# EDSGN100
# Design Project #2
# PROGRESS
# Report

## Increasing Sustainability of Street Lights

## Introduction to Engineering Design
## EDGSN 100

Team 1
Zheng Sun zos5121@psu.edu
Sung jin Bae sob5532@psu.edu
Raymond Richlin rer5211@psu.edu

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Prof. Smith
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# Executive Summary

Design Team#1 has designed a solar street lights focused on improving the sustainability. Through the process of external research and customer needs analysis, our team successfully generated, screened, and selected a final design that greatly improved upon the initial statement. This design factors, sustainable energy resource, brightness, aesthetics, materials, durability to weather conditions were made into a prototype.our team concluded that this design would improve the lighting levels in our campus as well as save huge amounts of money spent on the lighting system. One time investment, life long benefit.

## Increasing Sustainability in Street lights

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# 1.0 Introduction

In our engineering design class, we were required to make a system or a product that uses the intrinsic properties of aluminum. ALCOA is the world's leading producer of primary and fabricated aluminum, and it was the sponsor of our project. The problem statement we got from the company was to find an opportunity that benefits from using aluminum or the increased use of aluminum around campus. Aluminum has many properties that make it useful like being lightweight, being able to conduct heat and electricity, being the most reflective material, and recyclable. By taking advantage of these properties, our team designed a street light using the methods outlined in the design process that would be used around campus. The streetlights would include a lamp shade and a lamp post that would be made of aluminum, and a solar panel attached to it to increase the efficiency. This report contains information about how we defined our problem to the final design. It includes the problem statements, customer needs, external research, and the final design of our project.

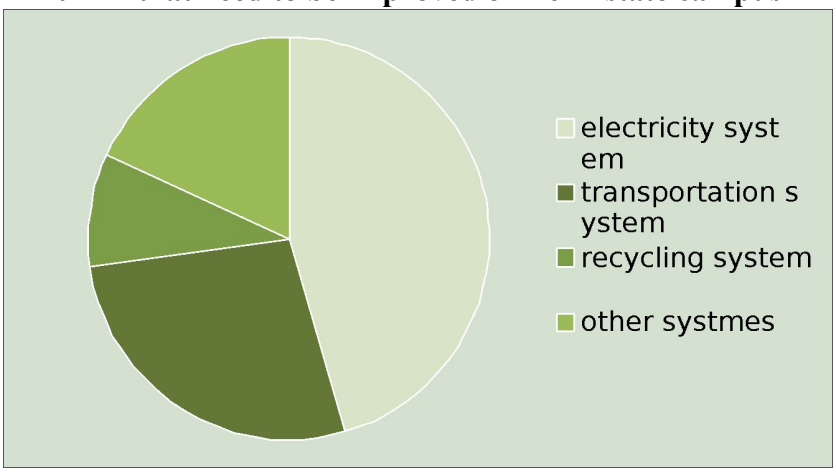
# 1.1 Initial mission Statement

Identify opportunities across campus to take advantage of aluminum's intrinsic properties for the purpose of increasing the efficiency of products and product systems.

# 2.0 Customer need assessment.

To begin the process of designing project with Aluminum, our team gathered the responses of interviewed college students in order to have a better grasp on ideas and needs that customers seem to value the most. This will in effect allow us to better implement improvements to the final design. In order to gain the goal, We interviewed 40 students on campus about what they really feel that needs to be improved on campus, so that we could find out the problems that may appear in our campus.

**Figure 1. Analysis of Customer Needs from Gathered Interview Data:what system do you think that need to be improved on Penn state campus**




From the survey we could find out that there might be some problems on campus in terms of energy, to make it more specific(to find out what exactly the thing we need to improve on

campus)our group members listed some of the concepts in our campus in terms of the energy and also related them to the mission statement of our project. We contacted the Penn State Office of the Physical Plant (OPP) and got a report detailing the costs of street lights during the past few years.

***"The electric rate for this year is $0.08101/kwh. So 300kW x 4300 hrs x $0.08101/kwh = $104,503, which is about one million dollars during the par 10 years. Street lighting fixtures are 95% 250W HPS fixtures. There are a FEW 400W HPS and LED fixtures around campus but the "average" is considered 250W HPS, Parking fixtures are 95% 250W HPS fixtures. There are a FEW 400W HPS and LED fixtures around campus but the "average" is considered 250W HPS, Walkway fixtures are 80% 100W MH fixtures. There are a FEW 70W or 150W MH and LED fixtures around campus but the "average" is considered 100W MH***
***HPS is High Pressure Sodium based High Intensity Discharge (HID) type lamps***
***MH is Metal Halide based High Intensity Discharge (HID) type lamps"***

From the report we found that the total cost is pretty high and it needed some improvements. To clarify what we really wanted to improve on the lights, besides the high-cost problem, we made another survey asking what people think needed to be improved on streetlights. We interviewed classmates and roommates about what attributes they valued most in streetlights and placed our findings into a Customer Needs analysis table. From here we turned the needs into metrics and put the needs into a hierarchy based on the nature of the responses, and the most frequently valued attributes. We used college students who live on campus as our target population, as they are more likely to have needs with the street lights than the people who live off campus.

**Figure 2. Table of customer need metrics**

| Metric# | Customer need# | Metric | Importance (1 is poor, 5 is best) | weight |
|---|---|---|---|---|
| 1 | 1,4,7,8, | Sustainable energy resource | 2 | 0.33 |
| 2 | 2,6,12 | Brightness | 1 | 0.25 |
| 3 | 3,11 | Aesthetic | 4 | 0.17 |
| 4 | 10 | Materials | 3 | 0.08 |
| 5 | 5,9 | Durability to weather conditions | 5 | 0.17 |

## 2.1 Hierarchy of Customer research

After our team has gathered the list of customer needs, we then put the needs into Hierarchy, organizes the raw input we received from customers so that we can better focus on the more overreaching input and to determine the needs to weight. From our analysis of the customer needs, we concluded that the five overreaching categories described were energy aesthetic material brightness and durability.

**Figure 3. Analysis of Customer Needs from Gathered Interview Data**

| Customer need# | Object | Customer need | Rank of importance |
|---|---|---|---|
| 1 | Street lights | The light should be motion; sound sensitive | 9 |
| 2 | Street lights | The lamp should effectively illuminate to ground around it. | 2 |
| 3 | Street lights | Aesthetically pleasing | 3 |
| 4 | Street lights | Has sustainable energy resource source | 1 |
| 5 | Street lights | Adverse weather condition (i.e. snow) | 5 |
| 6 | Street lights | The light of the lamp should not irritate our eyes(directions, type of lights) | 7 |
| 7 | Street lights | The bulbs should be energy efficient | 3 |
| 8 | Street lights | It should Save energy | 2 |
| 9 | Street lights | The lights should be low maintenance | 6 |
| 10 | Street lights | The lights should be made up of environmentally friendly materials | 4 |
| 11 | Street lights | The light should have a proper heights and width. | 8 |
| 12 | Street lights | Has a strong light | 2 |

## 2.2 Revised Problem Statement

Using the data above, a more precise problem statement was created. We need to focus on building a model of a street light with sustainable energy, aesthetically pleasing appearance, using

proper material, enough lightness so that people can see there way and also it has to be durable so that it can stand still even in bad weather.

# 3.0 External Search

To obtain a greater understanding of our current statement, to figure out what is now used in the market, we conducted external research in order to have a firm grasp on certain trends that play vital roles in the streetlights. We consulted important literary publications on current trends in street lights with all kinds of power consumption and identified patents on the design of the different parts of the street lights (the material, the shape that best reflects lights.)Performed a benchmarking evaluation on competing models, so that we could get a better understanding of designing the product

## 3.1 Literature Review

We contacted the Office of Physical Plant (OPP) that deals with everything that with the school's energy spending. We asked the current energy spending including various energy sources like steam, electricity. The response we received was as follows:

***"Street lighting fixtures are 95% 250W HPS fixtures. There are a FEW 400W HPS and LED fixtures around campus but the "average" is considered 250W HPS, Parking fixtures are 95% 250W HPS fixtures. There are a FEW 400W HPS and LED fixtures around campus but the "average" is considered 250W HPS, Walkway fixtures are 80% 100W MH fixtures. There are a FEW 70W or 150W MH and LED fixtures around campus but the "average" is considered 100W MH***

***HPS is High Pressure Sodium based High Intensity Discharge (HID) type lamps***

***MH is Metal Halide based High Intensity Discharge (HID) type lamps"***

Here, we noticed that most of the lights installed around campus were HPS lights when generally LED lights are efficient. Below is the information comparing the efficiency of the two light bulbs.

**Figure 4. Comparison of lumens/watt for LED and HPS light fixtures**

| Light Source | Lumens/watt |
|---|---|
| High Pressure Sodium | 80-140 |
| LED | 114-160 |

Here, it is clear that LED lights were much more efficient than High Pressure Sodium lights, considering the Lumens per watt. Lumens are the units measured of how bright the light source is. If one watt is used for a light bulb, Led light bulbs will have a higher brightness in the same area. This means that if we were to use the same amount of lumens per area and time, LED light bulbs will use less watts, which leads to saving energy.

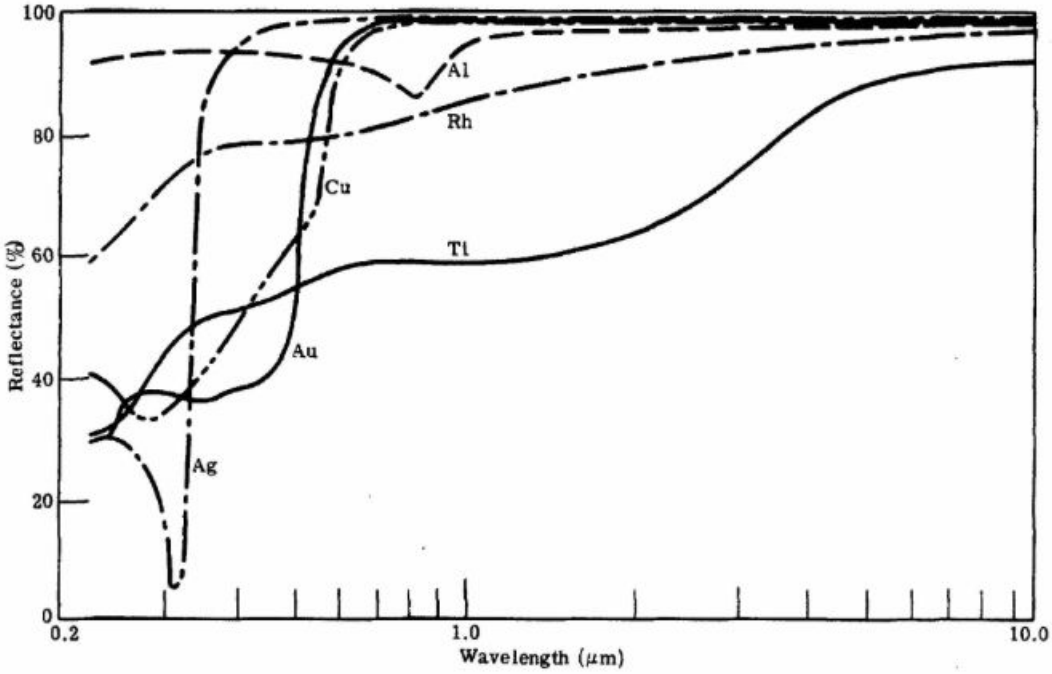
**Figure 5. Comparison of lifetime in hours of LED and HPS light fixtures**

| Light Source | Lifetime in Hours (x1000) |
|---|---|
| High Pressure Sodium | 10-24 |
| LED | 100+ |

From the table above, we can conclude that LED light bulbs last longer than HPS bulbs. We can then conclude that using LED light bulbs will make the lights much more efficient because HPS light bulbs would have to be replaced every 10-24 hours of usage while LED light bulbs make it up to 100 hours and more.

We concluded that our light bulb in the streetlight would be LED's because they last longer and saves the amount of watts used emitting the same amount of lumens. This went well with our concept of sustainability, so we chose LED light bulbs for our streetlights.

**Figure 6. Graph of reflectance of a metal on a wavelength scale**




While conducting research about the intrinsic properties of aluminum, we also found out that aluminum was one of the most reflective metals. As seen in the graph above, the percent of reflectance of the light per wavelengths shows us that aluminum is a great light reflector. out of the various wavelengths lighted on to the metal plates (aluminum, gold, silver, titanium, copper, rhodium were tested), aluminum had the highest reflectivity until the wavelength increased to a certain point; gold and silver had the most reflectivity when the wavelength was long, and aluminum had second. So we included gold, silver, and aluminum as the candidates for our lamp shades.

## 3.2 Patent Search

**Figure 7. Art-Function Matrix for street lights**

| Function | | | | |
|---|---|---|---|---|
| | Photo catalyst street lamp shade | LED street lamp with radiating fins on aluminum baseplate | LED street light | Solar-powered light pole and LED light fixture |
| Shade | CN102927523 | | | |
| Post | | CN201779561 U | | |
| Light Fixture | | | EP2557360 A1 | |
| Energy source | | | | WO2010050993 A1 |

First, based on the concept generation and selection, we have done some research on patents that we were going to use on Google patents. What we found were four: Photocatalyst street lamp shade, LED street lamp with radiating fins on aluminum baseplate, LED streetlight, and Solar-powered light pole and LED light fixture. These helped us design our product in precise ways from how it works to what it would look like.

## 3.3 Benchmarking

**Figure 8. Benchmarking of Four Products**

| | | Design Series, Off-Grid w/ AGM Batteries | | Yao Long Aluminum LED Single Pole | | Solar Viper | | LED way Series Street Lights | |
|---|---|---|---|---|---|---|---|---|---|
| Selection Criteria | Weight | Rating | Weighted score | Rating | Weighted score | Rating | Weighted score | Rating | Weighted score |
| Sustainable energy resource | 0.33 | 5 | 1.65 | 2 | 0.66 | 5 | 1.65 | 2 | 0.66 |
| Brightness | 0.25 | 2 | 0.5 | 3 | 0.75 | 4 | 1 | 5 | 1.25 |
| Aesthetic | 0.17 | 4 | 0.68 | 3 | 0.51 | 3 | 0.51 | 3 | 0.51 |
| Materials | 0.08 | 4 | 0.32 | 5 | 0.4 | 4 | 0.32 | 4 | 0.32 |
| Durability to weather conditions | 0.17 | 5 | 0.85 | 4 | 0.68 | 4 | 0.68 | 3 | 0.51 |
| Total Score | | | 4 | | 3 | | 4.16 | | 3.25 |
| Rank | | | 2 | | 4 | | 1 | | 3 |
| Picture | | | | | | | | | |

We made a table scoring the four product we found during research. In the table, we made a selection criteria, weight, the product names, and some pictures of the products. For the selection criteria, we used the same metrics we had for concept generation and selection which was sustainable energy resource, brightness, aesthetics, materials, durability to weather conditions. For the weight, we chosen the importance and converted them into numbers so that they would add up to one. We multiplied the weight with the rating we gave for each product and got a score for each criteria. We then added the scores together and ranked them. As result, product “Solar Viper” received the highest score. The reason Solar Viper got the highest score was because Solar Viper streetlights were made up of aluminum to prevent corroding, and also used solar power for sustainable energy. We had “Solar Viper” as our main benchmarking product.

## 3.4 Design Target

From our external search we learned that most of the street lights on Penn State's campus are HPS light fixtures. We learned that if we make the aluminum in the shade of the streetlamp polished it will reflect light better than if it were anodized or rough. We also determined that LED lights are the most efficient on electricity. We learned that solar energy is the most sustainable energy source for our area.

# 4.0 Internal search

At the conclusion of the external search phase, an extensive internal search was conducted in order to narrow-in on a final redesign concept that improves upon the original. This search consists of team members internally brainstorming, analyzing, and improving upon concepts that could potentially be used in the final design. Once this process is completed, the team will have finally selected a concept as the official prototype.

## 4.1 Concept generation

To begin the process of Concept Generation, our team brainstormed a wide variety of different improved and varying designs to the components of the current model. This brainstorming was organized through concept classification trees that divided our concepts into categories. From here, the most viable categories were put into a morphological chart to display the possible final design concepts our group had generated. We sketched almost all of the concepts that made it into the morphological chart.

**The classification trees below shows our team's brainstorm of possible component concepts.**

**Figure 9. Sustainable energy resource classification tree**

in terms of energy we need to find out a energy resource that is sustainable so we think of the energy source we may use and we first think out electric,solar and wind. we then mix them as solar&wind,wind&solar&electric, wind&electric.

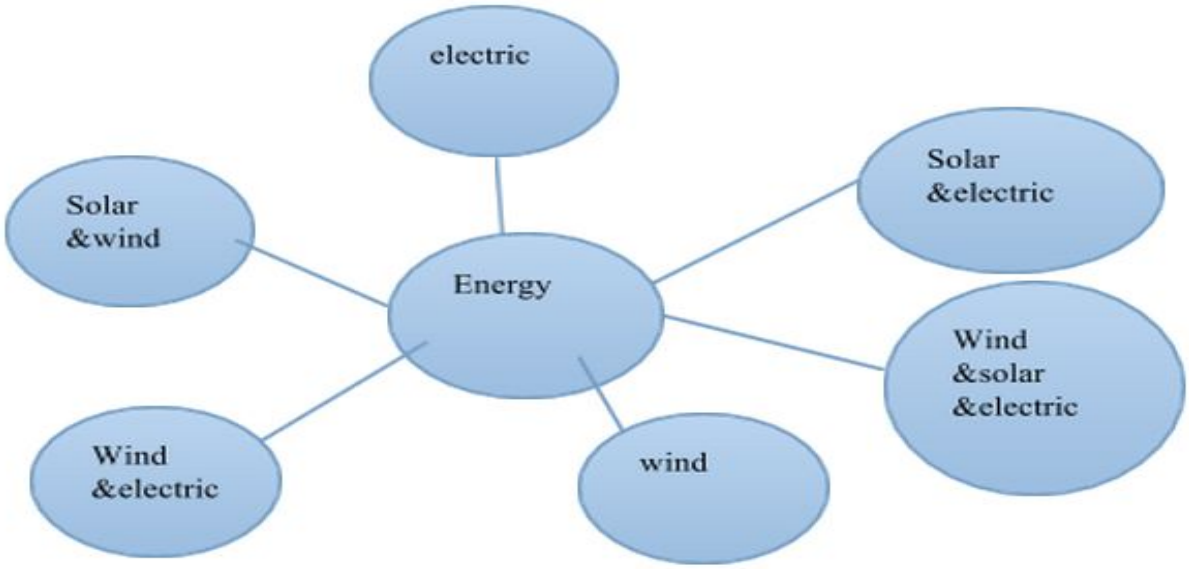


**Figure 10. Aesthetic Concept Classification Tree**

In terms of the aesthetics, we searched the internet and found out about different categories of the street lights and we got the concepts of single arms and double arms.

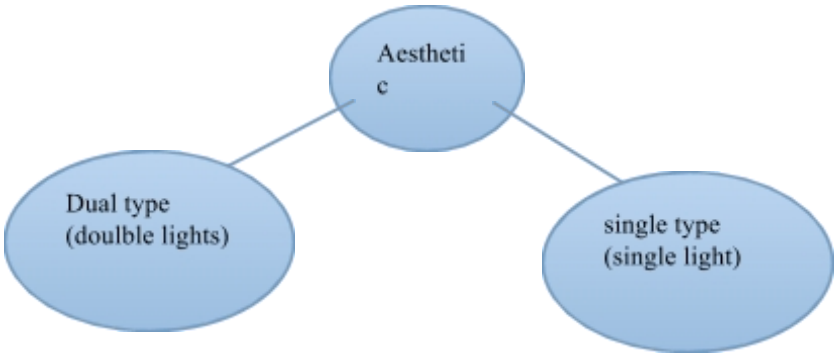



**Figure 11. Material Concept Classification Tree**

In terms of the materials that we are going to use, we found a lot of articles from the internet, after brainstorming and comparing, we came out with these two concepts that are mostly used in street lights: the aluminum alloy and the stainless steel.

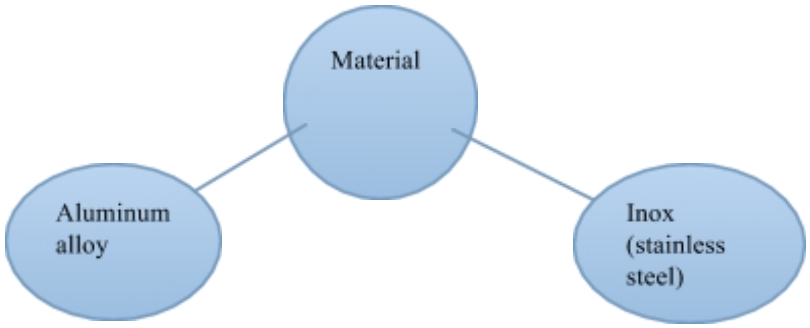


**Figure 12. Brightness Concept Classification Tree**

In terms of the brightness, to improve the lightness, we brainstormed these concepts in two different aspects: the bulb type and the reflecting material, as it relates to the rate of reflection(the efficiency). Also the strength of the light source, we came out with different concepts like LED, HPS and other bulbs that are mostly used in the market. Also we searched the materials' reflectance and listed some of the materials that may be used as our concepts in this case like the lens aluminum, nano film, crystal retroreflective sheet.

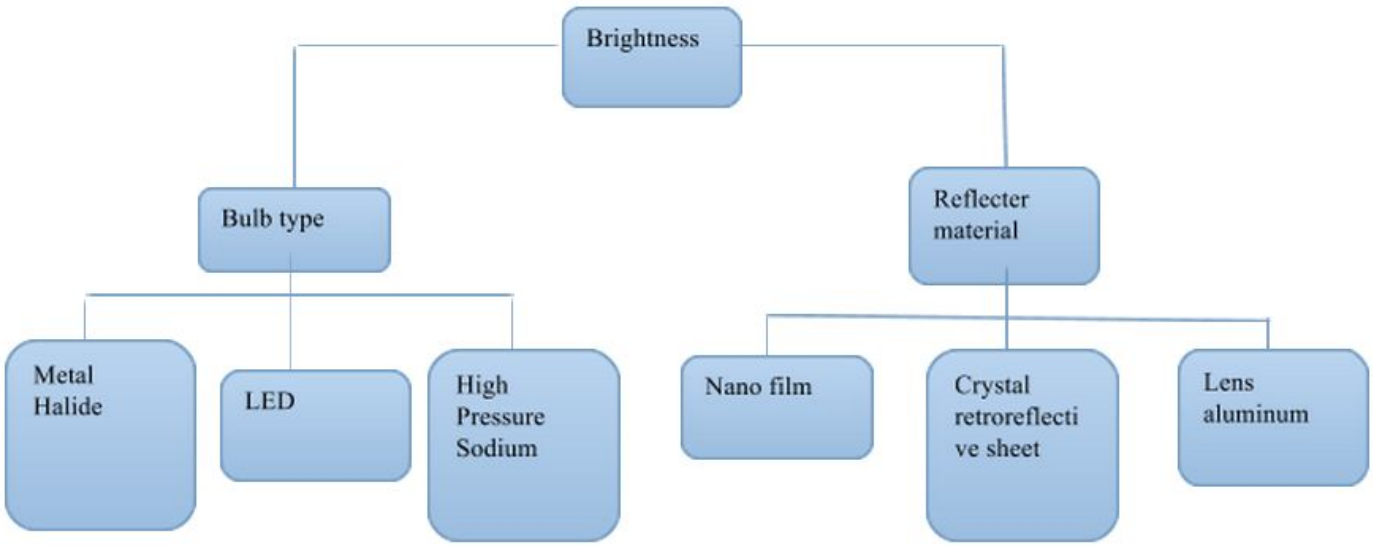


**Figure 13. Morphological chart**

| Concepts# | energy | aesthetic | material | Brightness | Sketch |
|---|---|---|---|---|---|
| 1 | solar | dual | AA | LED with nano film | |
| 2 | electric | Single | SS | HPS with lens aluminum | |
| 3 | Solar | single | AA | LED with lens aluminum | |
| 4 | Wind&electric | single | SS | HPS with nano film | |
| 5 | Solar&wind | dual | AA | LED with crystal retroreflective | |
| 6 | Solar&wind &electric | single | AA | MH with lens aluminum | |
| 7 | Solar&electric | single | AA | LED with polished aluminum | |
| 8 | electric | dual | SS | MH with crystal retroreflective | |
| 9 | Solar&wind | single | SS | MH with nano film | |
| 10 | Wind | dual | AA | HPS with lens aluminum | |

Above is our morphological chart, we used it to generate all the concepts we got after brainstorming and we put into different combinations.

## 4.2 concept selection

(this is what we based on when we scored these concepts)

1. We chose a single arch design as we are designing a street light which is used on campus. It does not need double arms because not only will it consume more energy and take more aluminum to make, but also the way in which we are using the light does not require light on both sides. When the street light has a single arm it looks more aesthetically pleasing as well.(according to a survey we made on BAIDU)

2. Aluminum alloy is the cheapest material compared with stainless steel and other materials showed in the table. Also, it is 100% recyclable, non-corrosive (won't rust), and durable.

3. The scoring of the lights chosen is based on the fact that LED saves much more energy than HPS ,as most of the street lights in our campus use the HPS bulbs in the street lights. However, this is only because they are outdated. Not only the brightness but also the energy efficiency of the HPS is not as good as the LED bulbs. Also we used the aluminum lens as our reflecting material because it has the highest rate of reflecting the lights (94%). Also it is the cheapest compared with other high-reflecting materials like gold and silver.

### We made a pugh chart and the concept scoring matrix

In the Pugh Chart below, we scored each of the ten morphological concepts based on the selection criteria. If the concept meets or exceeds a certain criterion, it received a plus in that criterion. If the concept is as good as the current product, it received a 0 in that criterion. If the concept either does not address or is detrimental to a specific criterion, it received a minus. At the end, the net score of each concept was calculated by adding the pluses and minuses and the six concepts with the highest net score moved on to be weighted and scored.

**Figure 14. Pugh chart**

| | Concept number | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Selection criteria | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Sustainable energy resource | + | - | + | + | + | 0 | + | - | + | + |
| brightness | 0 | + | + | 0 | - | + | + | - | 0 | + |
| aesthetic | 0 | - | 0 | 0 | 0 | 0 | 0 | - | 0 | - |
| materials | + | 0 | + | 0 | + | + | + | 0 | 0 | + |
| Durability weather conditions | + | + | + | + | + | + | + | + | + | + |
| pluses | 3 | 2 | 4 | 2 | 3 | 3 | 4 | 1 | 2 | 4 |
| zeros | 2 | 1 | 1 | 3 | 1 | 2 | 1 | 1 | 3 | 0 |
| minuses | 0 | 2 | 0 | 0 | 1 | 0 | 0 | 3 | 0 | 1 |
| net | 3 | 0 | 4 | 2 | 2 | 3 | 4 | -2 | 2 | 3 |
| rank | 3 | 9 | 1 | 6 | 6 | 3 | 1 | 10 | 6 | 3 |
| Develope? | YES | NO | YES | NO | NO | YES | YES | NO | NO | YES |

The Pugh chart shows that concept 7 and 3 were tied with a score of 4, concept 10,6,and 1 were tied with a score of 3, and the rest fell behind the cut of the top 5 concepts.

Now that the top five concepts have been selected, they will all be ranked once more and scored based on weighted criteria. The scores will be computed and the concept with the highest net score will be selected as the best concept for the improved prototype. From this analysis, Concept 7 is the best choice for the improved prototype.

## Figure 15. Concept scoring matrix

| | | CONCEPT 1 | CONCEPT 1 | CONCEPT 3 | CONCEPT 3 | CONCEPT6 | CONCEPT6 | CONCEPT 7 | CONCEPT 7 | CONCEPT 10 | CONCEPT 10 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Selection criteria | WEIGHT | RANK | Weight score | RANK | Weight score | RANK | Weight score | RANK | Weight score | RANK | Weight score |
| brightness | 0.25 | 3 | 0.75 | 4 | 0.75 | 3 | 0.75 | 5 | 1.25 | 5 | 1.25 |
| aesthetic | 0.17 | 2 | 0.34 | 4 | 0.68 | 4 | 0.68 | 4 | 0.68 | 2 | 0.34 |
| materials | 0.08 | 4 | 0.32 | 4 | 0.32 | 4 | 0.32 | 4 | 0.32 | 4 | 0.32 |
| durability | 0.17 | 5 | 0.85 | 5 | 0.85 | 5 | 0.85 | 5 | 0.85 | 5 | 0.85 |
| energy | 0.33 | 4 | 1.32 | 5 | 1.65 | 3 | 0.99 | 4 | 1.32 | 5 | 1.65 |
| total | 1 | | 3.58 | | 4.25 | | 3.59 | | 4.42 | | 4.31 |
| rank | | | 5 | | 3 | | 4 | | 1 | | 2 |

The scoring matrix shows that concept 7 wins with a score of 4.42.

### 4.3 Prototyping and Design Reviews

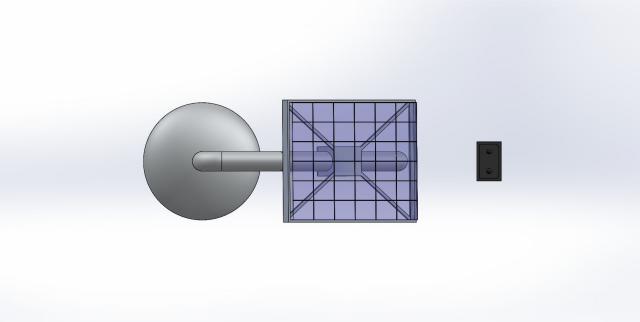
Upon arriving at the conclusion of the concept selection stage, our team decided that Concept 7 from the Morphological Chart was the best and most appropriate design to be selected. This concept uses solar & electric as the power supplement, a single arm shaped and made of Aluminum Alloy. It uses the LED with the aluminum lens inside the shade. We found this concept as the best decision because it met all the customer needs.

# 5.0 Final Design

The final design is an aluminum light pole with a single arch design. It uses solar energy as a renewable energy source. The design includes a battery to store the energy. The bulb is an LED and the shade is made of aluminum with a polished surface. The streetlamp is connected to the original electricity grid for a backup energy source in case the energy created from the day is not enough. This design addresses customer needs because it is made out of aluminum, has a bright LED light source, has a renewable energy source, and a high durability to weather due to aluminum's intrinsic properties.

## 5.1 Design Drawings and Parts List

**Figure. 16~19 3D drawings of final design**



Examples of drawings of the lamp post in the form of solidworks views.(isometric, top, front, and right)

## 5.2 Bill of materials

This is a bill of materials of the final design. It shows the function of the design. The material each piece is made of and their dimensions.

**Figure 20. Bill of materials**

| Part Name | Qty | Function | Material | Dimensions |
|---|---|---|---|---|
| Lamp Shade | 1 | Reflects the light from the LED bulb | Aluminum | Diameter of 2ft. |
| Solar Panel | 1 | Abosrbs light from the sun and converts it into energy | Solar cells | 2 ft. wide by 3ft. tall |
| Lamp Post | 1 | Elevates the light fixture to illuminate more area | Aluminum | 4 in diameter , 9ft. high |
| Battery | 1 | Stores power obtained from the solar power | High durability plastic | 8inx5inx5in |
| Led Light | 1 | Provides light | | |

### 5.3 How does it work?

This design works by collecting energy from the sun through its attached solar panel. The energy from the solar panel is then stored in a battery that is kept underground beneath the streetlamp. The lights turn on at night with the electricity grid timer and use the energy stored from the day to power the LED bulb. The polished aluminum of the lamp shade reflect the light to the surrounding area.

## 6.0 Conclusions

We were given a problem statement by Alcoa that we had to improve the durability or sustainability of a system or area on campus using the intrinsic properties of aluminum. From this we defined sustainability as a long term solution to a problem that takes advantage of recyclability and durability. We defined our customers as the students of penn state and surveyed them to come up with a concept. After we had out concept, which was to design a more sustainable street lamp, we did some external research to determine how we could improve the sustainability of the street lamps. We contacted the office of the physical plant (OPP) at penn state and got some information on the amount of lights and cost to run the lights annually. We generated concepts and narrowed them down to a single concept that satisfied the needs of our customers. Our final design ended up being a street lamp with an all aluminum body and shade. It also had a solar panel for renewable energy and used an LED light source to be as energy efficient as possible. Being made of aluminum meant that the street light was recyclable and durable and the solar panel and LED light combination made for an energy efficient final product.

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