EDSGN 100
Design Project #2
Report

ALUMINUM ID CARD

Introduction to
Engineering Design
EDGSN 100
SECTION 025

Team #4

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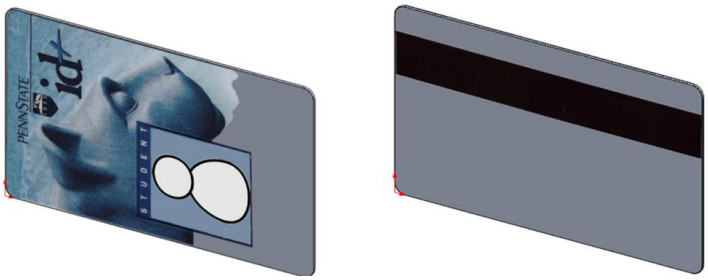

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Date: 12/13/2013

Executive Summary

Our objective is identifying opportunities around the campus and using aluminum to improve the efficiency of energy using as well as increase sustainability of the product of product system. After we gather and analyze company and user needs, we generate our final design (shows above). As a result, our idea can help reduce 1164.4kg plastic waste while save 7.66×10^6 kJ energy around all PSU campuses. Energy can be saved up to 34.0% in ID card production if the card is made from recycled aluminum. Also, we design a money refund system to encourage more students do recycling aluminum ID. Finally, this design can guide and motivate more people to protect environment as well as use renewable aluminum resources. To conclude, our design well satisfies both ALCOA and our student users.

ALUMINUM ID CARD

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1.0 Introduction

Alcoa, world's leading aluminum producer, assigned our EDSGN 100 class essentially with the question of "How can properties of aluminum benefit our campus?" With the population of nearly 42,000, State College provides a setting similar to a city environment. Thus, there can be many applications for aluminum. Our team approached task with deductive reasoning. We determined a general problem within our campus and then we selected a specific system to apply a solution. Through repeated steps of concept generation, scoring, and selection, our team arrived at one innovation that will most effectively cut down Penn State's waste in plastic.

First, we develop a flow chart to describe our process outline (see Appendix A). Second, we generate a Gantt chart as a schedule, and we use it as a tasks list (see Appendix B).

In section 1.0 to 1.2, we do basic research and preparation for our project. Section 2.0 to 2.2 selects our focusing direction. Section 3.0 to 3.3 selects the most possible school system. Section 4.0 to 4.2 selects idea. Section 5.0 to 5.3 is idea assessment. We use section 6.0 to 6.2 to assess user needs. Section 7.0 to 7.4 is used to set design target. Our team will generate and select concepts in section 8.0 to 8.2. We talk about our final design in section 9.0 to 9.2. Conclusion is in section 10.0.

1.1 Mission Statement

Our team was given the challenge to identify opportunities around the campus to take advantage of aluminum's intrinsic properties for the purpose of improving the efficiency of energy use and/or increase sustainability of the product of product system.

1.2 Initial Problem Statement

The product will be made of aluminum that can improve the efficiency of energy use and/or increase sustainability of the campus while the product can help build people's mind about recycling aluminum. Solutions should meet all applicable performance requirements, satisfy relevant regulatory codes, and is economically viable.

1.3 Definition of Sustainability and Efficiency

Before starting, our team will generate definition of sustainability and efficiency. Sustainability touches upon many aspects of life, such as the natural resources and the economy. If something is "sustainable" then it has the ability to be used up, or reused, without being completely destroyed, thus resulting in a longer lifespan. Aluminum portrays sustainability through multiple intrinsic properties. Aluminum exhibits superior corrosion-resistance due to the adherence of aluminum oxide, a side product of its formation. However, good sustainability does not necessarily entail good efficiency. Through the equation of energy efficiency, the amount of efficiency is the quotient of energy output divided by energy input. Aluminum is only able to decrease the results of this proportion as a whole. Aluminum's lighter weight allows for a lower requirement of work compared to a metal of heavier weight. Aluminum is often referred to as

“fuel efficient” due to its supreme energy conservation. However, the efficiency of aluminum compared to other metals is fairly equal.

2.0 Direction Research

Based on our definition of sustainability and efficiency, all of our team members did brainstorm and wrote down several possible directions for our design process. Those possible directions are: Fuel Efficiency, Substitute Plastic, Electric Conduction, Heat Conduction and Substitute Steel. And then we did basic research on each of them and compared them with both advantages and disadvantages.

2.1 Direction Generation & Comparison

Then we started our research process on the possible directions for project we generated together. And here are the summary for the research:

- **Fuel Efficiency**

Based on research, we found out that it will reduce the fuel consumption while decreasing the efficiency because aluminum is lightweight. But based on the fact that our team does not have sufficient time and relative knowledge, we will wisely consider whether or not we will involve in this area.

- **Substitute Plastic**

Plastic has a great consumption over the campus. Plastic does make our life easier because it is cheap and lightweight. It can be seen everywhere. Object such as bottles, bags, folders, tables, chairs, tableware, ID cards, tools and etc. are all made of plastic. And tons of plastic will be consumed every year at Penn State University, but not the entire big amount of plastic consumption is being recycled.

- **Electric Conduction**

As Penn State University has such a giant campus and large number of students and stuffs, it will consume a large amount of electricity---which also means it needs a larger number of wires for electric conduction. However, although that it will make such a big change if we replace all the cooper wire to aluminum wire, it is not allowed by the government of Pennsylvania.

- **Heat Conduction**

Because that Aluminum is a great heat conductor, it is good to replace other metals such as stainless steel in heat conduction system. However, Aluminum will corrode if the proper fluids are not used to produce and maintain a narrow pH range while stainless steel resists corrosion in a wide range of pH levels. The use of special manufacturer recommended heat transfer fluids and inhibitors when starting up and maintaining the system for Aluminum as heat conduction. So it increased the difficulty of technic and cost to use aluminum in heat conduction system.

- **Substitute Steel**

Aluminum is one third as light and half as strong as steel, or the inverse, steel is twice as strong but three times as heavy. So based on their characteristics, if we replaced steel with

aluminum, efficiency might go up as weight was cutting off while strength would be reduced and the safety is reduced. So only a limit part of steel can be replaced by aluminum.

2.2 Direction Selection

As a summary, we decided to choose substitute plastic to be the direction base of our design project. Because of the limited in technology and limit of government, it is hard to replace steel with aluminum or even use aluminum to enhance fuel efficiency or heat conduction. However, replacing plastic with aluminum will help a lot on environmental pollution as plastic is bad for environment and aluminum is easier to recycle than plastic. And this fit our main goal in this design project which is to achieve sustainability and efficiency.

3.0 School System Research

After we decide to choose substitute plastic as our design direction for this project, we decided to divide the big Penn State University campus into small systems, and did research about the plastic consumption in each of the systems. Those systems are Energy System, Transportation System, Student Life System and Food System, which are the several basic systems among University Park that can be considered to have great plastic consumption.

3.1 System Comparison & Selection

Here are our summary of the research and analyze to those school system:

- **Energy System**

The special properties of aluminum make it such a great heat and electric conductor. And it may allow aluminum to replace plastic in energy system. However, in energy system, materials are required to stand high temperature and pressure which is not a good ability for aluminum. And moreover, one of our costumer needs of the company required the replacement and changes can change people’s mind about recycling aluminum. Even if it was possible for us to replace plastic with aluminum in energy system, it still had nothing to do about changing people’s mind about recycling aluminum.

- **Transportation System**

CATA buses, taxis and cars are involved in transportation system over Penn State University. Car parts such as bumpers, fenders, doors, safety and rear-quarter windows, headlight and side-view mirror housing, trunk lids, hoods, grilles and wheel covers are made of plastic. Also, plastic waste in cars also involved excessive waste in oil. The presence of aluminum in cars have already improved in the past 27 years, raising up to 8.6% while the presence of plastic also rose up to 7.6% in the same period of time. Recently, car producers tend to mix plastic with other material instead of replace plastic with aluminum while building cars.

- **Student Life System**

Based on our research, the most common plastic daily things are plastic bags, plastic bottles, ID cards, study tools (such as pen, folder and computer), some furniture (such as table and chair) and etc. Based on the great amount of student number, it causes such a great consumption of plastic. Also, because the difficulty to recycle plastic, it will take lots of energy to recycle those plastic, and because of the properties of plastic, it will never be the same kind of plastic once it has been recycled. Also, parts of those plastic will pollute the environment.

- **Food System**

From research, we find out that the basic plastic things used in food system: package, plates, bowls, tableware and etc. And it is hard to replace plastic in food system with aluminum since aluminum is too active that it is easy to react with acid and base contained in food.

After we compare, our team decided to choose student life as our main system to replace plastic with aluminum, because there are a lot of consumption and waste in student life system. And also, when we change daily things form plastic to aluminum, it is easy for student to notice the big change and it will help to change their minds about aluminum recycling, while in other system such as energy system, transportation system and food system, the properties of aluminum make it impossible or too complicated to replace plastic with it.

3.2 Summary

To conclude, we first generated possible directions which followed our aim for the project which is to increase sustainability and efficiency of the campus while it can build people's mind about recycling aluminum. We thought about directions such as enhancing fuel efficiency, substituting plastic, increasing electric conduction and heat conduction, and substituting steel. And we decided to choose substituting plastic as our main direction to complete this design project. Then, we decide to choose a smaller system to follow our direction. So we divided the whole Penn State University into several small plastic consumption systems. Those systems are energy system, transportation system, student life system and food system. After research and comparing, we finally decided to pick student life system based on the large plastic consumption and waste in this system. Also, changing daily objects can help to build students mind about recycling aluminum which followed our project aim and our costumer needs of the company.

3.3 Revised Problem Statement

Our team are going to design a product which is involved in student life system, and this product is designed to substitute plastic in student life system in order to increasing sustainability and efficiency of the campus while giving people an idea about recycling aluminum.

4.0 Idea Selection

Based on our revised problem statement, we started our process of idea generation. Our team members do brainstorming and discussion in this process, and finally get several ideas. Those ideas are substituting plastic with aluminum of cell phone cover, laptop cover, water bottle,

electric fans, ID cards, mouse pad and plastic lamp. Then our team keeps doing research and analyzes those ideas in order to get a final idea assessment.

4.1 Idea Comparison

Table-1 shows analysis and summary of those ideas.

Table-1 Ideas Analysis

Ideas (Replacing plastic with aluminum of...)	Advantages	Disadvantages
Cell Phone Cover	• Frequently use • Available technic (IPhone 5)	• Not all students are willing to get new phone
Laptop Cover	• Frequently use • Available technic	• Not all students are willing to get new laptop
Water Bottle and Plastic Bags	• Large consumption (tons of plastic) • Saving energy and environment • Daily object	• Hard to be replaces with aluminum
Electric Fans	• Frequently use • Available technic	• Not a big consumption
ID Cards	• Large consumption (think about graduates each year) • Saving energy and environment • Daily object • Easy to replaced	• Relatively low consumption (compare with plastic bags and bottles)
Mouse Pad	• Frequently use • Available technic	• Not a big consumption
Plastic Lamp	• Frequently use • Available technic	• Not a big consumption

From the chart above, we decided to pick up the idea about replacing plastic ID cards with aluminum. Ideas such as replacing plastic with aluminum of mouse pad and plastic lamp were denied because of the consumption is not big. And for ideas such as making cell phone cover and laptop cover with aluminum were also denied because not all students were willing to get new phone and laptops. And even though making aluminum water bottles and bags seemed to be a good idea based on the huge amount of consumption, those ideas were also denied since it was not realistic to make aluminum bags. Also, since aluminum is so active, it is not safe enough to make aluminum water bottles because we cannot prevent that something that was acidic and basic will get into the bottles.

4.2 Conclusion

However, for aluminum ID cards, it is realistic to make. There are thousands of graduates from Penn State University each year, and this means thousands of ID cards are going to be thrown away. That is a great waste. Also, students will accidentally lose or break their ID cards during their student lives at Penn State University. Not all of those plastic ID cards are going to be recycled properly, which means this will also cause pollution to environment. If we design an aluminum ID cards, and recycle all the ID cards back from student after they graduate by paying, it can not only save the environment and energy, but also can build students' mind about recycling aluminum as they are following the recycling process. Also, aluminum ID cards is hard to break or bent, it will long the using age of the cards, which also followed our aim to achieve sustainability. So our team decided to design an ID cards that is made out of aluminum.

5.0 Idea Assessment

In this section we will do deep research on our selected idea. Exact data will be used to determine whether using aluminum is better than using plastic to make an ID card. The assessment will focus on pollution and energy consumption, and we will calculate the benefit also.

5.1 Postconsumer pollution

According to Elements Database, "The plastic the credit cards are made of is polyvinyl chloride acetate (PVCA)." PVCA is in the family of PVC (Polyvinyl chloride) which is the least postconsumer recycled plastic, per usage amount, in the United States (U.S. Environmental Protection Agency, 2012, p.2). As Commission of the European Communities claimed, the additives used in manipulations and PVC's inherent chlorine content complicates the recycling processes. As the result, less than a quarter of 1 percent is recovered for recycling. PVC waste will be deeply buried or incinerated. The material has been found to leak chlorine, carcinogens and other toxic chemicals into the soil and air over time. Our school ID is made of PVC. By using aluminum which is theoretically 100% recyclable, we can reduce postconsumer pollution extremely. After we make a survey of ID card consumption (see Appendix C), we summary the

result in Table-2 and calculate the total amount of plastic ID card consumed each year around campus.

Survey participants: male and female Penn State College students, randomly selected, age from 18 to 22, including students from a wide variety of cultures and ethnicities.

Table-2 Card Consumption Survey Feedback

Category	Percentage
Support aluminum ID card	69.1%
Willing to change aluminum card if their current card is broken or lost	69.1%
Expected card number that each student will consume	2

We send out 100 surveys and get 68 responses. The result shows 69.1% participants support aluminum ID card, and 69.1% participants are willing to change aluminum card if their current card is broken or lost. As the result, we can predict that there will be 69.1% students in University Park campus support or want to use Aluminum ID card. Every single student is expected to consume 2 cards.

There are 39192 undergraduate students enrolled in UP campus (U.S. News, 2013). Each plastic card is 0.012Ib. Assume there are total 39192 undergraduates enrolled in UP campus in the next 4 years, four years later, 78384 pieces of plastic card or 940.6Ib (426.6 kg) PVC will be reduced if Al ID is mandatory issued among new students. 54164 pieces of plastic card or 650.0Ib (294.8 kg) PVC will be reduced if the Al and plastic ID are both issued among new students.

5.2 Energy & Resource Use for Manufacture

According to Table-3, total electric and fuel energy consumption of producing one ton PVC is 18.33×10^6 Btu (19.34×10^6 kJ). Table-4 and Table-5 respectively summarize the energy requirement of the primary and secondary aluminum production process. Primary aluminum producing process costs huge amount of energy, but the energy requirements of producing aluminum from scrap are about 5% those of producing aluminum from bauxite. Base on this fact, it will be better to use recycled aluminum instead of primary aluminum to make the ID card. After some calculation, the energy needs to produce one ton softer alloy from scrap is 12.10×10^6 Btu (12.77×10^6 kJ), and the energy need to produce one ton harder alloy from scrap is 11.57×10^6 Btu (12.21×10^6 kJ). As the result, we can save energy up to 36.9% in ID card production if the card is made from recycled aluminum instead of PVC.

Based on the data from Table-2, in the next 4 years, we can save energy up to 2.88×10^6Btu (3.05×10^6 kJ) if school issues Al ID only or 1.99×10^6Btu (2.10×10^6 kJ) if school issues both Al and PVC ID.

Table-3 Raw Materials and Energy Consumed in the Production of the One Metric Tonne of PVC Resin

	Rock Salt (kg)	Ethane (kg)	Electricity (kWh)	Other Fuel (10^6 Btu)
Total consumed by the process	1000	1520	2325	10.4

Sources come from BuildingGreen.com
Sources adapted from Polyvinylchloride: Environmental Aspects of a Common Plastic. Walter Totsch and Hans Gaensslen. 1992 Elsevier Science Publishers Ltd., London and New York.

Table-4 Estimate Specific Energy Consumption (by Energy Source) of Primary Aluminium Production Processes (MJ/metric ton of primary aluminium, except as noted)

Energy Source	Specific Energy Consumption [10^6 Btu/ton]					
	Alumina Refining	Coke Production	Pitch Production	Anode Production	Aluminum Production (Smelting)	Primary Ingot Casting
Electricity	462 [0.40]	35 [0.03]	0.00	826 [0.72]	115,330 [99.85]	1,910 [1.65]
Natural Gas	23,336 [20.20]	763 [0.66]	20 [0.02]	696 [0.60]	752 [0.65]	2,417 [2.09]
Distillate Oil	--	327 [0.28]	8 [0.01]	149 [0.13]	20 [0.02]	698 [0.61]
Residual Oil	243[0.21]	--	--	--	5 [0.005]	698 [0.61]
Propane/LPG	--	--	--	149 [0.13]	8[0.01]	465 [0.40]
Coal	729 [0.63]	--	--	--	--	--
Gasoline	--	--	--	--	5[0.005]	372 [0.32]
Carbon Anodes	--	--	--	--	17,325 [15.00]	--
Total	24,770 [21.44]	1,125 [0.97]	28 [0.03]	1,820 [1.58]	133,445 [115.54]	6,560 [5.68]

Sources come from U.S. Department of Energy Office of Industrial Technologies (1997, pp.12-13): *Energy and Environmental Profile of the U.S. Aluminum Industry*

Table-5 Estimate Specific Energy Consumption (by Energy Source) of Secondary Aluminium Production Processes and Aluminium Semi-Fabrication Processes (MJ/metric ton of primary aluminium, except as noted)

Energy Source	Specific Energy Consumption [10^6 Btu/ton]				
	Scrap Pretreatment[1]	Secondary Melting/Refining[2,3]	Hot Rolling-Softer Alloys[4]	Hot Rolling-Harder Alloys[5]	Cold Rolling
Electricity	300 [0.26]	1,521 [1.31]	3,530 [3.05]	3,800 [3.29]	5,390 [4.67]
Natural Gas	1,300 [1.13]	4,247 [3.68]	2,536 [2.20]	1,766[1.53]	2,349 [2.03]
Distillate Oil/Diesel	--	44 [0.04]	29 [0.03]	20 [0.02]	27 [0.02]
Residual Oil	--	44 [0.04]	--	--	--
Lube Oil	--	--	146 [0.12]	102 [0.09]	135 [0.12]
Propane and LPG	--	66 [0.06]	29 [0.03]	20 [0.02]	27 [0.02]
Coal	--	--	146 [0.12]	102 [0.09]	135 [0.12]
Gasoline	--	--	29 [0.03]	20 [0.02]	27 [0.02]
Total	1,600 [1.39]	5,992 [5.13]	6,445 [5.58]	5,830 [5.05]	8,090 [7.00]

1. Energy per metric ton of scrap input
2. Energy per metric ton of scrap melted
3. Includes casting energy requirements
4. Softer alloys are represented by 3104
5. Harder alloys are represented by 5182

Sources come from U.S. Department of Energy Office of Industrial Technologies (1997, pp.12-13): *Energy and Environmental Profile of the U.S. Aluminum Industry*

5.3 Conclusion

The statistic data shows that using scrap aluminum instead PVC in ID card production can reduce a lot of energy consumption and plastic waste. The huge reduction on postconsumer pollution and energy consumption make this idea becomes very possible and achievable. This idea follows team definition of sustainability. Also, it cans influent huge population to protect our living environment by using renewable resources. We can move on and begin the user needs analysis.

The calculations in 5.1 and 5.2 are not comprehensive. The result has not included graduate students, faculties, other campus population, and current enrolled undergraduates. The final assessment will be generated in section 9.2.

6.0 User Needs Assessment

After we select our design project which is student ID card, we need to gather user needs to maximum both potential profit and market. Our users will be students in UP campus. By introducing more Al ID among students, we can achieve our goal which is reducing postconsumer pollution, saving energy, and guiding students to use renewable resources more successfully. We send out 100 surveys (see Appendix D) and get 68 responses. Participants are random selected among UP campus students. We selected this method because it is considered inexpensive, accomplished in a relatively short period of time and have a very small cost per participant. Also, survey is very useful in describing a general tendency for the characteristics of a large population. Therefore, in the short time and low budget conditions, we considered this is the best way to gather user needs. We ask participants to circle the answer that best represent their opinion. Result is summarized in Table-6.

Survey participants (users): male and female Penn State College students, randomly selected, age from 18 to 22, including students from a wide variety of cultures and ethnicities.

Table-6 User Needs Survey Feedback

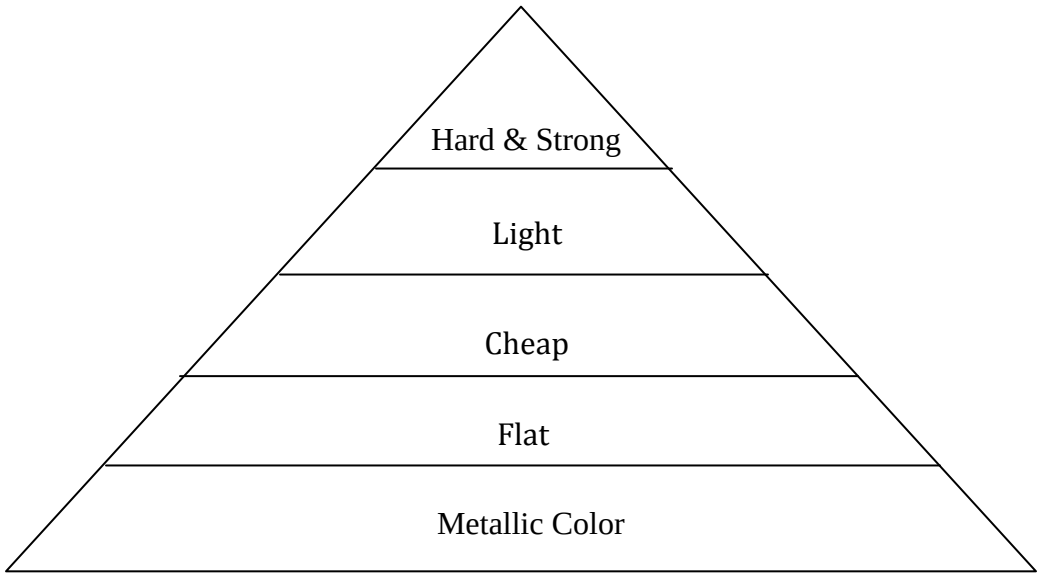
Category	Percentage
Want flat card	58.8%
Want hard & strong card	63.2%
Want metallic Color	44.1%
Want cheap	60.3%
Want Light	60.3%

6.1 Hierarchy of User Needs

After we count the survey feedback, a hierarchy of user needs is developed. The purpose of this step is to rank the most important user need in an organized manner; these become specific areas in which the team needs to focus on to develop a ID card that will attract and satisfy the users. Survey feedback shows that there are 58.8% participants expect their card be perfectly flat, and 63.2% participants want their cards be harder. 44.1% participants like metallic color card while 60.3% participants expecting inexpensive cards. It is noticeable that 60.3% participants do not want heavier cards. Because participants are randomly selected around UP campus, this survey can describ the characteristics of entire UP campus population. We also consider the

feedback from option “c” (I don’t care) in each question. People who choose “c”, their minds can be easily guided by several advertisements. They are considered our future users also. Next, we make a hierarchy of user needs (Figure-1).

Figure-1 Hierarchy of User Needs



6.2 Final Problem Statement

After we rank user needs, we make a final problem statement. The ID card should be made of aluminum, and it should meet all applicable performance requirements, satisfy relevant regulatory codes, and is economically viable. The card need to be hard and strong as well as light and cheap. Metal card will be made in flat shape. Although we will focus on a metallic color card, we need to consider how to give it a bright color also.

7.0 External Search

Before we begin concept generation, our team needs to do external search to collect relative information, such as properties of different aluminum alloys, size standard of ID card, and PSU policies about ID card. We will make a needs-metrics matrix to compare current PVC ID card with user needs. The purpose of this step is gathering crucial information and guiding us to generate concepts later.

7.1 Literature Review

This section includes information about aluminium, aluminium alloy, PSU ID policy, card size standards, and magnetic strip.

- **Aluminium**

Pure Aluminum is a kind of silvery-white metal. It is cheap and nontoxic. Its corrosion resistance can be excellent due to a thin surface layer of aluminum oxide that forms when the metal is exposed to air, effectively preventing further oxidation. This corrosion resistance is also often greatly reduced by aqueous salts, particularly in the presence of dissimilar metals. Its density is 2.7g/cm^3 while PVC having density of 1.1–1.35g/cm^3.

- **Aluminium Alloy**

The strongest aluminium alloys are less corrosion resistant due to galvanic reactions with alloyed copper.

Wrought and cast aluminum alloys use different identification systems. Wrought aluminum is identified with a four digit number, and the first digit indicates the major alloying elements. Table-7 shows different alloy series with their features.

To appeal to a campus consisting mainly of young adults, a change in aluminum's metallic appearance is necessary. Anodizing is an electrochemical process in which an oxide layer is chemically built on the surface of the metal. This new layer can be dyed in different colors. It also creates a barrier of corrosion resistance for the ID+ card.

Table-7 Features of Different Aluminium Alloy Series

Non-heat-treatable alloys are hardened primarily by cold working

Series	Features
1000	Pure aluminum, non-heat treatable
2000	Strengths comparable to steel, susceptible to stress corrosion cracking, may be subject to inter-granular corrosion. Most popular alloy and is commonly used in aircraft construction.
3000	Non-heat treatable, used in soda pop cans
4000	Low melting point, used in welding wire. When anodic oxide finishes are applied and hence are in demand for architectural applications.
5000	Moderate-to-high-strength, non-heat-treatable alloy. Good resistance to corrosion in marine atmospheres
6000	Heat treatable, relatively good corrosion resistance, medium strength
7000	Highest strengths, exhibit reduced resistance to stress corrosion cracking
8000	For aerospace applications

Sources:

- http://www.keytometals.com/page.aspx?ID=AluminumGrades&LN=EN
- http://en.wikipedia.org/wiki/Aluminium_alloy

- **PSU ID Policy**

According to PENN STATE – ADMINISTRATIVE, partial PSU ID policy is listed below:

1. The Penn State id+ Card is the official photo identification card of Penn State.
2. All cards are photo cards with a magnetic stripe on the back.
3. Only authorized University ID Offices are permitted to produce and issue id+ cards.
4. The first card received is issued at no charge.
5. Only the cardholder may be in possession of the id+ card.
6. Tampering with id+ cards and/or making color reproductions is prohibited.
7. Labels or stickers may not be added to any of the cards since their presence would interfere with the electronic reading of the card.
8. Punching holes (for hanging, etc.) and burning (branding) is also prohibited.
9. Id+ cards are no longer issued with an integrated computer chip.
10. An individual may possess only one active University id+ card at a time.
11. The PSU ID number will be displayed on the id+ card.

Through research of Penn State's ID+ card policy we learned that there are 5 PSU approved ID cards, which covers more than the student population. The 5 ID+ card types are: student, faculty/staff, faculty/staff/student, retiree, and affiliate. All Penn State ID+'s contain photo identification, a 9 digit PSU ID number, and magnetic strip that connects to an account that has the person's information. Only authorized University ID Offices are permitted to produce and issue these ID+ cards. The first card that Penn state issues has no charge; however, it will be 15 dollar for every replacement card after. Essentially, our design of the ID+ card can be created in various ways as long as they abide by these university restrictions.

- **Identification Card Sizes**

There are 4 different sizes of ID card. Table-8 summarizes their standards.

Table-8 Card Size Standards

Format	Dimensions	Thickness	Usage
ID-1	85.60 × 53.98 mm	0.76mm	Most banking cards and ID cards
ID-2	105 × 74 mm		German ID cards issued prior to November 2010
ID-3	125 × 88 mm		Passports and visas
ID-000	25 × 15 mm		SIM cards

Sources: http://en.wikipedia.org/wiki/ISO/IEC_7810

- **Magnetic Strip**

A huge controversy with aluminium ID cards is how it would react with the magnetic strip, also known as magstrip, located on the back of credit cards. One may wonder if the material will demagnetize the information on the card. Demagnification occurs due to the realignment of the iron particles embedded into the magstrip when it is near another magnetic field. Through research, our team discovered that aluminium is not that magnetic. It takes a strong magnetic field for aluminium to exhibit effects. Even though a magstrip would be possible on our aluminium ID+ card, our team was open to other forms of identification systems, such as Radio Frequency Identification (RFID) tags and Universal Product Code (UPC) bar codes. RFID tags, originally used to track cattle and luggage, are small tags that use inducts a magnetic field through wires placed on it. The tag would be encased by the ID card and would react with an RFID reader. The UPC bar code system would give a unique bar code sequence for each card to be scanned.

7.2 Patent Search

Our team perform a patent search to determine the key technologies used in the aluminum ID card. After we use USPTO (United States Patent and Trademark Office) website to deeply search all relative patents, we find there is no patent of aluminum ID/credit card.

7.3 Benchmarking

After we gather user needs, we generate Table-9 to associate each need with at least one corresponding metric. Then we collect information of current PVC ID card in Table-10 as the contrast to our further generated concepts.

Table-9 Needs-Metrics Matrix

		1	2	3	4	5
	Metric / Needs	Yield Strength	Weight	Price	Curved extent	Color
1	Hard &Strong	×				
2	Light		×			
3	Cheap			×		
4	Flat				×	
5	Metallic color					×
6	Bright color					×

Table-10 Features of PVC ID Compare With User Needs

Metric#	Need#	Metric	Imp	Units	PVC ID card
1	1	Yield Strength	1	psi	1450 - 3600
2	2	Weight	2	g	5.44
3	3	Price	3	$	Free ($15 for replacement)
4	4	Curved extent	4	--	Visible curved surface
5	5, 6	Color	5	--	White background

Source (PVC yield strength): Titow, W. V. (1984, p.1186)

Based on PVC features and needs survey feedback, our current plastic ID card cannot fully satisfy requirements of users. We use the features of school ID as our design starting point, the final designed product will be much better on satisfying users. The design target or the summary of this section will be generated in 7.4.

7.4 Design Target

After we review final problem statement and summary the information gathered through external search, we make the design target. This section will guide the upcoming concept generation, selection sections.

Our team will use aluminum or aluminum alloy to make a student ID card. The card will be relatively hard and strong compare with current PVC ID. At the same time, we try to minimize its cost as well as its weight. The card should not have visible curved surface, and its yield strength needs to greater than 7200 psi. The weight of our final design should be less than 15 grams. It will be great that the final cost is less than 5 dollars per card. At least, the alloy used in final design needs to be rated as fair for anodizing except we thinking out another way to color it. Its original metallic color should be comparable to fine steel.

Considered PSU ID policy and ID size standards, the final design must follows eleven PSU rules listed in 7.1, such as photo and magnetic stripe are required, no holes on the card, and integrated computer chip should not be used. Also, ID-1 standard is strongly recommended, which has dimension of 85.60 × 53.98 mm and thickness of 0.76mm.

8.0 Internal Search

In this section, our team will search solutions to the final problem statement done internal to the team. We will generate several concepts, and use concept selection matrix to select one or more concepts.

8.1 Concept Generation

We totally develop 5 concepts after the in-team brainstorming. Table-11 shows their sketches and design layouts. Table-12 summarizes their used alloy series, size, color, how to transaction, and other features.

Concept 1 uses series 7000 as its body, which gives the card a wonderful strength. It has the same size as a SIM card hence it will be very convenient that people can put it in the wallet. Radio-frequency identification (RFID) chip is built in the card that transaction can be finished by closing your card to the transaction machine. This idea makes the card more convenient. It has metallic color. Shrank student photo is printed on the front side. Important number will be printed on the back side, such as customer service and emergency phone number.

Concept 2 uses series 6000 as its body, which gives the card a good corrosion resistance. Also, smooth surface will make it good to anodizing. It is designed to a credit card size as same as our current ID. Magnetic strip will be kept for the transaction purpose. Students will not feel any different on using between current plastic ID and concept 2 ID. In general, series 6000 has smooth surface that allows it for anodizing. In other word, it can have both metallic color and bright color. Card layout will be kept. Student photo is printed on the front and instruction is printed on the back.

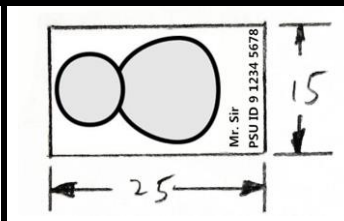
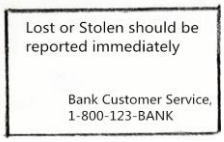
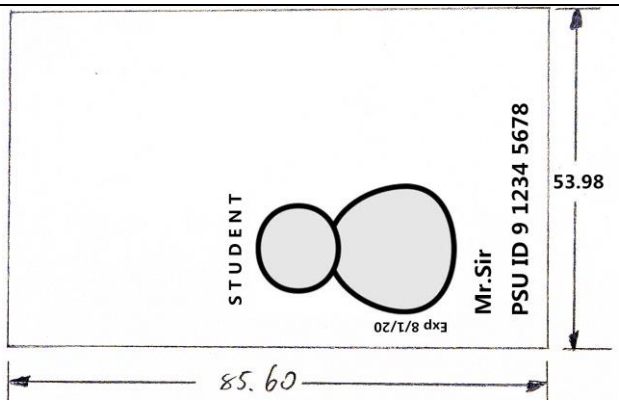
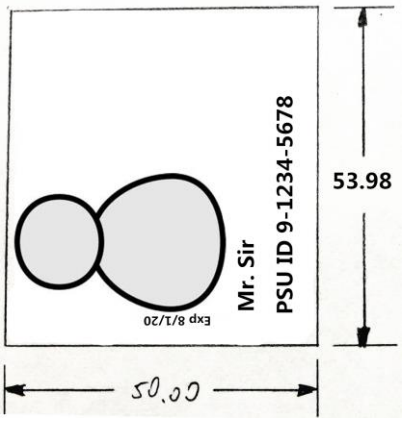
Concept 3 uses series 5000 as its body, which gives the card a good strength and corrosion resistance. It has a reduced size (50.00 $\times$ 53.98 mm) compare to credit card. Barcode and instruction will be printed on the back. Transaction will be done by scan the barcode. It has metal color only, and student photo will be printed on the front with original size.

Concept 4 uses series 2000 as its body, which gives the card a wonderful strength. Series 2000 is commonly used in aircraft construction, which will make our card very cool among students. It is designed to a credit card size as same as our current ID. Magnetic strip will be kept for the transaction purpose. The card will has a thin plastic coating which allows it be easily printed as well as preventing corrosion. As the result, the card will has bright color only. Card layout will be kept. Student photo is printed on the front and instruction is printed on the back.

Concept 5 uses series 6000 as its body, which gives the card a medium strength that makes the card easy to shape. Its size and shape will be different based on the requirement of each user, but in general, radio-frequency identification (RFID) chip will be built in the center of the card.

Also, student photo is printed in the center of the front with original size. Instruction will be printed in the center of the back. As the result of this layout, the edge of ID card can be cut without relocating chip, student photo, and instruction. Series 6000 has smooth surface that allows it for anodizing, so it can have both metallic color and bright color.

Table-11 Morphological Chart of Concepts (Unit: mm)
Thickness is 0.76mm for all concepts

#	Name	Front Design	Back Design
1	SIM ID		
2	Al Regular		
3	Barcode		

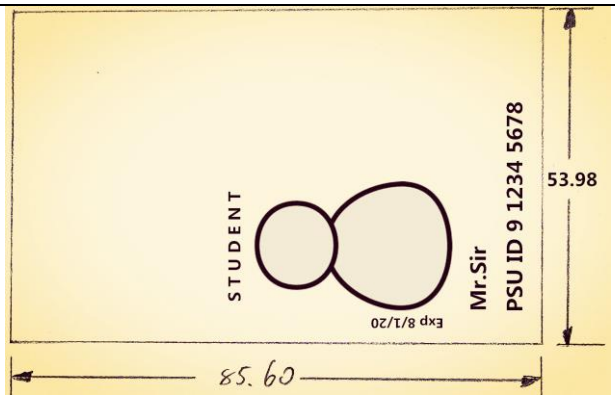
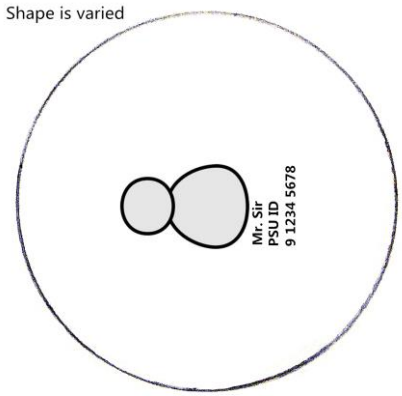
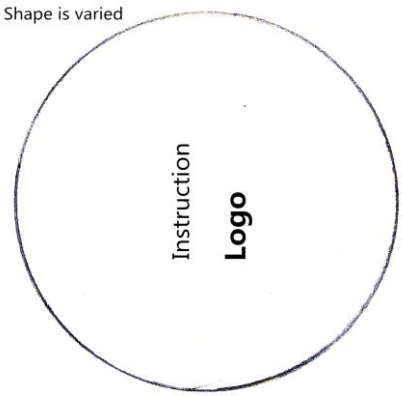
4	Plastic Coating		
5	Multiple Shapes		

Table-12 Concept Features

#	Name	Alloy Series	Size	Color	Transaction	Other Features
1	SIM ID	7000	ID-000	Metallic	RFID chip	Wonderful strength ; Convenient
2	Al Regular	6000	ID-1	Metallic & Bright	Magnetic strip	Good corrosion resistance
3	Barcode	5000	50.00 × 53.98 mm	Metallic	Barcode	Good strength; Reduced size
4	Plastic Coating	2000	ID-1	Bright	Magnetic strip	Wonderful strength & corrosion resistance
5	Multiple Shapes	6000	--	Metallic & Bright	RFID chip	Good corrosion resistance; Flexible shape

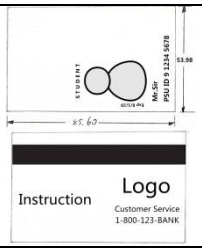
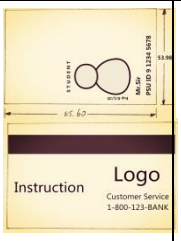
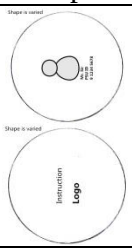
8.2 Concept Selection

In this section, we will use Pugh Chart (Table-13) to select the best concept that satisfies both company's needs and users' needs. Pugh Chart is used for ranking the multi-dimensional options of an option set. Based on user needs, we give a score from 1 to 6 to each design. As a result, we select concept 2 and 5.

Then, we decide to combine advantages from all concepts to generate final concept. According to user's needs, after we carefully compare 5 concepts, concept 2 can best fit all these needs. The only way to have selectable shapes is to use small RFID chip, but our school has to replace all current swiping machines. The cost will be really high. So, concept 2 will become our final design.

Table-13 Concepts Scoring & Selection

Excellent – 6
Poor/Unable – 1

Concept / Category		Current plastic ID	SIM ID	Al Regular	Barcode	Plastic Coating	Multiple Shapes
Sketch							
Criteria	Weight	Original	Design 1	Design 2	Design 3	Design 4	Design 5
Hard &Strong	30%	1	6	6	6	6	6
Light	20%	6	2	2	2	2	2
Cheap	20%	6	1	4	3	2	4
Flat	15%	1	6	6	6	6	6
Metallic color	9%	1	6	6	6	1	6
Bright color	6%	1	1	6	1	6	6
Net Score		3.2	3.9	4.8	4.3	3.95	4.8
Rank		5	4	1	2	3	1

9.0 Final Design

Our final design has dimension of 85.60 ×53.98 mm and thickness of 0.76mm. Magnetic strip will be used for transaction. The layout will be as same as our current plastic cards. Four corners are designed in round shape for safety purpose. The body is made of aluminum alloy 6063, because it has a surface finish that is far smoother than the other commercially available alloys, and second, its strength is significantly less (roughly half the strength of 6061, but much stronger

than PVC), making it suited for applications where strength is not the foremost consideration. Also, 6063 is rated as "Good" for forming and cold working operations, "Excellent" for anodizing, and "Fair" for machining. It has good corrosion resistance. The card can be colored perfectly by anodizing. Below, Figure-2 shows our design while Figure-3 gives the drawing.

Figure-2 Final Design

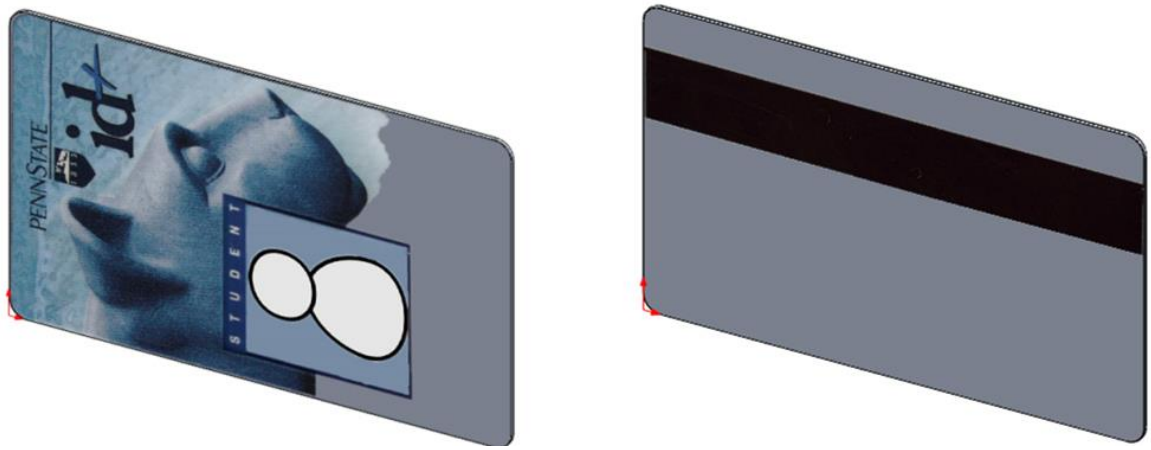
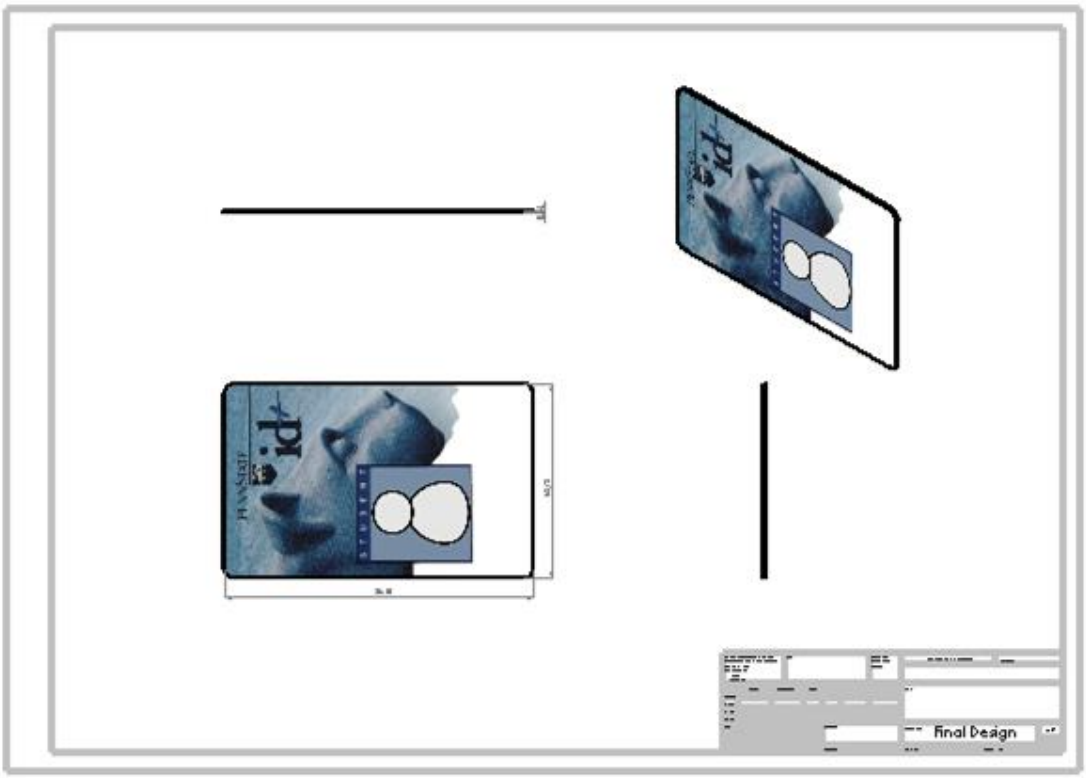


Figure-3 Final Design Drawing



9.1 Estimated Cost

Current PVC ID is weight 0.012Ib with density of 1.1–1.35 g/cm^3. Al alloy has density of 2.7-2.9g/cm^3. After calculation, in average, our designed card will weight 0.027 Ib. Approximately, aluminum alloy 6063 costs 5000 dollars per metric ton (2204.62Ib). As a result, the material cost will be 6 cents for each card.

According to bayphoto.com (http://www.bayphoto.com/metalprints/single/sizes-and-prices.htm), they can provide print service on aluminum card. The color will be brilliant while the surface is ultra-hard scratch-resistant as well as waterproofed. The print cost will be 1.8 dollars for each card. The cost of transportation and taking photo services will not be accounted, because our school pays for these fees currently.

So, the price difference which is less than 3 dollar will be paid by students.

9.2 Final Design Assessment

There are total 98,097 students (include undergraduate and graduate students) and 8,864 academic staffs (full and part time) enroll in Pennsylvania State University all over the campus. The card user population will be 106961. Based on the information mentioned in section 5, we can conclude that 213,922 pieces plastic card will be consumed every 4 years. Because the cost of each card is very low, our school will issue aluminum card only, no more plastic card will be provided. Each card will charge student 10 dollars, after the card be returned or recycled to school, 5 dollars will be given back. This money back system can encourage more students to do recycling.

After calculation (see Appendix E), our designed project can reduce 1164.4kg plastic waste while save 7.66×106 kJ energy. The aluminum ID card is approximately as heavy as a soda can.

Table-14 summaries main achievements and features of our project as well as compare them to company and user's needs. It shows our project well solves all problems as well as meets all needs.

Table-14 Features Compare to Needs

	Achievement and Project Feature								
Company Needs	Reduce Waste	Save Energy	Alloy 6063	Great Strength	Cheap (3$)	Light (0.028lb)	Flat	Smooth Surface Finish	Excellent for Anodizing
Use Energy Efficiently		×							
Increase Sustainability	×								
Made of Aluminum			×						
User Needs									
Hard &Strong				×					
Light						×			
Cheap					×				
Flat							×		
Metallic color								×	
Bright color								×	×

10.0 Conclusions

Our designed project perfectly meets both company and user needs. By satisfying more users, we can better achieve company's needs. By using money back system and meeting all user needs, we can guide maximum number of students to use renewable aluminum and recycle it. During design process, we not only brainstorm some fantastic ideas, but also generate outline for each steps elaborately.

In section 1, we state our mission. In section 2 to 4, we decide focus on substituting plastic in student life system. Then, we get our idea (Al ID) which is concluded achievable in section 5. We collect user needs and relative design information respectively in section 6 and 7. Five concepts are generated in section 8, and we combine 5 designs to make our final design. Finally, the final design is assessed in section 9.

Our final design is about using aluminum alloy 6063 to substitute PVC plastic to make our ID cards. PSU do not need to purchase any new equipment while students can use the Al card as they use current plastic card, because card layout and magnetic strip are kept. Low cost makes this design very achievable. Also, money back system makes students willing to recycle their cards. Our group's idea and design is great and wonderful.

References

Section 5

Commission of the European Communities: *European Commission Green Paper: Environmental Issues of PVC*. Retrieved from http://eur-lex.europa.eu/LexUriServ/site/en/com/2000/com2000_0469en01.pdf

Elements Database. (n.d.). *The Chemistry of Credit Cards*. Retrieved from http://www.elementsdatabase.com/the_chemistry_of_credit_cards.php

Table-3 comes from BuildingGreen.com.

Table-4 and Table-5 comes from U.S. Department of Energy Office of Industrial Technologies (1997): *Energy and Environmental Profile of the U.S. Aluminum Industry*

U.S. Environmental Protection Agency: *Documentation for Greenhouse Gas Emission and Energy Factors Used in the Waste Reduction Model (WARM): Plastics.* Retrieved from http://homeguides.sfgate.com/pvc-recycling-79771.html

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Section 7

Aluminum density and information retrieved from http://en.wikipedia.org/wiki/Aluminium

Magnetic strip info retrieved from http://money.howstuffworks.com/personal-finance/debt-management/magnetic-stripe-credit-card.htm and http://terpconnect.umd.edu/~wbreslyn/magnets/is-aluminium-magnetic.html

PENN STATE – ADMINISTRATIVE retrieved from http://guru.psu.edu/POLICIES/Ad24.html

RFID info retrieved from http://electronics.howstuffworks.com/gadgets/high-tech-gadgets/rfid.htm

Table-7 retrieved from http://www.keytometals.com/page.aspx?ID=AluminumGrades&LN=EN & http://en.wikipedia.org/wiki/Aluminium_alloy

Table-8 retrieved from http://en.wikipedia.org/wiki/ISO/IEC_7810

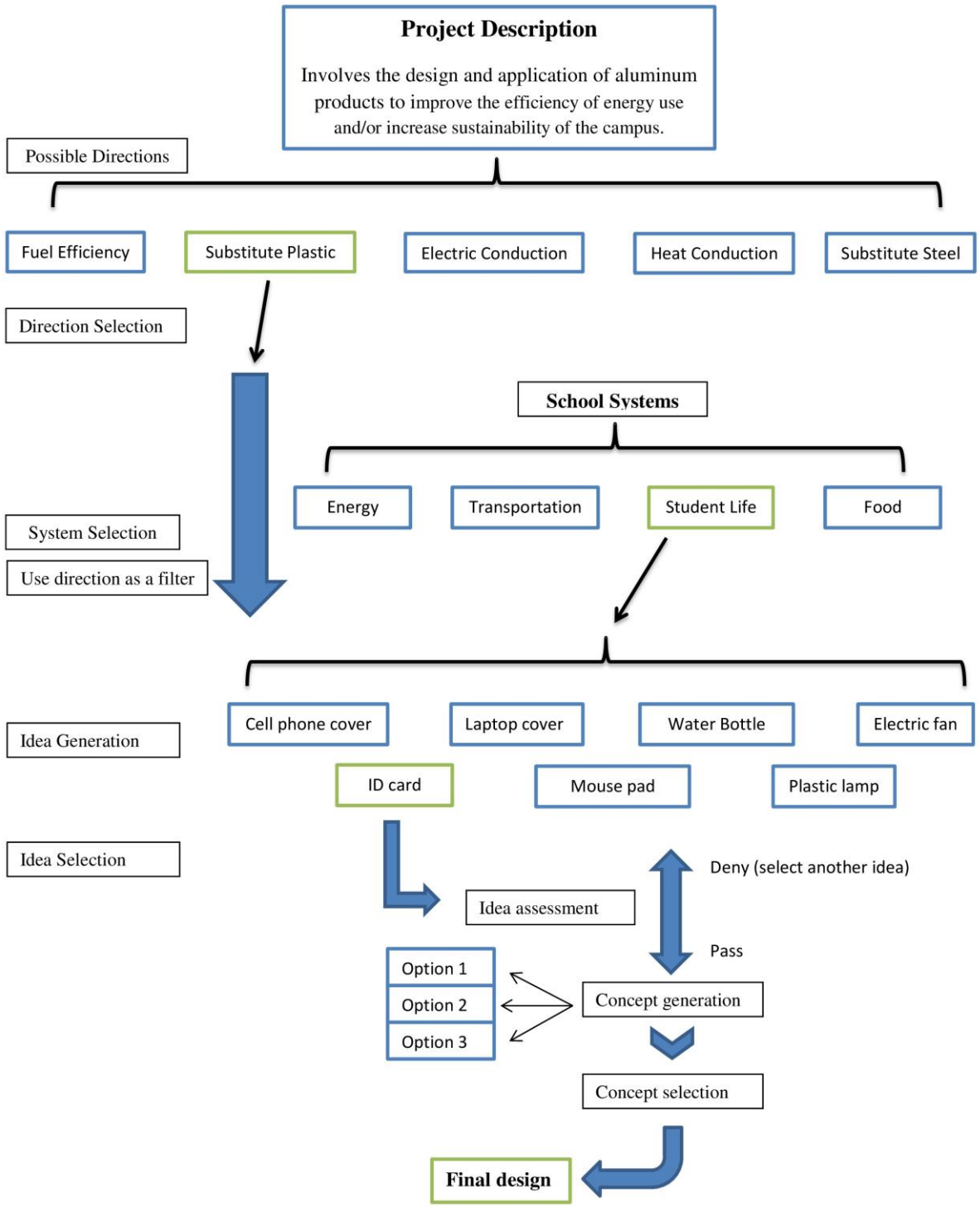
Titow, W. V. (1984). *PVC technology*. Springer.

Section9

PSU population retrieved from http://en.wikipedia.org/wiki/Pennsylvania_State_University

Appendix A

Process Flow Chart



Appendix B

X = completed or complete by date			28-Oct					4-Nov					11-Nov					18-Nov					25-Nov					2-Dec					9-Dec				
S = Started or start by date			M	T	W	T	F	M	T	W	T	F	M	T	W	T	F	M	T	W	T	F	M	T	W	T	F	M	T	W	T	F	M	T	W	T	F
Tasks	Owner(s)	% compl																																			
Design Project #2 Preparation			S				X																														
Define the problem of assigned task	Siyang	100	S		X																																
understand company needs	Siyang	100	S		X																																
Research Alcoa Company	Siyang	100	S		X																																
Research Aluminum Properties	Siyang	100	S		X																																
Survey campus For improvable/renewable features	Angeli	100	S				X																														
Develop an Design process	Siyang	100	S				X																														
review	Siyang	100																																			
Idea Selection								S				X																									
Direction Generation	Angeli	100						S		X																											
Direction Selection	Angeli	100						S		X																											
Summarize school systems	Sijie	100						S				X																									
System selection (based on direction)	Sijie	100						S				X																									
Possible ideas generation	Sijie	100						S				X																									
Idea selection	Siyang	100						S				X																									
review	Siyang	100																																			
Idea assessment/possibility research													S		X																						
Potential-market research (include survey)	Evan	100											S		X																						
Exact benefit from idea	Evan	100											S		X																						
Idea conclusion (pass or deny)	Sijie	100											S		X																						
Final-idea assessment report	Angeli	100											S		X																						
Review	Angeli	100																																			
User Needs Analysis (expand influence)	Evan	100													S		X																				
Define the project problem	Evan	100													S		X																				
Users Requirements	Evan	100													S		X																				
Target Population Research	Evan	100															S	X																			
Project Survey (what do users want?)	Evan	100															S	X																			
Market Research	Evan	100															S	X																			
Needs Statements	Evan	100															S	X																			
Review	Evan	100																																			
Establish Target Specifications	Siyang	100																		S		X															
Product Spec Metrics & Matrix	Siyang	100																		S		X															
Set target specifications	Siyang	100																		S		X															
Benchmarking	Siyang	100																		S		X															
a. Current/without Al substituted project capabilities	Siyang	100																		S		X															
b. Compare to Needs Statements	Siyang	100																		S		X															
Order User Needs into Hierarchy	Siyang	100																		S		X															
Review	Siyang	100																																			
Concept Generation	Evan	100																				S	X														
Clarify the problem	Evan	100																				S	X														
Develop a describing diagram	Evan	100																				S	X														
External search	Siyang	100																				S	X														
a. Aluminium Alloys Research include their properties	Siyang	100																				S	X														
a. Literature Review	Angeli	100																				S	X														
b. Patent Search	Angeli	100																				S	X														
Brainstorming	Evan	100																				S	X														
Review	Evan	100																																			
Concept Selection (Iterate as required)	Evan	100																					S		X												
Concept screening	Evan	100																					S		X												
Prepare the selection matrix	Evan	100																					S		X												
Rate the concepts	Evan	100																					S		X												
Rank the concepts	Evan	100																					S		X												
Combine and improve the concepts	Siyang	100																					S		X												
Select one or more concepts	Siyang	100																					S		X												
Review	Siyang	100																																			
Concept scoring	Angeli	100																										S		X							
Prepare the selection matrix	Angeli	100																										S		X							
Rate the concepts	Siyang	100																										S		X							
Rank the concepts	Siyang	100																										S		X							
Combine and improve the concepts	Evan	100																										S		X							
Select one or more concepts	Evan	100																										S		X							
Review	Evan	100																										S		X							
Establish Final Specifications	Angeli	100																												S		X					
Re-evaluate/Compare with Needs Statements	Angeli	100																												S		X					
Go back to 26???	Angeli	100																												S		X					
Update final specifications	Angeli	100																												S		X					
Review		100																												S		X					
Design and build	Siyang	100																														S	X				
Detail Design	Siyang	100																														S	X				
Prototype Construction (CAD/ physical)	Siyang	100																														S	X				
Review	Siyang	100																														S	X				
Report Preparation	Sijie	100	S																														X				
Abstract	Sijie	100	S				X																														
Introduction	Sijie	100	S				X																														
Mission Statement	Sijie	100	S				X																														
User Needs Analysis	Sijie	100						S															X														
External Research	Sijie	100						S															X														
Concept Generation	Sijie	100						S															X														
Concept Selection	Sijie	100																					S					X									
Design	Sijie	100																					S					X									
Conclusions	Sijie	100																					S					X									
References	Sijie	100																					S					X									
Presentation	Angeli	100																										S					X				
Prepare the presentation	Angeli	100																										S					X				
Present	Angeli	100																										S					X				
Milestones																																					

Appendix C

Survey 1: Please circle the answer that best represent your opinion

Aluminum ID card has better qualities than plastic card. Also, you can reduce postconsumer pollution and save energy by using aluminum. (May expensive than plastic card)

1. Do you support or want to use aluminum ID card?
   a. Yes b. No
2. Please predict how many ID cards you may lose or change during 4 year college experience.
   a. 0 b. 1 c. 2 d. 3 e. ≥4
3. If your ID card is broken or lost, do you willing to change an aluminum card.
   a. Yes, I want aluminum card b. No, I want plastic card

Counting Table

Question \ Option	a	b	c	d	e
1.	47	21	--	--	--
2.	27	21	13	3	4
3.	47	21	--	--	--

Appendix D

Survey 2: Please circle the answer that best represent your opinion

1. Do you expect your card be perfectly flat?
   a. Yes b. No c. I don't care
2. Do you want your card be stronger, scratch resisting, and harder to broken?
   a. Yes b. No c. I don't care
3. Do you want your card has metallic (original) color or bright color?
   a. Metallic color b. Bright color c. I don't care
4. If a metal card is more expensive than a plastic card, which ID card is your choice?
   a. Metal b. Plastic c. I don't care
5. Do you hope your current ID card be heavier?
   a. Yes b. No c. I don't care
6. Which ID card system in campus you prefer?
   a. Issue aluminum card only (lower cost, no more plastic card be provided)
   b. Issue both aluminum and plastic card (higher price, two options provided)
   c. I don't care

Counting Table

Question \ Option	a	b	c
1.	40	5	23
2.	43	3	22
3.	30	12	26
4.	16	41	11
5.	8	41	19
6.	25	22	21

Appendix E

213,922 pieces cards consumption every 4 years
Each card is weight 0.012Ib
2567.1Ib (1164.4kg) plastic will be reduced

Energy needs to produce one ton PVC is 18.33×10^6 Btu (19.34×10^6 kJ)
Energy needs to produce one ton softer alloy from scrap is 12.10×10^6 Btu (12.77×10^6 kJ)
Save energy up to 34.0% in ID card production if the card is made from recycled aluminum
Energy saved: 7.66×10^6 kJ

Al card is weight 0.027Ib
A soda can (355ml) is weight 0.028Ib
Our designed card is approximately as heavy as a soda can