Executive Summary:

The international steel company ArcelorMittal issued the challenge to reduce their waste stream and help them to reuse, reduce, or recycle refractory brick, totes, drum and pallets. These materials are used to transport materials necessary to the steel making process or used directly in it. Currently, these materials once used are taken to landfills as there are no measures to recycle them. Our project is to repurpose used steel drums so that may be diverted from landfills. Our design focuses on converting steel drums into suitable roofing material. We were asked to also develop a team generated definition of sustainability. For us, sustainability at its crux is the idea that nature and the resources available to us should be used conscientiously so future generations will have the same amount if not more than we do.

Introduction:

The goal of our project is to find an efficient and economical way to reuse, repurpose, or recycle pallets, drums, totes, or refractory brick to reduce the items the ArcelorMittal Steelton plant sends to landfills. As a result, this project not only requires the design to be practically applicable, but also minimize the cost so that the company may make economic profit. What’s more, the project should be environmentally friendly. There are several kinds used of material which are mentioned above, 55 gallon steel drums, 275 gallon totes, 330 gallon totes, wooden pallet and refractory bricks. We are going to have detailed information like cost, profit, and the dimension of the design.

Problem Statement:

We decided focus our efforts on the steel drums. Our plan is to reuse the steel drums by turning them into roofing tiles. We’ll do this by either reshaping or melting the drums and changing their shapes. We will likely make interlocking tiles for ease of installation. The tiles will have to be light but sturdy and rust proof. We will do analysis on costs, the ease of installing, and producing our product. We’ll look into any roofing projects similar to this on the internet in hopes of bettering our product. It is our hope that through the course of this project we will provide Arcelor Mittal with a way to curb steel drum waste.
Research:

Prior to developing our model we conducted some research. In our first phase of research we googled many pictures of all types of tiles, bathroom tiles, roofing tiles, tiles for back splashes, etc. so as to get an idea of what kinds of tiles were already out there. We did put some effort into building some models of different configurations of tiles. We tried out triangular and hexagonal tiles but found that they were too difficult to make. We looked into ways to interlocking the tiles by way of tabs that could fold under and atop each other, but eventually found that it was easier to make the tiles stackable. We wanted to find a tile that was aesthetically pleasing shape while being easy enough for us to manufacture ourselves. We eventually made rectangular tiles and folded the sides over because they ended up interlocking well enough and looked alright.

Calculations for Cost and Profit:

According to our market research, the average price of a 55 gallon steel drum is around $100. For a drum whose height is 34.5 in and diameter of 22.5 inches, the surface area of the drum would be:

\[ SA = 2\pi rh + 2\pi r^2 \]
\[= 2\pi r(h + r)\]
\[= 2\pi(11.25in)(34.5in + 11.25in)\]
\[= 3233.88in^2\text{ of steel per drum}\]
\[3233.88in^2 \times \left(\frac{1/ft^2}{144in^2}\right)\]
\[= 22,457.48ft^2\]

In this estimate it can be assumed that the circular top and bottom of the drums will be melted down and reshaped to be made into roofing as well. Our tiles are 1\(ft^2\) of steel. In consulting a website called metalroofnet.com it can be determined that medium quality stainless steel roofing tiles cost $2-$6 per tile. For our purposes, let’s say we sell the tiles for $4. So, according to renewableenergyworld.com the average roof size in the U.S. in 2009 was 2,700\(ft^2\) this would come out to $10,800 for the tiles alone. If we are able to do the installation as well according to metalroofnet.com installation by a full service contractor of a residential roof with reasonable pitch will cost $2-$5. Let’s say for our tiles it’ll cost $3 for the installation for a single tile, this comes out to $8,100 in installation costs. In total, a sample from outfitting a 2,700 \(ft^2\) roof with our tiles including installation would be $18,900. Excluding installation costs the tiles alone would be $10,800.

Customer Needs and Target Specification:

We sat down and each came up with five customer needs and then converted them to target specifications. In the left column are customer needs that we came up with during our group discussion and in the right column corresponds to the target specifications.

<p>| 1. Find a way to turn the drums into roofing (via crushing, melting, or cutting) | 1. Take the whole drum remove the top and bottom. Flatten out the middle rectangle cut out squares for tiles. |
| 2. Find out how we’ll transport the drums | 2. Take the drums from the ArcelorMital Steelton plant on trucks to the plant where they’ll be changed into tiles |
| 3. Keep their prices affordable (roofing tiles) | 3. Sell them in bulk and use machines to cut the drums so we don’t have to pay employees |
| 5. Find a way to make the roofing tiles | 5. Make them into small tiles. |</p>
<table>
<thead>
<tr>
<th><strong>interlocking for easy installation and replacement</strong></th>
<th>6. Maintain the structural integrity of the roof</th>
</tr>
</thead>
<tbody>
<tr>
<td>6. The steel form drums are melted and cast to form trapezoidal ribs on each steel tiles. And the steel tile is putted on wood frame</td>
<td></td>
</tr>
<tr>
<td>7. Make sure the tiles are not reactive or toxic, but safe</td>
<td>7. Before melting the steel, we clean out the chemicals in the steel drums.</td>
</tr>
<tr>
<td>8. Find out if the steel drums can be reshaped by the Steelton factory’s machines</td>
<td>8. The metal only needs to be melted and stamped</td>
</tr>
<tr>
<td>9. Find an appropriate rust inhibitor</td>
<td>9. A zinc coating is a good option to be a rust proofing coating because it also has chemical stability</td>
</tr>
<tr>
<td>10. Make sure the product and process are environmentally friendly</td>
<td>10. Our design may produce a small amount of waste going to the landfill</td>
</tr>
<tr>
<td>11. Make sure the tiles and roof are not too heavy</td>
<td>11. A typical metal roof weights 0.7-1.0 pounds per square feet. Metal roofing is one of the lightest roofs available. Other roofing materials: Concrete 5-10 pounds per sqft / Asphalt Shingles 3.5-5 pounds per sqft</td>
</tr>
<tr>
<td>12. Find a way to prevent roof tiles from warping due to temperature fluctuation</td>
<td>12. Use a high temperature roof layer in the architectural metal roof assemblies.</td>
</tr>
<tr>
<td>13. The tiles must be of a reasonable size</td>
<td>13. 12” wide / cut to specified length / 1.75” tall</td>
</tr>
<tr>
<td>14. Find out if the metal is porous enough to layer protectants on</td>
<td>14. Metal roof is non-porous in order to prevent the surface from trapping additional liquids and leadings to further corrosion</td>
</tr>
</tbody>
</table>
| 15. Find out if it’s cheaper to melt it down than to just reshape it | 15. Rapid fire Metal Melting Machine: $478.99  
Reshaping metal is much cheaper. |
Concept Generation:
We come up with three concepts. The first was to make a roof out of a single piece of steel.

The second concept was to make a tile in a sandwich style with wood in the middle sandwiched by stainless steel then sandwiched again with refractory brick.

The third concept was to make small steel tiles and use a special technique to interlock them together.

Concept Selection:

<table>
<thead>
<tr>
<th>Categories</th>
<th>Concept 1</th>
<th>Concept 2</th>
<th>Concept 3</th>
<th>Best Concept For Each Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost</td>
<td>1</td>
<td>-2</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Strength</td>
<td>-1</td>
<td>1</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Ease of installation</td>
<td>-1</td>
<td>0</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Rust proofing</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>2</td>
</tr>
</tbody>
</table>
### Preliminary Concepts:

After we decided to make a roof with small steel tiles, we started to design the shape and how the tiles would interlock with each other. At first we considered making our tiles into hexagons or triangles because tiles of either shape could be arranged easily. Also, we thought these kinds of tiles were visually pleasing. However, they had a common problem. First they are harder to produce than rectangular shaped tiles because it was harder to cut out hexagons and triangles. More calculations and measurements are needed to produce the triangular and hexagonal shaped tiles than necessary. What’s more, we could not find an appropriate way to interlock them with each other. Lastly, if we produced triangular or hexagonal tiles, there will be waste because if we want to cut out these shapes from a piece of steel, we cannot make any use of the oddments. As a result, we decided to make a rectangular shaped tile with two grooves on it. It is really easy to be produced, and the grooves on it allowed us to interlock the tiles together. For our prototype, we used hot glue to stick the tiles together, but in the case of a real roof and tiles this can be done by using nails. Below is a picture of some of the possible shaped tiles we thought of while we were still undecided.
Final Description:

Above is a CAD of the steel tile we would make out of the steel drums to make roofing tiles. It was a rectangle and bent on both side from the outer edge working inward. These tiles are easily stackable and capable of interlocking down the inclined plane of a roof.

System Diagram:

The system diagram below discrubs the whole production process of the steel tiles.

Implementation Plan:

Considering that there may be some broken drums, we will offer an option to melt down and reshape those broken drums. However, for the drums that are not broken, we will simply
reshape the drums. For example, in the case of our actual model we took some cans from a recycling bin near the lab. Then, cut off the top and the bottom to create a cylinder without a top and bottom. Then, we cut up the top and bottom free cylinder making a rectangle that we then flatten by rolling a bottle on. This flat larger rectangle was fairly easy to cut smaller rectangles out of. On an industrial scale, this process could be mechanized with machines like roll-former to make the steel into a flat panel. Then a precise computerized machine can cut the large panel to the right sized rectangle. As far as the size of the the tiles go, the customers can order a custom sizes for their tiles if needed, but the default size is about 1*1 sq ft. Then the tiles go into a stamping press, which applies force on the metal panel until it reaches the desired shape with double grooves on the steel tile.

Stamping press

Roll former
Metal cutting machine

Waste Stream Analysis:

Approx. Dimensions
inside height: 34.5 in
inside diameter: 22.5 in

\[ S.A. = 2\pi rh + 2\pi r^2 \]
\[ = 2\pi r \left( h + r \right) \]
\[ = 2\pi \left( 11.25 \right) \left( 34.5 + 11.25 \right) \]
\[ \approx 3,233.88 \text{ in}^2 \]

\[ 3233.88 \text{ in}^2 \times \frac{1 \text{ ft}^2}{14.4 \text{ in}^2} \]
\[ \approx 224.5 \text{ ft}^2 \text{ per 1000 steel drums} \]

Assuming the Arcelor Mittal Steelton plant uses 55 gallon steel drums for every 1000 drums, 224.5 ft² of steel will be diverted from landfills.
Conclusions:

The final concept with decent funding and a partnership with a firm that has all of the machinery necessary to manufacture the tiles became available to us this idea of turning steel drums into roofing material is definitely possible. This idea would also fulfill ArcelorMittal’s Steelton, PA plant’s goals to curb their waste products in the case of the steel drums. If the product could be manufactured these tiles could end up on the roofs of residential homes and businesses. They would be functional and would be doing a service to our planet in preserving our resources as the tiles could likely be recycled again after the house they’re on top of crumbles.

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