Client-Driven Design Project

Alcoa

EDSGN 100: Introduction to Engineering Design

Section 004

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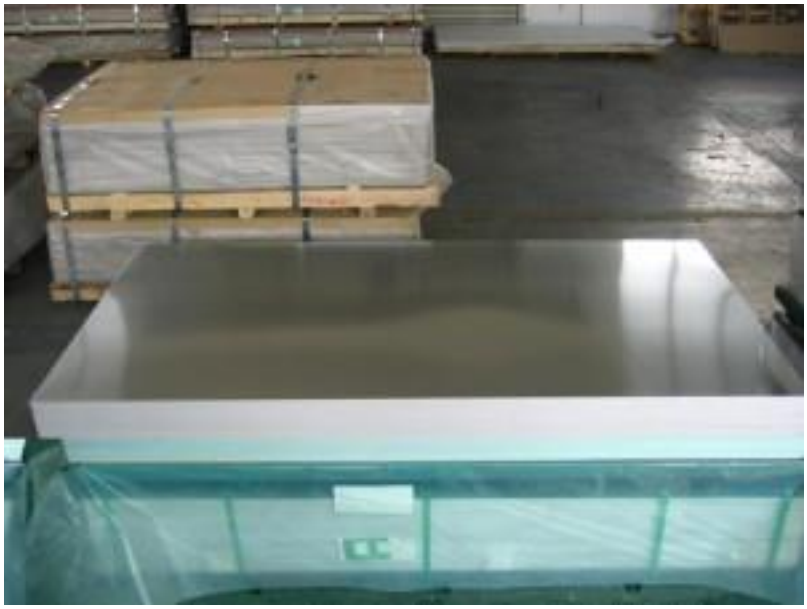

Figure 1: Reflector Sheet

Our project consists of an aluminum-based product that increases the efficiency of lighting systems in various classrooms at The Pennsylvania State University. Our product is a concave aluminum reflector sheet that will be connected to two sides of a ceiling light source. Aluminum 1050 is the alloy that we will be using.

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Background

Alcoa

Alcoa was founded in 1888 and was known at that time as the Pittsburgh Reduction Company. In 1907, it became known as the Aluminum Company of America, the change in name reflected the actual work of the company. It remained the Aluminum Company of America until 1999 when it was officially renamed as Alcoa. Alcoa provides aluminum to many different industries for construction. In 1901, Alcoa started working on lightweight automobiles with aluminum and in 1903 started working on airplanes as well. In 1938, the Justice Department charged Alcoa with illegal monopolization, and demanded that the company be dissolved. The case of *United States v. Alcoa* was settled six years later. Some of the notable inventions that have come from Alcoa include aluminum foil, which was introduced in 1910 and the first aluminum beer bottle created in 2004.

Alcoa conducts operations in 31 countries where it mostly is a producer of primary aluminum, fabricated aluminum, and alumina combined, with participation in all major aspects of the industry: technology, mining, refining, smelting, fabricating, and recycling. Aluminum and alumina represent more than three-fourths of Alcoa's revenue. It is currently the third biggest producer of Aluminum products. The products include consumer electronics, aluminum construction materials, and aluminum packaging.

Figure 2: Alcoa Logo

Aluminum

Aluminum is the third most abundant element in the world, behind oxygen and silicon. It is the most abundant elemental metal; however it does not usually exist in nature as a pure substance because of its high reactivity. Its most common form is bauxite ore, a compound of hydrated aluminum oxide and hydrated iron oxide. Most of the world's bauxite deposits are concentrated on the tropical and sub-tropical belt in Australia, Guinea, Jamaica, and Brazil. However aluminum needs to be separated from the bauxite and extracted in a process known as the Hall-Heroult process.

The Hall-Heroult process is the major industrial process for the production of elemental aluminum. It involves dissolving alumina in molten cryolite, and electrolyzing the molten salt bath. The molten bath needs to be heated to roughly 1,000 C (1,830 F) when it is electrolyzed, by passing low voltage direct current through it. The liquid aluminum metal is deposited at the cathode while the oxygen from the alumina combines with carbon from the anode to produce carbon dioxide.

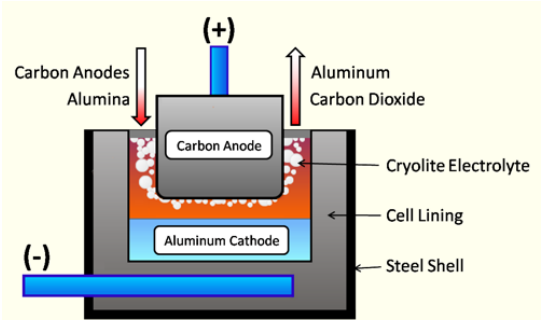


Figure 3: Hall-Heroult Process

Aluminum itself is very light and soft and often needs to be strengthened by other metals, therefore most useful aluminum products are actually aluminum alloys. Some of the more popular alloys include aluminum and tin, and aluminum and copper. Aluminum is also incredibly popular for its low density and its rather unique ability to resist corrosion through passivation. It resists corrosion by forming a thin layer of aluminum oxide when exposed to air. This thin layer of aluminum oxide resists further corrosion.

Aluminum is both ductile and malleable, lending it to have a wide variety of uses. Some of its more common uses include parts of transportation vehicles, packaging, construction, household items, etc. Most of these aluminum products are in the 3+ oxidation state. The coordination number of such compounds varies, but generally Al 3+ is a six-coordinate or tetracoordinate. Aluminum also possesses incredible reflecting capabilities reflecting as much as 92% of visible light and as much as 98% of infrared radiation.

Another attractive feature of aluminum is it is theoretically 100% recyclable without loss of its natural qualities. As such, recycling has become a large part of the aluminum industry because it requires only 5% of the energy used to produce aluminum from ore.

Aluminum alloys with a wide range of properties are used in engineering structures. Alloy systems are classified by a number system (ANSI) or by names indicating their main alloying constituents (DIN and ISO). Aluminum does not glow red before melting as steel does and so it makes its thermal properties somewhat uncertain.

While aluminum is highly un-toxic to humans (500g for an 80kg person) it does cause great damage to the environment.

Bauxite

Bauxite is an aluminum ore and is the main source of aluminum. Bauxite is a rock that consists of many different minerals, mainly, gibbsite, boehmite, and diaspore. Bauxite was named after the village Les Baux in Southern France, where it was first recognized as containing aluminum and named by the French geologist Pierre Berthier in 1821.

There are two main classifications of bauxite: Lateritic bauxites (silicate bauxites) and karst bauxite (carbonate bauxites). Carbonate bauxites were discovered first and occurred predominantly in Europe and Jamaica above carbonate rocks (limestone and dolomite) where they were formed by residual accumulation of intercalated clays or by clay dissolution residues of the limestone. The lateritic bauxites are found mostly in the tropics. They were formed by lateritization (soil types rich in iron and aluminum, formed in hot and wet tropical areas) of various silicate rocks such as granite, gneiss, basalt, and shale.

Australia and Guinea have been two of the top producers of the world's bauxite for aluminum production. Despite the fact that the demand for aluminum has increased rapidly, the known reserves of bauxite contain enough aluminum to satisfy the world's demand for many centuries. Increased recycling will considerably extend the use of the world's bauxite reserves while simultaneously lowering electrical output.

Bauxite is usually strip mined because it is almost always found near the surface of the terrain. Much of the world's bauxite is first processed into alumina through the Bayer process, and then into aluminum by electrolysis.

Usually bauxite is heated in a pressure vessel along with a sodium hydroxide solution at a temperature of 150-200C. The aluminum is dissolved as an aluminate at these temperatures (Bayer Process). The remaining ferruginous residue is separated by filtering, pure gibbsite is precipitated when the liquid is cooled, and then seeded with fine-grained aluminum hydroxide. Gibbsite is converted to aluminum oxide (Al_2O_3) and the mineral is dissolved in molten cryolite at 960C. This molten substance can yield metallic aluminum by passing an electric current through it in the process of electrolysis, which is known as the Hall-Heroult process.

Aluminum Alloys

Aluminum alloys are alloys in which aluminum is the predominant metal. The typical alloying elements are copper, magnesium, manganese, silicon, and zinc. There are two principal classifications of these alloys: 1) Casting alloys 2) Wrought alloys. Both of these are further subdivided into the categories heat-treatable and non-heat-treatable. Most aluminum is used for wrought products (roughly 85%) for things such as rolled plate, foils, and extrusions. Cast alloys yield cost-effective products due to their low melting point (requires less energy to make) although the tradeoff is that they generally have lower tensile strength than wrought alloys. The most important cast aluminum alloy system is the Al-Si, where the high levels of silicon contribute to give good casting characteristics.

Aluminum alloys have a wide range of properties and can be used in various engineering structures and applications. Selecting the right alloy for a given application entails considerations of its tensile strength, density, ductility, formability, workability, weldability, and corrosion resistance, among other properties.

An alloy that is wrought is one that is worked by being forged or hammered. A cast alloy is when the molten alloy is poured into a mold to give it its shape, and has very little strength.

Copper Alloys- Copper has been the most common alloying element almost since the beginning of the aluminum industry, and a variety of alloys in which copper is the major addition were developed. In the cast alloys, the basic structure consists of cored dendrites of aluminum solid solution, with a variety of constituents. Wrought products consist of a matrix of aluminum solid solution with the other soluble and insoluble constituents dispersed within it. The copper provides substantial increases in strength and facilitates precipitation hardening. The introduction of copper to aluminum can also reduce ductility and corrosion resistance. The susceptibility to solidification cracking of aluminum-copper alloys is increased; consequently, some of these alloys can be the most challenging aluminum alloys to weld. These alloys include some of the highest strength heat treatable aluminum alloys. The most common applications for the 2xxx series alloys are aerospace, military vehicles and rocket fins.

Manganese (Mn) 3xxx – The addition of manganese to aluminum increases strength somewhat through solution strengthening and improves strain

hardening while not appreciably reducing ductility or corrosion resistance. These are moderate strength nonheat-treatable materials that retain strength at elevated temperatures and are seldom used for major structural applications. The most common applications for the 3xxx series alloys are cooking utensils, radiators, air conditioning condensers, evaporators, heat exchangers and associated piping systems.

Silicon (Si) 4xxx – The addition of silicon to aluminum reduces melting temperature and improves fluidity. Silicon alone in aluminum produces a nonheat-treatable alloy; however, in combination with magnesium it produces a precipitation hardening heat-treatable alloy. Consequently, there are both heat-treatable and nonheat-treatable alloys within the 4xxx series. Silicon additions to aluminum are commonly used for the manufacturing of castings. The most common applications for the 4xxx series alloys are filler wires for fusion welding and brazing of aluminum.

Magnesium (Mg) 5xxx - The addition of magnesium to aluminum increases strength through solid solution strengthening and improves their strain hardening ability. These alloys are the highest strength nonheat-treatable aluminum alloys and are, therefore, used extensively for structural applications. The 5xxx series alloys are produced mainly as sheet and plate and only occasionally as extrusions. The reason for this is that these alloys strain harden quickly and, are, therefore difficult and expensive to extrude. Some common applications for the 5xxx series alloys are truck and train bodies, buildings,

armored vehicles, ship and boat building, chemical tankers, pressure vessels and cryogenic tanks.

Magnesium and Silicon (Mg_2Si) 6xxx – The addition of magnesium and silicon to aluminum produces the compound magnesium-silicide (Mg_2Si). The formation of this compound provides the 6xxx series their heat-treatability. The 6xxx series alloys are easily and economically extruded and for this reason are most often found in an extensive selection of extruded shapes. These alloys form an important complementary system with the 5xxx series alloy. The 5xxx series alloy used in the form of plate and the 6xxx are often joined to the plate in some extruded form. Some of the common applications for the 6xxx series alloys are handrails, drive shafts, automotive frame sections, bicycle frames, tubular lawn furniture, scaffolding, stiffeners and braces used on trucks, boats and many other structural fabrications.

Zinc (Zn) 7xxx – The addition of zinc to aluminum (in conjunction with some other elements, primarily magnesium and/or copper) produces heat-treatable aluminum alloys of the highest strength. The zinc substantially increases strength and permits precipitation hardening. Some of these alloys can be susceptible to stress corrosion cracking and for this reason are not usually fusion welded. Other alloys within this series are often fusion welded with excellent results. Some of the common applications of the 7xxx series alloys are aerospace, armored vehicles, baseball bats and bicycle frames.

Iron (Fe) – Iron is the most common impurity found in aluminum and is intentionally added to some pure (1xxx series) alloys to provide a slight increase in strength.

Chromium (Cr) – Chromium is added to aluminum to control grain structure, to prevent grain growth in aluminum-magnesium alloys, and to prevent recrystallization in aluminum-magnesium-silicon or aluminum-magnesium-zinc alloys during heat treatment. Chromium will also reduce stress corrosion susceptibility and improves toughness.

Nickel (Ni) – Nickel is added to aluminum-copper and to aluminum-silicon alloys to improve hardness and strength at elevated temperatures and to reduce the coefficient of expansion.

Titanium (Ti) – Titanium is added to aluminum primarily as a grain refiner. The grain refining effect of titanium is enhanced if boron is present in the melt or if it is added as a master alloy containing boron largely combined as TiB_2. Titanium is a common addition to aluminum weld filler wire as it refines the weld structure and helps to prevent weld cracking.

Zirconium (Zr) – Zirconium is added to aluminum to form a fine precipitate of intermetallic particles that inhibit recrystallization.

Lithium (Li) - The addition of lithium to aluminum can substantially increase strength and, Young's modulus, provide precipitation hardening and decreases density.

Lead (Pb) and Bismuth (Bi) – Lead and bismuth are added to aluminum to assist in chip formation and improve machinability. These free machining alloys are often not wieldable because the lead and bismuth produce low melting constituents and can produce poor mechanical properties and/or high crack sensitivity on solidification.

Aluminum 1050 – To produce this alloy, copper, magnesium, silicon, iron, manganese, zinc and titanium are all added to aluminum. This produces an alloy that is corrosion resistant, highly ductile, and very reflective.

Aluminum Alloy Recycling

Most of the common aluminum alloys have relatively low amounts of the other metals in their products, and as such, are fairly easy to recycle by simply melting down. There are some alloyed products that pose a great challenge to the aluminum and recycling community such as the parts in aerospace and automotive products. These parts are often highly specialized and incredibly pure, while containing high levels of the alloyed metal, making them very difficult to recycle as each one requires a specific process. Therefore, many aluminum alloys that contain high levels of the alloyed metal are not regularly recycled.

Problem Overview

Below is a list of buildings on campus that had very high electricity bills in January 2012. We obtained this information from the Office of Physical Plant (OPP). Next to each building name, the electricity consumption (in kilowatt-hour) and the electricity bill (in US dollars) is listed for the month of January 2012.

Old Main: *Electricity 67,760.00 kWh $6,232.32*

Pattee Library: *Electricity 644,773.00 kWh $58,782.09*

Sheilds Building: *Electricity 157,729.00 kWh $14,421.44*

Hub: *Electricity 661,577.00 kWh $60,806.90*

Eisenhower Chapel: *Electricity 44,408.00 kWh $4,044.69*

Pollock Building: *Electricity 58,488.00 kWh $5,345.67*

Computer Building: *Electricity 627,121.00 kWh $56,399.33*

Eisenhower Auditorium: *Electricity 48,848.00 kWh $4,553.28*

Willard Building: *Electricity 74,230.00 kWh $6,884.26*

Wagner Building: *Electricity 52,147.00 kWh $4,765.53*

Keller Building: *Electricity 89,175.00 kWh $8,173.58*

Telecommunications Building: *Electricity 60,355.00 kWh $5,456.52*

Bookstore Building: *Electricity 360,623.00 kWh $32,264.49*

Academic Activities: *Electricity 168,114.00 kWh $15,262.69*

Ford Building: *Electricity 94,590.00 kWh $8,653.04*

Business Building: *Electricity 171,798.00 kWh $15,750.30*

Earth and Engineering Science: *Electricity 152,430.00 kWh $13,812.02*

Life Sciences*: Electricity 452,848.00 kWh $40,928.81*

IST Building: *Electricity 300,867.00 kWh $27,249.78*

Bryce Jordan Center*: Electricity 263,815.00 kWh $24,523.52*

Chemistry Building: *Electricity 598,620.00 kWh $54,075.52*

Nittany Lion Inn: *Electricity 291,000.00 kWh $26,926.73*

Frear North Building: *Electricity 187,344.00 kWh $16,912.54*

Food Science: *Electricity 281,407.00 kWh $25,649.19*

Ag Sciences and Industries: *Electricity 346,041.00 kWh $31,275.57*

Chemical Ecology Lab: *Electricity 172,892.00 kWh $15,687.67*

University Supply Building I: *Electricity 79,400.00 kWh $7,321.18*

University Supply Building II: *Electricity 125,200.00 kWh $11,400.34*

Research Building West: *Electricity 345,006.00 kWh $31,468.69*

Electrical Engineering West: *Electricity 329,383.00 kWh $29,683.62*

Wartik Lab: *Electricity 266,756.00 kWh $24,204.57*

Fenske Lab: *Electricity 344,493.00 kWh $31,206.28*

Academic Projects Building: *Electricity 159,040.00 kWh $14,633.19*

Kern Grad Building: *Electricity 103,981.00 kWh $9,530.45*

Holser Building: *Electricity 383,519.00 kWh $35,293.98*

Walker Building: *Electricity 219,184.00 kWh $19,921.71*

Carnegie Building: *Electricity 49,397.00 kWh $4,578.78*

Theater Building: *Electricity 114,483.00 kWh $10,394.23*

Intramural Building: *Electricity 104,001.00 kWh $9,463.83*

Football Stands: *Electricity 1,449,879.00 kWh $131,292.98*

Holuba Hall*: Electricity 95,100.00 kWh $8,860.83*

Hotsetter Business Center: *Electricity 172,609.00 kWh $15,878.27*

Physical Plant Building: *Electricity 247,588.00 kWh $22,861.33*

230 Building: *Electricity 237,986.00 kWh $21,716.74*

Outreach Innovation Building: *Electricity 123,425.00 kWh $11,232.62*

Katz Building: *Electricity 93,781.00 kWh $8,648.54*

Applied Science Building: *Electricity 112,000.00 kWh $9,820.51*

Problem Statement

Alcoa challenged us to integrate aluminum's properties into the design of The Pennsylvania State University campus for the purpose of increasing the efficiency or sustainability of the campus. Based off of the electricity costs listed above, The Pennsylvania State University needs to create a more sustainable output of electrical energy.

Sustainability

The online dictionary defines sustainability as “the quality of not being harmful to the environment or depleting natural resources, and thereby supporting long-term ecological balance.” This gives the impression that being sustainable is related to being self-sufficient, eco-friendly and beneficial in the long run. Furthermore, the EPA (United States Environmental Protection Agency) goes on to explain that, “sustainability creates and maintains the conditions under which humans and nature can exist in productive harmony, that permit fulfilling the social, economic and other requirements of present and future generations.” This suggests that for sustainability to exist, different systems are required to work together. Sustainability is crucial to our everyday lives as there are certain necessities that we need to keep being provided with, such as water. Therefore in this project we aim to be environmentally, economically and socially sustainable. For example, this can be achieved by creating a product that is cost-effective and energy efficient.

Different lighting systems:

Incandescent bulbs produce light when an electric current passes through a filament and causes it to glow. Because they are less energy efficient than other light sources, they are best used for task lighting that demands high levels of brightness.

Fluorescent bulbs produce light when an electric arc passes between cathodes to excite mercury and other gases producing radiant energy, which is

then converted to visible light by a phosphor coating. They use 1/5 to 1/3 as much electricity as incandescent with comparable lumen ratings and last up to 20 times longer.

Light Emitting Diodes (LEDs) produce light when voltage is applied to negatively charged semiconductors, causing electrons to combine and create a unit of light. In simpler terms, an LED is a chemical chip embedded in a plastic capsule. Because they are small, several LEDs are sometimes combined to produce a single light bulb. LED lighting in general is more efficient and longer lasting than any other type of light source.

Ambient lighting provides an area with overall illumination. Also known as general lighting, it radiates a comfortable level of brightness without glare and allows you to see and walk about safely.

Task lighting helps you perform specific tasks, such as reading.

Accent lighting adds drama to a room by creating visual interest. As part of an interior design scheme, it is used to draw the eye to houseplants, paintings, sculptures and other prized possessions.

The aluminum that we are using for our reflector is aluminum alloy 1050 which is known for its corrosion resistance, high ductile, and a highly reflective finish.

Customer Needs Assessment

The three main stakeholders are Alcoa, the students at The Pennsylvania State University and the Office of Physical Plant (OPP), which works with The Pennsylvania State University. As one of our customers, Alcoa aims to take advantage of aluminum's properties to increase the efficiency or sustainability of products and product systems across campus. Furthermore Alcoa wants to make use of a product that is currently being produced in one of its production lines. For Alcoa to take this product or product system into consideration, it must be profitable which means that the costs would have to be reasonably low. This information was gathered from the PDF given to us by Alcoa at the start of the project.

On 21 November 2013, we carried out a survey with 10 Penn State students. Here are their responses:

On a scale of 1-10 how satisfied are you with lighting in Penn State classrooms?

Response 1: 6

Response 2: 8

Response 3: 10

Response 4: 7

Response 5: 7

Response 6: 8

Response 7: 5

Response 8: 10

Response 9: 9

Response 10: 7

Do you think Penn State should attempt to save money on electricity costs?

9 said yes

1 said no

Does the quality of lighting in the classroom affect your learning?

7 said yes

3 said no

Is aluminum easily recyclable?

4 said yes

6 said no

What is Aluminum's most favorable property?

Response 1: low weight

Response 2: ductility

Response 3: weight

Response 4: weight to strength ratio

Response 5: Ability to conduct electricity

Response 6: Strength

Response 7: Ability to easily manipulate

Response 8: Price

Response 9: Versatility

Response 10: weight

After looking over the results of our survey, we realized that students think that there is a need for Penn State to save money on electricity costs

According to the Penn State Sustainability Strategic Plan the vision is “to embed sustainability as a fundamental value at the University.” Therefore OPP desires to use an affordable product that does not negatively affect students’ ability to learn. Plus, the product/product system has to be either as good as or better than a current product being used but cheaper.

Design Specifications

In order to develop an appropriate lighting system design, the following are five principles that we can use to evaluate all of our ideas. First of all, the product should be affordable. Initial cost, installation cost, and operation cost are the three major costs we need to take into consideration. Initial cost includes the expense of reflectors and other materials that are needed to construct the lighting system, also, the transportation fees. Manpower is required to replace the old lighting system into our new product; therefore, installation cost is taken into account. Among the other two costs, operation cost is the most important factor. Operation costs consist of: maintenance fee and electric bill which brings out the second principle – energy efficiency. The product should be more energy efficient than the current system, which means it can save money spent on electricity. In the long term (roughly a year), the money saved can cover the initial and installation costs, and lets the university profit by the new system. Third, the product needs to emit the same or more amount of light than the current one to provide students with light sufficient places to study. The product used has to reflect at least 80% luminance in order to be a viable product. Fourth, since there are a lot of buildings and classrooms on campus, the more easily the product is

installed, the less time and efforts it takes to renew all the lighting systems. The objective is to create a product that does not take more than an hour to install per light fixture. Finally, other than fully functional, our product should also be aesthetically pleasing to lighten up the study environment.

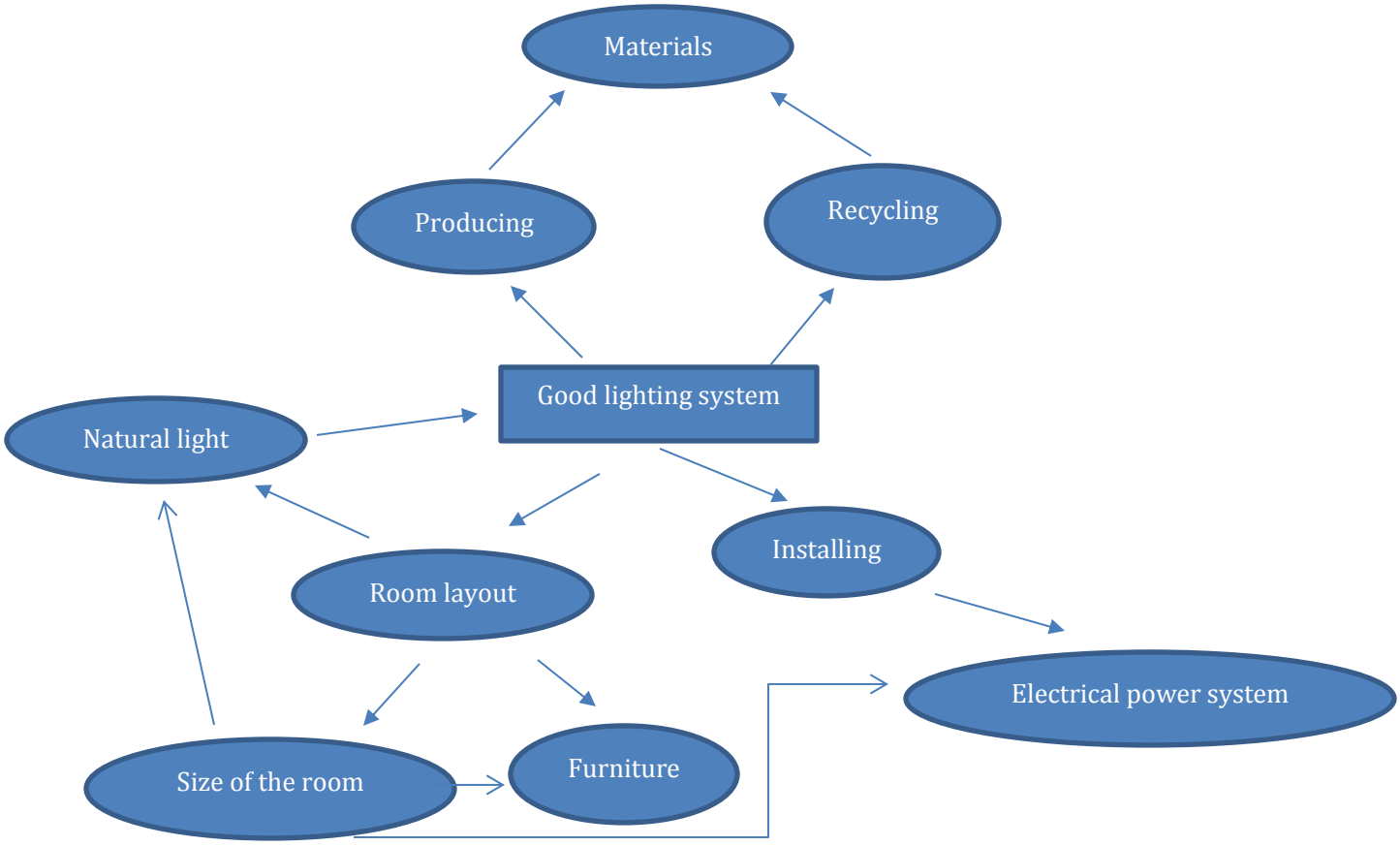
Systems

The systems that must all be taken account for, while designing our product. The systems consist of include the room layout, the lighting systems in the room, and the natural lighting. They must all work together with the product that Alcoa is selling to The Penn State University to create an effective way to reduce energy costs.

1. Room Layout- The layout of the room that the product is going to be implemented in is extremely important. The product should effectively fit inside the room and work around any obstructions near where it is implemented. It must also disperse the light across the room to the areas that require it, allowing Penn State to eliminate some of the light sources in the room, lowering energy costs.
2. Lighting System- Depending on how the lighting is set up, our product should interact with the lighting systems to create an opportunity to increase energy efficiently and let the University eliminate lights across campus.

3. Natural Light- The product should also efficiently use natural light during the daytime hours and effectively illuminate the room.
4. Recycling- After the product is used to completion, it can be easily recycled.
5. Producing- The product should be designed in a way that can be manufactured by an existing production line to reduce the production costs.
6. Installing- Since most of the lighting systems on campus are already installed, our product must fit the current systems. Also, the product should be installed easily.
7. Materials choosing- The lighting system is consisted of several different elements, such as, reflector and light bulb. For every element, there are many types of products we can choose to build our lighting system. For example, Incandescent bulbs, Fluorescent bulbs, and Light Emitting Diodes (LEDs) are three types of light bulbs we can choose to make our product.
8. Electrical power system- Old buildings already have their own electrical power system which will affect the way our product be installed.
9. Furniture- Furniture that has higher height might block the light and influence the light distribution.
10. Size of the room- The size of the room would change the number of the light we install and also the position.

Systems Integration



Brainstorming

While brainstorming, as a group we aimed to come up with ideas that would meet current customer needs. Furthermore we decided on ideas that we thought would be practical and reasonably easy to implement. (For all our ideas, we used room 316 in the Hammond Building as the sample room in which we would envision our ideas.)

Idea One:

Our first idea that makes use of aluminum's properties is using aluminum reflectors on the walls of the classroom. The room takes on the shape of a

rectangle, two of the walls have windows and the other two walls do not have windows. We thought of attaching two aluminum reflector sheets on the walls that do not have windows cut through them. Since, the classroom already consists of 4 rows of lighting that are parallel to the walls that do not have windows, for this idea, we plan to eliminate the two middle rows of lights. A possible way of eliminating lights is by placing ceiling tiles instead of the existing LED lights. Our aim from this idea is that both, the natural and the artificial light would be equally dispersed across the room, while at the same time decreasing the energy costs from the lights in the room. The room is approximately 13 meters long, so each aluminum sheet would be about 13m x 0.3m. The aluminum sheets would be placed high up the wall in order to reflect as much light as possible on the tables in the classroom.

Idea Two:

Our second idea consists of a single aluminum sheet that runs down the center of the room. This reflective sheet would be 13m x 0.3m and would be in between the two middle rows of lights. We thought that having a reflective sheet close to the two rows might maximize the light being reflected off of the aluminum reflector. For this idea, in order to reduce energy costs, we plan to eliminate the outer two rows of lights in the classroom.

Idea Three:

This idea involves placing concave shaped aluminum reflectors along each light source. The shape will be concave down in order to reflect light directly on the

tables in the classroom. A concave reflector looks more aesthetically pleasing than a straight edge. For this idea, we plan to eliminate half the lights in the room, which could be done by possibly eliminating every other light in each row.

Evaluation

Table 1: Pairwise Comparisons

	A	B	C	D	E	Row totals	Row total/total
A	1	3	1	1	3	9	0.28
B	1/3	1	1/3	1/2	1	3.17	0.1
C	1	3	1	1	3	9	0.28
D	1	2	1	1	3	8	0.25
E	1/3	1	1/3	1/3	1	3	0.09
					Total	32.17	

A: Affordable

B: Aesthetically pleasing

C: More energy efficient than current method

D: Emits high light intensity

E: Easy to install

Table 2: Screening Matrix

	Concept Variants			
Selection criteria	Reflectors on the walls	Reflectors on the middle	Concave reflectors per light source	REF.
Affordable	0	+	0	0
Aesthetically pleasing	0	0	0	0
More energy efficient than current method	+	+	+	0
Emits high light intensity	-	-	+	0
Easy to install	+	0	0	0
Pluses	2	2	2	
Sames	2	2	3	
Minuses	1	1	0	
Net	1	1	2	
Rank	2	2	1	
Continue?			Yes	

Table 3: Weighted Matrix

		Reflectors on the walls		Reflectors on the middle		Concave reflectors per light source	
Selection criteria	Weight (%)	rating	Weighted score	**rating**	**Weighted score**	**rating**	**Weighted score**
Affordable	28	3	0.84	5	1.4	4	1.12
Aesthetically pleasing	10	3	0.3	2	0.2	5	0.5

More energy efficient than current method	28	5	1.4	5	1.4	5	1.4
Emits high light intensity	25	3	0.75	2	0.5	5	1.25
Easy to install	9	4	0.36	2	0.18	2	0.18
Total score		3.65		3.68		4.45	
Rank		3		2		1	

Description of Possible Solutions

Idea One: Aluminum reflectors on the wall.

Aluminum reflectors on the walls of classrooms were our initial idea. It appeared to be useful because aluminum has incredible reflecting abilities, and the location of these sheets would keep the area by the lights uncluttered. However, the size of these sheets and their distance from the light source directly correlate to their ability to effectively reflect light. In light of this knowledge, having the reflectors along the walls was ruled out due to its vast inefficiencies. These reflectors would most likely only reflect light from the lights from periphery of the classroom, rendering them effectively useless.

Idea Two: Reflective sheet down the center of the room

An aluminum sheet running down the center of the room was the second idea because it solves the problem of only reflecting light from the periphery of the room. It also brings the aluminum closer to the source of the light allowing for

greater reflecting capability. However, its ability to effectively illuminate areas of the room located further from the center would be diminished. While it is more effective than idea one, it still falls short of energy-efficient and cost-effective.

Idea Three: Concave aluminum reflectors along the light bulbs **(Best Solution)**

Placing reflectors close to the source of the light allows for them to be much more effective at reflecting and therefore energy efficient. This would effectively allow the reduction of light/electrical use in the classroom, saving Penn State money by cutting costs. The concave shape lends itself to a greater surface area of reflection and multiple reflection points as opposed to a flat sheet of aluminum. Therefore the concave aluminum reflector along the light bulbs is clearly the most energy-efficient and cost-effective method of illuminating a classroom. We decided to carry out this solution.

Engineering Analysis

Aluminum 1050

Our aluminum product, made of aluminum 1050, is a low-alloy complex that is easy to recycle. Below are tables that contain all the properties of aluminum 1050.

Table 4: Typical chemical composition for aluminum alloy 1050

Element	% Present
Cu	0-0.05
Mg	0-0.05%
Si	0-0.25%
Fe	0-0.4%
Mn	0-0.05%
Zn	0-0.07%
Ti	0-0.05%
Al	Balance

Table 5: Typical physical properties for aluminum alloy 1050

Property	Value
Density	2.71 kg/m^3
Melting Point	650°C
Modulus of Elasticity	71 GPa
Electrical Resistivity	0.0282×10^{-6} Ω.m
Thermal Conductivity	222 W/m.K
Thermal Expansion	24×10^{-6} /K

Table 6: Typical mechanical properties for aluminum alloy 1050

Temper	H12	H14	H16	H18	0
Proof Stress 0.2% (MPa)	85	105	120	140	35
Tensile Strength (MPa)	100	115	130	150	80
Shear Strength (MPa)	60	70	80	85	50
Elongation A5 (%)	12	10	7	6	42
Hardness Vickers (HV)	30	36	-	44	20

Cost Analysis

Penn State employs maintenance men that are on average paid $47,000 annually. These maintenance men would be the people to install the reflectors in the classrooms and to perform maintenance upon them. These maintenance men are already part of the Penn State payroll so there is no need to hire more for this product.

The equipment required to install the reflectors include a drill that could be able to put self-tapping screws through the aluminum into the tiles above. Self-tapping screws are good for drilling through aluminum. They cost around 25 cents a screw. Depending if OPP keeps drills in stock, they would cost around $100 each. Also Penn State will need to put tiles over the lights that are being turned off, these costs around $2 per square foot.

The product itself costs $2 per square foot, depending on how many lights are planned to receive the reflectors the cost will vary. Shipping costs will vary, but it seems it will cost nearly $100 per ton shipped. This cost occurs because the product will most likely be put together at a factory and shipped to a warehouse for storage until they are shipped to the Penn State campus.

Table 7: List of Costs

Maintenance Worker	$47,000 annually
Self-tapping screws	$.25 per screw
Tiles	$2 square foot
Aluminum reflector	$2 square foot
Shipping	Up to $100 per ton

Savings of each idea

Reflective Aluminum sheets cost around $2 dollars a square foot. For our sample room, we estimated the length of Hammond 312 to be 42.6 feet long. We will be switching off 16 lights in this room.

Idea 1 which is lighting strips along the sides of the wall we would need twice the room length to illuminate the room. 85.2 square feet multiplied by the cost which is 2 dollars a square foot equals the cost of $170.40 total. (This product would have a width of one foot)

Idea 2 would have aluminum reflective mirrors long the middle, the cost would be 42.6 multiplied by $2 which equals $85.20. (This product would have a width of one foot)

Idea 3 is to surround two sides of each light with reflective mirror. The cost is sixteen lights multiplied by 2.62 feet for each light which equals 41.92 square feet of aluminum needed to be purchased. 41.92 multiplied by $2 = $83.84 dollars. (This product would have a width of one foot)

Savings would be achieved by switching off 16 lights in the room. Sixteen lights multiplied by .038 Kilo Watt per light multiplied by 168 hours a week = 102.144 KW/h multiplied by 0.13 cents which is the cost per KW hour = $13.27 saved a week for each idea.

Implementation Plan

After receiving the shipment of aluminum reflectors, maintenance men will install them at the predetermined lighting areas. To install the aluminum reflectors, the maintenance workers will need to drill small holes into the ceiling so as to allow screws to be placed along the tile on the exterior of the lights. Four screws for each end will be more than adequate, because aluminum is an incredibly light-weight metal. These screws would be self-tapping screws, which have the ability to advance when turned, while creating its own thread. It is important for these type of screws to be used, as they would be able to penetrate the aluminum, which while light weight, is much tougher than wood, the typical material that screws are associated with.

In addition to installing the aluminum reflectors, the maintenance workers would also have to remove the lighting fixtures that have been rendered obsolete and wasteful by the addition of the reflectors. That would require tools specific to light fixture movement, such as hammer, drills, and a safe and efficient waste removal process. Then these vacant light fixtures would have to be covered up with tile fixtures, or whatever other material is used for the ceiling, in order to create an aesthetically pleasing environment.

Testing

To test our product we decided to take something that was similar to aluminum 1050 in composition and see if it reflected light effectively. Aluminum 1050 is almost completely aluminum with only a few other added elements, less than one percent of the total. So we used aluminum foil, which is very similar in that it is mostly aluminum with a very similar level of reflectiveness. To measure the luminosity at various points at the room we used an iPad feature that measures lumens. We first took the control measurement at various points and recorded the values. Then we covered certain lights and measured the lumens in the room. Then we added aluminum foil at different points in the room to see if we could obtain the amount of lumens as the control. The method that worked best is to add aluminum foil around the light, along two of the light's sides.

Visual Design of Product

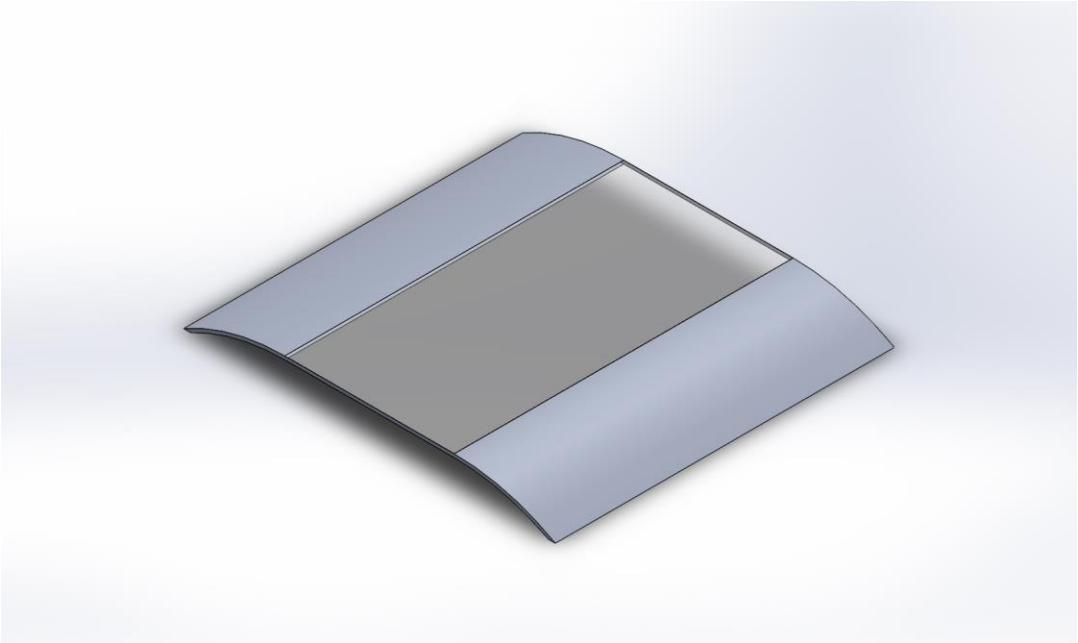


Figure 4: CAD drawing of product, the middle rectangle represents the light source.

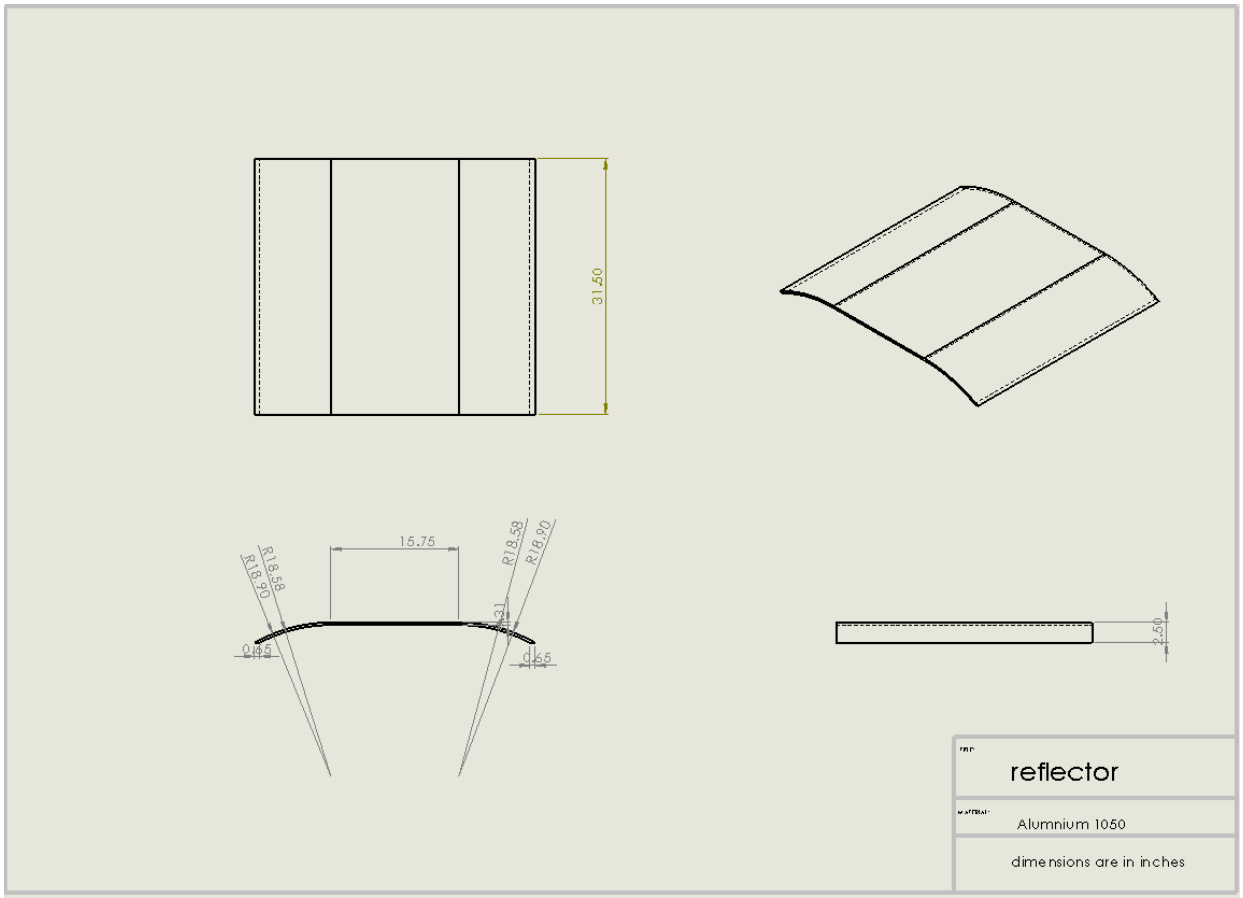


Figure 5: Section views of the product and light source

Table 8: Final Specifications of each reflector

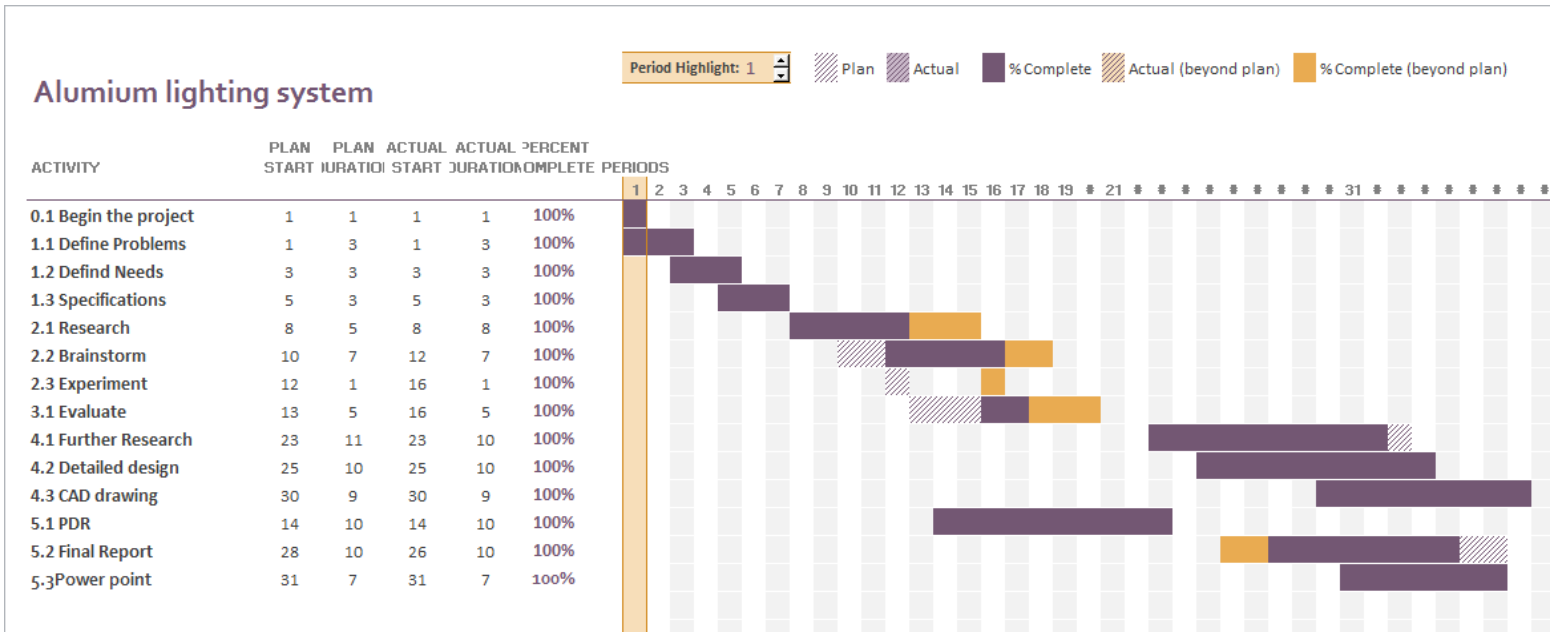
Height	2.5 Inches
Width	9.38 inches
Thickness	.314 inches
Weight	1.2pounds

Conclusion:

In conclusion, we would like to reiterate that Alcoa challenged us to find a way in which to incorporate aluminum products with the Penn State campus to create a more sustainable environment. After careful research, and much

brainstorming, we recognized the reduction of the great output of electrical energy would be beneficial to Penn State both economically and environmentally. Therefore, we sought to create a product that used aluminum to reduce the amount of electricity used. We created an aluminum reflector for each ceiling light source, because aluminum has an incredible propensity to reflect light, which reduces the number of illuminating devices needed within a classroom. In this way, Alcoa's challenge to use aluminum product was met, as well as creating a more sustainable environment.

Gantt Chart



References

1. How and why alloying elements are added to aluminum. ESAB. 23 Nov. 2013. <http://www.esabna.com/us/en/education/knowledge/qa/How-and-why-alloying-elements-are-added-to-aluminum.cfm>
2. The Element Aluminum. Jefferson Lab. 23 Nov. 2013.< http://education.jlab.org/itselemental/ele013.html>
3. Aluminum Element Facts. Chemicool. 24 Nov. 2013. <http://www.chemicool.com/elements/aluminum.html>
4. Aluminum. Wikipedia. 24 Nov. 2013 http://en.wikipedia.org/wiki/Aluminium
5. Sustainability. Dictionary.com. 26 Nov. 2013 <http://dictionary.reference.com/browse/sustainability>
6. What is sustainability? EPA. 26 Nov. 2013 http://www.epa.gov/sustainability/basicinfo.htm
7. Aluminum Alloys. 7 Dec. 2013 http://www.azom.com/article.aspx?ArticleID=2798
8. Penn State Sustainability Strategic Plan. 7 Dec 2013 http://sustainability.psu.edu/sustainability-strategic-plan