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Sokoban Wood Village Project in Kumasi, Ghana

Jelle Maddens
Prachi Snehal
Ria Kapila
Pangea Advisors

in collaboration with

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Editor-and-Chief: Dr. Susan M. Blaustein, sblaustein@ei.columbia.edu

Editor: Paulo Cunha, former Project Manager, Millennium Cities Initiative, pmc2105@columbia.edu

Managing Editor: Joanna Brucker, Social Sector and Media Specialist, jbrucker@ei.columbia.edu

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Introduction

In the spring of 2013, the KNUST School of Business (KSB) at the Kwame Nkrumah University of Science and Technology (KNUST), together with the Columbia Earth Institute's Millennium Cities Initiative (MCI), partnered with Columbia Business School's Pangea advisors to conduct a feasibility study regarding sawdust waste in Sokoban, Ghana. Sokoban, a carpenter village in the Kumasi metropolis, produces about 100-150 metric tons of sawdust per day. Most of the sawdust is burned, causing respiratory illnesses and other medical problems, as well as environmental damage. The goal of the KNUST and Columbia partnership is to identify several products that could use the sawdust waste for profitable endeavors.

This report primarily addresses the first segment of the project: it assesses market demand for particleboard, one potential product made out of sawdust. The report also offers insight on some additional products and opportunities that arose out of the first stage of the study. Future stages will likely include market analysis of sawdust products other than particleboard, as well as costs associated with manufacturing particleboard and alternative products.

Executive Summary

The research team found that constructing and operating a particleboard plant is not feasible, primarily because:

- Achieving the economies of scale and operational expertise necessary for an adequate market price would take too long.
- Feasibility relies heavily on export volume (roughly 90 percent at first), which is too uncertain.
- Plywood competition, potential use of sawdust by other plants and the decline of Ghana's timber industry point to worse conditions in the future.

When investigating briquettes, the team found that a company named Abellon is already working on this and claims it can use all of the sawdust in the Kumasi area. Competing would be unwise and possibly contrary to the high-level goals of this study, since Abellon is a clean energy company that intends to use Kumasi's sawdust waste.

The way forward includes an assessment of whether the sawdust issue should be pursued, given Abellon's presence; an investigation of whether similar studies are useful outside of Kumasi or with waste products other than sawdust; and the identification of additional projects and partnership opportunities.

Research

Assumptions and Limitations

The study assumes that:

- Particleboard demand consists of three categories of users: small-scale carpenters, large-scale carpenters, and the export market.
- Particleboard plant construction and cash flows would start in 2015.
- For the purpose of this study, cash flows were discounted at the risk-free rate. Once the costs of a plant are estimated, cash flows should be modeled using a more appropriate discount rate.

Methodology

The study relied on a combination of primary and secondary sources, which were analyzed using the financial model included in this report. Research methods included a survey, interviews, and the analysis of internet articles and databases.

- **Survey Research:** a survey was created with input from all parties involved as well as an outside professor and consultant. It was administered through interviews with 17 carpenters in Sokoban and Oforikrom, two areas in Kumasi. The initial survey was expanded to include several quantitative questions after the first few interviews. The final survey is included in Appendix A.

Interviews: the study uses interviews conducted both in the United States and in Ghana. Interviews were conducted in person, by phone, and through email, and included carpenters, lumber mill managers, government officials, academia, briquette manufacturers, and others.

Internet Research: the study also uses online sources, primarily to estimate market sizing for exports, the sawdust supply in Kumasi, and various financial rates. Notable sources include FAOSTAT, the Statistics Division of the United Nations' Food and Agriculture Organization, and the Timber Industry Development Division (and) of the Government of Ghana.

Findings

Context

Sawdust supply

- Sawdust is produced in many areas of Kumasi and Ghana. Sokoban produces about 100-150 metric tons of sawdust per day. One large-scale lumber producer (over 350,000 cubic meters per year) generates about 40 cubic meters of sawdust waste per day, and there are two comparable mills in Kumasi, with an additional 4 medium-sized (210,000 to 350,000 cubic meters per year) and 10 small-sized (below 210,000 cubic meters per year) lumber mills. According to one lumber producer, sawdust amounts to roughly one-third of wood product exports.¹ Based on this estimate, we calculated sawdust production in 2012 as 75,373 cubic meters, down from 95,952 cubic meters in 2011.² In

¹ Anonymous, Personal Interview, May 23, 2013.

² The Forestry Commission of Ghana. "Report on Export of Wood Products."

[http://www.fcghana.org/library_info.php?doc=56&publication:Report%20on%20Export%20of%20Wood%](http://www.fcghana.org/library_info.php?doc=56&publication:Report%20on%20Export%20of%20Wood%20)

addition to sawdust, Ghana produces scrap wood in other forms, such as cut-offs (scraps left after cutting wood to size/shape) and shavings.

- Sawdust is produced in many varieties of sizes, densities, and wood types, especially in Sokoban. Wood used in manufacturing in Ghana includes white and black odum, ofram, mahogany, *wawa*, and *oyina*.³ Lumber mills produce a smaller variety of sawdust. One mill, for example, produces 50 percent *wawa*, 30 percent redwood, and 20 percent various other species. About 50 percent of this mill's sawdust is dry, and 50 percent is wet.
- Both lumber mills we interviewed used roughly 50 percent of their sawdust to make steam, which they need for veneer production. They dump the other 50 percent and would give it away for free.
- One lumber producer anticipates demand for briquettes in export and local markets and may start production using its own sawdust. This expansion has been postponed due to too many concurrent projects.

Timber Industry

- Ghana's timber industry is declining. Two major factors in the timber industry decline are: 1) the distance/transportation to harvesting sites, and 2) the amount of raw materials (trees allowed to harvest), especially since TIDD has started an initiative to manage deforestation.
- Major lumber producers do not associate much and are not well-connected to each other, limiting the potential for the diffusion of knowledge and new technologies.⁴
- Plywood exporters and furniture manufacturers (both small- and large-scale) are required to register with TIDD.⁵

Current Distribution Network

- Roads are adequate for distribution around Ghana and to export outlets, and wood users and manufacturers are generally located in cities. The distribution network, therefore, is robust and not a significant obstacle to reaching markets.⁶
- Particleboard is currently imported. Although Ghana has had two local manufacturers, both are now out of business.⁷

Particleboard

Particleboard Analysis Summary

- Investing in a particleboard plant would require about GHS 60,000,000 (\$30,000,000), and a plant for medium-density fiberboard, a similar product to particleboard, would require about GHS 200,000,000 (\$100,000,000).
- Reaching the optimistic demand forecasts (about GHS 30,000,000 per year) requires extreme circumstances, including high export volume, cheap particleboard, operational expertise and significant economies of scale immediately after plant construction. Recouping investments in particleboard under this scenario would require at least three

[20Products%20%28Timber%20Industry%20Development%20Division%29&id=16](#) (last visited May 29, 2013).

³ Niboi, Bennet Elvis, "Initial Comments on the Research Documents," Email to Prachi Snehal, Jelle Maddens, Ria Kapila, Paulo Cunha, Ahmed Agyapong, Samuel Akomea, April 24, 2013.

⁴ Anonymous, Personal Interview, op.cit.

⁵ The Forestry Commission of Ghana, Report on Export of Wood Products, op. cit.

⁶ Amamoo – Eshun, Anthony, Personal Interview, April 22, 2013.

⁷ Owusu, Togbui., Personal Interview, April 24, 2013.

years. More realistically, however, revenues would range from GHS 1,000,000 to GHS 23,000,000, especially in initial years, making investment in a particleboard plant unrealistic.

- Given Ghana's declining timber industry, the difficulty of manufacturing particleboard cheaply in time, reaching satisfactory export volume quickly, and a low total revenue forecast for roughly a decade, we do not recommend investing in a particleboard plant.

Current Uses:

- In Kumasi: cabinets (kitchen, office, etc), office furniture, wardrobes, bedsides, TV stands; large-scale company furniture, chairs, speakers.
- In US: all non-structural furniture, shelving, flooring underlayment (non-structural sheets of wood underneath tiles, carpet, etc).

Substitutes:

- In Kumasi: plywood and (to a lesser extent) hardwood.
- In US: hardwood, plywood, medium-density fiberboard.
- Note: according to TIDD, particleboard and plywood are not perfect substitutes for each other (carpenters will not necessarily pick the cheapest, because they perform different functions). TIDD staff also believes that particleboard can be sold all throughout Ghana.

Advantages of particleboard

- Cited by Kumasi Carpenters (Sokoban and Oforikrom):
 - Faster to work with (production time/time to customers)
 - Polished surface; it's nicer and more uniform
- Cited by carpenters in US
 - Less expensive (outside of Ghana)
 - Denser
 - More uniform
 - Won't bend
- Notes: particleboard's finishing and ease of use may be negated because the overlay can be applied to plywood as well.

Disadvantages:

- Cited by Kumasi Carpenters (Sokoban and Oforikrom):
 - Soaks in water and bubbles
 - Flakes
 - Needs education to be adopted
 - Nail heads show
 - Need different working materials (screws, adhesive, plugs, caps)
 - Not readily available
 - Expensive
 - Doesn't have as wide a variety of sizes as does plywood
 - Outer sealing/cover needs to be sold with it, so that it can be applied after cutting and retain the particleboard's aesthetic value.
 - Not as durable as hardwood and plywood
 - Weaker than hardwood, not good for structural support
 - Less flexible than plywood

- Cited by carpenters in US:⁸
 - Weaker than hardwood, not good for structural support
 - Not as aesthetically pleasing as hardwood
 - Soaks in water, bubbles and expands when in contact with moisture
 - Less flexible than plywood

Current supply of particleboard:

- There is currently no major commercial manufacturer of particleboard in Ghana. A Public Private Venture (BMK Limited) in Ghana's Western Region was undertaking this activity, but ceased operations due to mismanagement.⁹ Most particleboard on the market in Ghana is imported from Europe (UK and Italy).¹⁰
- The current price for a 10'x2' piece of particleboard is GHS 170-180. We found that price is the primary reason that more local carpenters don't use particleboard.
- Two companies used to make particleboard: BMK in Takoradi (for 10 years), and Novotex, in Nkawkaw.¹¹

Demand for particleboard

- Based on carpenter interviews, particleboard would almost completely replace domestic plywood use if similarly priced. For this reason, this report considers them substitutes in the domestic market, and domestic particleboard market size is based on the current and projected market size and price of plywood. The accompanying model assumes, however, that the substitution would not be instantaneous, and estimates adoption speed using a Bass Model (marketing model that estimates adoption rates for new technology). If immediate adoption rates are suspected, then the Bass Model should be updated accordingly.
- Based on the differences between particleboard and plywood, however, we assume that particleboard exports would not replace plywood exports.
- This report also assumes that exports would depend on whether Ghanaian manufacturers of particleboard are able to manufacture below the international market price (after accounting for transportation, exchange rates, duty charges, etc). To gauge potential exports, we used the ratios of particleboard to plywood exports for comparable West African countries.
- According to the table below (based on the accompanying model), total revenues could range from around GHS 27,000,000 to GHS 32,500,000 per year. The total of all revenues, discounted at the risk-free rate of 12, would reach GHS 123,541,693 in 2021. This is very optimistic however, and relies primarily on exports, which may not in fact be comparable to the average for Ghana's neighbors.
- Without exports, the market size is much smaller, ranging from about GHS 1,300,000 to GHS 21,000,000 and accumulating discounted revenues in the amount of GHS 29,994,422 by 2021. High demand, therefore, would rely almost entirely on the ability to reach high export volume quickly.

⁸ eHow.com, "The Uses of Particle Board," http://www.ehow.com/list_6165830_uses-particle-board.html#ixzz2O0YLbF2O (last visited June 1, 2013).

⁹ Owusu, Personal Interview, op.cit.

¹⁰ Owusu, Personal Interview, op.cit.

¹¹ Amamoo – Eshun, Personal Interview, op. cit.

¹² Note: the risk-free rate is not an appropriate discount rate for potential operations that manufacture sawdust products. Once costs for these operations have been assessed, a more appropriate discount rate should be calculated. The risk-free rate is merely used to lend some perspective to the market analysis.

Estimated total demand for particleboard in Ghana (in GHS)

Expected Value of Revenues/Demand	2015	2016	2017	2018	2019	2020	2021
Small-scale manufacturers	953,164	2,229,069	3,902,980	6,039,995	8,670,832	11,759,581	15,174,654
Large-scale manufacturers	370,675	866,860	1,517,826	2,348,887	3,371,990	4,573,171	5,901,254
Exports	30,956,813	26,243,000	22,250,374	18,868,251	16,002,968	13,575,263	11,518,058
Total Revenues	32,280,652	29,338,929	27,671,180	27,257,133	28,045,789	29,908,015	32,593,967
Discounted Revenues	32,280,652	24,048,302	18,591,225	15,010,691	12,659,844	11,065,943	9,885,036
Cumulative Discounted Revenues	32,280,652	56,328,954	74,920,180	89,930,870	102,590,714	113,656,657	123,541,693
Total Revenues w/out Exports	1,323,839	3,095,929	5,420,806	8,388,882	12,042,822	16,332,752	21,075,908
Discounted Revenues w/out Exports	1,323,839	2,537,647	3,642,036	4,619,815	5,436,119	6,043,106	6,391,861
Cumulative Discounted Revenues w/out Exports	1,323,839	3,861,486	7,503,521	12,123,336	17,559,455	23,602,561	29,994,422

Source: Pangea Advisors, "Particleboard Demand Model 2013 05 28," May 28, 2013.

Analysis

- According to plywood manufacturers, a particleboard factory would require an investment of about GHS 60,000,000 (\$30,000,000). A plant for medium-density fiberboard, similar to particleboard, would require an investment of GHS 200,000,000 (\$100,000,000).
- In order to achieve projected levels of demand, a particleboard plant would have to reduce the price of particleboard roughly to the level of plywood. This would require significant economies of scale, technological assets, and operational expertise, which would take at least several years to develop (Ghana's two former particleboard manufacturers may have gone out of business for this reason).
- With optimistic export forecasts and without operating expenses, a plant could recoup an investment of GHS 60,000,000 in 2-3 years. This is unrealistic, however, because comparable particleboard and plywood prices and significant exports – both necessary to reach the projected market size – would take longer to achieve. Additionally, exports vary greatly among Ghana's neighbors; accounting for one standard deviation in export value results in exports of only GHS 6,500,000 to GHS 23,000,000 per year, with cumulative discounted cash flows of GHS 46,155,233 through 2021. Recouping GHS 60,000,000, even at the risk-free discount rate and without operating costs, would take at least until 2024.
- Additionally, the decline of Ghana's timber industry makes investments in the timber industry risky and even unrealistic, according to plywood manufacturers. This decline is why plywood manufacturers have not started manufacturing particleboard themselves, although one manufacturer also cited a lack of space and unknown market size as a deterrent.

- Given Ghana's declining timber industry, the difficulty of manufacturing particleboard cheaply in time, reaching satisfactory export volume quickly, and a low total revenue forecast for roughly a decade, we do not recommend investing in a particleboard plant at this time.

Briquettes (also known as pellets)

Briquette Analysis Summary

- A company named [Abellon](#) is currently building a pellet plant in Sokoban and plans to create a power plant as well. According to Abellon, it could use up most of the sawdust in Kumasi.
- Pangea Advisors recommends completing a market analysis that incorporates Abellon's presence prior to considering further investment in briquettes, as well as research into small-scale pellet manufacturing possibilities outside of Abellon's operating area.

Uses

- Current: Cooking (home and commercial);
- Potential: Boilers

Substitutes:

- In Kumasi: charcoal (primarily), firewood, gas, sawdust
- Internationally: charcoal (primarily), firewood, gas, sawdust, coal, oil

Advantages

- Carbon-neutral (cleaner than charcoal);¹³ even if briquettes pollute, they would be an improvement over charcoal and burning the sawdust waste¹⁴
- Fewer fumes, smells better than firewood and charcoal
- More sustainable than other fuels (can use other waste if necessary, for ex, bamboo)

Disadvantages

- Would need demonstrations and education on how to use briquettes instead of charcoal¹⁵

Current and expected supply

- Price: A medium-sized sack is GHS 12; a larger size (about 1 meter height and 40 cm in diameter) is GHS 20. This price is stable.
- One company in the Eastern Region tried to manufacture briquettes but closed down. Currently, briquettes are mostly created by small-scale manufacturers.
- Abellon is currently building a pellet plant estimated to produce about 200-250 tonnes of pellets per day.¹⁶ Abellon also plans to build a power plant that will use 200-250 tonnes of sawdust per day, although tariffs are currently inhibiting construction.
- A major issue in briquette/pellet manufacture is the collection model for sawdust. Plants need to be able to collect sawdust efficiently from many places, since they would have the capacity to go beyond Kumasi for more sawdust. Local policies mandating that sawdust producers allocate some of their sawdust waste to clean energy could help and might be proposed by relevant stakeholders
- Another major obstacle is financing, since many banks hesitate to take the risk in such new technology and industry.

¹³ Mishra, Pragnesh, Personal Interview, May 23, 2013.

¹⁴ Simmons, Paa Kwasi, Director, Metropolitan Planning, Kumasi Metropolitan Assembly Personal Interview, May 22, 2013.

¹⁵ Mishra, Personal Interview, op. cit.

¹⁶ Mishra, Personal Interview, op. cit.

- In addition to Abellon, the manager of one major lumber producer said he would be willing to try a prototype of a briquette production facility at his mill.

Demand

- This report does not include an analysis of the market size for briquettes. An analysis could be completed, however, using a similar to model to the one accompanying this report.

Analysis

- Although Abellon's construction of a pellet plant indicates optimism in the demand for pellets, Pangea Advisors does not recommend investing in such a plant before conducting an analysis of pellet demand that incorporates the presence of Abellon. Given that Abellon already has plans to expand and claims an ability to use most of the sawdust in the Kumasi area, it is possible that successfully building a second briquette plant could create too much competition for either plant to succeed.
- Small-scale pellet production models, however, could be viable in areas where Abellon does not yet operate.

Other Sawdust Products

If KSB and MCI decide to continue feasibility studies on the use of sawdust for commercial products, Pangea Advisors recommends investing in the following products, which might be candidates for mass production in Ghana. These can be assessed using models similar to that accompanying this report, which projects the demand on the part of small-scale users, large-scale users, and the export market.

Potential Products

- Fertilizer¹⁷
 - Must be mixed with manure¹⁸
 - Can be used in Hugelkultur¹⁹
 - Only correct wood types²⁰
 - [Past attempts](#)
- Tuber storage²¹
- Growing mushrooms²²
- Fiberboard/MDF
- Sawdust Stove Fuel
- Masonite (hard, smooth material)
- I-Beams
- Insulation
- Sawdust Toilet
- Concrete aggregate
- Panels/tiles
- Compost/Mulch/Humus
- Wood pulp
- Pykrete (slow-melting, tough ice)
- Feed extender
- Filler for paper and cardboard
- Linoleum
- Woodstone (Xyolith)
- Electricity generation
- Bonding agent in wall restructuring
- Cement backerboard (sheets used behind wall (or other) panels)
- Cabinet Pieces (knobs, pulls, handles, etc)

¹⁷ Simmons, Personal Interview, op. cit.

¹⁸ Colorado State University Extension. "Organic Materials as Nitrogen Fertilizers," <http://www.ext.colostate.edu/pubs/crops/00546.html> (last visited June 1, 2013).

¹⁹ Temperate Climate Permaculture. "Permaculture Project: Hugelkultur," <http://www.tcpermaculture.blogspot.com/2011/06/permaculture-projects-hugelkultur.html> (last visited June 1, 2013); and:

Permies.com, "Hugelkultur in Hot, Arid Climate," <http://www.permies.com/forums/posts/list/80/12150> (last visited June 1, 2013).

²⁰ Permies.com. "Hugelkultur - Good wood, Bad wood," <http://www.permies.com/forums/posts/list/40/12206> (last visited June 1, 2013).

²¹ Simmons, Personal Interview, op. cit.

²² Simmons, Personal Interview, op. cit.

Conclusions

1. Returns from a particleboard plant would not be greater than its costs. Realistic cash flows do not exceed initial investments until a decade later, even with an optimistic discount rate and no operational costs. This could change, given significant developments in the timber industry, but investment considerations would first require an update to the accompanying model.
2. Sokoban's sawdust problem may be solved through Abellon's pellet and power plants. Any pursuit of an additional briquette plant should be preceded by market analysis incorporating Abellon's presence and projecting its likely response to a second factory. At first glance, at least, Abellon seems to be a positive force in the area, creating a cleaner environment, less sawdust waste, and more jobs. Partnering with Abellon to improve sawdust supply chains may be beneficial for KSB and Kumasi's carpenters.
3. Research into additional products may be more useful when also considering areas outside of Kumasi, since Abellon may use up the local sawdust supply.

Recommendations

General Recommendations

1. KSB and its affiliates should not invest in a particleboard plant. As described in prior analysis and conclusions, we estimate that costs would exceed realistic revenues.
2. If investment in particleboard is nevertheless considered in the future, the accompanying model should be updated for more accuracy, particularly in the areas of export ratios based on comparable exporting countries; the total number of master carpenters in Kumasi; and a refined ratio of small-scale to large-scale particleboard use. This analysis should be followed by more detailed research into particleboard plant costs, especially in small-scale production. Additionally, any particleboard production should be accompanied by education for carpenters, since this would greatly increase particleboard's adoption rate.
3. Consideration of a briquette/pellet plant should begin with a demand analysis of briquettes that incorporates the presence and reactions of Abellon. Given that Abellon claims it can use all the sawdust in the area, Pangea Advisors believes that a second plant would not be beneficial. Unless a stakeholder has significant expertise in pellet production, Pangea Advisors recommends waiting until Abellon's first plant is completed to gauge the remaining demand for briquettes and supply of sawdust.
4. Similarly, Pangea Advisors recommends that mass production of sawdust products should not be pursued at this time, since Abellon is likely to consume most local sawdust waste in a manner consistent with KSB's and MCI's goals of benefiting local communities. Given Abellon's sawdust use, research into further products may be moot.
5. KSB/KNUST should assess whether to continue researching the sawdust issue, given that Abellon's operations may have solved the problem.

Stakeholder-Specific Recommendations

For Sokoban:

- In anticipation of the Abellon plant's completion, we recommend that Sokoban's carpenters begin investigating ways to separate, collect, and transport sawdust efficiently. We also recommend that carpenters engage in basic bookkeeping to facilitate assessment of potential returns on selling or giving sawdust to the Abellon plant.
- Sokoban carpenters can investigate the major differences between Sokoban furniture and furniture imported from China, in order to gain some of Chinese manufacturers' competitive advantage in aesthetics.

For KSB/KNUST:

- We recommend periodic updates and reassessment of the particleboard market analysis and the accompanying model, since changes in the industry may affect the price of plywood or other significant factors, causing a change in the feasibility of particleboard plants.
- If particleboard becomes commercially viable in the future, we recommend using free samples and demonstrations by Sokoban carpenters to educate others on its multiple uses. This should significantly speed up adoption rates and full market potential.
- If continued focus on Sokoban is a possibility, we recommend assisting Sokoban carpenters with the basic bookkeeping and sawdust distribution analysis mentioned above.
- Since the sawdust issue in Kumasi seems to be resolved at the moment, we recommend that KSB/KNUST either investigate similar sawdust problems elsewhere in Ghana or begin looking into municipal solid waste management, which is important to the City as a whole and which overlaps with the sawdust question in various ways.
- In terms of future partnerships with Pangea Advisors and Columbia Business School, we recommend that KSB find clearly defined projects that can be completed in a brief time period or broken into different segments. Creating segmented projects will permit Pangea Advisors to add value more easily and will promote collaboration between the two universities. Additionally, KSB can increase collaboration with Columbia Business School by identifying business-related internships within Ghana and promoting them through Columbia Business School's Social Enterprise Program.

For MCI:

- We recommend that MCI investigate a partnership with Abellon, which wants to use waste sawdust in Kumasi and potentially grow bamboo on mining sites. Abellon is investigating whether it could help miners use their waste from deforestation for power needs and then help regrow lands after mining.
- We recommend that MCI research the Abellon model, which may be replicable in other cities and regions. In some regions, MCI may be able to invite Abellon to set up facilities to turn waste into biofuel. The minimum amount of usable waste for an Abellon plant is 150 tonnes of waste per day. Additionally, pellets made by Abellon are purportedly carbon-neutral and may be useful for Earth Institute research.
- If MCI finds that Abellon would be beneficial to the local communities, we recommend that MCI investigate liaising with the Kumasi Metropolitan Assembly and the Ghanaian Environmental Protection Agency to explain the value of regulations requiring sawdust producers to dispose of a certain percentage of sawdust through briquette manufacturers (guaranteeing the briquette manufacturers a supply of sawdust). In this

case, MCI should also investigate initiatives that help Abellon explain the value of pellets/briquettes and educate the public as to their various potential uses.

- Future research opportunities for MCI discovered through the sawdust study include:
 - Turning municipal solid waste into fuel, recycled materials, fertilizer.
 - Feasibility studies on additional sawdust products: fertilizer (including compost and mulch), insulation, sawdust toilet, concrete aggregate, panels/tiles, wood pulp, sewage treatment, dessicant, feed extender, linoleum (waterproof wallpaper/flooring material), electricity generation (Abellon), cement backerboard, bonding materials in wall restructuring.

For Pangea Advisors:

- We strongly recommend additional products with KSB/KNUST for the following reasons:
 - KSB/KNUST was very helpful in providing access to relevant sources of information, including the Dean of KSB, the KNUST Chancellor, and several KNUST professors.
 - KSB/KNUST provided major support to research efforts, including a team in Ghana to conduct research before the Pangea team's arrival and accompany/work with the Pangea team while in Ghana, a driver to take all team members around Kumasi, arrangements for meetings with various stakeholders, and accommodations for the Pangea team.
 - KSB/KNUST has expressed interest in future collaboration and has access to project experience that is beneficial to Columbia Business School's students and cannot be found in the US.
- We also recommend that the Pangea Advisors sourcing team investigate a partnership with Abellon, which is interested in partnering with Columbia Business School on various clean energy projects.

Next Steps

- KSB/KNUST should assess whether to continue researching the sawdust issue, given that Abellon's operations may have solved the problem.
- Pangea Advisors, MCI and KSB/KNUST should assess which other projects could lead to fruitful partnerships.

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Appendix A: Particleboard Usage – Carpenter Survey

Aim: This survey aims to generate information on the demand, supply, and future trend of Particleboard usage in furniture, shelves, floor underlayment, and similar products in Ghana.

Respondents: Furniture Manufacturers and Importers of Particleboard.

Inference: We want to use the responses to generate a cost-revenue analysis to estimate current and future trends of particleboard and the profit expectations three years out.

Sample size: If possible, 20 responses from users (furniture manufacturers, builders, and other users).

Questions for Users

Do they use particleboard in building furniture, floor underlayment, shelves, construction, etc?

<i>IF YES</i>	<i>IF NO</i>
What do they use particleboard for?	Why? Is it because they are not aware of particleboard, or they don't prefer it?
Why do they prefer particleboard over other wood (low cost factor, accessibility, others)?	If the particleboard was made readily available, will they use it?
Would they increase the usage if particleboard was available more readily (without a price change)?	Why, Why not?
Does the usage of particleboard affect the prices of their end product? By how much?	If they don't prefer it, what factors do they dislike? (cost, availability, durability, customer acceptance?)
How much are they willing to pay per square meter for particleboard?	How much are they willing to pay per square meter for particleboard?
How do they see the demand of their products increasing in near future (1 year, 2 years)?	What are their concerns with particleboard?
Will they prefer using particleboard to meet those demands, if it is readily available?	What materials do they use currently for furniture, floor underlayment, shelves, etc?
What other materials do they use as substitute for particleboard?	DO they use particleboard in anything else?

For all

How many pieces of furniture do carpenters make per year (or per week, if estimate is too hard)?
On average, how many sheets of plywood are used per piece of furniture?
Approximately how many master carpenters work in this area?

Appendix B: Particleboard Market Size Estimation Model

Accompanying this report is a financial model using Microsoft Excel. This model estimates the potential market size for domestic small-scale users, domestic large-scale users, and exports. The model also contains the initial sections of a discounted cash flows model (DCF). To complete the DCF, operating and fixed assets costs should be added and an appropriate discount rate calculated. These calculations were outside the scope of this project, but successive Pangea Advisor teams will be quite familiar with these subjects and can insert them into the accompanying model.

This model can also be adjusted to incorporate new findings and can be replicated for additional sawdust products. To use the model, enter your assumptions on the second worksheet to the best of your knowledge (prior research is recommended). You can also update the green fields in the worksheets directly, but this is not recommended unless you are familiar with spreadsheet modeling, market analysis, and discounting cash flows.