klockner-pentaplast-introduces-resysta-new-rice-and-polymer-composite

European Commission CORDIS (2002): Innovative technology for panel manufacture from fiberisedagriwaste. https://cordis.europa.eu/project/rcn/39537_en.html

European Commission, European Council, European Economic and Social Committee & Committee of the Regions (2015).Closing the loop - An EU action plan for the Circular Economy. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52015DC0614

FirstPost (2017): European Union to help India move to a resource efficient 'circular economy' https://www.firstpost.com/world/european-union-to-help-india-move-to-a-resource-efficient-circular-economy-3763101.html

Global Wood Markets Info (2016): India: Century Ply builds large MDF plant in Punjab. https://www.globalwoodmarketsinfo.com/india-century-ply-sets-up-mdf-unit-in-punjab/

GoI (2014) National Policy for Crop Residue Management.. http://agricoop.nic.in/sites/default/files/NPMCR_1.pdf

Greenply Industries Ltd. (2014): Our factories. http://www.greenply.com/our-factories

Greenply Industries Ltd. (2016):Analyst meet presentation. https://www.greenply.com/images/pdf/Analyst-Meet-Presentation-2016.pdf

Greenply Industries Ltd. (2017): Analyst Meet Presentation 2017. https://www.greenply.com/images/pdf/Analyst-Meet-Presentation-2017.pdf

Halvarsson, S. (2010): Manufacture of straw MDF and fibreboards. Thesis for the degree of Doctor of Technology, Mid Sweden University.http://www.diva-portal.org/smash/get/diva2:324791/FULLTEXT02

Han, G. et al. (2012): Performance of Zinc-Borate-treated oriented structural straw board against fungi, decay fungi, and termintes - a preliminary trial. In: BioRessources 7(3). http://www.novofibre.com/files/downloads/Tech-Report-2_Zinc-Borate-treated-OSSB.pdf

Imarc (2017): Indian Plywood Market: Industry Trends, Share, Size, Growth, Opportunity and Forecast 2018-2023. Description.https://www.imarcgroup.com/indian-plywood-market

IPIRTI (2018a): Wood and Bio-Fibre Composites. http://www.ipirti.gov.in/woodcomposites.html

IPIRTI (2018b): History. http://www.ipirti.gov.in/history.html

Jain, N. et al. (2014): Emission of Air Pollutants from Crop Residue Burning in India. In:
Aerosol and Air Quality Research, 14: 422–430.
http://aaqr.org/files/article/619/40_AAQR-13-01-OA-0031_422-430.pdf

Ken Research (2015): India Plywood Market Outlook to 2019 - Increasing Households and Rising Commercial Space to Shape Future growth. Executive Summary. https://www.kenresearch.com/manufacturing-and-construction/construction-materials/india-plywood-market-report/640-97.html

Mantanis, G. et al. (no date): Turning agricultural straw residues into value-added composite products: A new environmentally friendly technology. http://www.wfdt.teilar.gr/papers/strawboard_1.pdf

Matthan, R. (2018): The circular economy. In: LiveMint. https://www.livemint.com/Opinion/eaOA3l04xwUbFVhqvNu37H/The-circular-economy.html

MoneyControl (no date): Century Plyboards. http://www.moneycontrol.com/company-facts/centuryplyboards/locations/CP9

MoneyControl (2018): Ideas for Profit. Indian wood panel industry: Building on a secular theme. https://www.moneycontrol.com/news/business/moneycontrol-

research/ideas-for-profit-indian-wood-panel-industry-building-on-a-secular-theme-2551225.html

NCCF (2017): Draft Policy Paper on Promoting Sustainable Trade of Wood and Wood Based Products in India .http://nccf.in/wp-content/uploads/2017/03/Draft-Policy-Paper-on-Wood-based-industries_NCCF_feb-2017.pdf

NL Agency (2013): Rice straw and Wheat straw Potential feedstocks for the Biobased Economy.
https://english.rvo.nl/sites/default/files/2013/12/Straw%20report%20AgNL%20June%202013.pdf

NPCS (no date): Project Report. Wood and Wood Products, Plywood, Board, Particle Board, Wooden Furniture, Bamboo, Engineered wood, Forest product, Lumber, Tree, Wood drying, Wood plastic composite, Door, Window, Modular Furniture, Timber, Woodworking, Decorative Laminated Sheets. https://www.niir.org/profile-project-reports/profiles/wood-wood-products-plywood-board-particle-board-wooden-furniture-bamboo-engineered-wood-forest-product-lumber-tree-wood-drying-wood-plastic-composite-door-window-modular-furniture-timber-woodworking-decorative-laminated-sheets/z,,1f,28,a/index.html?_sort_by=default:

Pandey, C.N. & Sujatha D. (2009): Crop residues, the alternate raw materials of tomorrow for
the preparation of composite board. In: Proceedings of the ICAR-CIRCOT Seminar 2009.
https://www.icac.org/projects/CommonFund/20_ucbvp/papers/06_pandey.pdf

Plyreporter.com (2017): Timber import grows despite week wood panel demand.
http://www.plyreporter.com/article/10028/timber-import-grows-despite-weak-wood-panel-demand

Research and Markets (2017): Imarc Report 2017 - Indian Plywood Market: Industry Trends, Share, Size, Growth, Opportunity and Forecast 2018-2023. Description.
https://www.researchandmarkets.com/reports/4535109/indian-plywood-market-industry-trends-share

Sardar, Z. (2009): Stak Block makes green use of rice straw.
https://www.sfgate.com/homeandgarden/article/Stak-Block-makes-green-use-of-rice-straw-3280541.php

Sawmill Owners & Plywood Manufacturers Association (no date): List of Plywood Manufacturers. http://www.sopma.org/Plywood%20manufactures.pdf

Shah, N. & P. Shah (2015): Wood panel sector. Seize the Opportunity. In: India Research Building Materials. Antique Stock Broking Ltd.
http://www.centuryply.com/files/download/6a2f07fb62d2830

Sharma, M. & O Dikshit (2016): Comprehensive Study on Air Pollution and Green House Gases (GHGs) in Delhi. IIT Kanpur. http://delhi.gov.in/DoIT/Environment/PDFs/Final_Report.pdf

Singh, R.B. et al. (1995): Rice straw - its production and utilization in India. In: Kiran Singh and J.B. Schiere (eds.): Handbook for Straw Feeding Systems. ICAR, New Delhi, India, http://edepot.wur.nl/333859

Sood, J. (2014): Not a waste until wasted. In: DownToEarth. http://www.downtoearth.org.in/coverage/not-a-waste-until-wasted-40051

Srivats, K.R. (2015): Anti-dumping duty imposed on plain MDF board from Vietnam, Indonesia. In: The Hindu. Business Line. July 2015. https://www.thehindubusinessline.com/economy/antidumping-duty-imposed-on-plain-mdf-board-from-vietnam-indonesia/article8853520.ece

TechSci Research (2018): India Organic Food Market By Product Type (Organic Beverages, Organic Cereal & Food Grains, Organic Meat, Poultry & Dairy, Organic Spices & Pulses, Organic Processed Food & Others), Competition Forecast & Opportunities, 2013 – 2023. Description.https://www.techsciresearch.com/report/india-organic-food-market/1761.html

Teri & Yes Bank (2018): Circular Economy: A Business Imperative for India. http://www.teriin.org/sites/default/files/2018-03/TERI-YES_BANK_Circular_Economy_Report.pdf

The Indian Express (2018): Stubble burning doubles Delhi pollution: Harvard study. http://indianexpress.com/article/india/stubble-burning-doubles-delhi-pollution-harvard-study-5121665/

The Times of India (2014): Organised plywood sector to grow 25 pc year-on-year. https://timesofindia.indiatimes.com/business/india-business/organised-plywood-sector-to-grow-25-pc-year-on-year/articleshow/61640945.cms

Treehugger (2004): Kirei Sorghum Board. https://www.treehugger.com/green-architecture/kirei-sorghum-board.html

Wikipedia (no data): Circular economy. https://en.wikipedia.org/wiki/Circular_economy#cite_note-:2-1

Wrap (2018): WRAP and the circular economy http://www.wrap.org.uk/about-us/about/wrap-and-circular-economy

Yasin, M. et al. (2010): Efficient Utilization of Rice-wheat Straw to Produce Value – added Composite Products. In: International Journal of Chemical and Environmental Engineering Vol. 1, No. 2.
https://pdfs.semanticscholar.org/d8c6/ecb0ad59cf46e847e209fb5014db5c162fe2.pdf