Pallets for the People
ArcelorMittal

E Design 100 – Section 22
Professor Ritter

The Woodchuckers
Group 1
Patrick Barder, Davis Haynes, Vasudev Vohra, Trevor Moser
pjb5369@psu.edu, dgh5119@psu.edu, vfv5008@psu.edu, tam5623@psu.edu
Abstract:

The purpose of our project and research is to find a solution to the problem presented to us by ArcelorMittal concerning the waste produced by wooden shipping pallets used in their steel manufacturing process. ArcelorMittal currently lacks a viable method for recycling these pallets causing further emissions and landfill waste. The focus of this report is to convey an affordable and eco-friendly method for recycling the pallets in a non-disruptive manner to their steelmaking processes. This can be achieved through lengthening the life-cycle of these pallets by converting the pallets into other recycled wood products. This method could potentially provide an industry wide solution that could significantly decrease the environmental concerns of the steelmaking process.
**Introduction and Problem Statement:**

We would like to help ArcelorMittal achieve a more efficient production method by eliminating waste through the use of wooden pallets in their steel production process. Ideally, we believe that the wood should be able to be fully recycled in an environmentally safe and economical way. Currently, the wood ArcelorMittal cannot reuse is either relocated into a landfill or given to its employees. This method wastes the otherwise recyclable wood and causes increased deforestation and further emissions. This problem must be solved throughout the entire industry as soon as possible to minimize harm to the global community. Additionally, the failure to reuse the wooden pallets results in loss of profit for ArcelorMittal. By analyzing current recycling methods, ArcelorMittal’s production process, and the current lifecycle of a typical wooden pallet, we believe we can find a cost effective and environmentally safe solution to recycle these wooden pallets.

**Our Definition of Sustainability:**

Sustainability is the ability of a process, product, or system to continue to provide utility without consuming a disproportionate amount of resources. A sustainable process should be eco-friendly with minimal negative externalities to the global community. Sustainability can be increased in a process, product, or system by maximizing the use of inputs through increased efficiency or lengthened life cycle.

**Background:**

Collectively, wooden pallet waste has a large impact on the global community, particularly the environment. There is an estimated 2 billion wooden pallets currently in use in the US, and all of them will be discarded after one use (environmentalleader.com). This seems like a drastic waste
of resources, especially when there are ways to extend the lifecycle of these pallets. Current methods of recycling wood pallets require a third party to take them to a recycling plant, increasing transportation costs to the ArcelorMittal and the environment through emissions. Integrating the process locally into steel factories across the country would save ArcelorMittal time and money, as well as encourage other companies to adopt a similar process. Additionally, there exists a large market for the recycled materials that come from wooden pallets such as wood mulch, wood chips, wood pellets, etc. This provides a financial incentive to ArcelorMittal to invest in a pallet recycling process because there is a potential to profit off of otherwise wasted materials. There are no patents for any wood recycling processes, however a patented machine would have to be bought from a third party to shred to wood pallets.
Customer Needs:

To evaluate our customer’s needs, specifically the needs of ArcelorMittal, we took into account as many stakeholders as possible when picking our eight criteria. We determined that our solution must have the following characteristics to satisfy the maximum amount of stakeholders:

- Solution must be safe
- Solution must be affordable
- Solution is environmentally friendly
- Solution is efficient
- Solution does not disrupt the steelmaking process
- Solution is speedy
- Solution is durable
- Solution is easy to use

In order to determine the various ranks of importance of the characteristics of our solution we conducted an AHP matrix to weigh the criteria against one another (see table below). By conducting this matrix, we came to the conclusion that the most important characteristics were affordability, environmentally friendly, and non-disruptive to the steelmaking process. On the other hand, the least important characteristic was speed. Overall, the AHP matrix was a very important part of our customer needs assessment because it gave us a more narrow scope on which criteria we should focus on the most during the rest of our design process.
**AHP Matrix:** The data below supports the fact that the most important criteria to our design process were: affordability, environmentally friendly, and non-disruptive to the steelmaking process.

<table>
<thead>
<tr>
<th></th>
<th>Safety</th>
<th>Affordability</th>
<th>Eco-friendly</th>
<th>Efficiency</th>
<th>Non-disruptive (steel making)</th>
<th>Speed</th>
<th>Durability</th>
<th>Easy to use</th>
<th>Total</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Safety</td>
<td>1</td>
<td>.5</td>
<td>.5</td>
<td>1</td>
<td>.5</td>
<td>1.5</td>
<td>1.25</td>
<td>1</td>
<td>7.25</td>
<td>9.58</td>
</tr>
<tr>
<td>Affordability</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>2.5</td>
<td>2</td>
<td>14.5</td>
<td>19.15</td>
</tr>
<tr>
<td>Eco-friendly</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>2.5</td>
<td>2</td>
<td>14.5</td>
<td>19.15</td>
</tr>
<tr>
<td>Efficiency</td>
<td>1</td>
<td>.5</td>
<td>.5</td>
<td>1</td>
<td>.5</td>
<td>1.5</td>
<td>1.25</td>
<td>1</td>
<td>7.25</td>
<td>9.58</td>
</tr>
<tr>
<td>Non-disruptive (steel making)</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>2.5</td>
<td>2</td>
<td>14.5</td>
<td>19.15</td>
</tr>
<tr>
<td>Speed</td>
<td>.66</td>
<td>.33</td>
<td>.33</td>
<td>.66</td>
<td>.33</td>
<td>1</td>
<td>.83</td>
<td>.66</td>
<td>4.8</td>
<td>6.33</td>
</tr>
<tr>
<td>Durability</td>
<td>.8</td>
<td>.4</td>
<td>.4</td>
<td>.8</td>
<td>.4</td>
<td>1.2</td>
<td>1</td>
<td>.66</td>
<td>5.66</td>
<td>7.5</td>
</tr>
<tr>
<td>Easy To use</td>
<td>1</td>
<td>.5</td>
<td>.5</td>
<td>1</td>
<td>.5</td>
<td>1.5</td>
<td>1.25</td>
<td>1</td>
<td>7.25</td>
<td>9.58</td>
</tr>
</tbody>
</table>

<p>| | | | | | | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
</table>

<p>| | | | | | | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
</table>

<p>| | | | | | | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
</table>

<p>| | | | | | | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
</table>

75.71 100%
**Concept Generation:**

After brainstorming for solutions to the problems, we came up with four major design concepts that could adequately solve the problem faced by ArcelorMittal. These were namely donating the wooden pallets, producing charcoal, shredding into wooden chips and producing wood gas.

The first solution, donating the wooden pallets to people in need, is already in use in the ArcelorMittal steel production process to some extent. Some amount of excess wood is given away to employees who might use it for their personal use or even as domestic fuel. This solution can be improvised to create a set-up that is organized to collect this wood and distribute it to the people in need.

The second solution, producing charcoal from the waste wood, involves the combustion of these wooden pallets in the absence of oxygen in steel silos. Charcoal has historically been important as an industrial fuel and has wide application in blast furnaces and finery forges, and could be an important resource in the steelmaking process.

The third solution, shredding the wood involves the use of a wood chipper. This solution comes with a comparatively large set-up cost, but promises to pay back and generate profit in a short period. Wood chipping would involve reducing the wooden pallets to a product of modifiable size and a variety of uses such as mulch and wood pellets.

A fourth solution involved the creation of a syngas fuel called “wood gas” that can be used as a fuel for furnaces, stoves and vehicles. It can also be used to power internal combustion engines at relatively high efficiencies.
**Concept Selection:**

The table below shows that the most feasible solution based on the data provided is shredding the wood pallets into wood chips, wood shavings, mulch, and wood pellets.

<table>
<thead>
<tr>
<th>Feature</th>
<th>Safety</th>
<th>Eco-friendliness</th>
<th>Life Cycle Length</th>
<th>Non Disruptiveness</th>
<th>Speediness</th>
<th>Affordability</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design 1 (Donate)</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>5</td>
<td>4</td>
<td>2</td>
<td>49</td>
</tr>
<tr>
<td>Design 2 (Charcoal)</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>3</td>
<td>4</td>
<td>44</td>
</tr>
<tr>
<td>Design 3 (Shredding)</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>50</td>
</tr>
<tr>
<td>Design 4 (Wood Gas)</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>39</td>
</tr>
</tbody>
</table>

A major limitation of the donating process is the absence of an economic advantage and loss of valuable resources, whereas charcoal generation is a slow process that ends the life cycle of the wood instead of extending it. Synthesis of wood gas also proved ineffective when tested due to the release of nitrogen and carbon monoxides as well as methane gas which defeats the dual purposes of environmental sustainability and the cradle to cradle approach.
The only approach that passed the standards of safety, eco-friendliness, life cycle analysis, non-disruptiveness, speediness as well as affordability was the use of a wood chipper in wood shredding. This method not only extends the life cycle of the wood, but also avoids the production of emissions during the production process.

It helps ArcelorMittal reduce waste stream at their steel production facilities through an opportunity to reuse and recycle one of the largest sources of refuse: pallets from incoming material delivery, thus accomplishing the primary objective of this design project. It also does this without release of any harmful emissions, thus reducing ArcelorMittal’s carbon footprint.

This concept can easily be implemented at one of ArcelorMittal's major facilities through an initial investment in the form of purchase of a wood chipper. It would require minimal input in the form of human capital, limited to just a few employees. The wood pallets would then be shredded into products of various sizes as per requirement and separated from the staples through an electromagnet integrated into the chipping process. Some examples of its applications include the use of mulch as packaging material in the shipment of steel goods and the sale of wood pellets to a third party firm in the distribution/transportation network of ArcelorMittal.
**Life Cycle Analysis:**

The very decision of selecting this concept was based with the life cycle analysis in mind. Typically, wood pallets are used once and then disposed of in a landfill, rendering them a significant problem to the environment. Furthermore, getting only one use out of them drastically decreases the utility of the raw materials used to make them. The wood needed to produce the country's pallet supply makes up about 50 percent of the US’s annual wood harvest (environmentalleader.com), and simply disposing of this large volume of wood is a waste of resources and contributes to deforestation.

With this in mind, the central idea of the project was to efficiently extend the life of the wood by creating an opportunity to further its use in the form of pellets, chips or mulch. Inputs include wood from pallets, energy for shredding and magnetic separation and labor while the output is a wooden product of modifiable size as per requirement. An initial thought was to burn the wood pallets to create wood gas, however this concept was abandoned in favor of extending the life of the wood beyond the ArcelorMittal factory floor in order to better utilize the vast amount of wood that becomes wood pallets each year.
Design Review:

Through the design review activity that we conducted with group 5, we received quality feedback on both the positive aspects of our system and the aspects that still need improvement in our system. Group 5 stated in the design review report that our requirements made logical sense, our proposed product met all customer needs, and our prototype/model was effective in representing our system and product. They also liked how we took into account the bigger system during our design process by identifying one of our main consumers of our final wooden products as ArcelorMittal’s neighboring communities. ArcelorMittal would be able to supply these communities with a quality product while making a profit and improving the community as a whole.

However, group 5 thought we could improve our model by incorporating the wood products into ArcelorMittal to lengthen their life cycle even further instead of directly selling the various wood products. They also sighted that directly putting the wooden pallets into our shredder without removing the staples could potentially damage the shredder itself and that we should look into a way to remove the staples prior to shredding. Overall, by making these few slight changes to our system, group 5 agreed with us that our product would be economically viable, feasible, and environmentally friendly.
3D Model/Prototype: Above is our 3D model of our design. The model shows the wooden pallets on the left on a conveying belt leading to the shredder. The large feature in the middle is the shredder itself, and on the right, you can see the wood products that would be produced from our system.
According to our problem statement, as a group we set out to help ArcelorMittal eliminate the amount of waste that they produce from their wooden pallets. As seen in our systems diagram, we achieved a solution that is both cost effective and environmentally safe. The inputs of the system which include money (the initial cost of the wood chipper), the wooden pallets themselves, the staples that hold the wooden pallets together, the wood chipper, the electromagnet, and the electricity it takes to power the machine are minimal. In the system, our
goal of eliminating the pallets, but continuing the wood’s life cycle is achieved in an economical way by producing a product that can be sold. The system also emits very small amounts of emissions due to the electrically powered chipper, and the only other output that is a product of our system is the staples which ArcelorMittal could melt down and use again in their production process if they so choose.

**Cost and Feasibility Analysis:**

The estimated upfront cost of a pallet shredding system is $100,000. However we believe that this cost will be offset by the ability to produce and sell wood chips. Additionally, the elimination of stored pallets would allow the space currently occupied to be better utilized for the steelmaking process. Additional costs required to operate the system include basic labor, and transportation costs. We estimate that the system will start to generate profits within a period of 2-3 years with the chips sold at $160/ton (recycle.net). There are a few ways in which Arcelormittal can generate revenue from shredded wood, this wood could be sold as a resource, or could be made into fuel or building products. There shouldn’t be a reason why stakeholders would not want to adopt this system, as it generates profit, is sustainable, and adds a positive appeal to ArcelorMittal.
Conclusions:

Our design takes advantage of existing recycling methods and makes them more convenient and environmentally friendly for ArcelorMittal. The cost of recycling represents a significant deterrent when businesses consider whether or not to adopt a recycling policy, however we have provided a method to possibly profit off of the recycled materials or at least minimize cost. By keeping the process in house, ArcelorMittal does not have to forfeit the pallets to a third party if they plan to recycle it. One tradeoff of this is that an initial investment is required to place wood shredding machinery onto the factory floors. Also there is a small cost of labor involved in working and maintaining the machinery, as well as handling the recycled materials. Furthermore, the staples in the pallets will be separated by a magnet integrated into the shredding machine, representing an innovative and time saving feature of our design. Additionally, it is unlikely the machinery as a whole will disrupt the steelmaking process or typical work done within the plant, and the process is quick and efficient and requires minimal manual labor.

Future modifications to the design may depend of the specifics of each factory floor where ArcelorMittal decides to implement the system. There is likely a variety of machines that will best fit the needs of each steelmaking plant. Furthermore, the output of the process may be dependent on which recycled materials are in demand, or which ones ArcelorMittal can profit from the most. Additional labor may be needed to inspect the shredded wood for metal pieces and assess the effectiveness of the magnet. Depending on the results of this assessment, the system may have to be modified so that the staples are taken out of the wood before it is shredded.

Our team grew and learned in a variety of ways, most notably we were made more aware of the environmental costs associated with something as basic and commonplace as wood pallets.
Furthermore, after accounting for transportation emissions and recycling costs, we learned that recycling them can incur a cost to the environment as well. The importance of extending the lifecycle of a product became a huge emphasis of ours as we got further into the project. In conclusion, we gained skills and design techniques that can be applied across many disciplines to design sustainable systems and products in the future.
Works Cited


