A Comprehensive Method for the Selection of Sustainable Materials for Building Construction

A Thesis

Submitted to the Faculty of

Worcester Polytechnic Institute

In partial fulfillment of the requirements for the

Degree of Masters of Science in

Construction Project Management

By

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May 2012

APPROVED:

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Abstract

In the design phase of any building industry, appropriate material selection is critical for the entire project. A poor choice of material may affect the quality of the project, lead to high cost during the long term operation and maintenance phases, and even endangering humans and the environment. Since the inception of the United States Green Building Council (USGBC) in 1993, “green” buildings have become a hot topic and people have become concerned about how sustainable their buildings are. In order to determine the level of sustainability in buildings, the Leadership in Energy and Environmental Design (LEED) has developed a rating system that has been established now as the common denominator in the industry. However, the LEED rating system simplifies, or even ignores, explicit considerations for Lifecycle Assessment (LCA) in determining the selection of building materials. This lack of explicit consideration for LCA does not permit a full assessment in determining how truly sustainable the chosen materials are.

This research analyzes the factors impacting the selection of the green materials and reviews the current standards used in green material. It proposes a more comprehensive rating method for the green material selection illustrating its applicability through a case study analysis based on new WPI Sports and Recreation Center. It is expected that this study would contribute to a better understanding of the sustainable materials selection and can improve help to improving their long term performance in buildings.

Acknowledgements

There are many people who helped me during the time when I was writing this thesis. It was one of the toughest periods of my student life. I want to express my appreciation to those people who conveyed selfless assistance not only in physical way but also in mental way.

First, I want to give my special thanks to my advisor Professor Guillermo Salazar. He has always inspired me whenever I encounter difficulties in the research. His academic and practical experience guided me to the right orientation many times when I almost lost myself. I know I could not have finished my research with good quality and on time without his support and guidance. Even when he was off the campus, working for another program which sometimes lasted as long as two months, we still kept in close touch with each other through email and the phone.

Thanks to Lynne Deninger AIA, LEED AP, who helped me fill the gap between the academic world and the real world by not only setting up a group conference, but also assisted me in reviewing concepts developed in my research.

Also, I would like to thank my thesis committee member, Professor Leonard Albano, for his involvement and support. And thanks to Pete Northern and Rachel Cerulli for their answers in the group conference.

Lastly, I would like to thank my husband who always supports me and gives me a lot of suggestions when I have a hard time.

Thanks to all my family members and friends who care about my thesis and have supported me.

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Chapter 1 Introduction

Construction and operation of buildings account for one-sixth of the world's fresh water withdrawals, one-quarter of world's wood harvest, and two-fifths of world's material and energy flows (Roodman and Lessen, 1995). The desire and need for more energy efficient products eventually affects construction. "Energy efficiency" in construction industry evolves into a broad field called "sustainable building". As defined by U.S. Environmental Protection Agency, "A green, or sustainable, building is the practice of creating and using healthier and more resource-efficient models of construction, renovation, operation, maintenance and demolition." The United States Green Building Council (USGBC) which created the Leadership in Energy and Environmental Design (LEED) was established in 1993. LEED is a rating system that has been established as the common denominator in the industry to determine the level of sustainability in buildings. When a project goes through LEED rating system, earns certain credits according to the system, and finally attain a final credit which determines whether the project can be certified as LEED Platinum, Gold, Silver or nothing.

Materials Efficiency is one of the elements of green building design and construction that contains the selection of green materials as the first step in developing sustainable buildings. The LEED rating system has one separated section called Materials and Resources. This section mainly focuses on requirements of the reused and recycled amount of materials in the project, construction waste management, transport distance between site and the storage of materials and the emissions after fabrication and installation.

In order to meet the requirements of the LEED rating system, architects need to consider whether the materials they chose consume less energy, have lower carbon emission features, contain recycled materials or regional reachability. More importantly, those considerations should be quantified in documentation to attain LEED certification further. The process of quantification and documentation, because it is very detailed and complicated, is quite time-consuming.

From another point of view—how to define the level of green of a product—is a very complex problem. It's difficult to balance all of the different and often unrelated- considerations. For example, a product with a high level of recycled content may release harmful VOCs (volatile organic compounds). Also, for different individual products, that is, for each product, there are different levels of "green".

In the LEED rating system, Materials and Resources (MR) account for almost 13% possible points of the total possible points. And among the possible points of the LEED MR, building reuse can get 1 to 4 points but it is very difficult to get, especially for new construction. Except for building reuse, other requirements all ask for incorporating the project's LEED features, such as construction waste management, materials reuse, recycled content of materials, regional materials, rapidly renewable materials and certified wood.

However, in any given project not all of the materials used have LEED features. The issue then is how to control the high consumption level of materials which do not contain LEED features which is a crucial problem beyond the LEED requirements. For example, it is not possible that each material of a project contains recycled content. Then what about materials without

recycled content? Can these get the LEED points if the manufacturer makes the process of production “greener” in order to produce environment-friendly materials? The answer at this point in time is no, referring to LEED MR. Moreover; the LEED MR simplifies or even ignores some important environmental impacts if the entire lifecycle energy consumption of a material is not being considered. What if certain products with regional materials consume much more energy during their production than products without regional materials? Will architects choose these regional materials in order to attain points of LEED by ignoring their energy consumptions during the manufacturing process?

Without a consideration of the entire lifecycle energy consumption of the materials, the LEED rating system may simplify or even ignore important environmental factors in determining the true sustainability building materials. Also, it may not inspire manufacturers to put more effort on reducing the environmental impacts of non-green materials. The LEED rating system simplifies or even ignores explicit considerations for Lifecycle Assessment (LCA) in determining the selection of building materials. This lack of explicit consideration for LCA does not permit a full assessment in determining how truly sustainable the chosen materials are.

This research analyzes the factors impacting the selection of green materials and reviews the current standards used in green materials. It proposes a more comprehensive rating method for the green material selection illustrating its applicability through a case study analysis based on new WPI Sports and Recreation Center. It is expected that this study would contribute to a better understanding of the sustainable materials selection and can improve help to improving their long term performance in buildings.

Chapter 2 Background

2.1. Material/Product Selection Process

Before understanding the process of material/product selection, it is important to know the entire process of a construction project. As **Figure 1** indicates, any project of this kind mainly contains seven phases. In the first programming phase, the project has just started to be planned and the owner has only a general concept about the project. Also all potential participants have to decide whether to join in this project and get ready for bidding. In the second phase, schematic design, the project is handed to the architects and, with the assistance of the owner the architects finish the schematic design of the project. Then, in the third phase, the architects detail the design drawings and provide enough information needed for the construction phase. Afterwards, the architects are responsible for detailing all their works in documents, which is handed out to the contractors. Then, according to the documents, contractors prepare bids for their work and present them to the owner. Once a contractor is selected and is being awarded for the construction work the construction of the project begins. After the successful construction, the project can be occupied by the users.

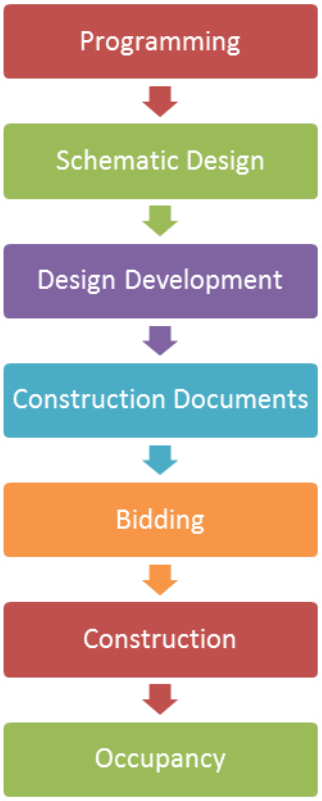

Figure 1-Construction Project Phases

The most important decisions on material/product selection are always made in the schematic design phase. This process continues to a lesser extent in the following phases. Usually, there are three steps of material/product selection: research, evaluation and selection (Froeschle, 1999). All of the technical information of materials/products such as geometric properties, LEED features and testing results is collected in the first step. And learning technical information of different materials/products becomes crucial in this step. The second step involves confirmation of the technical information and more importantly compare different materials/products with the same functions. LCA tools can be very helpful in this step. The final step selection often involves the use of individual criteria including the LEED rating system to make the final decision. The architect should be the one who makes the final decision about

every product, including green products and the one who takes the most responsibility for material/product selection. In reality, the leading architect teams up with the specification writer and other architects like interior architects. The leading architect mainly concerns the visual design of the entire building. Since many green products are relatively new, only the architect can perform significant research or find verification that the product is suitable and code-compliant. The Interior architect makes interior design and selects materials/products for interior use. The specification writer often helps architects with materials/products selection by collecting and classifying the information of materials/products. When the green product is suitable to use, the specification writer can incorporate that product in master specification and use it on other projects. Whenever possible and based on the contractual project arrangement, the contractor can give suggestions/recommendations to help architect when he or she didn't have enough information or experience about the materials and products. Moreover, because of the contractors' professional experiences about construction, it is possible for them to check whether the products are used for the right purpose. Also, during the process of material/product selection, the expert of materials characteristics must be the product manufacturers. To assist the architect, specification writer, or contractor with all their knowledge about materials/products, the product manufacturers should follow the technical standards like standards of American Society for Testing and Materials (ASTM) to test each product.

2.2. Typical Product Information for Green Materials

In the last section, we knew the basic knowledge of material/product selection and realized how difficult and time consuming the selection is. To address these problems, the industry provides many ways to help with the selection and try to make the selection easier. In the following paragraphs, two typical products information for green materials provided by the industry are included. One is green product standards and the other is green product directories. Both of them provide useful information of the green materials/products and keep adding more suitable materials/products to their database which help the process of material/product selections.

2.2.1 Green Product Standards

Green product standards are a wide range--from government regulations and rules to industry guidelines and the third party certification standards. The Environmental Protection Agency (EPA) Comprehensive Procurement Guidelines (CPG) authorized by the US Congress since 1995 is one of the examples of government regulations and rules. For the purpose of promoting the use of materials recovered from solid waste, CPG provides resources to participants to help them get enough information about recommended practices of buying recovered materials. The materials are grouped into eight categories from construction, landscaping, paper and transportation to vehicular, park and recreation, non-paper office and miscellaneous. The Carpet and Rug Institute (CRI), which provides science-based sources for the facts about carpet and rugs, is an example of industry guidelines. When it comes to third party certification standards of green materials, Forest Stewardship Council (FSC) cannot be ignored. From the first day FSC was formed in 1993, it devoted itself to creating a practice of sustainable forestry

worldwide. Forest Management Standards and the required management plan from every landowner make forests sustainable. FSC even become one of the standards addressed by LEED and FSC-certified products become necessary for sustainable building using wood products.

2.2.2 Green Product Directories

Mostly, green product directories are created based on the LEED requirements. There are more than 10 green product directories in the United States. Most of them provide searchable online database with difference categories of green products for choosing. Collecting green products which meet LEED certification is the main purpose of those green product directories. They serve as a connection between the architects, who need to choose appropriate green products, and the manufactures, which can provide these green products. The green product directories help the architects to make fast and better decisions about selecting materials and also help manufactures to sell their green products. An Atlanta-based company ecoScoreCard was formed in early 2007 and publishes ecoScoreCard which is one of the green product directories for architects when they select materials. In addition to providing the necessary and transparent product documentation for specification and the LEED rating system, experts of ecoScoreCard, update the information of the product they list as frequently as any changes happening in the LEED rating system.

However, no matter how the green product directories provide information about these products, there are still some limitations in the information available to the architects. . Lack of manufacturers all over the states, limited categories of products, high requirements of installations and some weather factors limit the options available to the architects. . Also,

because of the principals in the green product directories almost always refer to the LEED rating system, there are some environmental impacts beyond the consideration of LEED that are likely to be ignored.

2.3. Two Existing Rating Methods

The goal of this section is to review two currently used methods for the green material selection. Several organizations and private companies have established principles to determine how sustainable materials are and how to select them.

2.3.1 Green Building Rating Systems

Many developed countries in the world have their own green building rating systems. For example, the United Kingdom has Building Research Establishment Environmental Assessment Method (BREEAM), United States and Canada has Leadership in Energy and Environment Design (LEED), Germany has Deutsche Gesellschaft für Nachhaltiges Bauen (DGNB) and Japan has Comprehensive Assessment System for Built Environment Efficiency (CASBEE). They are all helping the owners and architects to build and design more sustainable buildings. In the United States, LEED covers the whole construction project process from the design phase to the operation phase. It is separated into New Construction (LEED NC), Existing Buildings: Operations & Maintenance (LEED EB: O+M), Core and Shell (LEED CS), Neighborhood Development (LEED ND). There is a specific rating system for each of these particular types of construction. Each of these rating systems contains five major sections: Sustainable Sites, Water Efficiency, Energy and Atmosphere, Materials and Resources, Indoor Environmental Quality. LEED also has an

alternative rating system for international projects. Since its inception in 1998, more than 32,271 projects around the world were certified by LEED, covering 1,875,454,951 square feet *(USGBC, usgbc.org, 04/20/2012)*.

2012 is a critical year for LEED since the new LEED-LEED 2012 will ballot the program during June and launched in November. USGBC is collecting all the public comments from professionals all over the world as this thesis report is being written. From March 1st to the 20th, the third public comment period was open. By comparing the latest version of LEED certification and the prior versions, the differences in the contents of the rating system and the draft scorecards are clear. In order to make LEED more popular and more open to the public, a website called *LEEDuser.com* has been established by the USGBC. *LEEDuser.com* is a forum for public comments which is one further step toward making a more reasonable and completed rating system for the future. As far as now, one of the major changes in the proposed LEED 2012 rating system is to increase the number of LEED AP; Accredited Professionals involved the project from one to three. Under the new GBCI-run accreditation exams are required. Another change refers to some easy-to-get points like installing a bike rack on the building site have become a prerequisite, graded together with other prerequisites. Also, recycled content in LEED raised its threshold. For example, materials made of steel will no longer receive certification points; instead, only "non-structural" steel materials will be allowed to be contributed. In addition, bio-based materials are still seek after and will be awarded certification points, however, just like steel, wood structures will be excluded from the rating. Moreover, low-emitting materials was graded as a general category based on the total performance of various materials before; however, the new rating system provides separately awards for different

materials, in this way, to inspire more effort devoted to the research of lower emitting materials to the environment.

It should be noted that with the proposed changes for Materials and Resources *(USGBC, LEED MR 2012 Changes)* credits will be more difficult to get in this section because of the two more prerequisites and the new adds-in mentioned above. **Figure 2** illustrates how LEED BD+C 2009 changes to 2012 after second public comments are collected, construction and demolition debris management will become one of the prerequisites, and the required credits of transparent non-structural materials as well as avoiding chemicals of concern in building materials are integrated into the new rating system. The LEED 2012, with the help of Environmental Product Declarations (EPDs), makes an all-out effort in creating transparent information of materials.

To conclude, the changes in Materials and Resources, LEED 2012 will become more transparent in product information thereby causing architects to feel challenged in the more transparent material selection condition than before. Whether their traditional ways of material selection are appropriate to the new requirements of LEED requires many more considerations and thoughts. As the information of product becomes more transparent and important, manufacturers need to provide more detailed information about their products to the architect, which means more tests and measurements will be carried on. Whether doing more will cause a rise of the product price also needs some considerations.

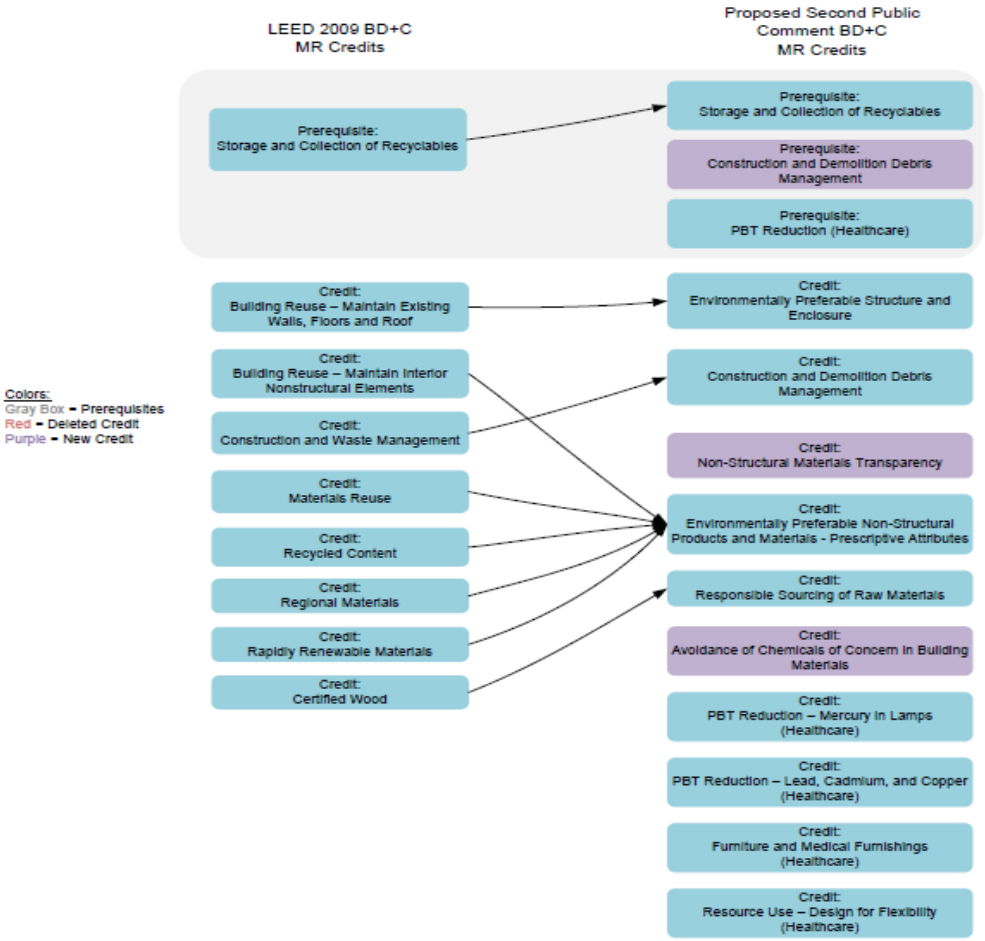

Figure 2-LEED BD+C-MR Credits 2009 and 2012

2.3.2 Life-Cycle Assessment and Life-Cycle Inventory

In this section, another common rating method, life-cycle assessment (LCA), was introduced. Also, the quantifying phase of LCA called Life-Cycle Inventory (LCI) was presented to support the introduction of LCA. And, three common tools applying LCA were presented in order to have a better understanding of LCA and LCA tools.

When awareness of protecting the environment increases, industries and businesses alike will be concerned about how their products affect the environment. Many of them have responded

to this awareness by providing “greener” products and using “greener” processes. Investigating a way to measure how sustainable the products are becomes a key issue. Life-Cycle Assessment (LCA) as a tool can help the manufacturers to figure out the long–term environmental performance of their products. This concept considers the entire life cycle of a product (Curran, 1996). United States Environmental Protection Agency (EPA) defined LCA as “a technique to assess the environmental aspects and potential impacts associated with a product, process, or service, by: compiling an inventory of relevant energy and material inputs and environmental releases; evaluating the potential environmental impacts associated with identified inputs and releases and interpreting the results to help you make a more informed decision to help architects with their decisions” *(Laboratory)*.

Life-Cycle Inventory (LCI) is the process of quantifying releases for the entire life cycle of a product, process, or activity. LCA is a method of the entire life cycle assessment of product and LCI is one of the most important phases of an LCA. All of releases of a product from raw material extraction through materials processing, manufacture, distribution, use, repair, maintenance, to disposal or recycling are quantified in LCI. Releases are including energy and raw materials, atmospheric emissions, waterborne emissions, solid wastes, etc. According to EPA’s 1993 document, “Life-Cycle Assessment: Inventory Guidelines and Principles,” and 1995 document, “Guidelines for Assessing the Quality of Life Cycle Inventory Analysis,”, four steps of a LCI were defined: “Develop a flow diagram of the processes being evaluated, develop a data collection plan, collect data and evaluate and report results (National Risk Management Research Laboratory and U.S. Environmental Protection Agency, 2006 May)”. There are several

LCA tools to aid designers in their analysis, we review three of them ATHENA, BEES and U.S. LCI Database.

2.3.2.1. ATHENA® Environmental Impact Estimator (ATHENA® EIE)

ATHENA® is a commercial software application that works like estimating software which requires user to fill in project information, such as structural design, assembly, envelope components, etc., and it takes into account the environmental impacts of resource extraction, recycled content, related transportation, on-site construction, regional variations in energy use, transportation and other factors, building type and assumed lifespan, maintenance repair and replacement effects, demolition and disposal, operating energy emissions and pre-combustion effect *(ATHENA)*. Also, after the general information about the project has been defined and the dimensions of structure such as the roof width, roof span, decking type, etc., have been identified, the user can select the materials for wall, opening and envelope in more detail. For example, a roof assembly indicated in **Appendix A**. Also, the user can add roof membrane, gypsum board, insulation, vapor barrier to the envelope to create an envelope system of a roof showed in **Appendix B**. After the user has entered all of information, you can generate a bill of materials report to view the quantity of each material showed in **Appendix C** and a report on environmental performance of the project which contains Energy Consumption, Acidification Potential, Global Warming Potential, HH Resp. Effects Potential, Ozone Depletion Potential, Smog Potential, Eutrophication Potential, and Weighted Resource Use. Moreover, ATHENA provides a good platform for comparing alternative designs of a project. An example of comparison of Smog Potential between Ethylene-Propylene-Diene-Monomer (EPDM) roofing and Polyvinyl-Chloride (PVC) roofing was showed in **Appendix D**. The user can add totally

different projects or could be the same project using different materials to compare. It's very helpful tool in comparing your baseline design with other alternatives.

2.3.2.2. BEES® (Building for Environmental and Economic Sustainability)

The BEES (Building for Environmental and Economic Sustainability) created by (NIST) National Institute of Standards and Technology Building and Fire Research Laboratory is another software applies LCI. It measures the environmental and economic performance of each product included in its product list by using LCA approach specified in the ISO 14040 series of standards. ISO 14040 series of standards describes the principles and framework in details for LCA users which guarantee the valid results of BEES. Compared to ATHENA, the results of BEES® are more understandable. It provides a score for each of the attributes being evaluated in terms of both environmental performance and economic performance, and combines these into an overall score for each green product, showed by **Figure 3** below. Also identical to ATHENA, all stages in the life of a product are analyzed; these include raw material acquisition, manufacture, transportation, installation, use and recycling and waste management.

How BEES online software works was presented using an example of selecting floor coverings. After the user clicked on the BEES online software to analyze building products, the webpage showed by **Appendix E**, he or she came to the analysis parameters section. In this section, the user needed to choose the weights for each environmental impact such as global warming, acidification, eutrophication, etc. The user can define the weights as he or she wants or chooses the optional weights provided by BEES stakeholder panel or EPA experts. Also, the user should define the percentage of environmental performance and economic performance, discount rate and the category of products. In this example, we defined 40% to the environmental

performance, 2.7 for the discount rate and chose floor coverings of interior finishes. Afterward, the user clicked “Next” button on the right corner, he or she came to the webpage of product selection showed in **Appendix F**. We selected Forbo Linoleum and Generic Nylon Carpet Tile for a comparison and required the system to compute and show the results for us. An example of the report showed in **Appendix G**.

Although BEES contains 230 building products, the selection of green materials is still limited. Neither customized products nor products beyond their product list can be selected and compared.

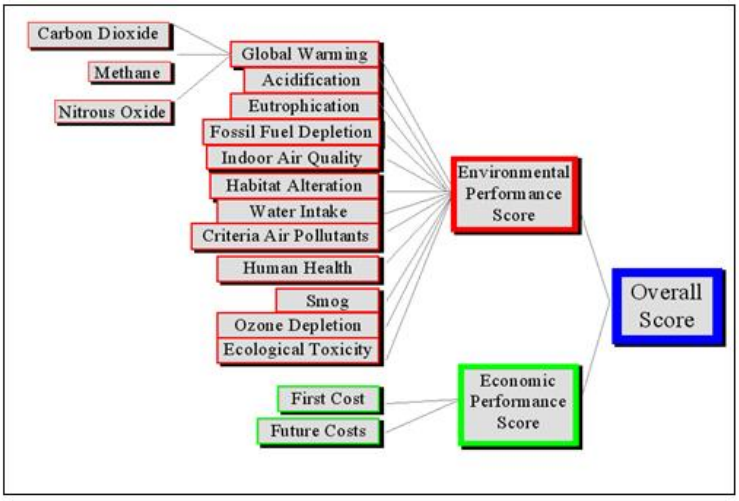

Figure 3-BEES Model *(Barbara Lippiatt, Anne Lanfield Greig and Priya Lavappa, 2011)*

2.3.2.3. U.S. Life-Cycle Inventory (LCI) Database

This database is created by National Renewable Energy Laboratory (NREL) and its partners. This publicly available database allows users to review objectively and compare analysis results that are based on similar data collection and analysis methods. It covers 19 categories in the industry from air, rail, and truck to mining, utilities and water.

In this chapter, some basic knowledge of material/product selection has been reviewed, such as the material/product selection process, all participants responsibility of material/product selection, information and methods the industry used in this process, etc. Both product information and existed rating methods help architects understand the products better and make their minds clear. However, LEED MR takes material/product selection as a whole by ignoring the selection of each material, especially for materials/products without LEED features. Moreover, even though materials with LEED features such as the recycled content, certified wood and regional materials did use less energy in certain phases of their life time than materials without LEED features, LEED MR doesn't care about the total life-cycle consumption of materials. And for now, although software of LCA and LCI fill the gap ignored by LEED, the limited amount of products in product lists and limited software design make customized software and freely information insert out of the question. Also, if LCA cannot combine with LEED requirements, it is not easy for the industry to accept such difficult and time-consuming assessment of each material/product.

Chapter 3 A Proposed Comprehensive Rating Method

3.1 A Proposed Comprehensive Rating Method

In order to address the issues noted in the previous chapter, it is herein proposed to develop the concept of a comprehensive rating method by combining two of the existing green material /product methods: LEED and BEES, and matching these to building performance as indicated in **Figure 4** below. In this way the initial LEED requirements for environmental performance of the product are tracked through its long-term impact to the environment during its life cycle. In addition, the economic performance measured by the initial and life cycle product costs are also incorporated in the assessment. Finally, the expected environmental and economic performance of the selected material/product is correlated to the expected design performance for the building. For example, the choice of the wall insulation products directly influences the thermal comfort of building. And the materials credits are sourced from LEED requirements and extended to the product life cycle. All of the requirements in LEED related to the materials are included in the material credits-LEED section.

Building Performance	LEED	BEES	Comprehensive Rating Method
Building Performance	Materials Credits-LEED	Environmental Performance	Environmental Performance
		Economic Performance	Economic Performance
			Building Performance
			Materials Credits-LEED

Figure 4-Three Components Integration

The proposed comprehensive rating method contains four sections: environmental performance, economic performance, building performance and material credits-LEED as shown in **Figure 5** below. The Environmental Performance is assessed through eight factors: fossil fuel consumption, acidification potential, global warming potential, human health respiratory potential, ozone depletion potential, smog potential, eutrophication potential and weighted resources use (water intake). Those factors are either internationally accepted or are referenced measures in various international standards documents related to buildings and their evaluations are from international standards such as ISO 21930 & ISO 21931 and International Green Construction Code. The Economic Performance of the material/product is measured through two cost factors: first cost and future costs of a product which cover the life cycle of the product. The Building Performance covers aesthetic aspect of a product like available colors and texture, energy efficiency, indoor air quality, thermal comfort, lighting comfort and acoustic comfort. A given product may not have all of them. As an example, an interior light fixture can only relate to the lighting comfort and aesthetic aspect of the building. The Material credits are often involved in the specifications of any project. Architects require each manufacturer to provide the information about their products and all the information related to the LEED requirements are enclosed in the material credits sheet (**Appendix I**). This information acknowledges states whether the product can reduce the heat island effect or not; whether it contains FSC certified wood or recycled content; whether the materials made of the product are regional materials or low emitting materials. For instance, PVC (Polyvinyl-Chloride) roof membrane produced by Sika Corporation contains 9% pre-consumer/ 1% post-consumer recycled content refer to the technical report of PVC roof membrane (Sika Corporation).

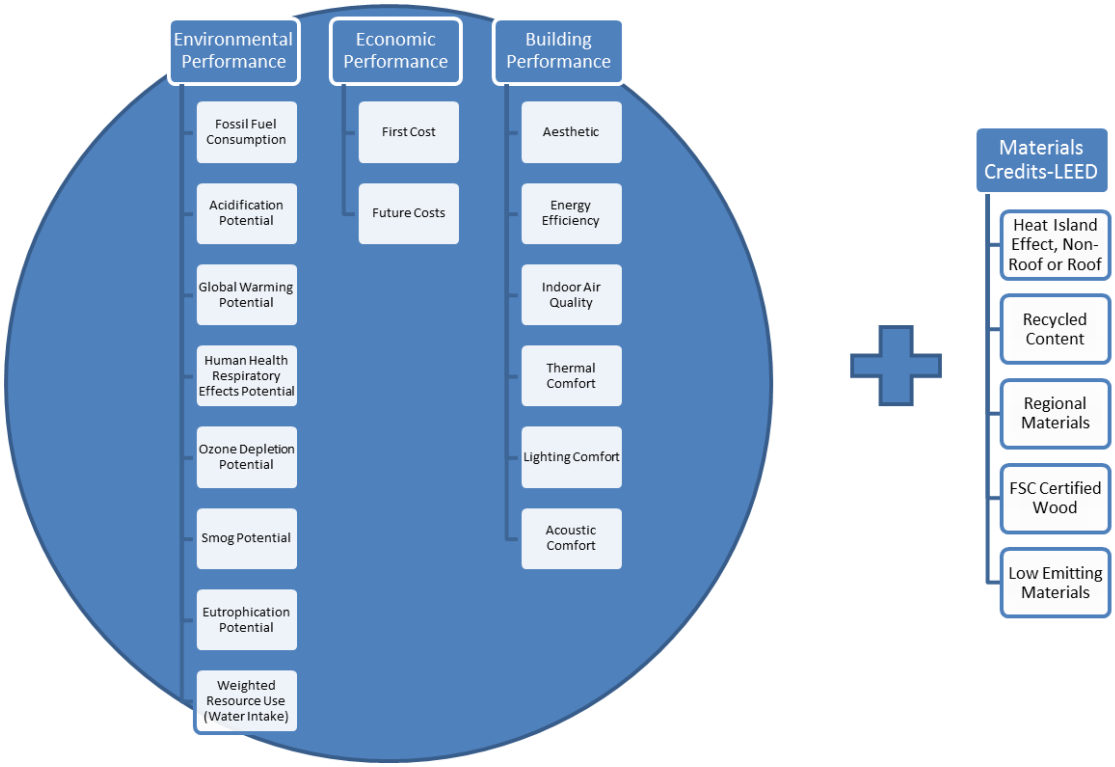

Figure 5-The Comprehensive Rating Method

3.2 Advantages of the Comprehensive Rating Method

From the comparison of the two existing rating methods and the comprehensive rating method, the latter method captures mainly three important aspects needed for a thorough evaluation of the "green" characteristics of any given material/product: it provides an integrated short term/long term approach for the selection of sustainable materials, it integrates ideology and practice, and it quantifies benefits and costs.

First, the comprehensive rating method includes almost every consideration the architect thinks about during material selection and all of the considerations are grouped into four categories. This ideology guides the architect to systematically and explicitly consider the requirements of environment, economy, building performance and LEED rating system. The

more comprehensive considerations the architects give to these factors, the better selections on materials they make. From the owner's perspective, their concerns about the economic performance of the project are also addressed. The first cost of the project must be controlled within the budget, but given considerations to long-term cost implications for the facility operation and maintenance provides a wider picture of the real economic benefits on the use of green products. Building performance is the second most important factor to the owner, the comprehensive approach allows to include considerations such as how the building looks like, how to reduce the energy bill and how comfortable the people feel when they go inside the building or stay in the building. The comprehensive rating method for material/product selection allows the architect to address most of the owner concerns.

Second, the part of requirements about the selection of materials embodied in the LEED rating system is involved in this comprehensive rating method. The combination of environmental performance, economic performance, building performance for the project together with material credits-LEED allows the architect to take a more comprehensive approach in improving the whole performance of the project by considering not only factors specific to the materials, but also from the standard used by the industry in measuring sustainability of a building. Any updating information about the industry and the requirements of LEED can be included in Material Credits-LEED section of the comprehensive rating method. Moreover, by the guide of this comprehensive rating method, it is easy for the architects who have not been involved in any sustainable building design to follow the important factors they should be concerned when they first select materials for sustainable building projects.

Third, when all the different considerations can be quantified, tradeoffs become less difficult. The comprehensive rating method is to provide a helpful way of measuring all of the tradeoffs for architects. Using this method, the architect can first assign an equal weight to each category when they only have a general understanding on the project. As the project development proceeds and the design becomes more detailed, architects can change these weights as they sees it fit based on the specific demands and objectives of the project. For environmental and economic performance, architects can refer to LCA tools and the weighted grade provided by the experts of EPA (Environmental Protection Agency). For material credits-LEED, architects can use the LEED rating system and its checklist. Only for the building performance, architects should refer to their experiences about the materials or ask contractors and manufacturers for such information.

The next chapter illustrates the application of the method through a case study.

Chapter 4 Case Study: WPI Sports and Recreation Center

In this chapter, information such as the specifications and design drawings of WPI Sports and Recreation center was used to provide a specific example of material/product selection applying the comprehensive rating method. The EPDM (Ethylene-Propylene-Diene-Monomer) roof and PVC (Polyvinyl-Chloride) roof derived from the specifications were used to simulate the architect's considerations on how to select material/product between a baseline design (PVC roof) and an alternative design (EPDM roof). These two roofs are analyzed separately and compared with each other under heading evaluation. Same weights for each factor are applied in the comparison to show how architects make material/product decision in the beginning of the project when they only had a general understanding on the project. The result of the comparison showed in the section of preliminary results. Afterwards, different weights for factors are enclosed under heading quantification in order to create the level of green of each material/product.

4.1 Case Introduction

The case study used in this thesis is the Sports and Recreation Center (Rec. Center) in Worcester Polytechnic Institute (WPI). The Rec. Center is under construction and is scheduled to open in August 2012. Rec. Center was chose by this thesis because of two reasons. The first one is that The Rec. Center was designed to attain at least LEED silver certification which is exactly the case of selecting sustainable materials. Second, information of the Rec. Center is

reachable since the writer of this thesis is studying in WPI. There are basically 12 LEED features[1] designed for Rec. Center:

- High efficiency lighting systems. The average lighting power density target was in the 0.6 to 0.8 W/SF range, compared with the code allowed 1.5w/sf. This was achieved using high efficiency ballasts and luminaires and LED lighting as appropriate.
- Energy saving ceiling mounted passive infrared and dual technology type sensors occupancy sensors, are used. These sensors automatically turn off lights and HVAC equipment after a pre-set time delay when the space is not occupied.
- A time clock / photocell lighting control system for exterior lighting systems.
- A desiccant wheel energy recovery ventilation system for all suites and apartments.
- Evaporative coolers on the ventilation units to supplement the air-cooled DX cooling system.
- ECM motors and a variable flow fan coil system for each HVAC unit serving each suite and apartment.
- Chilled beam systems for common, low occupancy areas.
- Substantial day lighting usage for the different occupancies in the building.
- Exterior shading components (non-mechanical) for the optimization of energy and day lighting.

[1] 12 LEED features as provided by the lead architect of the Rec. Center

- Building envelope options for optimizing building performance.
- Demand control ventilation systems.
- Solar thermal domestic water heating.

Besides the 12 LEED features, according to the LEED scorecard designed for the Rec. Center (see **Appendix H**) and the Material Credits Documentation Sheet of the specifications (see **Appendix I**), materials with LEED features such as heat island effect, recycled content, FSC certified wood, regional materials and low emitting materials are required.

4.2 Interview with Building Designers

In the morning of March 13th, 2012, we had a conference call with the building designers. It included three participants from the design team of the architect's firm: the lead architect, the interior architect and the specification writer. Before the conference a set of questions related to the material/product selection process were sent to these individuals for discussion. These questions are listed below.

Question1. Did you create a list of materials products for the Rec. Center that meet LEEDs requirements? If so, how it was created? What percentage of specified materials/products have you specified before? What percent of these are materials/products you have never specified before? To what extent did you get the owner/contractor's input in selecting these materials?

Question2. Do you use any other criteria beyond Material Credit Documentation Sheet (included in the specifications for the Rec. Center) to meet LEED standard in Material and Resources?

Question3. Do you have any internal rules (company procedures/policies) at your firm on how to go about product selection?

Question4. How do you make a final decision about products without LEED features and with LEED features?

Question5. What criteria do you apply when selecting products and sustainable products?

Question6. For green products, do you use any Life-Cycle Assessment tools to determine the green benefits of the material/product?

Question7. With regards to life-cycle assessment, do you use any of ATHENA, BEES, SETAC, ISO 14040 Environmental Management, U.S.Life-Cycle Inventory (LCI) Database?

Question8. Which--between cost and environmental--performance of a product is more important in selecting the material/product?

At the telephone conference, not all the questions were answered in the order they were sent, however a rich discussion around these questions took place. The following text describes the highlights on the most interesting aspects of this discussion.

First, building designers often hire consultants who have significant experience in selecting materials to assist them. The design team also collects information from their own project database on this regard and/or consults internally with their own design experts. When there are some brand new products which they are not familiar with, they typically conduct additional research on how those products are expected to perform and how they have been used in other projects. Also some manufacturers directly contact the firm's design professionals to promote the use of new products and supply written documentation for reference. Before

the design team makes a decision on which product to use, they always go for all the reachable information about the product and its materials, such information as online product technical report, literature about the materials, or LEED checklist to see how the product function and whether the product include requirements in LEED.

Secondly and with relation to the use of Life Cycle tools such as ATHENA and BEES, it was mentioned that they were aware of them but these are not used in all projects. When they do, ATHENA is their most common choice.

Third, the owner project preferences and budget limitations are the most important things the design team should always keep in mind. Whenever the designer chose material/product, he or she had to refer to the preferences of the owner and budget limitations. The designer made a lot of effort to balance the use of materials/products and the budget limitations.

Fourth, although during the design, the lead architect, the interior architect and the specification writer have different responsibility, they communicate with each other quite frequently. Meeting twice a day is the lowest requirements for them to talk about what they have done, what are needed to be done and what are the difficulties they met during the selection.

Fifth, any proposed material substitutions by contractors should be enclosed in the bidding documents in several locations such as specifications, bid form, agreement, etc. And if the substitutions include green properties such as volatile organic compounds (VOC), recycled content and distance from manufacture plant to construction site, that information must be clearly documented in the bidding documents for the design team to make decisions.

Sixth, the design team usually follows up in observing product performance in the long-term performance. However, such follow-up is quite difficult when they ask the feedback from occupants. And when the product has very poor perform during project operation, they will get complains from the owner or the occupants. An example for this is the bamboo flooring they used for previous project. The bamboo flooring is so soft that there will have dents when women wear high heal walking on it.

4.3 Compilation of Materials

As mentioned above the Recreation and Sports Center (Rec. Center) was designed to attain at least LEED silver certification. Therefore, in order to better understand how this design is reflected in the materials and products selected for this purpose, a product list attached in **Appendix J-Appendix FFFF** from the design specifications of this facility was compiled. The product list contains major five sections: Concrete showed in **Appendix J-Appendix R**, Masonry showed in **Appendix S-Appendix CC**, Steel showed in **Appendix DD-Appendix TT**, Wood showed in **Appendix UU-Appendix XXX** and Roof showed in **Appendix YYY-Appendix FFFF**. The total amount of products include in the specification of Rec. Center are more than 7000. The major five sections including 1000 products were selected these products are the necessary materials in every project and the common material/product of each section is limited to two or three.

The roof section was selected first for the purpose of illustrating the process of the comprehensive rating method and testing implementation of the proposed method. More specifically, two materials were evaluated: the base line design PVC (Polyvinyl-Chloride) roofing and an alternative design EPDM (Ethylene-Propylene-Diene-Monomer) roofing.

4.4 Evaluation

Following the steps of the proposed comprehensive method, the first one is to find out the environmental performance of each product. For this purpose, ATHENA Impact Estimator, one of LCA tools, was used to report the environmental performance. Then preceding sequentially, step by step the economic performance, building performance and material credits for PVC and EPDM roofing were evaluated by following specific rubrics for each factor.

4.4.1. Environmental performance

Two kinds of roofing were evaluated according to the eight factors involved their product life-cycle as shown in **Figure 6** below:

Item	Measurements	EPDM Roofing	Unit	PVC Roofing	Unit
1	Acidification	21,500	millimoles	54,500	millimoles
2	Ozone Depletion Potential	0.0000009	Grams	0.00000001	Grams
3	Eutrophication Potential	2	Grams	2	Grams
4	Global Warming Potential	7,160	Grams	9,360	Grams
5	Fossil fuel Consumption	144.06	MegaJoules	214.94	MegaJoules
6	Human Health Respiratory Effects Potential	9	Grams	20	Grams
7	Smog Potential	20	Grams	30	Grams
8	Weighted Resource Use	9.41	L	11.95	L

Figure 6-Environmental Performance in Life-Cycle[2]

All of the numbers above are derived from ATHENA Impact Estimator for Building. Since the final report from ATHENA cannot show the exactly amount of consumption with the chart, instead, several software adjustments are made to show the consumption beside the project name. In **Appendix GGGG-Appendix NNNN**, the exactly amount of consumption for each factor

[2] Figure 6 is source from ATHENA Impact Estimator for Building

of 1 square foot roof was showed. Take the 20 grams smog potential consumption of EPDM roof membrane for an example. Smog potential consumption is measured by NOx equivalent mass; the 20 grams smog potential consumption means EPDM roofing release 20 grams NOx to the environment in its life time. (More information refers to Athena Impact Estimator for Buildings V 4.1 Software and Database Overview *(ATHENA Impact Estimator for Buildings, 2010))*. These different units as indicated in **Appendix GGGG-Appendix NNNN** are transferred into the units shown in **Figure 6** above in order to compare with the yardstick.

4.4.2. Economic Performance

First cost

According to online roof price calculator, EPDM roofing cost less than PVC roofing. EPDM roofing cost around $180,000 and PVC roofing cost around $250,000 for a 107ft×248ft roof ($6.78/S.F. for EPDM roof and $9.42/S.F. for PVC roof) which is a low slope roof and needs R-20 insulation. The dimension of the roof was got from the architectural drawings of the Rec. Center showed in **Appendix OOOO and Appendix PPPP**. Referring to the specification of Rec. Center, “H. Roofing system insulation shall provide a five year aged "R" value of 20.0, unless otherwise indicated on Drawings. I. For tapered insulation the "R" value stated is to be considered an overall average "R" value.”, and “J. Energy Performance: Provide roofing system that is listed on the DOE's ENERGY STAR "Roof Products Qualified Product List" for low -slope roof products.”

Future Cost

According to online roof price calculator in MA *(Roofing Calculator)*, PVC roofing has energy savings in MA (around $4,000) and has an expected life for more than 30 years. However,

EPDM roofing has no energy savings and its life time is 10-15 years as shown in **Appendix QQQQ**.

When compare the life-cycle cost of EPDM roof and PVC roof, formula $DPV = \frac{FV}{(1+i)^n}$ from discounted cash flow analysis in finance was used to calculate the discounted present cost of EPDM roof and PVC roof. i is the inflation rate which equal to 2.55% sources from **Appendix RRRR and Appendix SSSS.** Then, the total life-cycle discounted cost of EPDM roof is $\mathrm{P} = \frac{180{,}000}{(1+2.55\%)^{15}} + 180{,}000 = 303{,}377.95$ and the total life-cycle discounted cost of PVC roof is $\mathrm{P} = \frac{-4000}{(1+2.55\%)^{30}} + 250{,}000 = 248{,}120.7$. Therefore, the sub-result of economic performance is that PVC roof cost less than EPDM roof in their 30 years life time.

4.4.3. Building Performance

Building performance contains aesthetic aspect, energy efficiency, indoor air quality, lighting comfort, thermal comfort and acoustic comfort which directly relate to the occupants' feeling. Since the use of roof doesn't relate to indoor air quality, lighting comfort and acoustic comfort, these factors are not involving in building performance of roof.

Aesthetic Aspect

Referring to product information, PVC membrane provides several colors for the roof; however, EPDM membrane only provides white on black. From this point, the selectable colors PVC membrane provides make other materials such as exterior wall to have more optional colors which meets the aesthetic need of the Rec. Center better. Even though the color of the roof

wasn't explicitly specified in the specifications, the architect can choose a color from several available colors to fit the color of the building façade and the surrounding environment.

Energy Efficiency

Energy Efficiency is considered the energy saving of each year or the life time of the product to ensure its durability. As mentioned before, PVC roofing can save around $4,000 energy for the Rec. Center. According to the data of U.S. Energy Information Administration *(EIA, 2012)*, the average cost per kilowatt hour (KWH) for all sectors and all kinds of project was 9.44 cents. Therefore, the PVC roofing can save around 42372 KWH for its 30 years life time. Comparing PVC and EPDM roofing in energy efficiency, PVC overrides EPDM roofing not only in the energy saving, but also for its twice longer life time.

Thermal Comfort

R-value must be the best measurement for thermal comfort. The Rec. Center requires a five year 20 R-value in the specifications for the roof which both PVC and EPDM roofing must meet.

4.4.4. Material Credits-LEED

Heat Island Effects

LEED uses Solar Reflectance Index (SRI) to measure the extent of heat island effect. From the product technical report of PVC and EPDM membrane, SRI of Sarnafil G410 PVC white membrane from Sika Sarnafil is 104 and SRI of Non-reinforced White EPDM white on black membrane from Firestone is 105.

Recycled Content

According to the product technical report of PVC membrane *(Sika Corporation)* and EPDM membrane *(Firestone Building Products)*, PVC membrane 10' and 5' can provide 9% pre-consumer or 1% post-consumer recycled content but EPDM membrane cannot provide any recycle content.

Regional Materials

PVC membrane produced by Sika Sarnafil Inc. is sold directly to a select group of trained, authorized contractors. In New England region, they have almost 24 elite contractors who not only provide the PVC membrane to their customers, but also provide construction and installation service. However, EPDM produced by Firestone can only produce in Prescott, AR.

Low Emitting Materials

The specifications of Rec. Center require the VOC (volatile organic compounds) limits by using EPA Method 24 which attached in **Appendix TTTT**. Requirements for PVC and EPDM roofing are same.

4.5 Preliminary Results

In the step by step evaluation for the four sections above, preliminary results can be achieved. Among these evaluations, not all of them are easy to compare between EPDM and PVC roof. Some of them have the specific results from a specific method, and some are not. When the architect only knows general information of a project, he or she may just place a check mark to show which material is better than the other. The results as shown in tables below are the initial results under this condition. After getting the sub results from each section, the final result can be made.

For the marks below, the one which placed a check mark means the better one. When the analyzed result are same, both of them were put letter “same”. And “--“was placed to show the factors are not relevant to the selection of EPDM roof or PVC roof.

Environmental Performance in Life-Cycle			
Number	Factors	EPDM Roofing	PVC Roofing
1	Ozone Depletion Potential		√
2	Eutrophication Potential	same	same
3	Global Warming Potential	√	
4	Fossil Fuel Consumption	√	
5	Human Health Respiratory Effects Potential	√	
6	Smog Potential	√	
7	Weighted Resource Use	√	
8	Acidification Potential	√	
	Sub-result	√	

Table 1-Environmental Performance in Life-Cycle-EPDM and PVC Roofing

Economic Performance in Life-Cycle			
Number	Factors	EPDM Roofing	PVC Roofing
1	First Cost	$6.78/S.F.(√)	$9.42/S.F.
2	Future Cost		$4000 for 30 Year(√)
	Sub-result	$303,377.95	$248,120.73 (√)

Table 2-Economic Performance in Life-Cycle-EPDM and PVC Roofing

Building Performance			
Number	Factors	EPDM Roofing	PVC Roofing
1	Aesthetic Aspect		√
2	Energy Efficiency		√
3	Indoor Air Quality	--	--
4	Thermal Comfort	same	same
5	Lighting Comfort	--	--
6	Acoustic Comfort	--	--
	Sub-result		√

Table 3-Building Performance-EPDM and PVC Roofing

Materials Credits-LEED			
Number	Factors	EPDM Roofing	PVC Roofing
1	Heat Island Effects	√	
2	Recycled Content		√
3	Regional Materials		√
4	FSC Certified Wood	--	--
5	Low Emitting Materials	same	same
	Sub-result		√
	Final Result (with equal weight for each factor)		**√**

Table 4-Material Credits-LEED-EPDM and PVC Roofing

In conclusion, with the equal weight for each factor of the comprehensive rating method, PVC roof is better than EPDM roof. The evaluation and its preliminary result is an example to show how the comprehensive rating method works in the beginning of the project when the architect is not able to give the specific weights for each factor.

4.6 Quantification

Although doing research on green materials/products is the responsibility of each architect, with lots of tasks to do architects may not have time to do material/product research. Quantifying the result of material/product selection, first help the architect to have a clear mind and to think about the priority of each factor by giving weights to each factor. Also, guide

them to select materials using the level of green for each material/product. The level of green is a range of scores that can be created for each material/product. For the method of quantification, weighted evaluation approach was used. This approach is commonly applied in value engineering when a project has several available design alternatives to choose. Since the principle of this approach is quite similar to the selection of different materials/products with the same function, the approach will be used for materials/products selection. Moreover, this approach involves the weights and performance rating which can be very helpful to get the level of green based on the final scores of each material/product.

Basically, the process of quantification sourced from weighted evaluation approach (Hunter, 2002) contains the following four steps:

1. Identify decision criteria based on project objectives and requirements.

2. For each criterion *i* define: – Weighting factor Wi based on preferences and trade-off analyses.

3. For each solution alternative *j* calculate:

– Performance rating Pij = rating on a scale of 1 (low) to 10 (high).

– Total Performance =∑ Wi Pij

– Value = Total Performance/Cost

4. Use Value to select amongst alternatives.

In the quantification of the comprehensive rating method, the first step of weighted evaluation approach was addressed before. Decision criterions of weighted evaluation approach are factors in the comprehensive rating method such as smog potential in the environmental performance section, first cost in the economic performance section, thermal comfort in the

building performance section, and FSC certified wood in the material credits-LEED section, etc. Then the second step becomes identify weight for each factor involved in the evaluation. This is done by comparing the relative importance between two factors in one section. Take environmental performance for example, the rating is from the BEES Normalization Values indicated by **Figure 9** developed by U.S. EPA Office of Research and Development. The third step is to figure out the performance rating Pij for each factor. The rating is on a scale of 1 (low) to 10 (high). Also in the third step, the results, Wi and Pij, from previous two steps are put together and multiply to get the weighted performance of each factor. Then the total weighted performance of particular product is obtained by adding all the weighted performance of each factor. And the total weighted performance of each product called “the level of green”. Refer to the principle of the approach, the lower score means the higher level of green. From this point, there is no need to calculate the value mentioned in the step four of the weighted evaluation approach since the comprehensive rating method embodied the life-cycle cost of each material/product in economic performance section.

The following sections illustrate, the process discussed above to determine how “the level of green” is created using the example of one product of Ethylene-Propylene-Diene-Monomer (EPDM) roof membrane called EcoWhite EPDM by Firestone Building Products.

4.6.1. Environmental Performance Scores

As defined above, the second step is to identify the weights for each factor. The process of quantification is staring from the second step. In the environmental performance section of this method, the weights of the factors are sourced from the weights from BEES which were

concluded from the opinions of EPA Science Advisory Board. In **Figure 7**, there are 12 factors and 12 corresponding weights from BEES provided by EPA which are different from the 8 factors from ATHENA. The comparison of these differences was indicated in **Figure 8**. Because the comprehensive rating method uses LCA tools, BEES and ATHENA, and the environmental factors in this method must be consistently; therefore, the same 8 factors are used in the comprehensive rating method and the other 4 factors (highlight in **Figure 8**) were not included. But the only problem here is to transfer the weights for 12 factors into weights for 8 factors. The weights for 12 factors of BEES are showed again in **Table 5**. The weights for the 8 factors based on the weights of 12 factors are calculated and normalized to 100 points as shown by **Table 6**. For example, the raw score of Ozone depletion potential is 5 (see **Table 6**) which is same as the weight of ozone depletion potential in **Table 5**. And the weight 9 of ozone depletion potential in **Table 6** is equal to (5/56)*100 which is (raw score/total raw scores)*100.

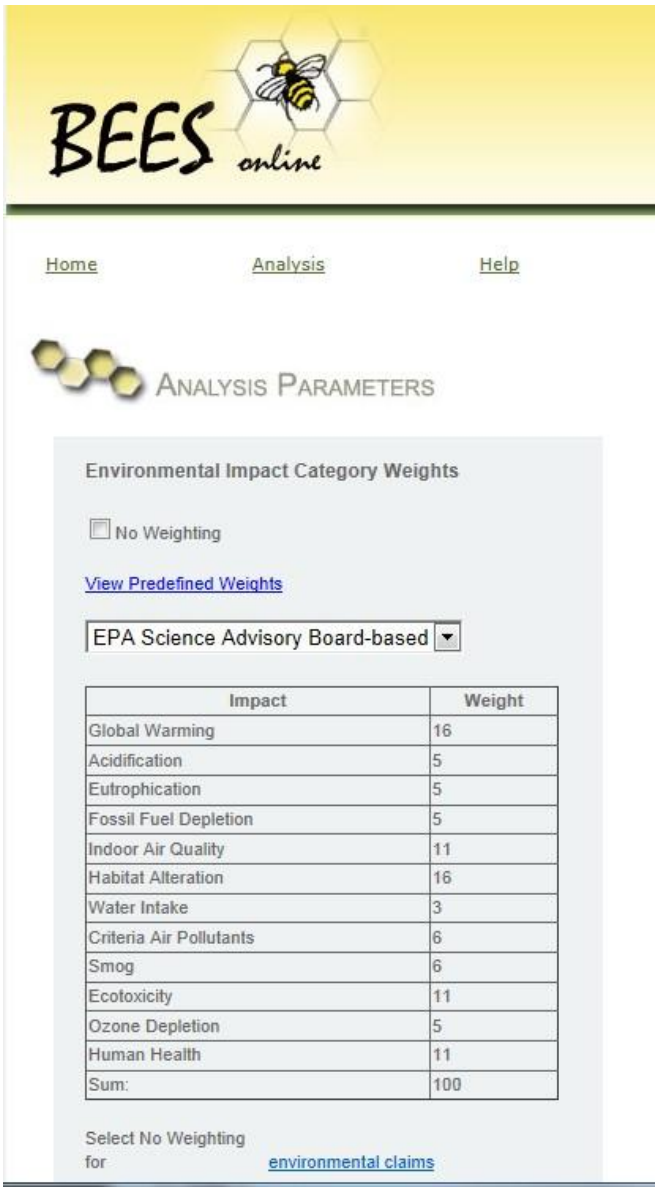

Figure 7-Environmental Performance Weights of BEES

Environmental Performance			
Number	Factors From ATHENA	Factors From BEES	Number
1	Ozone Depletion Potential	Ozone Depletion Potential	1
2	Eutrophication Potential	Eutrophication Potential	2
3	Global Warming Potential	Global Warming Potential	3
4	Fossil Fuel Consumption	Fossil Fuel Consumption	4
5	Human Health Respiratory Effects Potential	Human Health Respiratory Effects Potential	5
6	Smog Potential	Smog Potential	6
7	Weighted Resource Use (Water Intake)	Weighted Resource Use (Water Intake)	7
8	Acidification Potential	Acidification Potential	8
		Habitat Alteration	9
		Criteria Air Pollutants	10
		Ecotoxicity	11
		Indoor Air Quality	12

Figure 8-Comparison of 7 Factors and 12 Factors

Environmental Performance Weights of BEES	
Item	*Weight*
A. Ozone Depletion Potential	5
B. Eutrophication Potential	5
C. Global Warming Potential	16
D. Fossil fuel Consumption	5
E. Human Health Respiratory Effects Potential	11
F. Smog Potential	6
G. Weighted Resource Use(Water Intake)	3
H. Acidification	5
TOTAL	**56**

Table 5-Weights for 7 Factors from BEES

Environmental Performance		
Item	*Raw Score*	*Weight*
A. Ozone Depletion Potential	5	9
B. Eutrophication Potential	5	9
C. Global Warming Potential	16	29
D. Fossil fuel Consumption	5	9
E. Human Health Respiratory Effects Potential	11	20
F. Smog Potential	6	11
G. Weighted Resource Use	3	5
H. Acidification	5	9
TOTAL	**56**	100

Table 6-Environmental Performance Weights

Then the third step is to create a performance rating with a scale of 1 to 10 to determine the specific rating for the factors of each product. According to the scoring method of BEES (The National Institute of Standards and Technology (NIST)), Normalization Values in **Figure 9** can be the yardstick and are the highest ratings for the performance rating. The performance rating equals 10 times of the ratio of the consumption of each factor to the highest rating showed in **Table 7**. For example, the performance rating of item G weighted resource use (water intake) in **Table 9** is 0.000177561, which is calculated from dividing the consumption of each factor by the highest rating in **Table 8** (9.41/529,957.75)*10. Therefore, the weighted performance in **Table 9** of weighted resource use is 0.0005912 which is the result of multiplying 0.000177561 by 5 which is the item weight.

BEES Normalization Values

Impact	*Normalization Value*
Global Warming	25 582 640.09 g CO_2 equivalents/year/capita
Acidification	7 800 200 000.00 millimoles H+ equivalents/year/capita
Eutrophication	19 214.20 g N equivalents/year/capita
Fossil Fuel Depletion	35 309.00 MJ surplus energy/year/capita
Indoor Air Quality	35 108.09 g TVOCs/year/capita
Habitat Alteration	0.00335 T&E count/acre/capita[a]
Water Intake	529 957.75 liters of water/year/capita
Criteria Air Pollutants	19 200.00 microDALYs/year/capita
Smog	151 500.03 g NO_x equivalents/year/capita
Ecological Toxicity	81 646.72 g 2,4-D equivalents/year/capita
Ozone Depletion	340.19 g CFC-11 equivalents/year/capita
Human Health	158 768 677.00 g C_7H_7 equivalents/year/capita

[a] One acre is equivalent to 0.40 hectares.

Figure 9-BEES Normalization Values

Environmental Performance Rating		
Item	*Unit of Measurement*	0-1(result times 10 to get 1-10 rating scale)
A. Ozone Depletion Potential	g	0-340.19
B. Eutrophication Potential	g	0-19,214.2
C. Global Warming Potential	g	0-25,582,640.09
D. Fossil fuel Consumption	MJ	0-35,309
E. Human Health Respiratory Effects Potential	g	0-158,768,677
F. Smog Potential	g	0-151,500.03
G. Weighted Resource Use (Water Intake)	L	0-529,957.75
H. Acidification	millimoles	0-7,800,200,000

Table 7-Environmental Performance Rating Parameters

Item	Measurements	EPDM Roofing	Unit	Yardstick	Unit
1	Acidification	21,500	millimoles	7,800,200,000.00	millimoles
2	Ozone Depletion Potential	0.0000009	Grams	340.19	Grams
3	Eutrophication Potential	2	Grams	19,214.20	Grams
4	Global Warming Potential	7,160	Grams	25,582,640.09	Grams
5	Fossil fuel Consumption	144.06	MegaJoules	35,309.00	MegaJoules
6	Human Health Respiratory Effects Potential	9	Grams	158,768,677.00	Grams
7	Smog Potential	20	Grams	151,500.03	Grams
8	Weighted Resource Use	9.41	L	529,957.75	L

Table 8-Environmetal Performance Report from ATHENA

Environmental Weighted Performance				
Item	*Item Weight*	*Unit of Measurement*	*Performance Rating*	*Weighted Performance*
A. Ozone Depletion Potential	9	g	2.64558E-08	0.0000002
B. Eutrophication Potential	9	g	0.001040897	0.0092937
C. Global Warming Potential	29	g	0.002798773	0.0799649
D. Fossil fuel Consumption	9	MJ	0.040799796	0.3642839
E. Human Health Respiratory Effects Potential	20	g	5.66862E-07	0.0000111
F. Smog Potential	11	g	0.001320132	0.0141443
G. Weighted Resource Use	5	g	0.000177561	0.0009512
H. Acidification	9	millimoles	2.75634E-05	0.0002461
TOTAL PERFORMANCE				**0.468896**

Table 9-Environmental Weighted Performance of EPDM Roof Membrane

4.6.2. Economic Performance Scores

Economic Performance	*B. Future Cost*
A. First Cost	*A*
B. Future Cost	[redacted]

Table 10-Economic Performance Weighting

In economic performance section showed in **Table 10**, first cost and future cost need to be weighted. Compare first cost to future cost, the first cost typically overrides the future cost unless the life time of a project is between 5 to 10 years refer to the leading architect of the Rec. Center. Then the raw score in **Table 11** shows the weights of two factors. First cost and future cost comprise the total life cycle cost of each product.

Economic Performance		
Item	*Raw Score*	*Weight*
A. First Cost	*1*	*50*
B. Future Cost	*1*	*50*
TOTAL	*2*	*100*

Table 11-Economic Performance Weights

After having the weights for each factor, it is time to figure out the rating parameters. First the unit of measurements for first cost and future cost are dollar per square foot. Also according to RSMeans online version (RSMeans), the cost of most products is below 100 dollar per square

foot, therefore the 10 scales with the same break down extent 10 are showed in **Table 12**. In the case of EPDM roof membrane, the cost of that is around $6.78/S.F. which is in the range of 0 to 9 as shown in **Table 12**, so the performance rating of EPDM roof membrane's first cost is 1. Using the same way, the future cost is 1. The result of EPDM roof membrane's economic weighted performance is showed in **Table 13**.

Economic Performance Rating											
Item	*Unit of Measurement*	1	2	3	4	5	6	7	8	9	10
A. First Cost	$/sf	0-9	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90+
B. Future Cost	$/sf	0-9	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90+

Table 12-Economic Performance Rating Parameters

Economic Weighted Performance				
Item	*Item Weight*	*Unit of Measurement*	*Performance Rating*	*Weighted Performance*
A.First Cost	50	$/sf	1	50
B. Future Cost	50	$/sf	1	50
TOTAL PERFORMANCE				**100**

Table 13-Economic Weighted Performance of EPDM Roof Membrane

4.6.3. Building Performance Scores

In the building performance section, five factors needed to be weighted first. The weights which showed in **Table 14** were the result of some discussions between the writer and the design team of the Rec. Center. And the result is concluded in **Table 15** using the same method mentioned in environmental performance scores.

The building performance rating parameters were shown in **Table 16**, the parameters and possible results were analyzed one by one.

First, since the aesthetic aspect includes the available colors and textures for each product, the online product categories for most of the products were used. After analyzing, the results are mostly range from 1 to 10 available colors and textures. Then in order to keep the principle that the lower rating, the better performance, 1 was set as more than 10 available options until 10 was set as only 1 option.

Second, the energy efficiency is measured by the electric savings during operation and maintenance. 1 was set as more than $10000 (105932 KWH) electric savings until 10 was set as less than $1999 (21175 KWH) electric savings.

Third factor, indoor air quality, is measured by the Section 4 through 7 of ASHRAE Standard 62.1-2010 which is commonly used in the rating system of LEED by USGBC as the minimum requirement of sustainable buildings. A Product which meets the requirement of this standard can get 1 score, but when product doesn't meet the standard, it will be given 10 score.

For the next three factors, thermal comfort can be measured by R value; acoustic comfort and lighting comfort are measured by their relative standards. The most possible R value is from the range of R 0 to R 100. Therefore, under the principle of the comprehensive rating method, 1 was set as R 100 to R 90 until 10 was set as R 9 to R 0.

With all the parameters of building performance mentioned above, the rating of each factor for EPDM roof can be obtained. According to product technical report, the color of EPDM membrane is only white on black. Its energy saving is 0. The standard of indoor air quality doesn't require the performance of roof membrane but its R value 20 is required by the specification. Then using all of information of EPDM roof, the performance rating for each

factor is indicated in **Table 17**. For example, because the R-value of EPDM roof was required to be 20 in the specifications of the Rec. Center, and 20 is within the range of 29 to 20 (**Table 16**), so that the corresponding rating is 8.

Building Performance	B. Energy Efficiency	C. Indoor Air Quality	D. Thermal Comfort	E. Lighting Comfort	F. Acoustic Comfort
A. Aesthetic Aspect	B	C	D	E	F
B. Energy Efficiency		B	B	B	B
C. Indoor Air Quality			C	C	C
D. Thermal Comfort				D	D
E. Lighting Comfort					E

Table 14-Building Performance Weighting

Building Performance		
Item	*Raw Score*	*Weight*
A. Aesthetic Aspect	1	6
B. Energy Efficiency	5	31
C. Indoor Air Quality	4	25
D. Thermal Comfort	3	19
E. Lighting Comfort	2	13
F. Acoustic Comfort	1	6
TOTAL	16	100

Table 15-Building Performance Weights

Building Performance Rating											
Item	*Unit of Measure*	1	2	3	4	5	6	7	8	9	10
A. Aesthetic Aspect	Availability	10+	9	8	7	6	5	4	3	2	1
B. Energy Efficiency	$/sf	10000+	9999-9000	8999-8000	7999-7000	6999-6000	5999-5000	4999-4000	3999-3000	2999-2000	1999-0
C. Indoor Air Quality	Qualification	meet Section 4 through 7 of ASHRAE Standard 62.1-2010									doesn't meet
D. Thermal Comfort	R Value	100-90	89-80	79-70	69-60	59-50	49-40	39-30	29-20	19-10	9-0
E. Lighting Comfort	Qualification	meet lighting requirements of ASHRAE Standard 90.1-2010									doesn't meet
F. Acoustic Comfort	Qualification	meet ISO 91.120.20: Aoustices in building. Sound insulation/meet ISO 15665: Acoustices--Acoustic insulation for pipes, vales and flanges									doesn't meet

Table 16-Building Performance Rating Parameters

Building Weighted Performance				
Item	*Item Weight*	*Unit of Measurement*	*Performance Rating*	*Weighted Performance*
A. Aesthetic Aspect	6	Availability	10	63
B. Energy Efficiency	31	$/sf	10	313
C. Indoor Air Quality	25	Qualification	0	0
D. Thermal Comfort	19	R Value	8	150
E. Lighting Comfort	13	Qualification	0	0
F. Acoustic Comfort	6	Qualification	0	0
TOTAL PERFORMANCE				**525**

Table 17-Building Weighted Performance of EPDM Roof Membrane

4.6.4. Material Credits-LEED Scores

In the last section, material credits-LEED, all six factors are sourced from LEED requirements about the material. The first factor, heat island effects for roof or non-roof building, is from the Sustainable Sites (SS) Credit 7 of LEED rating system. Recycled content, regional materials, FSC (Forest Stewardship Council) certified wood and rapidly renewable materials are derived from Materials and Resources (MR) Credit 4, 5, 6 and 7 of LEED rating system. The last one, low

emitting materials, is from Indoor Environmental Quality (IEQ) Credit 4. **Table 18** shows the weighting process of each factor and **Table 19** presents the weights of each factor discussed with the leading architect of Rec. Center.

The performance rating parameters are presented in **Table 20**.

LEED rating system measures how much solar reflectance index (SRI) a roof or non-roof system has and requires SRI at least 29. Therefore, 1 in the scale was set as 90 to more than 100 SRI and 10 was set as 0 to 9 SRI. And then the break down extent is 10.

Recycled content in LEED rating system is measured by the sum of postconsumer recycled content plus ½ of the pre-consumer content and LEED rating system requires it should be at least 10% or 20%. Also it is possible that a product may not contain any recycled content or it can provide 100% of postconsumer plus ½ of the pre-consumer recycled content. According to that, the scale range from 0% to 100% with 10% increment was designed.

For regional materials, LEED requires building materials or products to be extracted, harvested or recovered, as well as manufactured, within 500 miles. In order to grade complying with the LEED requirement, from 401 miles to 500 miles the grade was set as 5. From 0 to 400 miles and from 500 to 900 miles, the grades were quantified with 100 miles increments. In other words, the grades were set respectively from 1 to 4 and 6 to 9. Anything above 900 miles was graded as 10.

The left three factors were graded based on the qualification source from LEED requirements. Wood-based materials and products should be certified in accordance with the FSC's principles

and criteria. Rapidly renewable materials are produced with the materials that are harvested within 10 years. Materials such as adhesive, painting, and sealant should meet the particular requirements in IEQ Credit 4: Low-Emitting Materials.

When took EPDM roof membrane for an example, the grade of each factor is showed in **Table 21**. According to the product technical report, the SRI of EPDM roof membrane is 105, which was graded as 1 for the EPDM roof. Because EPDM membrane cannot provide any recycled content, it got 10 for recycled content factor. For the regional materials, EPDM roof membrane got 10 in this factor since its manufacturer Firestone can only produce EPDM membrane in Prescott, AR. Moreover, EPDM roof membrane does not involved in any LEED requirements of low emitting materials, rapidly renewable materials or FSC certified wood, so they all got 0.

Material Credits-LEED	B. Recycled Content	C. Regional Materials	D. FSC Certified Wood	E. Low Emitting Materials	F. Rapidly Renewable Mat
A. Heat Island Effects	B	C	D	E	F
B. Recycled Content		B	B	E	B
C. Regional Materials			D	C	C
D. FSC Certified Wood				E	D
E. Low Emitting Materials					E

Table 18-Material Credits-LEED Weighting

Material Credits-LEED		
Item	*Raw Score*	*Weight*
A. Heat Island Effects	1	6
B. Recycled Content	4	25
C. Regional Materials	3	19
D. FSC Certified Wood	3	19
E. Low Emitting Materials	4	25
F. Rapidly Renewable Materials	1	6
TOTAL	16	100

Table 19-Material Credits-LEED Weights

Material Credits-LEED Performance Rating											
Item	*Unit of Measurement*	1	2	3	4	5	6	7	8	9	10
A. Heat Island Effects	SRI Value	90-100+	80-89	70-79	60-69	50-59	40-49	30-39	**20-29 (LEED require >29)**	10-19	0-9
B. Recycled Content	%	90-100	80-89	70-79	60-69	50-59	40-49	30-39	**20-29**	**10-19**	0-9
C. Regional Materials	miles	0-100	101-200	201-300	301-400	**401-500**	501-600	601-700	701-800	801-900	901+
D. FSC Certified Wood	Qualification	contain FSC certified wood									doesn't contain
E. Low Emitting Materials	Qualification	meet LEED requirements									doesn't meet
F. Rapidly Renewable Materials	Qualification	harvested within a 10-year or shorter cycle.									harvested more than 10-year

Table 20-Material Credits-LEED Rating Parameters

Material Credits-LEED Weighted Performance				
Item	*Item Weight*	*Unit of Measurement*	*Performance Rating*	*Weighted Performance*
A. Heat Island Effects	6	SRI Value	1	6
B. Recycled Content	25	%	10	250
C. Regional Materials	19	miles	10	188
D. FSC Certified Wood	19	Qualification	0	0
E. Low Emitting Materials	25	Qualification	0	0
F. Rapidly Renewable Materials	6	Qualification	0	0
TOTAL PERFORMANCE				**444**

Table 21-Material Credits-LEED Weighted Performance of EPDM Roof Membrane

4.6.5. Definition of “the level of green”

After the calculation/quantification of each and every single factor involved in the comprehensive method grades of four sections, it is possible now to make a final conclusion of how sustainable the EPDM roof membrane is. In order to combine the results from four sections, the weight of each section is needed. Using the same weighted evaluation approach, the raw score as shown in **Table 23** is concluded by the times they appeared in **Table 22**. The weights of four sections were presented in **Table 23**, which are normalized to 100%. After having the weight for each section, total performance of EPDM roof presented in **Table 24** is calculated by section total performance multiply each section weight and divided by 100. The section total performance is source from weighted performance scores of each section. The score of the product total performance shows "the level of green" of the product. Compare to other products of roof membrane, the EPDM roof membrane has a lower level of green.

According to the principle of the comprehensive rating method, the lower score of product total performance means the higher level of green for this product. However, how sustainable this EPDM roof membrane is, with 244.71 total performance needed to be compared with other roof membrane products in the industry.

Four Sections Compare	B. Economic Performance	C. Building Performance	D. Material Credits-LEED
A. Environmental Performance	B	C	D
B. Economic Performance		B	B
C. Building Performance			D

Table 22-Four Sections Weighting

Four Sections Comparison		
Section	*Raw Score*	*Weight*
A. Environmental Performance	1	14
B. Economic Performance	3	43
C. Building Performance	1	14
D. Material Credits-LEED	2	29
TOTAL	**7**	**100**

Table 23-Four Sections Weights

Firestone Building Products: EcoWhite EPDM Roof Membrane			
Product Total Performance			
Section	*Raw Score*	*Section Weight*	*Section Total Performance*
A. Environmental Performance	1	14	0.468896
B. Economic Performance	3	43	100
C. Building Performance	1	14	525
D. Material Credits-LEED	2	29	444
PRODUCT TOTAL PERFORMANCE			**244.71**

Table 24-Product Total Performance-EPDM Roof Membrane

4.6.6. Results and Assessment

In the previous section, the final performance rating of EPDM roof membrane (the level of green of EPDM roof membrane) is 244.71. In the following section, the meaning of level of green is explained, and the ideal number and unacceptable level of level of green. For the purpose of explaining these questions and defining “the level of green” for the common products made with common materials, the comprehensive rating method was applied.

The materials depending on their functions are categorized in three sections: shell, substructure and interiors. For the shell section, Ethylene-Propylene-Diene-Monomer (EPDM) and Polyvinyl-Chloride (PVC) roof membrane are included for the roof coating assessment. Also,

Oriented Strand Board (OSB) and plywood, which are two kinds of wall sheathing, were graded and compared to determine “the level of green”. Moreover, brick, stucco and aluminum siding in exterior enclosure are assessed. The steel and wood framing in framing is also included. In the substructure of the project, 15% fly ash cement and 20% fly ash cement for foundation slab were graded and compared. At last, for the interiors, ceramic tile with recycled glass, wool carpet tile with low VOC (volatile organic compounds) adhesive and linoleum floor coverings were assessed.

4.6.6.1. Roof Coating Assessment-EPDM and PVC

In the assessment of roof coating, EPDM and PVC were assessed applying the comprehensive rating method. The score of EPDM is 244.71 and the score of PVC is 193.85 shown in **Appendix VVVV and Appendix XXXX**, respectively. The principle of the rating method is the one with lower score is the better one. Therefore, the PVC is greener than the EPDM roof membrane for their performances in four aspects. Although EPDM has a lower first cost than PVC and PVC has a lower future cost than EPDM, all the costs are so little that same scores are given in the economic performance.

Talking about their environmental performance rating, PVC roof membrane was 0.680420 showed in **Appendix WWWW,** which is 0.21 higher than the rating of EPDM roof membrane as shown in **Appendix UUUU**.

The difference between the two materials in the section related to LEED is remarkable. The rating of EPDM roof membrane in this section is 444, which is almost twice of the PVC roof

membrane, because only one manufacture plant in the United States produces EPDM roof membrane.

According to the final scores of the two products, although EPDM has better environmental performance than PVC, EPDM has a lower level of green than PVC when considering the environmental performance, economic performance, building performance and material credits-LEED as a whole. It is recommended to choose roof membranes products whose score are lower than 193.

4.6.6.2. Wall Sheathing Assessment-OSB and Plywood

The use of OSB or plywood is always debatable by builders and architects. According to the book "A Builder's Guide-Green from the Ground Up" wrote by David Johnston and Scott Gibson, OSB is the prime choice from the sustainability stand of point, because it's made from wood fibers instead of whole medium-to large-diameter trees. In the product of plywood, FSC certified wood and regional materials cannot always exist at the same time (Johnston, David and Gibson, Scott, 2008), which is also proved in the assessment process**.**

The products from the famous wood manufacturer, Georgia-Pacific's, were chosen for the assessment. The final weighted performance of OSB is 182.15 comparing to 214.29 which is the plywood's performance score (See **Appendix ZZZZ and BBBBB).** Judging from the scores, OSB wall sheathing is greener than plywood, which is also commonly accepted by architects and contractors.

The scores are quite different in the last section-Material Credits-LEED. Since the plywood can be transported from the manufacturer to sites from 401 to 500 miles, which is showed in **Appendix YYYY and AAAAA**, the plywood was graded as 5 for regional materials. However, plywood cannot satisfy the requirements of FSC certified wood, which got the highest 10 score.

From these two kinds of wall sheathing products, it is suggested for the architects to choose wall sheathing products with the scores around 182 and no more than 214.29.

4.6.6.3. Wall Framing Assessment-Steel and Wood Framings

In the wall framing assessment, two popular framings in the country: steel framing and wood framing were picked.

Appendix DDDDD and FFFFF shows the results of the final and section performance of steel framing and wood framing. In the final performance, steel framing got 276.79 and wood framing got 194.64. Differences reside in all four sections. In the environmental performance shown in **Appendix CCCCC and EEEEE**, wood framing scored 0.01, which is less than four times of the environmental performance of the steel framing. In the economic performance shown in **Appendix CCCCC and EEEEE**, steel framing costs more than wood framing, which causes a twice difference in the ratings of first cost between them. The steel framing product was chosen from CEMCO, which has five standardized lengths of studs and five standardized lengths of tracks (CEMCO). And the wood framing has six standardized lengths which scored 4 for the aesthetic aspect (Georgia-Pacific). About the recycled content, according to the CEMCO technical report, steel framing may consist up to 30% recycled content. The last difference in the performance resides in the regional materials section. Referring to BEES product list of generic wood

framing-treated (NIST, Generic Wood Framing), the deliverable distance from the manufacture plant to the sites are around 200 mile. Also, the steel framing produced by CEMCO can provide delivery service within 500 miles.

Therefore, comparing to the steel framing, wood framing is a more sustainable choice. Architects should choose framing with the total performance around 194 and lower.

4.6.6.4. Exterior Enclosure Assessment-Brick, Stucco and Aluminum Siding

The brick, stucco and aluminum siding advantages and disadvantages in different aspects. Although it takes a lot of energy to manufacture brick, the high quality and durability provide a higher performance than the other exterior finish products. Stucco is an effective fire-resistant barrier, so it is often used over wood-frames. The stucco itself is a green material. However, the installation of stucco is very labor intensive, and in some parts of the country professional plasterers who can construct with stucco are scarce. Aluminum siding is the cheapest option in the three finishes alternatives, which cost around $3 to $5 per square foot including the labor cost. It can be finished with wood grain texture, and painted into many colors. The most important green feature for the aluminum siding is that, the aluminum can be recycled (Johnston, David and Gibson, Scott, 2008).

The results are showed in **Appendix HHHHH, JJJJJ and LLLLL**. Stucco has the best final performance whose grade is 171.46, the second best is aluminum siding which scores 191.08. The worst product fired clay brick scores 1.02 greater than aluminum siding. In the section of economic performance, brick has the highest first cost than the other two. The Human Health Respiratory Effects Potential in the environmental performance section showed, (**Appendix**

GGGGG, **IIIII and KKKKK**) the stucco's score in this factor is 10 times more than the other two. The high score means the construction process can be greatly harmful to the plasterers without protective measurements.

For the materials/products selection of exterior enclosure, architects should choose products with grade 170 and lower and considering the grades of environmental performance.

4.6.6.5. Substructure Assessment-15% Fly Ash Cement and 20% Fly Ash Cement

As the development of technology, fly ash is used as a replacement of Portland cement content of concrete. When mixing the fly ash with the Portland cement, the concrete becomes stronger and more durable. Because adding the fly ash to the Portland cement reduces the amount of cement's usage, the environmental impact is accordingly reduced (Fly Ash Concrete, 2005). The two products in substructure only differ in the percentage of fly ash.

In **Appendix NNNNN and PPPPP**, the difference between the total performance of 15% fly ash and 20% fly ash is very small. 15% fly ash got 364.41 and 20% fly ash got 357.26. The only difference came from the volume of recycled content showed in **Appendix MMMMM and OOOOO**. However, comparing to other products such as wall sheathing, framing, sidings, etc., the scores of substructure is very high. The environmental performance rating of cement or concrete is around 0.8, which is 0.6 greater than any other products' ratings. Moreover, the first cost of cement is around $90 per cubic yard, which is the most expensive products among other assessed products.

For the substructure, architects can choose products with scores less than 360.

4.6.6.6. Interiors Assessment-Ceramic Tile, Wool Carpet Tile and Linoleum Flooring

In the interiors assessment, ceramic tile, wool carpet tile and linoleum flooring were chosen. Each one has their specific features. Linoleum flooring is not vinyl flooring and it is a better choice than vinyl because it's manufactured with less toxic materials. However, linoleum flooring needs more maintenance than ceramic tile to make it polished and clean. Another product also needs to be cleaned is the wool carpet, for which professional clean every year or two is required.

Appendix RRRRR, TTTTT and VVVVV shows the scores for these products. The final performance score of ceramic tile, wool carpet and linoleum is 150.91, 217.31 and 208.04, respectively. Since wool and linoleum are rapidly renewable materials, the score of this factor for both of them is 1 shown in **Appendix SSSSS and UUUUU**. Ceramic tile's score for rapidly renewable material is 0 showed in **Appendix QQQQQ**. Also the first cost of wool carpet and the future cost is very high comparing to other two products which result in the higher total performance score.

According to the comprehensive rating method, the recommended score for interiors is around 150.

In conclusion, with the quantification of six categories of materials, the recommended level of green for each category shown in **Table 25**. These recommended levels of green came from the products comparison within each category. Within the limited time, the recommended level of green was only concluded from the comparison of two or three products. Even though the comprehensive rating method needed to be improved, this method works in helping balance all

of the considerations from the selection of material/product and quantifying these considerations into the level of green. With the recommended level of green for products, the material/product selection becomes easy. Also, when selecting all of the recommended products, the green of building based on materials are achieved.

Number	Category	Materials	Manufacture	The Level of Green	Recommended Level
1	Roof Coating	EPDM	Firestone Building Products	244.71	193
2		PVC	Sarnafil Inc	193.85	
3	Wall Sheathing	OSB	Georgia-Pacific	182.15	182
4		Plywood	Georgia-Pacific	214.29	
5	Wall Framing	Steel	Cemco	276.79	194
6		Wood	Georgia-Pacific	194.64	
7	Exterior Enclosure	Brick	Stiles & Hart Brick Company	194.66	170
8		Stucco	Stucco and Weatherization, Inc	171.46	
9		Aluminum Siding	Rollex	191.08	
10	Substructure	15% Fly Ash Cement	Cemex	364.41	360
11		20% Fly Ash Cement	Cemex	357.26	
12	Interiors	Ceramic tile	American Olean Tile Co	150.91	150
13		Wool Carpet Tile	Flor	217.31	
14		Linoleum Flooring	Armstrong	208.04	

Table 25-Recommended Level of Green

Chapter 5 Conclusions

The goal of this thesis is to help people understanding material selection and to help architects select materials for the purpose of improving buildings' long term performance, In order to fulfill this aim; the industry's current situation about select sustainable materials was reviewed firstly. Then by analyzing the important factors architects often consider when they select materials, a comprehensive rating method was created to help architects make appropriate decision about material. The analysis was carried out by classify important considerations into four sections and measure the weight of each section and the included factors. After having the validated weights, the grade for each product or material can be obtained. Six categories of products have been assessed and their levels of green were created.

The comprehensive rating method systematized the architects thinking process when they select sustainable materials and simplify the trade-offs. The assessments of six categories of products basically proved that the validated weights and the entire rating method are correct in the real world. Also, the weights are changeable, when they should be changed for some particular projects.

For the specific case of the Rec. Center, two kinds of roof membrane are assessed under the comprehensive rating method. The result of the assessment is that PVC roof membrane has a better total performance than EPDM roof membrane which is the exactly choose of Rec. Center. To understand the sustainability of the building, environmental performance, economic performance, building performance and material credits-LEED are considered together. The

sustainability of a building is not only relating to the environmental performance of materials or building, but also relating to other three performances.

Chapter 6 Recommendations

With the limited time, the assessment of materials only covers 12 products. Additional assessments with a large amount of products are needed to implement the comprehensive rating method, therefore to further prove the truth of this method. Also, this method should be validated with enough amounts of experts such as architects and owners. Moreover, the process of the comprehensive rating method may be too difficult and time-consuming to follow which should be simplified.

5.1. The Comprehensive Rating Method and LEED

The comprehensive rating method integrated LEED in one section and used LEED requirements to measure the grade for each factor in this section; however, most of LEED requirements are based on the sustainable performance of entire project not material itself. Even though the situations of the entire project can response the condition of each material, it cannot stimulate manufacturers directly to greener their materials and greener the process of production. To improve the level of sustainable materials and building, it is important to satisfy or stimulate materials producers. If LEED can combine the comprehensive rating method in its requirement and give manufacturers some credits or rebate when they can perform this method, they would love to provide the detailed sustainable report of their products and make their products greener.

5.2. The Comprehensive Rating Method and LCA

The comprehensive rating method involved LCA tools in environmental performance section to directly get the scores from LCA tools. Since the limitations of each LCA tools, the comprehensive method cannot apply in every product. In the future, as the development of LCA and its tools, this problem will solve. Also, it is possible that manufacturers can measure their products using LCA or its tools to get the information about each environmental impact of the products. Then the LCA report may export directly into the comprehensive rating method to simplify the rating of first section. Moreover, in the future the rating method can add on into LCA tools to get a report combine LCA results and grades.

5.3. The Comprehensive Rating Method and Building Information Modeling(BIM)

Building Information Modeling (BIM) will be very useful when the well-defined information about the project can be used on LCA tools. If one dimension of BIM like 10D is to show the sustainable information about the project and the materials you clicked on. Everything will become simply. Also, the comprehensive rating method can be one tab involved in software using BIM like Revit. When you click this tab, the total weighted performance for each product and the entire project will showed in a sheet.

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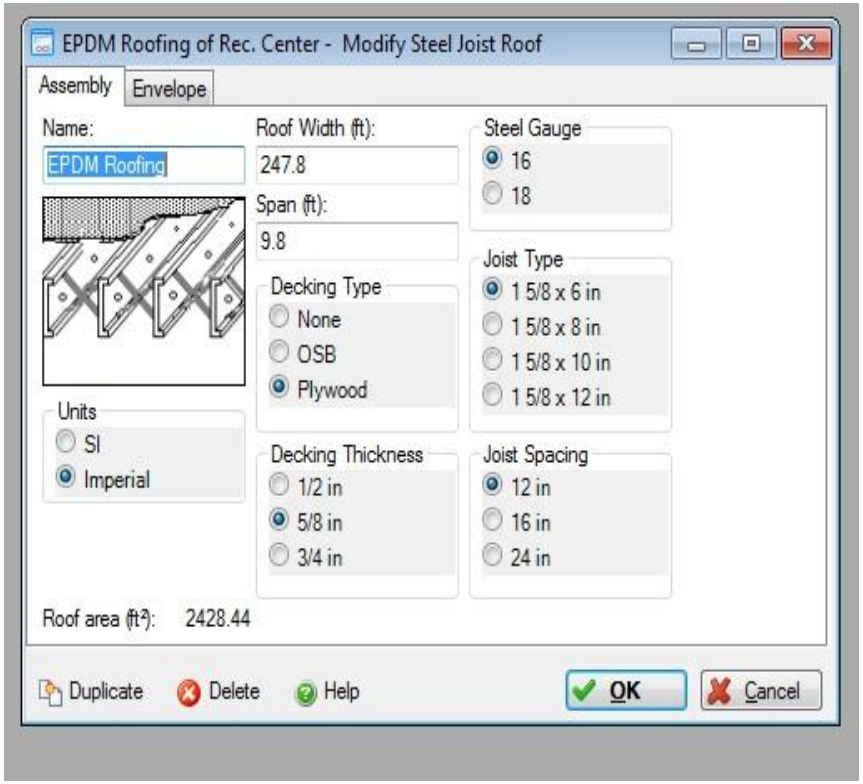
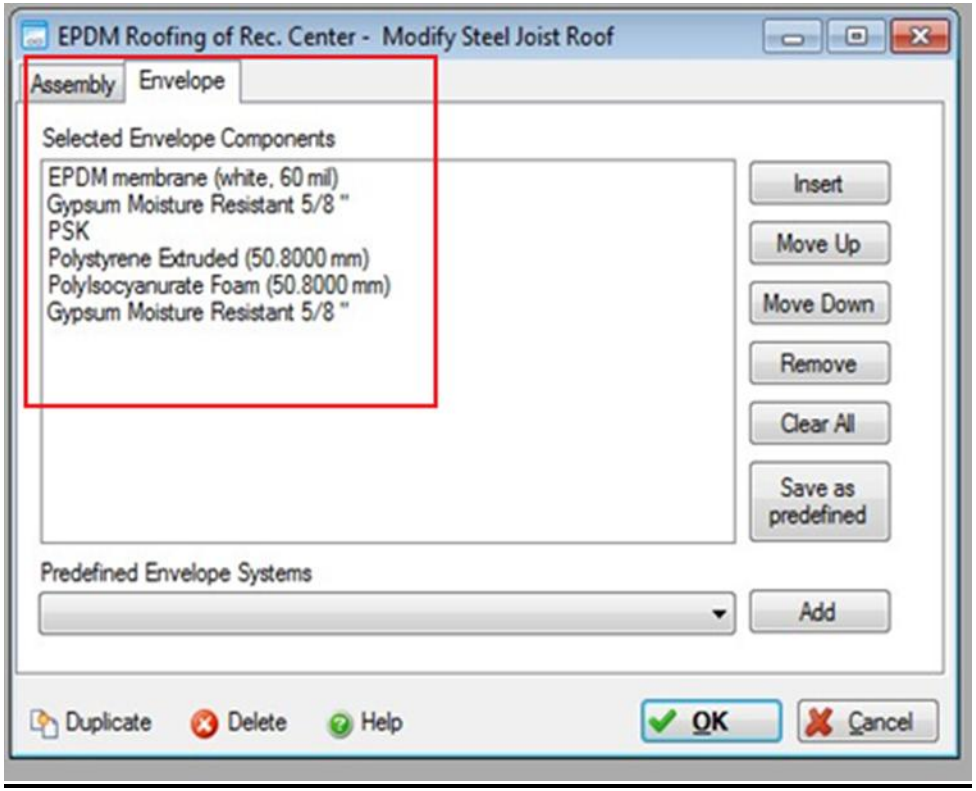
USGS. (n.d.). *USGS*. Retrieved 11 04, 2011, from Cement Statistic and Information-2010: http://minerals.usgs.gov/minerals/pubs/commodity/cement/mcs-2011-cemen.pdf

Appendices

Appendix A-Assembly Information of EPDM Roof



Appendix B-Adding Information to Envelope



Appendix C-Bill of Materials Report of EPDM Roofing

Bill Of Materials Report

Project EPDM Roofing

Material	Quantity	Unit
5/8" Moisture Resistant Gypsum Board	5342.5678	sf
EPDM membrane (white, 60 mil)	5110.2446	lbs
Extruded Polystyrene	5054.9305	sf(1")
Foam Polyisocyanurate	5068.6667	sf(1")
Galvanized Studs	3.3513	Tons
Joint Compound	0.5461	Tons
Nails	0.0359	Tons
Paper Tape	0.0063	Tons
Polypropylene Scrim Kraft Vapour Retarder Cloth	2576.0891	sf
Screws Nuts & Bolts	0.0359	Tons
Softwood Plywood	4.0261	msf (3/8 Basis)

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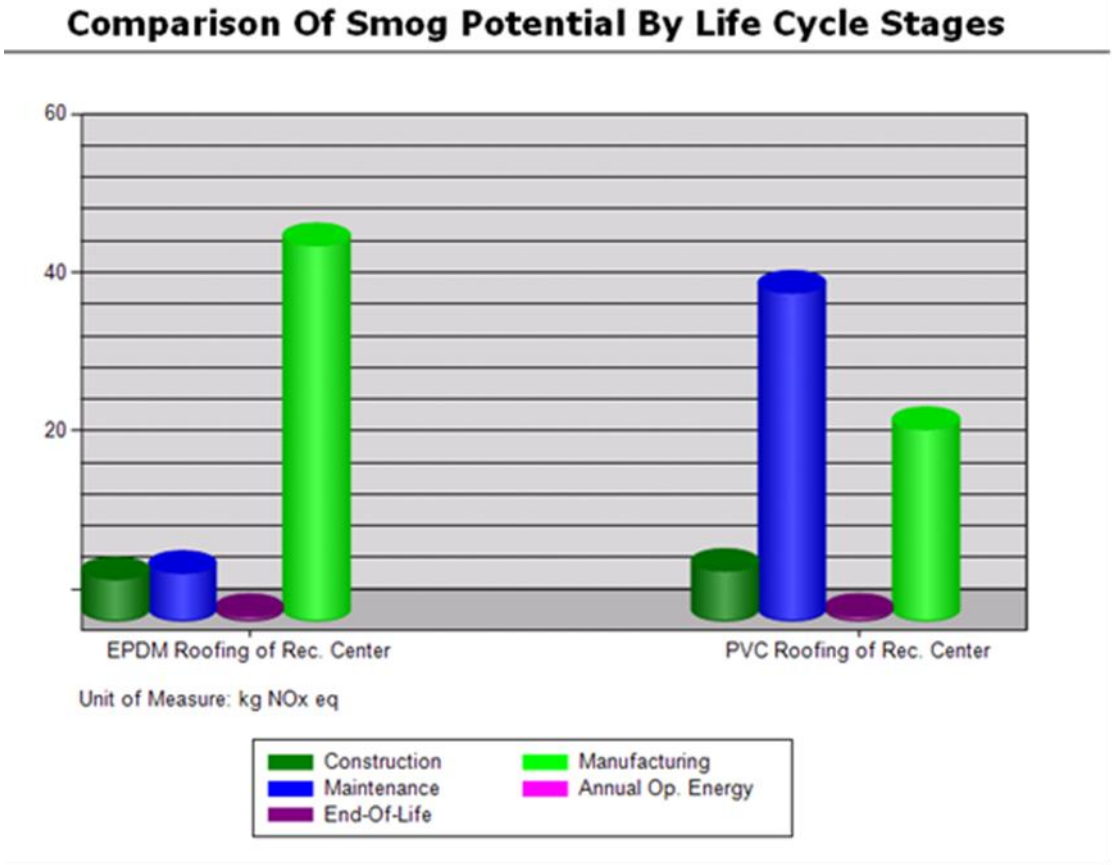
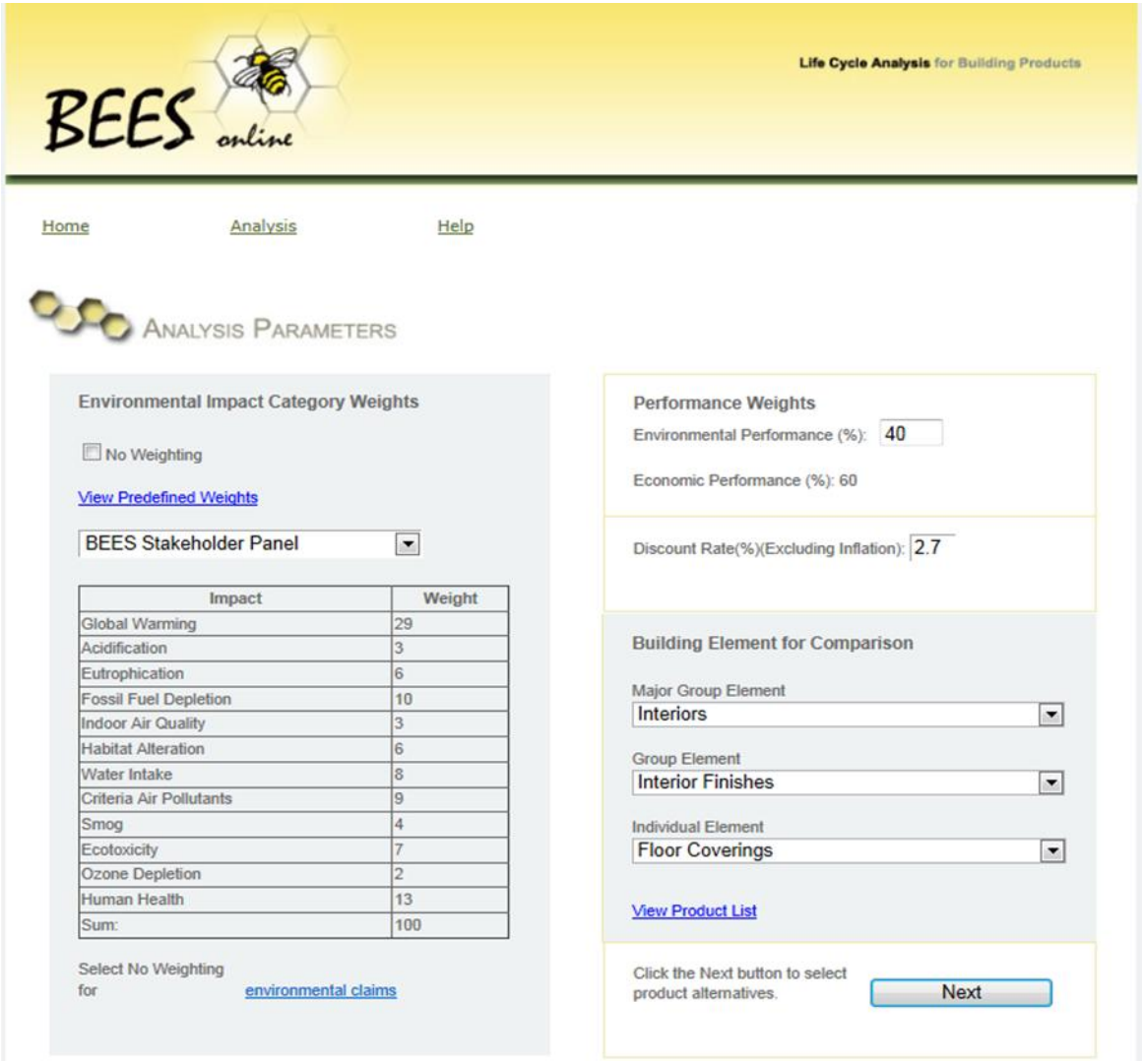
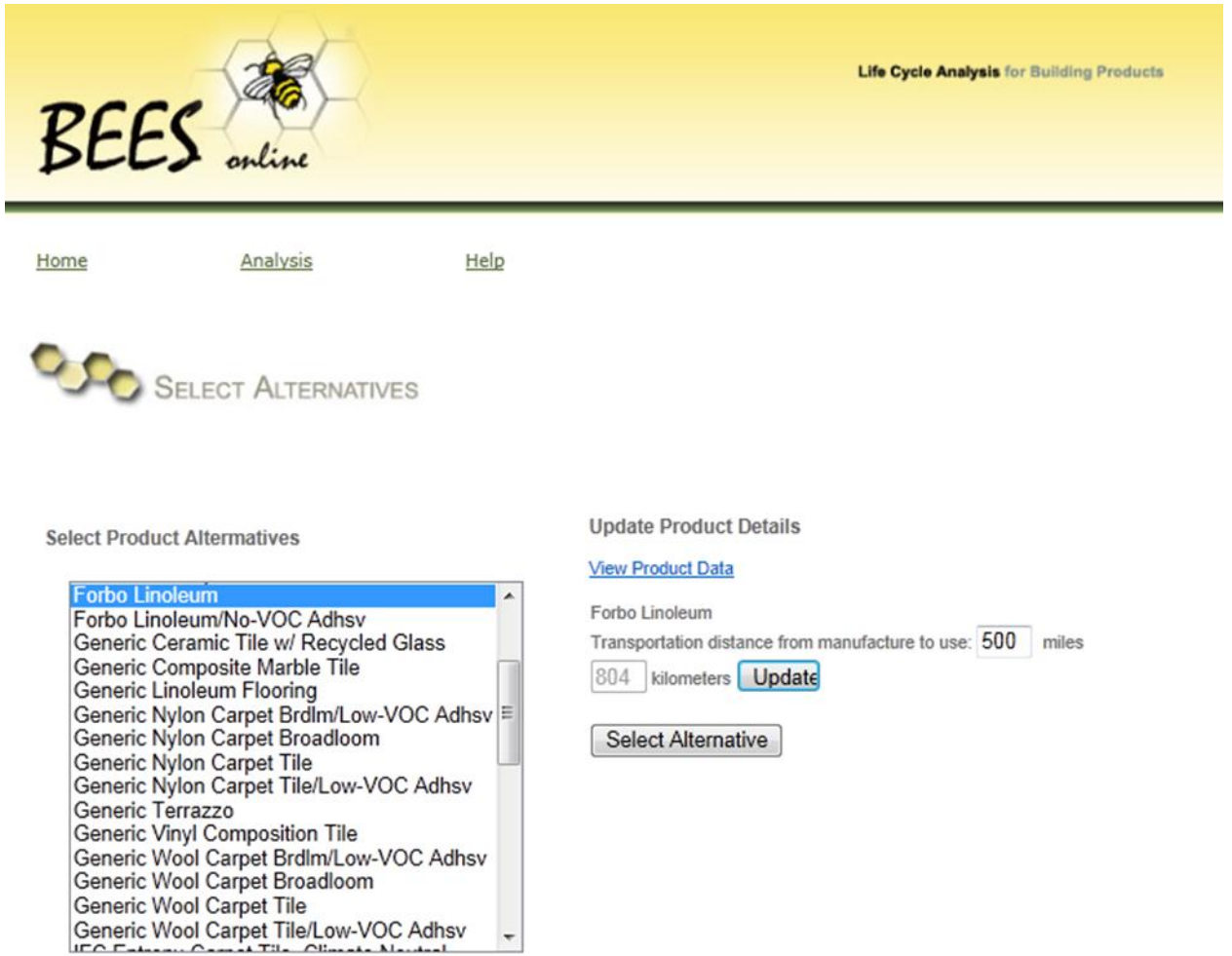
Appendix D-Comparison of Smog Potential Between EPDM Roof and PVC Roof



Appendix E-Analysis Parameters of BEES



Appendix F-Product Selection of BEES



Appendix G-Report of BEES

BEES online

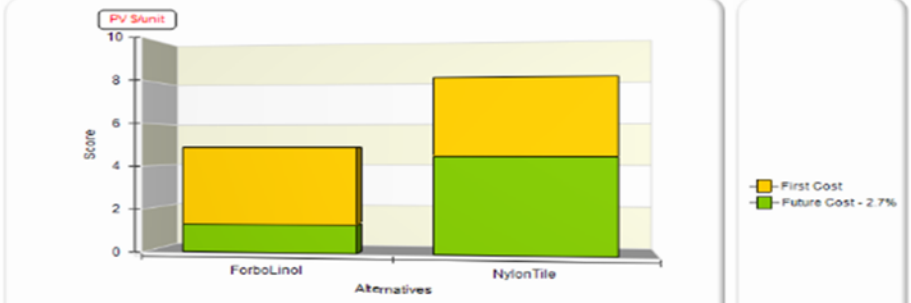
Life Cycle Analysis for Building Products

Home Analysis Help

- Summary Graphs
- Life-Cycle Stage Graphs
- Environmental Flow Graphs
- Embodied Energy Graphs

Economic Performance

Economic Performance



Category	ForboLinol	NylonTile
First Cost	3.58	3.58
Future Cost - 2.7%	1.29	4.46
Sum	4.87	8.04

The National Institute of Standards and Technology (NIST) is an agency of the U.S. Commerce Department.

Appendix H-LEED scorecard of Recreation Center

LEED for New Construction v2.2
Registered Project Checklist

Project Name: Worcester Polytechnic Institute - Recreation Center
Project Address: Worcester, MA
Spreadsheet Date: October 25, 2010

Yes	?	No			
7	1	6	**Sustainable Sites**		14 Points
Y			Prereq 1	**Construction Activity Pollution Prevention**	Required
1			Credit 1	**Site Selection**	1
1			Credit 2	**Development Density & Community Connectivity**	1
		1	Credit 3	**Brownfield Redevelopment**	1
1			Credit 4.1	**Alternative Transportation**, Public Transportation Access	1
1			Credit 4.2	**Alternative Transportation**, Bicycle Storage & Changing Rooms	1
		1	Credit 4.3	**Alternative Transportation**, Low-Emitting & Fuel-Efficient Vehicles	1
1			Credit 4.4	**Alternative Transportation**, Parking Capacity	1
		1	Credit 5.1	**Site Development**, Protect of Restore Habitat	1
		1	Credit 5.2	**Site Development**, Maximize Open Space	1
1			Credit 6.1	**Stormwater Design**, Quantity Control	1
		1	Credit 6.2	**Stormwater Design**, Quality Control	1
	1		Credit 7.1	**Heat Island Effect**, Non-Roof	1
1			Credit 7.2	**Heat Island Effect**, Roof	1
		1	Credit 8	**Light Pollution Reduction**	1
Yes	?	No			
3		2	**Water Efficiency**		5 Points
1			Credit 1.1	**Water Efficient Landscaping**, Reduce by 50%	1
		1	Credit 1.2	**Water Efficient Landscaping**, No Potable Use or No Irrigation	1
		1	Credit 2	**Innovative Wastewater Technologies**	1
1			Credit 3.1	**Water Use Reduction**, 20% Reduction	1
1			Credit 3.2	**Water Use Reduction**, 30% Reduction	1
8		9	**Energy & Atmosphere**		17 Points
Y			Prereq 1	**Fundamental Commissioning of the Building Energy Systems**	Required
Y			Prereq 2	**Minimum Energy Performance**	Required
Y			Prereq 3	**Fundamental Refrigerant Management**	Required
5		5	Credit 1	**Optimize Energy Performance**	1 to 10
				10.5% New Buildings or 3.5% Existing Building Renovations	1
				14% New Buildings or 7% Existing Building Renovations	2
				17.5% New Buildings or 10.5% Existing Building Renovations	3
				21% New Buildings or 14% Existing Building Renovations	4
			5	24.5% New Buildings or 17.5% Existing Building Renovations	5
				28% New Buildings or 21% Existing Building Renovations	6
				31.5% New Buildings or 24.5% Existing Building Renovations	7
				35% New Buildings or 28% Existing Building Renovations	8
				38.5% New Buildings or 31.5% Existing Building Renovations	9
				42% New Buildings or 35% Existing Building Renovations	10
1		2	Credit 2	**On-Site Renewable Energy**	1 to 3
			1	2.5% Renewable Energy	1
				7.5% Renewable Energy	2
				12.5% Renewable Energy	3
1			Credit 3	**Enhanced Commissioning**	1
1			Credit 4	**Enhanced Refrigerant Management**	1
		1	Credit 5	**Measurement & Verification**	1
		1	Credit 6	**Green Power**	1

continued....

Yes	?	No			
5	2	6	**Materials & Resources**		13 Points
Y			Prereq 1	**Storage & Collection of Recyclables**	Required
		1	Credit 1.1	**Building Reuse**, Maintain 75% of Existing Walls, Floors & Roof	1
		1	Credit 1.2	**Building Reuse**, Maintain 100% of Existing Walls, Floors & Roof	1
		1	Credit 1.3	**Building Reuse**, Maintain 50% of Interior Non-Structural Elements	1
1			Credit 2.1	**Construction Waste Management**, Divert 50% from Disposal	1
1			Credit 2.2	**Construction Waste Management**, Divert 75% from Disposal	1
		1	Credit 3.1	**Materials Reuse**, 5%	1
		1	Credit 3.2	**Materials Reuse**, 10%	1
1			Credit 4.1	**Recycled Content**, 10% (post-consumer + ½ pre-consumer)	1
	1		Credit 4.2	**Recycled Content**, 20% (post-consumer + ½ pre-consumer)	1
1			Credit 5.1	**Regional Materials**, 10% Extracted, Processed & Manufactured Regic	1
	1		Credit 5.2	**Regional Materials**, 20% Extracted, Processed & Manufactured Regic	1
		1	Credit 6	**Rapidly Renewable Materials**	1
1			Credit 7	**Certified Wood**	1
Yes	?	No			
12		3	**Indoor Environmental Quality**		15 Points
Y			Prereq 1	**Minimum IAQ Performance**	Required
Y			Prereq 2	**Environmental Tobacco Smoke** (ETS) **Control**	Required
1			Credit 1	**Outdoor Air Delivery Monitoring**	1
		1	Credit 2	**Increased Ventilation**	1
1			Credit 3.1	**Construction IAQ Management Plan**, During Construction	1
1			Credit 3.2	**Construction IAQ Management Plan**, Before Occupancy	1
1			Credit 4.1	**Low-Emitting Materials**, Adhesives & Sealants	1
1			Credit 4.2	**Low-Emitting Materials**, Paints & Coatings	1
1			Credit 4.3	**Low-Emitting Materials**, Carpet Systems	1
1			Credit 4.4	**Low-Emitting Materials**, Composite Wood & Agrifiber Products	1
1			Credit 5	**Indoor Chemical & Pollutant Source Control**	1
1			Credit 6.1	**Controllability of Systems**, Lighting	1
		1	Credit 6.2	**Controllability of Systems**, Thermal Comfort	1
1			Credit 7.1	**Thermal Comfort**, Design	1
1			Credit 7.2	**Thermal Comfort**, Verification	1
		1	Credit 8.1	**Daylight & Views**, Daylight 75% of Spaces	1
1			Credit 8.2	**Daylight & Views**, Views for 90% of Spaces	1
Yes	?	No			
4	1		**Innovation & Design Process**		5 Points
1			Credit 1.1	**Innovation in Design**: Education Panel	1
1			Credit 1.2	**Innovation in Design**: Water Use 40%	1
1			Credit 1.3	**Innovation in Design**: Green House Keeping Supplies	1
	1		Credit 1.4	**Innovation in Design**: Regional 40%? Recycled content: 30%?	1
1			Credit 2	**LEED® Accredited Professional**	1
Yes	?	No			
39	4	26	**Project Totals** (pre-certification estimates)		69 Points

Certified: 26-32 points, Silver: 33-38 points, Gold: 39-51 points, Platinum: 52-69 points

Appendix I-Material Credits Documentation Sheet of Recreation Center

New Recreation Center
Worcester Polytechnic Institute
Cannon Design Project No. 003074.00

March 22, 2010

MATERIALS CREDIT DOCUMENTATION SHEET
LEED ™ NC 2.2 Rating System

Name: _____ Signature: _____
Company: _____ Date: _____

Instructions to Contractor/Installer: Please complete the following information an all appropriate categories. Use one document sheet for each product or material (e.g. tile and grout each get their own sheet). Note as N/A if not applicable. Attach manufacturer's letter of certification (MLC) verifying all applicable credits.

MATERIAL OR PRODUCTS:	
MATERIAL COST (LESS LABOR AND EQUIPMENT):	
Contractor/Installer:	Manufacturer:
Address:	Manufacturer Address (Location where material/product is manufactured):
Contact:	

LEED CREDIT SS 7.1 Heat Island Effect, Non-Roof
Does site hardscapes meet Solar Reflectance Index (SRI) of at least 29?

Product Material:	SRI Value:	Area:

LEED CREDIT SS 7.2 Heat Island Effect, Roof
Does roofing material meet Solar Reflectance Index (SRI) of at least 29 for slope ≥ 2:12 and at least 78 for slope ≤ 2:12?

Product Name:	Slope:	SRI Value:	Area:

LEED CREDIT MR 4 Recycled Content
Does the material/product contain post-consumer or pre-consumer recycled content?

Product Name:		Cost:
Percentage of Post-Consumer Content:		
Percentage of Pre-Consumer Content:		

Assemblies: If only part of the assembly contains recycle content, fill in the detail chart below:

Assembly Name:	Weight:	% Post Cons.	%Pre Cons.
Components:			
Total Cost:			

New Recreation Center
Worcester Polytechnic Institute
Cannon Design Project No. 003074.00

March 22, 2010

LEED CREDIT MR 5 Regional Material
Has the material/product been extracted, harvested or recovered, as well as manufactured, within 500 miles of the project site?

Product/Material:	Dist.between Project & Manufacturing (miles):	Dist.between Project & Extraction (miles):	Product /Material Cost:	Information Source:

Assemblies with some regional material.

Assembly Name: Components:	Weight (lbs):	Dist from Project & Extraction (miles):	Contributing Weight (lbs):	Percentage:
Total:				

LEED CREDIT MR 7 FSC
Does the Product/Material contain FSC Certified Wood?

Product/Material:	Chain-of-Custody #:	Cost of Product/Material:

Assemblies with some FSC Certified Wood.

Assembly Name: Components:	Weight (lbs):	Chain-Of-Custody #:	Contributing Weight (lbs):	Percentage
Total:				

LEED CREDIT EQ 4.1 Low Emitting Materials (Adhesives/Sealants).
Does the product/material comply with VOC limits of SCAQMD Rule 1168 or Green Seal GS-36?

Product/Material:	VOC Content (g/L):

LEED CREDIT EQ 4.2 Low Emitting Materials (Paints/Coating).
Does the product/material comply with VOC limits of SCAQMD Rule 1113 or Green Seal GS-03 or GS-11?

Product/Material:	VOC Content (g/L):

LEED CREDIT EQ 4.3 Low Emitting Materials (Carpet System).
Does the Carpet/Cushion comply Carpet Institute's Green Label Plus (Green Label for Cushion) Program?

Product/Material:	Backing Type:	CRI Identification:

LEED CREDIT EQ 4.4 Low Emitting Materials (Composite Wood & Agrifiber products).
Does the Product/Material and Laminating Adhesives contain added Urea-formaldehyde (UF) resins?

Product/Material:	Added UF(Yes/No):	Binder Type:

Appendix J-Product List-Concrete-Shotcrete-1

Concrete		
Section 03	**3713 Shotcrete**	
1	Form Materials	Form-facing panels that will provide continuous, straight, smooth, concrete surfaces.
		Furnish panels in largest practicable sizes to minimize number of joints.
2	Reinforcing Materials	
	Recycled Content of Steel Products	Provide products with an average recycled content of steel products so postconsumer recycled content plus one-half of preconsumer recycled content is not less than 25 percent.
	Reinforcing Bars	ASTM A 615/A 615M, Grade 60, deformed
	Low-Alloy-Steel Reinforcing Bars	ASTM A 706/A 706M, deformed.
	Plain-Steel-Wire	ASTM A 82, as drawn.
	Plain-Steel-Welded Wire Fabric	ASTM A 185, fabricated from as-drawn steel wire into flat sheets.
	Supports	Bolsters, chairs, spacers, ties, and other devices for spacing, supporting, and fastening reinforcing steel in place according to CRSI's "Manual of Standard Practice" and as follows:
		1. Use CRSI Class 2, stainless-steel bar supports.
	Reinforcing Anchors	ASTM A 36/A 36M, unheaded rods.
		1. Finish: Plain, uncoated.
3	Shotcrete Materials	
	Portland Cement	ASTM C 150, Type I or III. Use only one brand and type of cement for Project
	Silica Fume	ASTM C 1240, amorphous silica
	Normal-Weight Aggregates	ASTM C 33, from a single source, and as follows:
		1. Aggregate Gradation: ACI 506R, Gradation No. 1 with 100 percent passing 3/8-inch sieve.

Appendix K-Product List-Concrete-Shotcrete-2

	Water	Potable, complying with ASTM C 94/C 94M, free from deleterious materials that may affect color stability, setting, or strength of shotcrete
	Ground Wire	High-strength steel wire, 0.8 to 1 mm in diameter
	Joint Filler Strips	ASTM D 1751, asphalt-saturated cellulosic fiber or ASTM D 1752, cork or self-expanding cork.
4	Chemical Admixtures	
		General: ASTM C 1141, Class A or B, but limited to the following admixture materials. Provide admixtures for shotcrete that contains not more than 0.1 percent chloride ions. Certify compatibility of admixtures with each other and with other cementitious materials.
		1. Air-Entraining Admixture: ASTM C 260.
		2. Water-Reducing Admixture: ASTM C 494/C 494M, Type A.
		3. Water-Reducing and Retarding Admixture: ASTM C 494/C 494M, Type D.
		4. Water-Reducing and Accelerating Admixture: ASTM C 494/C 494M, Type E.
		5. High-Range, Water-Reducing Admixture: ASTM C 494/C 494M, Type F.
		6. Accelerating Admixture: ASTM C 494/C 494M, Type C.
5	Curing Materials	
	Absorptive Cover	AASHTO M 182, Class 2, burlap cloth made from jute or kenaf, weighing approximately 9 oz./sq. yd. dry
	Moisture-Retaining Cover	ASTM C 171, polyethylene film or white burlap-polyethylene sheet
	Water	Potable
6	Shotcrete Mixtures, General	
		Prepare design mixes for each type and strength of shotcrete
		Limit water-soluble chloride ions to maximum percentage by weight of cement or cementitious materials permitted by ACI 301.
	Admixtures	When included in shotcrete design mixes, use admixtures and retarding admixtures according to manufacturer's written instructions.

	Admixtures	When included in shotcrete design mixes, use admixtures and retarding admixtures according to manufacturer's written instructions.
	Design-Mix Adjustments	Subject to compliance with requirements, shotcrete design-mix adjustments may be proposed when characteristics of materials, Project conditions, weather, test results, or other circumstances warrant.
7	Shotcrete Mixtures	
		Proportion dry mixtures by field test data methods and wet mixtures according to ACI 211.1 and
		ACI 301, using materials to be used on Project, to provide shotcrete with the following properties:
		1. Compressive Strength (28 Days): 4000 psi 3500 psi.
8	Shotcrete Equipment	
9	Batching and Mixing	

Appendix L-Product List-Concrete-Precast Structural Concrete-1

Section 03	4100 Precast Structural Concrete	
1	Formwork	
2	Reinforcing Materials	
	Reinforcing Bars	ASTM A 615, Grade 60, deformed, unless otherwise indicated.
	Weldable Reinforcing Bars	ASTM A 706, Grade 60, deformed
	Epoxy-Coated Reinforcing Bars	ASTM A 775, Grade 60, deformed bars, epoxy coated, with less than 2 percent damaged coating in each 12-inch bar length.
	Steel Wire	ASTM A 82, plain, cold-drawn, steel.
	Welded Plain-Steel Wire Fabric	ASTM A 185, flat sheets.
	Supports for Reinforcement	Provide supports for reinforcement including bolsters, chairs, spacers and other devices for spacing, supporting and fastening reinforcing, complying with CRSI
3	Prestressing Tendons	
		Uncoated, 7-wire stress-relieved strand complying with ASTM A 416. Use either Grade 250 or Grade 270 unless grade specifically indicated on drawings.
4	Concrete Materials	
	Portland Cement	ASTM C 150, Type I or Type III.
	Aggregates	ASTM C 33, and as herein specified. Provide aggregates from a single source throughout project for exposed concrete.
	Water	Potable; free from deleterious material that may affect color stability, setting, or strength of concrete and complying with chemical limits of PCI MNL 116.
	Air-Entraining Admixture	ASTM C 260, certified by manufacturer to be compatible with other required admixtures.
	Water-Reducing Admixture	ASTM C 494, Type A.
	Calcium Chloride or Admixture	Containing more than 0.1% chloride ions is expressly prohibited from use.

Appendix M-Product List-Concrete-Precast Structural Concrete-2

			Corrosion-Inhibiting Admixture	Commercially formulated, anodic inhibitor or mixed catholic and anodic inhibitor; capable of forming a protective barrier and minimizing chloride reactions with steel reinforcement in concrete.
5	Connection Materials			
		Steel Shapes and Plates		ASTM A 36
		Anchor Bolts		ASTM F 1554, Gr. 36, low-carbon steel bolts, regular hexagon nuts and carbon steel washers.
		High-Strength Threaded Fasteners		Heavy hexagon structural bolts, heavy hexagon nuts, and hardened washers complying with ASTM A 325
		Welded Headed Studs		ASTM A 108, AISI 1018 through AISI 1020, cold finished, AWS D1.1, Type B, with arc shields and with minimum mechanical properties of PCI MNL 116.
		Stainless-Steel Plate		ASTM A 666, Type 304, of grade suitable for application
		Finish of Steel Units		Stainless steel ASTM A666, Type 304.
		Shim Stock		Stainless steel, ASTM A666, Type 304
		Bearing Pads		Provide bearing pads for precast concrete units as indicated on drawings
			Elastomeric Pads	AASHTO M 251, plain, vulcanized, 100 percent chloroprene (neoprene) elastomer, molded to size or cut from a molded sheet, 50 to 70 Shore, Type A durometer hardness, ASTM D 2240; minimum tensile strength 2250 psi, ASTM D 412.
			Random-Oriented, Fiber-Reinforced Elastomeric Pads	Preformed, randomly oriented synthetic fibers set in elastomer. 70 to 90 Shore, Type A durometer hardness, ASTM D 2240; capable of supporting a compressive stress of 3000 psi with no cracking, splitting, or delaminating in the internal portions of pad. Test 1 specimen for every 200 pads used in Project.
			Sliding Pads	Manufactured assembly with Polyetrafluoroethylene (PTFE) surface, with glass fiber reinforcing as required for service load bearing stress. Combine with elastomeric base where required for full contact bearing.
		Welding Electrodes		Comply with AWS standards.
		Accessories		Provide clips, hangers, and other accessories required for installation of project units and for support of subsequent construction or finishes.

6	Grout Materials			
				Non-metallic Shrinkage-Resistant Grout: Proprietary pre-mixed, non-metallic, non-corrosive, non-staining product containing selected silica sands, portland cement, shrinkage compensating agents, plasticizing and water reducing agents, complying with ASTM C 1107, Grade A for drypack and Grades B and C for flowable grout and of consistency suitable for application within a 30-minute working time.. Minimum cube strength of 9000 psi at 28 days when placed at
			Products: Subject to compliance with requirements, provide one of the following:	
			1. Euco N.S.; Euclid Chemical Co.	
			2. Crystex; L&M Construction Chemicals.	
			3. Masterflow 713; Master Builders	
			4. Five Star Grout; U.S. Grout Corp.	
			5. Upcon; Upco Chem. Div., USM Corp.	
			6. Propak; Protex Industries, Inc.	
			7. Other approved equal.	

Appendix N-Product List-Concrete-Precast Architectural Concrete-1

Section 03	4500 Precast Architectural Concrete	
1	Mold Materials	
	Molds	Rigid, dimensionally stable, non-absorptive material, warp and buckle free, that will provide continuous and true precast concrete surfaces within fabrication tolerances indicated; nonreactive with concrete and suitable for producing required finishes.
		1. Mold-Release Agent: Commercially produced liquid-release agent that will not bond with, stain or adversely affect precast concrete surfaces and will not impair subsequent surface or joint treatments of precast concrete.
2	Reinforcing Materials	
	Recycled Content of Steel Products	Provide products with an average recycled content of steel products so postconsumer recycled content plus one-half of preconsumer recycled content is not less than 60 percent.
	Reinforcing Bars	ASTM A 615/A 615M, Grade 60Grade 420, deformed.
	Galvanized Reinforcing Bars	ASTM A 706/A 706M, deformed bars, ASTM A 767/A 767M
		Class II zinc coated, hot-dip galvanized, and chromate wash treated after fabrication and bending.
	Epoxy-Coated Reinforcing Bars	ASTM A 706/A 706M, deformed bars, ASTM A 775/A 775M or ASTM A 934/A 934M epoxy coated.
	Plain-Steel Weled Wire Reinforcement	ASTM A 185, fabricated from galvanized steel wire into flat sheets.
	Deformed-Steel Welded Wire Reinforcement	ASTM A 497/A 497M, flat sheet
	Epoxy-Coated-Steel Wire	ASTM A 884/A 884M, Class A coated, plain or deformed, flat sheet, Type 1 bendable coating.
	Supports	Suspend reinforcement from back of mold or use bolsters, chairs, spacers, and other devices for spacing, supporting, and fastening reinforcing bars and welded wire reinforcement in place according to PCI MNL 117.

Appendix O-Product List-Concrete-Precast Architectural Concrete-2

3	Concrete Materials	
	Portland Cement	ASTM C 150, Type I or Type III, gray, unless otherwise indicated.
		1. For surfaces exposed to view in finished structure, mix gray with white cement, of same type, brand, and mill source.
	Supplementary Cementitious Materials	Fly Ash: ASTM C 618, Class C or F, with maximum loss on ignition of 3 percent.
	Normal-Weight Aggregates	Except as modified by PCI MNL 117, ASTM C 33, with coarse aggregates complying with Class 5S. Stockpile fine and coarse aggregates for each type of exposed finish from a single source (pit or quarry) for Project.
		1. Face-Mixture-Coarse Aggregates: Selected, hard, and durable; free of material that reacts with cement or causes staining; to match selected finish sample.
		2. Face-Mixture-Fine Aggregates: Selected, natural or manufactured sand of same material as coarse aggregate, unless otherwise approved by Architect.
	Coloring Admixtures	ASTM C 979, synthetic or natural mineral-oxide pigments or colored water reducing admixtures, temperature stable, and nonfading.
	Water	Potable; free from deleterious material that may affect color stability, setting, or strength of concrete and complying with chemical limits of PCI MNL 117.
	Air-Entraining Admixture	ASTM C 260, certified by manufacturer to be compatible with other required admixtures.
	Chemical Admixtures	Certified by manufacturer to be compatible with other admixtures and to not contain calcium chloride, or more than 0.15 percent chloride ions or other salts by weight of admixture
		1. Water-Reducing Admixtures: ASTM C 494/C 494M, Type A.
		2. Retarding Admixture: ASTM C 494/C 494M, Type B.
		3. Water-Reducing and Retarding Admixture: ASTM C 494/C 494M, Type D.
		4. Water-Reducing and Accelerating Admixture: ASTM C 494/C 494M, Type E.
		5. Plasticizing and Retarding Admixture: ASTM C 1017/C 1017 M.

Appendix P-Product List-Concrete-Precast Architectural Concrete-3

4	Steel Connection Materials	
	Carbon-Steel Shapes and Plates	ASTM A 36/A 36M
	Carbon-Steel-Headed Studs	ASTM A 108, AISI 1018 through AISI 1020, cold finished, AWS D1.1/D1.1M, Type A or B, with arc shields and with minimum mechanical properties of PCI MNL 117, Table 3.2.3.
	Carbon-Steel Plate	ASTM A 283/A 283M
	Malleable Iron Castings	ASTM A 47/A 47M
	Carbon-Steel Castings	ASTM A 27/A 27M, Grade 60-30Grade 415-205
	Wrought Carbon-Steel Bars	ASTM A 675/A 675M, Grade 65Grade 450
	Deformed-Steel Wire or Bar Anchors:	ASTM A 496 or ASTM A 706/A 706M
	Carbon-Steel Bolts and Studs	ASTM A 307, Grade AASTM F 568M, Property Class 4.6; carbon-steel, hex-head bolts and studs; carbon-steel nuts, ASTM A 563ASTM A 563M; and flat, unhardened steel washers, ASTM F 844.
	Zinc-Coated Finish	For exterior steel items, steel in exterior walls, and items indicated for galvanizing, apply zinc coating by hot-dip process according to ASTM A 123/A 123M or ASTM A 153/A 153M.
		1. For steel shapes, plates, and tubing to be galvanized, limit silicon content of steel to less than 0.03 percent or to between 0.15 and 0.25 percent or limit sum of silicon and 2.5 times phosphorous content to 0.09 percent.
		2. Galvanizing Repair Paint: High-zinc-dust-content paint with dry film containing not less than 94 percent zinc dust by weight, and complying with DOD-P-21035A or SSPC-Paint 20.
	Shop-Primed Finish	Prepare surfaces of nongalvanized steel items, except those surfaces to be embedded in concrete, according to requirements in SSPC-SP 3 and shop-apply lead- and chromate-free, rust-inhibitive primer, complying with performance requirements in MPI 79 according to SSPC-PA 1
	Welding Electrodes	Comply with AWS standards

Appendix Q-Product List-Concrete-Precast Architectural Concrete-4

5	Bearing Pads		Provide one of the following bearing pads for architectural precast concrete units as recommended by precast fabricator for application:
			1. Elastomeric Pads: AASHTO M 251, plain, vulcanized, 100 percent polychloroprene (neoprene) elastomer, molded to size or cut from a molded sheet, Type A durometer
			hardness of 50 to 70, ASTM D 2240, minimum tensile strength 2250 psi15.5 MPa, ASTM D 412.
			2. Random-Oriented, Fiber-Reinforced Elastomeric Pads: Preformed, randomly oriented synthetic fibers set in elastomer. Type A durometer hardness of 70 to 90, ASTM D 2240; capable of supporting a compressive stress of 3000 psi 20.7 MPa with no cracking, splitting, or delaminating in the internal portions of pad. Test one specimen for every 200 pads used in Project.
			3. Cotton-Duck-Fabric-Reinforced Elastomeric Pads: Preformed, horizontally layered cotton-duck fabric bonded to an elastomer; Type A durometer hardness of 80 to 100,
			ASTM D 2240; complying with AASHTO's "AASHTO Load and Resistance Factor (LRFD) Bridge Design Specifications, Division II, Section 18.10.2, or with MIL-C-
			4. Frictionless Pads: Tetrafluoroethylene (Teflon), glass-fiber reinforced, bonded to stainless or mild-steel plate, of type required for in-service stress.
			5. High-Density Plastic: Multimonomer, nonleaching, plastic strip.
6	Accessories		
	Precast Accessories		Provide clips, hangers, plastic or steel shims, and other accessories required to install architectural precast concrete units.
7	Grout Materials		
	Sand-Cement Grout		Portland cement, ASTM C 150, Type I, and clean, natural sand, ASTM C 144 or ASTM C 404. Mix at ratio of 1 part cement to 2-1/2 parts sand, by volume, with minimum water required for placement and hydration.

Appendix R-Product List-Concrete-Precast Architectural Concrete-5

	Nonmetallic, Nonshrink Grout	Premixed, nonmetallic, noncorrosive, nonstaining grout containing selected silica sands, portland cement, shrinkage-compensating agents, plasticizing and water-reducing agents, complying with ASTM C 1107, Grade A for drypack and Grades B and C for flowable grout and of consistency suitable for application within a 30-minute working time.
	Epoxy-Resin Grout	Two-component, mineral-filled epoxy resin; ASTM C 881/C 881M, of type, grade, and class to suit requirements.
	Polyurethane Grout	Hydrophobic polyurethane grout designed to seal leaking joints and cracks in concrete structures by forming a flexible gasket or plug in the joint or crack. Milky white nonflammable liquid uncured, grout expands when coming into contact with water and curing to tough flexible, closed-cell foam essentially unaffected by corrosive environments.
		1. Basis-of-Design Product: "Hydro Active® Flex 1000" by De Neef Construction Chemicals, Inc. Subject to compliance with requirements, provide Basis-of-Design product or an acceptable equivalent product.
8	Concrete Mixtures	
		A. Prepare design mixtures for each type of precast concrete required.
		1. Limit use of fly ash and silica fume to 20 percent of portland cement by weight; limit metakaolin and silica fume to 10 percent of portland cement by
		B. Design mixtures may be prepared by a qualified independent testing agency or by qualified precast plant personnel at architectural precast concrete fabricator's option.
		C. Limit water-soluble chloride ions to maximum percentage by weight of cement permitted by ACI 318 ACI 318M or PCI MNL 117 when tested according to ASTM C 1218/C 1218M.
	Normal-Weight Concrete Mixtures	Proportion face and backup mixtures or full-depth mixtures, at fabricator's option by either laboratory trial batch or field test data methods according to
		211.1, with materials to be used on Project, to provide normal-weight concrete with the following properties:
		1. Compressive Strength (28 Days): 5000 psi 34.5 MPa minimum.
		2. Maximum Water-Cementitious Materials Ratio: 0.45.
	Water Absorption	6 percent by weight or 14 percent by volume, tested according to PCI MNL 117
		G. When included in design mixtures, add other admixtures to concrete mixtures according to manufacturer's written instructions.

Appendix S-Product List-Masonry-Unit Masonry-1

Masonry			
Section 04	**2000**	**Unit Masonry**	
1	Masonry Units, Geneal		
	Defective Units		Referenced masonry unit standards may allow a certain percentage of units to contain chips, cracks, or other defects exceeding limits stated in the standard. Do not use units where such defects will be exposed in the completed Work.
	Fire-Resistance Ratings		Where indicated, provide units that comply with requirements for fire-resistance ratings indicated as determined by testing according to ASTM E 119, by equivalent masonry thickness, or by other means, as acceptable to authorities having jurisdiction.
2	Concrete Masonry Units		
	Regional Materials		Provide CMUs that have been manufactured within 500 miles (800 km) of Project site from aggregates and cement that have been extracted, harvested, or recovered, as well as manufactured, within 500 miles (800 km) of Project site.
	Shapes		Provide shapes indicated and as follows, with exposed surfaces matching exposed faces of adjacent units unless otherwise
			1. Provide special shapes for lintels, corners, jambs, sashes, movement joints, headers, bonding, and other special conditions.
			2. Provide square-edged units for outside corners unless otherwise indicated.
	CMUs		ASTM C 90.
			1. Density Classification: Lightweight.
			2. Size (Width): Manufactured to dimensions 3/8 inch less than nominal dimensions.

Appendix T-Product List-Masonry-Unit Masonry-2

			2. Size (Width): Manufactured to dimensions 3/8 inch less than nominal dimensions.
			3. Exposed Faces: Provide color and texture matching the range represented by Architect's sample.
	Concrete Building Brick		ASTM C 55.
			1. Density Classification: Lightweight.
			2. Size (Actual Dimensions): 3-5/8 inches (92 mm) wide by 2-1/4 inches (57 mm) high by
			7-5/8 inches (194 mm) long, unless otherwise indicated or required by applications.
	Pre-faced CMUs		Lightweight hollow concrete units complying with ASTM C 90, with manufacturer's standard smooth resinous facing complying with ASTM C 744.
			1. Size: Manufactured to dimensions specified in "CMUs" Paragraph but with pre-faced surfaces having 1/16-inch- (1.5-mm-) wide returns of facing to create 1/4-inch- (6.5-mm-) wide mortar joints with modular coursing.
			2. Colors and Patterns: As selected by Architect from manufacturer's full range.
	Acoustical CMUs		Lightweight hollow concrete units complying with ASTM C90, with two slot type apertures and two factory-installed noise attenuating fibrous fillers with laminated metal septum.
			1. Products: Subject to compliance with requirements, provide "SOUNDBLOX Acoustical Concrete Masonry Units" by The Proudfoot Company.

Appendix U-Product List-Masonry-Unit Masonry-3

3	Brick			
	Regional Materials			Provide brick that has been manufactured within 500 miles (800 km) of Project site from materials that have been extracted, harvested, or recovered, as well as manufactured, within 500 miles (800 km) of Project site.
	General			Provide shapes indicated and as follows, with exposed surfaces matching finish and color of exposed faces of adjacent units:
				1. For ends of sills and caps and for similar applications that would otherwise expose unfinished brick surfaces, provide units without cores or frogs and with exposed surfaces finished.
				2. Provide special shapes for applications where stretcher units cannot accommodate special conditions, including those at corners, movement joints, bond beams, sashes, and lintels.
				3. Provide special shapes for applications requiring brick of size, form, color, and texture on exposed surfaces that cannot be produced by sawing.
				4. Provide special shapes for applications where shapes produced by sawing would result in sawed surfaces being exposed to view.
	Face Brick			Facing brick complying with ASTM C 216.
				1. Products: Subject to compliance with requirements, provide the following: a. "College Blend - Waterstruck" by Morin Brick Co.
				2. Grade: SW.
				3. Type: FBX.
				4. Initial Rate of Absorption: Less than 30 g/30 sq. in. (30 g/194 sq. cm) per minute when tested per ASTM C 67.
				5. Efflorescence: Provide brick that has been tested according to ASTM C 67 and is rated "not effloresced."
				6. Size (Actual Dimensions): 3-1/2 inches (89 mm) wide by 2-1/4 inches (57 mm) high by
				7-1/2 inches (190 mm) long, unless otherwise indicated on

Appendix V-Product List-Masonry-Unit Masonry-4

	7-1/2 inches (190 mm) long, unless otherwise indicated on
	7. Application: Use where brick is exposed unless otherwise
Regional Materials	Provide aggregate for mortar and grout, cement, and lime that have been extracted, harvested, or recovered, as well as manufactured, within 500 miles (800 km) of Project site.
Portland Cement	ASTM C 150, Type I or II, except Type III may be used for cold-weather construction. Provide natural color or white cement as required to produce mortar color indicated.
Hydrated Lime	ASTM C 207, Type S.
Colored Cement Product	Packaged blend made from portland cement and hydrated lime and mortar pigments, all complying with specified requirements, and containing no other ingredients.
	1. Products: Subject to compliance with requirements, provide one of the following:
	a. Colored Portland Cement-Lime Mix:
	1) Capital Materials Corporation; "Riverton Portland Cement Lime Custom Color."
	2) Holcim (US) Inc.; "Rainbow Mortamix Custom Color Cement/Lime."
	3) Lafarge North America Inc.; "Eaglebond Portland & Lime."
	2. Formulate blend as required to produce color indicated or, if not indicated, as selected from manufacturer's standard colors.
	3. Pigments shall not exceed 10 percent of portland cement by
Aggregate for Mortar	ASTM C 144.
	1. For mortar that is exposed to view, use washed aggregate consisting of natural sand or crushed stone.
	2. For joints less than 1/4 inch (6 mm) thick, use aggregate graded with 100 percent passing the No. 16 (1.18-mm) sieve.
	3. White-Mortar Aggregates: Natural white sand or crushed white stone.

Appendix W-Product List-Masonry-Unit Masonry-5

		4. Colored-Mortar Aggregates: Natural sand or crushed stone of color necessary to produce required mortar color.
	Aggregate for Grout	ASTM C 404
	Cold-Weather Admixture	Nonchloride, noncorrosive, accelerating admixture complying with ASTM C 494/C 494M, Type C, and recommended by manufacturer for use in masonry mortar of composition indicated.
	Water	Potable
4	Reinforcement	
	Masonry Joint Reinforcement, General	ASTM A 951/A 951M.
		1. Interior Walls: Hot-dip galvanized, carbon steel.
		2. Exterior Walls: Hot-dip galvanized, carbon steel.
		3. Wire Size for Side Rods: 0.148-inch (3.77-mm) diameter.
		4. Wire Size for Cross Rods: 0.148-inch (3.77-mm) diameter.
		5. Wire Size for Veneer Ties: 0.148-inch (3.77-mm) diameter.
		6. Spacing of Cross Rods, Tabs, and Cross Ties: Not more than 16 inches (407 mm) o.c.
		7. Provide in lengths of not less than 10 feet (3 m), with prefabricated corner and tee units.
	Masonry Joint Reinforcement for Single-Wythe Masonry	Either ladder or truss type with single pair of side rods.
	Masonry Joint Reinforcement for Multiwythe Masonry	1. Ladder type with 1 side rod at each face shell of hollow masonry units more than 4 inches
		(100 mm) wide, plus 2 side rods at each wythe of masonry 4 inches (100 mm) wide or less.
		2. Adjustable (two-piece) type, either ladder or truss design, with one side rod at each face shell of backing wythe and with separate adjustable ties with pintle-and-eye connections having a maximum adjustment of 1-1/4 inches (32 mm). Size ties to extend at least halfway through facing wythe but with at least 5/8-inch (16-mm) cover on outside face.

Appendix X-Product List-Masonry-Unit Masonry-6

				Ties have hooks or clips to engage a continuous horizontal wire in the facing wythe.
	Masonry Joint Reinforcement for Veneers Anchored with S			Single 0.187-inch- (4.76-mm-) diameter, hot-dip galvanized, carbon - steel continuous wire.
5	Ties and Anchors			
	Materials			Provide ties and anchors specified in this article that are made from materials that comply with the following unless otherwise
				1. Hot-Dip Galvanized, Carbon-Steel Wire: ASTM A 82/A 82M; with ASTM A 153/A 153M,
				Class B-2 coating.
				2. Steel Sheet, Galvanized after Fabrication: ASTM A 1008/A 1008M, Commercial Steel, with ASTM A 153/A 153M, Class B coating.
				3. Stainless-Steel Sheet: ASTM A 666, Type 304.
				4. Steel Plates, Shapes, and Bars: ASTM A 36/A 36M.
	Wire Ties, General			Unless otherwise indicated, size wire ties to extend at least halfway through veneer but with at least 5/8-inch (16-mm) cover on outside face. Outer ends of wires are bent 90 degrees and extend 2 inches (50 mm) parallel to face of veneer.
	Individual Wire Ties			Rectangular units with closed ends and not less than 4 inches (100 mm) wide.
				1. Where wythes do not align or are of different materials, use adjustable ties with pintle-and-eye connections having a maximum adjustment of 1-1/4 inches (32 mm).
				2. Wire: Fabricate from 1/4-inch- (6.35-mm-) diameter, hot-dip galvanized steel wire.
	Adjustable Anchors for Connecting to Structural Steel Fram			Provide anchors that allow vertical or horizontal adjustment but resist tension and compression forces perpendicular to plane of
				1. Anchor Section for Welding to Steel Frame: Crimped 1/4-inch- (6.35-mm-) diameter, hot-dip galvanized steel wire.

Appendix Y-Product List-Masonry-Unit Masonry-7

				2. Tie Section: Triangular-shaped wire tie, sized to extend within 1 inch (25 mm) of masonry face, made from 0.187-inch- (4.76-mm-) diameter, hot-dip galvanized steel wire.	
	Partition Top anchors			0.105-inch- (2.66-mm-) thick metal plate with 3/8-inch- (9.5-mm-) diameter metal rod 6 inches (152 mm) long welded to plate and with closed-end plastic tube fitted over rod that allows rod to move in and out of tube. Fabricate from steel, hot-dip galvanized after	
	Rigid Anchors			Fabricate from steel bars 1-1/2 inches (38 mm) wide by 1/4 inch (6.35 mm)	
				thick by 24 inches (610 mm) long, with ends turned up 2 inches (51 mm) or with cross pins unless otherwise indicated.	
				1. Corrosion Protection: Hot-dip galvanized to comply with ASTM A 153/A 153M	
	Adjustable Masonry-Veneer Anchors			1. General: Provide anchors that allow vertical adjustment but resist tension and compression forces perpendicular to plane of wall, for attachment over sheathing to wood or metal studs, and as follows:	
				a. Structural Performance Characteristics: Capable of withstanding a 100-lbf (445-N) load in both tension and compression without deforming or developing play in excess of 0.05 inch (1.3 mm).	
				2. Screw-Attached, Masonry-Veneer Anchors: Units consisting of a wire tie and a metal anchor section.	
				a. Wire Tie: V-shape; 0.19-inch (4.76-mm) diameter wire; hot-dip galvanized with not less than 1.5 oz per sq ft per side (460 g per sq m per side); length as required to accommodate details shown on Drawings.	
				b. Metal Anchor: Slotted design with holes in body of anchor to minimize thermal transmission; 16 gage (1.367 mm) base steel thickness; hot-dip galvanized with not less than 1.5 oz per sq ft per side (460 g per sq m per side) ; 0.7-inch (18 mm) overall between exterior face of insulation and exterior face of backing.	

Appendix Z-Product List-Masonry-Unit Masonry-8

				c. Insulation Support Plate: Polyethylene, fitting over outboard end of metal anchor.
				d. Basis-of-Design Product: "Slotted Heavy-Duty Rap-Tie" by Fero Corporation.
				3. Seismic Masonry-Veneer Anchors: Units consisting of a metal anchor section and a connector section designed to engage a continuous wire embedded in the veneer mortar joint.
				a. Products: Subject to compliance with requirements, provide the following:
				1) Dayton Superior Corporation, "Dur-O-Wal Division; D/A 213S."
				2) Hohmann & Barnard, Inc.; "DW-10-X-Seismiclip."
				3) Wire-Bond; "RJ-711 with Wire-Bond clip."
				b. Fabricate sheet metal anchor sections and other sheet metal parts from 1.05-inch-
				(2.66-mm-) thick, steel sheet, galvanized after fabrication.
				c. Fabricate wire connector sections from 0.187-inch- (4.76-mm-) diameter, hot-dip galvanized, carbon -steel wire.
				4. Polymer-Coated, Steel Drill Screws for Steel Studs: ASTM C 954 except manufactured with hex washer head and neoprene or EPDM washer, No. 10 (4.83-mm) diameter by length required to penetrate steel stud flange with not less than three exposed threads, and with organic polymer coating with salt-spray resistance to red rust of more than 800 hours per ASTM B 117.
				a. Products: Subject to compliance with requirements, provide one of the following:
				1) ITW Buildex; "Teks Maxiseal" with "Climaseal" finish.
				2) Textron Inc., Textron Fastening Systems; "Elco Dril-Flex" with "Stalgard" finish.

Appendix AA-Product List-Masonry-Unit Masonry-9

6	Embedded Flashing Materials	
	Metal Flashing	Provide metal flashing complying with SMACNA's "Architectural Sheet Metal Manual" " and as follows:
		1. Stainless Steel: ASTM A 240/A 240M, Type 304, 0.016 inch (0.40 mm) thick.
		2. Fabricate continuous flashings in sections 96 inches (2400 mm) long minimum, but not exceeding 12 feet (3.7 m). Provide splice plates at joints of formed, smooth metal flashing.
		3. Fabricate through-wall flashing with drip edge unless otherwise indicated. Fabricate by extending flashing 1/2 inch (13 mm) out from wall, with outer edge bent down 30 degrees and hemmed.
	Solder and Sealants for Sheet Metal Flashings	1. Solder for Stainless Steel: ASTM B 32, Grade Sn60, with acid flux of type recommended by stainless-steel sheet manufacturer.
		2. Elastomeric Sealant: ASTM C 920, chemically curing urethane sealant; of type, grade, class, and use classifications required to seal joints in sheet metal flashing and trim and remain watertight.
	Adhesives, Primers, and Seam Tapes for Flashings	Flashing manufacturer's standard products or products recommended by flashing manufacturer for bonding flashing sheets to each other and to substrates.
7	Miscellaneous Masonry Accessories	
	Compressible Filler	Premolded filler strips complying with ASTM D 1056, Grade 2A1; compressible up to 35 percent; of width and thickness indicated; formulated from neoprene, urethane, or PVC.
	Preformed Control-Joint Gaskets	Made from styrene-butadiene-rubber compound, complying with ASTM D 2000, Designation M2AA-805 or PVC, complying with ASTM D 2287, Type PVC-65406 and designed to fit standard sash block and to maintain lateral stability in masonry wall; size and configuration as indicated.

Appendix BB-Product List-Masonry-Unit Masonry-10

Weep/Vent Products	Use the following unless otherwise indicated:
	1. Cellular Plastic Weep/Vent: One-piece, flexible extrusion made from UV-resistant polypropylene copolymer, full height and width of head joint and depth 1/8 inch (3 mm) less than depth of outer wythe, in color selected from manufacturer's standard.
	a. Products: Subject to compliance with requirements, provide one of the following:
	1) Advanced Building Products Inc.; "Mortar Maze" weep vent.
	2) Dayton Superior Corporation, Dur-O-Wal Division; "Cell Vents."
	3) Heckmann Building Products Inc.; "No. 85 Cell Vent."
	4) Hohmann & Barnard, Inc.; "Quadro-Vent."
	5) Wire-Bond; "Cell Vent."
Cavity Drainage Material	Free-draining mesh, made from polymer strands that will not degrade within the wall cavity.
	1. Products: Subject to compliance with requirements, provide one of the following:
	a. Advanced Building Products Inc.; "Mortar Break II."
	b. Dayton Superior Corporation, Dur-O-Wal Division; "Polytite MortarStop."
	c. Mortar Net USA, Ltd.; "Mortar Net."
	2. Provide one of the following configurations:
	a. Strips, full-depth of cavity and 10 inches (250 mm) high, with dovetail shaped notches 7 inches (175 mm) deep that prevent clogging with mortar droppings.
	b. Strips, not less than 1-1/2 inches (38 mm) thick and 10 inches (250 mm) high, with dimpled surface designed to catch mortar droppings and prevent weep holes from clogging with mortar.

Appendix CC-Product List-Masonry-Unit Masonry-11

8	Mortar and Grout Mixes	
	General	Do not use admixtures, including pigments, air-entraining agents, accelerators, retarders, water-repellent agents, antifreeze compounds, or other admixtures, unless otherwise indicated.
		1. Do not use calcium chloride in mortar or grout.
		2. Use portland cement-lime mortar unless otherwise indicated.
		3. For exterior masonry, use portland cement-lime mortar.
	Mortar for Unit Masonry	Comply with ASTM C 270, Proportion Specification. Provide the following types of mortar for applications stated unless another type is indicated.
		1. For masonry below grade or in contact with earth, use Type M.
		2. Cannon Note: Delete first subparagraph below if no masonry is grouted and reinforced with steel reinforcing bars. For exterior, above-grade, load-bearing and non-loadbearing walls and parapet walls; for interior load-bearing walls; for interior non-load-bearing partitions; and for other applications where another type is not indicated, use Type N.
	Pigmented Mortar	Use colored cement product or select and proportion pigments with other ingredients to produce color required. Do not add pigments to colored cement products.
		1. Pigments shall not exceed 10 percent of portland cement by
		2. Mix to match Architect's sample.
	Colored-Aggregate Mortar:	Produce required mortar color by using colored aggregates and natural color or white cement as necessary to produce required
		1. Mix to match Architect's sample.
	Grout for Unit Masonry	Comply with ASTM C 476.
		1. Use grout of type indicated or, if not otherwise indicated, of type (fine or coarse) that will comply with Table 1.15.1 in ACI 530.1/ASCE 6/TMS 602 for dimensions of grout spaces and pour height.
		2. Provide grout with a slump of 8 to 11 inches (203 to 279 mm) as measured according to ASTM C 143/C 143M

Appendix DD-Product List-Steel-Structural Steel Framing-1

Steel					
Section 05	**1200**	**Structural Steel Framing**			
1	Materials				
	Structural Steel	Minimum requirements			
		Shape/Type	ASTM Grade	Yield Strength (Fy in Ksi)	Post Consumer and Pre-Consumer Recycled Content
		Rolled WF & WT	A992	50	50%, 5%
		Plates	A36	36	85%, 10%
		Base Plates	A572	42	85%, 10%
		Structural Pipe	A53 Grade B	35	50%, 5%
		Square/Rectangular	A500 Grade B	46	50%, 5%
		All Other Steel	A36	36	50%, 5%
	High Strength Bolts, Nuts and Washers			ASTM A325 or A490; cold forged with rolled threads. Do not mix A325 and A490 bolts of the same diameter. Different grade bolts must vary in diameter by a minimum of 1/4 inch.	
	Anchor Rods for base plates			ASTM F-1554 Grade 36, 55, or 105 as given on the drawings	
	Headed Studs			ASTM A108, Grades 1010, 1015, 1017 or 1020, and cold finished carbon steel	
	Galvanizing			Hot dips galvanize steel where indicated as follows:	
				1. Rolled, forged and pressed shapes - ASTM A123.	
				2. Iron and steel hardware - ASTM A153.	
				3. Assembled steel products - ASTM A123.	
				4. Welds subsequent to galvanizing - coat with approved zinc rich primer.	

Appendix EE -Product List-Steel-Structural Steel Framing-2

Filler Metal for Welding		Conform to AWS Code D1.1 with addenda and the following requirements:	
		1. Shielded metal-arc welding, AWS A5.1 and A5.5, E70 series.	
		2. Submerged arc-welding, AWS A5.17 and A5.23.	
		3. Flux Core Arc Welding: AWS A5.20 and A5.29.	
		4. Gas Metal Arc Welding: AWS A5.18 and A5.28.	
Torque Control Bolts		: ASTM F1852 Type I:	
		1. LeJeune T.C. Bolts, LeJeune Bolt Company, Burnsville, Minnesota.	
		2. Tru-Tension Bolts, Nucor Corporation, St. Joe, Indiana.	
Direct Tension Indicatros		ASTM F959	
		1. "Coronet Load Indicators" by TurnaSure, LLC, Langhorne, PA	
Expansion Anchors		Install in accordance with manufacturer's printed instructions. Use only with prior review and acceptance by the Architect/Engineer for the specific applications indicated. Minimum service load capacity in pounds per anchor:	
	Diameter	Tension	Shear
	3/8"	900	1200
	1/2"	1400	2200
	5/8"	2500	3300
	3/4"	3800	4200
	7/8"	4500	6000
Adhesive Anchors		Install in accordance with manufacturers printed instructions. Use only with prior review and acceptance by Architect/Engineer for the specific applications indicated.	
		Subject to compliance with requirements, provide one of the following:	
		1. HY-150 by Hilti.	
		2. Power-Fast by Powers Fastening.	

Appendix FF-Product List-Steel-Structural Steel Framing-3

	3. Ceramic Six by Ramset/Red Head.
Paint-Shop Primer	(Steel not exposed to the elements):
	1. Series 10-99 Alkyd Primer by Tnemec Co.
	2. Carbocoat 115 by Carboline Co.
Paint-Shop Primer	(Steel exposed to the elements):
	1. Series 90-97 Urethane Zinc Primer by Tnemec Co.
	2. Carbozinc 859 by Carboline Co.
Galvanizing Repair Paint	SSPC – Paint 20 with dry film containing a minimum of 94 percent zinc dust by weight.
	1. Galvilite by ZRC Worldwide.
	2. Approved equal.
Structural Slide Bearings	1. Maximum static and kinetic coefficients of friction do not exceed 0.06 at pressures over 600 psi, as installed.
	2. Lower elastomeric pad consists of bonded multiple plies of reinforced elastomer having a top surface of pure unfilled "Teflon" (PTFE). Upper pad has a bottom sliding surface of polished stainless steel.
	3. Bearings are chemically inert, weatherproof and require no maintenance.
Elastomeric Bearing Pads	Comply with AASHTO "Standard Specifications for Highway Bridges" - Section 25. Minimum durometer rating of 60.
All Other Materials	Type best suited for the purpose intended. Follow manufacturer's recommendations.

Appendix GG-Product List-Steel-Steel Decking-1

Section 05		**3100 Steel Decking**			
	1	Manufacturers			Subject to compliance with project requirements, provide products of one of the following:
					1. Canam Steel Corp.; The Canam Manac Group.
					2. Consolidated Systems, Inc.
					3. Epic Metals Corp.
					4. Nucor Corp.; Vulcraft Div.
					5. United Steel Deck, Inc.
					6. Wheeling Corrugating Company; Div. Of Wheeling-Pittsburgh Steel Corporation
	2	Materials			
		Steel Roof Deck			Fabricate panels, without top-flange stiffening grooves, to comply with "SDI Specifications and Commentary for Steel Roof Deck," in SDI Publication No. 30, and with the following:
					1. Galvanized Steel Sheet: ASTM A 653/A 653M, Structural Steel (SS), Grade 33, G90 zinc coating.
					2. Recycled Content: Minimum 50% post-consumer and 5% pre-consumer recycled content.
		Acoustic Cellular Steel Roof Deck			Fabricate panels, without top-flange stiffening grooves, to comply with "SDI Specifications and Commentary for Steel Roof Deck," in SDI Publication
					No. 30, and with the following:
					1. Galvanized Steel Sheet: ASTM A 653/A 653M, Structural Steel (SS), Grade 33, G90 zinc coating.
					2. Acoustic Perforations: Cellular deck units with manufacturer's standard perforated flatbottom plate welded to ribbed deck.

Appendix HH-Product List-Steel-Steel Decking-2

				3. Sound-Absorbing Insulation: Manufacturer's standard premolded roll or strip of glass or mineral fiber.	
				a. Factory install sound-absorbing insulation into cells of cellular deck.	
				b. Installation of sound-absorbing insulation is specified in Division 07.	
				4. Acoustic Performance: NRC 0.75, tested according to ASTM C 423.	
	Composite Steel Floor Deck			Fabricate panels, with integrally embossed or raised pattern ribs and interlocking side laps, to comply with "SDI Specifications and Commentary for Composite	
				Steel Floor Deck," in SDI Publication No. 30, with the minimum section properties indicated, and with the following:	
				1. Galvanized Steel Sheet: ASTM A 653/A 653M, Structural Steel (SS), Grade 33, G60 zinc coating.	
	Acoustic Composite Cellular Steel Deck			Fabricate panels with integrally embossed or raised pattern ribs and interlocking side laps, to comply with "SDI Specifications and Commentary for Composite Steel Floor Deck, " in SDI Publications N0. 30, with the minimum section properties indicated, and with the following:	
				1. Galvanized Steel Sheet: ASTM A653/A653M, Structural Steel (55), Grade 33, G60 zinc coating.	
				2. Acoustic Perforations: Cellular deck units with manufacturer's standard perforated flatbottom plate welded to ribbed deck.	

				3. Sound-absorbing Insulation: Manufacturer's standard premolded roll or strip of glass or mineral fiber:	
				a. Factory install sound-absorbing insulation into cells of cellular deck.	
				b. Installation of sound-absorbing insulation is specified in Division 07.	
				4. Acoustic performance: NRC 0.75, tested according to ASTM	
	Miscellaneous Steel Shapes			ASTM A 36.	
				1. Recycled Content: Minimum 80% post-consumer and 10% pre-consumer recycled content.	
	Shear Connectors			Through deck welded headed stud type, ASTM A 108, Grade 1015, 1017 or 1020, cold finished carbon steel; AWS D1.1, with arc shields; with dimensions complying with Contract Documents. Studs shall extend a minimum of 1-1/2 inches above the top of the steel upper deck surface. Minimum yield	
	Welding electrode			E60XX min.	
	Galvanizing			ASTM A 653	
	Acoustic Sound Barrier Closures			Manufacturer's standard mineral fiber closures.	

Appendix II-Product List-Steel-Cold-Formed Metal Framing-1

Section 05	4000	Cold-Formed Metal Framing		
1	Manufacturers			Subject to compliance with requirements, provide cold-formed metal framing by one of the following:
				1. Clark Steel Framing.
				2. Dale/Incor.
				3. Dietrich Metal Framing; a Worthington Industries Company.
				4. MarinoWare; a division of Ware Industries.
				5. Super Stud Building Products, Inc.
				6. United Metal Products, Inc.
2	Materials			
	Recycled Content of Steel Products			Provide products with an average recycled content of steel products so postconsumer recycled content plus one-half of preconsumer recycled content is not less than 25 percent.
	Steel Sheet			ASTM A 1003/A 1003M, Structural Grade, Type H, metallic coated, of grade and coating weight as follows:
				1. Grade: As required by structural performance.
				2. Coating: G90 (Z275) or equivalent.
	Steel Sheet for vertical deflection or Drift Clips			ASTM A 653/A 653M, structural steel, zinc coated, of grade and coating as follows:
				1. Grade: As required by structural performance.
				2. Coating: G90 (Z275).
3	Exterior Non-Load-Bearing Wall Framing			
	Steel Studs			Manufacturer's standard C-shaped steel studs, of web depths indicated, punched, with stiffened flanges, and as follows:
				1. Minimum Base-Metal Thickness: 0.0538 inch (1.37 mm), unless otherwise required by structural performance.

Appendix JJ-Product List-Steel-Cold-Formed Metal Framing-2

				2. Flange Width: 1-5/8 inches (41 mm).
	Steel Track			Manufacturer's standard U-shaped steel track, of web depths indicated, unpunched, with unstiffened flanges, and as
				1. Minimum Base-Metal Thickness: Matching steel studs.
	Vertical deflection Clips			Manufacturer's standard [bypass] [head] clips, capable of accommodating upward and downward vertical displacement of primary structure through positive mechanical attachment to stud web.
	Single Deflection Track			Manufacturer's single, deep-leg, U-shaped steel track; unpunched, with unstiffened flanges, of web depth to contain studs while allowing free vertical movement, with flanges designed to support horizontal and lateral loads and transfer them to the primary structure, and as follows:
				1. Minimum Base-Metal Thickness: 0.0677 inch (1.72 mm).
	Double Deflection Tracks			Manufacturer's double, deep-leg, U-shaped steel tracks, consisting of nested inner and outer tracks; unpunched, with unstiffened flanges
	Drift Clips			Manufacturer's standard bypass or head clips, capable of isolating wall stud from upward and downward vertical displacement and lateral drift of primary structure.
4	Framing Accessories			
5	Anchors, Clips, and Fasteners			
	Steel Shapes and Clips			ASTM A 36/A 36M, zinc coated by hot-dip process according to ASTM A 123/A 123M.
	Anchors Bolts			ASTM F 1554, Grade 55, threaded carbon-steel bolts and carbon-steel nuts; and flat, hardened-steel washers; zinc coated by hot-dip process according to ASTM A 153/A 153M, Class C

Appendix KK-Product List-Steel-Cold-Formed Metal Framing-3

	Expansion Anchors			Fabricated from corrosion-resistant materials, with capability to sustain, without failure, a load equal to 5 times design load, as determined by testing per ASTM E 488 conducted by a qualified independent testing agency.
	Mechanical Fasteners			ASTM C 1513, corrosion-resistant-coated, self-drilling, self-tapping steel drill screws.
				1. Head Type: Low-profile head beneath sheathing, manufacturer's standard elsewhere.
	Welding Electrodes			Comply with AWS standards
6	Miscellaneous Materials			
	Galvanizing Repair Paint			ASTM A 780
	Cement Grout			Portland cement, ASTM C 150, Type I; and clean, natural sand, ASTM C 404.
				Mix at ratio of 1 part cement to 2-1/2 parts sand, by volume, with minimum water required for placement and hydration.
	Nonmetallic, Nonshrink Grout			Premixed, nonmetallic, noncorrosive, nonstaining grout containing selected silica sands, portland cement, shrinkage-compensating agents, and plasticizing and water-reducing agents, complying with ASTM C 1107, with fluid consistency and 30-minute working time.
	Shims			Load bearing, high-density multimonomer plastic, nonleaching
	Sealer Gaskets			Closed-cell neoprene foam, 1/4 inch (6.4 mm) thick, selected from manufacturer's standard widths to match width of bottom track or rim track members.

Appendix LL-Product List-Steel-Metal Fabrications

Section 05	5000 Metal Fabrications	
1	Metals, General	Provide materials with smooth, flat surfaces unless otherwise indicated. For metal fabrications exposed to view in the completed Work, provide materials without seam marks, roller marks, rolled trade names, or blemishes.
2	Ferrous Metals	
	Recycled Content of Steel Products	Post-consumer recycled content plus one-half of preconsumer recycled content not less than 25 percent.
	Steel Plates, Shapes, and Bars	ASTM A 36/A 36M
	Abrasive-Surface Floor Plate	Steel plate with abrasive granules rolled into surface with abrasive material metallically bonded to steel.
		1. Products: Subject to compliance with requirements, available products that may be incorporated into the Work include, but are not limited to, the following:
		a. IKG Industries, a division of Harsco Corporation; "Mebac."
		b. SlipNOT Metal Safety Flooring, a W. S. Molnar company; " SlipNOT."
	Steel tubing	ASTM A 500, cold-formed steel tubing
	Steel Pipe	ASTM A 53/A 53M, standard weight (Schedule 40) unless otherwise indicated or required by structural loads.
	Slotted Channel Framing	Cold-formed metal box channels (struts) complying with MFMA-
		1. Size of Channels: As indicated.
		2. Material: Galvanized steel, ASTM A 653/A 653M, commercial steel, Type B, with G90 (Z275) coating; 0.108-inch (2.8-mm) nominal thickness.
		3. Material: Cold-rolled steel, ASTM A 1008/A 1008M, commercial steel, Type B; 0.0966- inch (2.5-mm) minimum thickness; hot-dip galvanized after fabrication.
	Cast Iron	Either gray iron, ASTM A 48/A 48M, or malleable iron, ASTM A 47/A 47M, unless otherwise indicated or required by structural
3	Nonferrous Metals	
	Aluminum Plate and Sheet	ASTM B 209 (ASTM B 209M), Alloy 6061-T6.
	Aluminum Extrusions	ASTM B 221 (ASTM B 221M), Alloy 6063-T6.
4	Fasteners	
5	Miscellaneous Materials	
	Welding Rods and Bare Electrodes	Select according to AWS specifications for metal alloy welded.
	Epoxy Zinc-Rich Primer	Complying with MPI#20 and compatible with topcoat.
		1. Products: Subject to compliance with requirements, [provide the following] [provide one of the following] [available products that may be incorporated into the Work include, but are not limited to, the following]:

Appendix MM-Product List-Steel-Metal Stairs-1

Section 05	5100 Metal Stairs			
1	Metals, General			
	Metal Surfaces, General			Provide materials with smooth, flat surfaces, unless otherwise indicated. For components exposed to view in the completed Work, provide materials without seam marks, roller marks, rolled trade names, or blemishes.
	Recycled Content of Steel Products			Provide products with an average recycled content of steel products so postconsumer recycled content plus one-half of preconsumer recycled content is not less than 25 percent.
2	Ferrous Metals			
	Steel Plates, Shapes, and Bars			ASTM A 36/A 36M
	Iron Castings			Either gray or malleable iron, unless otherwise indicated.
				1. Gray Iron: ASTM A 48/A 48M, Class 30, unless another class is indicated or required by structural loads.
				2. Malleable Iron: ASTM A 47/A 47M.
	Uncoated, Cold-Rolled Steel Sheet			ASTM A 1008/A 1008M, either commercial steel, Type B, or structural steel, Grade 25 (Grade 170), unless another grade is required by design loads; exposed.
3	Fasteners			
	General			Provide zinc-plated fasteners with coating complying with ASTM B 633, Class Fe/Zn
				25 for exterior use, and Class Fe/Zn 5 where built into exterior walls. Select fasteners for type, grade, and class required.
	Bolts and Nuts			Regular hexagon-head bolts, ASTM A 307, Grade A (ASTM F 568M, Property
				Class 4.6); with hex nuts, ASTM A 563 (ASTM A 563M); and, where indicated, flat washers.

Appendix NN-Product List-Steel-Metal Stairs-2

	Anchor Bolts			ASTM F 1554, Grade 36.
				1. Provide hot-dip or mechanically deposited, zinc-coated anchor bolts for stairs indicated to be shop primed with zinc-
	Machine Screws			ASME B18.6.3 (ASME B18.6.7M
	Plain Washers			Round, ASME B18.22.1 (ASME B18.22M).
	Lock Washers			Helical, spring type, ASME B18.21.1 (ASME B18.21.2M).
4	Miscellaneous Materials			
	Welding Rods and Bare Electrodes			Select according to AWS specifications for metal alloy welded.
	Zinc-Rich Primer			Complying with SSPC-Paint 20 or SSPC-Paint 29 and compatible with topcoat.
				1. Use primer with a VOC content of 420 g/L (3.5 lb/gal.) or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
				2. Available Products:
				a. Carboline Company; Carbozinc 621.
				b. ICI Devoe Coatings; Catha-Coat 313.
				c. International Coatings Limited; Interzinc 315 Epoxy Zinc-Rich Primer.
				d. Moore, Benjamin, & Co.; Epoxy Zinc-Rich Primer CM18/19.
				e. PPG Architectural Finishes, Inc.; Aquapon Zinc-Rich Primer 97-670.
				f. Sherwin-Williams Company (The); Corothane I GalvaPac Zinc Primer.
				g. Tnemec Company, Inc.; Tneme-Zinc 90-97.
	Bituminous Paint			Cold-applied asphalt emulsion complying with ASTM D 1187.
	Nonshrink, Nonmetallic Grout			Factory-packaged, nonstaining, noncorrosive, nongaseous grout complying with ASTM C 1107. Provide grout specifically recommended by manufacturer for interior and exterior applications.

Appendix OO-Product List-Steel-Metal Stairs-3

	Concrete Materials and Properties		Comply with requirements in Division 03 Section "Cast-in-Place Concrete" for normal-weight, air-entrained, ready-mix concrete with a minimum 28-day compressive strength of 3000 psi (20 MPa), unless otherwise indicated.
	Nonslip-Aggregate Concrete Finish		Factory-packaged abrasive aggregate made from fused, aluminum-oxide grits or crushed emery; rustproof and nonglazing; unaffected by freezing, moisture, or cleaning
	Welded Wire Fabric		ASTM A 185, 6 by 6 inches (152 by 152 mm)--W1.4 by W1.4, unless otherwise indicated.
5	Farication, General		
6	Steel-Framed Stairs		
	Available Manufacturers		1. Alfab, Inc.
			2. American Stair, Inc.
			3. Sharon Companies Ltd. (The).
	Stair Framing		1. Fabricate stringers of steel plates or channels.
			a. Provide closures for exposed ends of channel stringers.
			2. Construct platforms of steel headers and miscellaneous framing members as needed to comply with performance
			3. Weld stringers to headers; weld framing members to stringers and headers.
			4. Where stairs are enclosed by gypsum board assemblies, provide hanger rods or struts to support landings from floor construction above or below. Locate hanger rods and struts where they will not encroach on required stair width and will be within the fire-resistancerated stair enclosure.
			5. Where masonry walls support metal stairs, provide temporary supporting struts designed for erecting steel stair components before installing masonry.

	Metal-Pan Stairs		Form risers, subtread pans, and subplatforms to configurations shown from steel sheet of thickness needed to comply with performance requirements but not less than 0.0677 inch (1.7
			1. Steel Sheet: Uncoated cold -rolled steel sheet, unless otherwise indicated.
			2. Directly weld metal pans to stringers; locate welds on top of subtreads where they will be concealed by concrete fill. Do not weld risers to stringers.
			3. Shape metal pans to include nosing integral with riser.
			4. At Contractor's option, provide stair assemblies with metal-pan subtreads filled with reinforced concrete during
			5. Provide subplatforms of configuration indicated or, if not indicated, the same as subtreads. Weld subplatforms to platform framing.

Appendix PP-Product List-Steel-Pipe and Tube Railings-1

Section 05	5213 Pipe and Tube Railings		
1	Manufacturers		Subject to compliance with requirements, provide products by one of the following:
			1. Steel Pipe and Tube Railings:
			a. Pisor Industries, Inc.
			b. Wagner, R & B, Inc.; a division of the Wagner Companies.
			2. Stainless-Steel Pipe and Tube Railings:
			a. Blum, Julius & Co., Inc.
			b. Pisor Industries, Inc.
			c. Sterling Dula Architectural Products, Inc.; Div. of Kane Manufacturing.
			d. Wagner, R & B, Inc.; a division of the Wagner Companies.
2	Metals, General		
	Metal Surfaces, General		Provide materials with smooth surfaces, without seam marks, roller marks, rolled trade names, stains, discolorations, or blemishes
	Brackets, Flanges, and Anchors		Cast or formed metal of same type of material and finish as supported rails unless otherwise indicated
3	Steel and Iron		
	Recycled Content of Steel Products		Provide products with average recycled content of steel products so postconsumer recycled content plus one-half of preconsumer recycled content is not less than 25 percent.
	Plates, Shapes and Bars		ASTM A 36/A 36M
	Cast Iron		Either gray iron, ASTM A 48/A 48M, or malleable iron, ASTM A 47/A 47M, unless otherwise indicated.

Appendix QQ-Product List-Steel-Pipe and Tube Railings-2

4	Stainless Steel	
	Tubing	ASTM A 554, Grade MT 304
	Pipe	ASTM A 312/A 312M, Grade TP 304
	Plate and Sheet	ASTM A 240/A 240M or ASTM A 666, Type
5	Fasteners	
	General	Provide the following:
		1. Hot-Dip Galvanized Railings: Type 304 stainless-steel or hot-dip zinc-coated steel fasteners complying with ASTM A 153/A 153M or ASTM F 2329 for zinc coating.
		2. Stainless-Steel Railings: Type 304 stainless-steel fasteners.
	Fasteners for Anchoring Railings to Other Construction	Select fasteners of type, grade, and class required to produce connections suitable for anchoring railings to other types of construction indicated and capable of withstanding design
6	Miscellaneous Materials	
	Welding Robs and Bare Electrodes	Select according to AWS specifications for metal alloy welded.
		1. For stainless-steel railings, provide type and alloy as recommended by producer of metal to be welded and as required for color match, strength, and compatibility in
	Etching Cleaner for Galvanized Metal	Complying with MPI#25.
	Galvanizing Repair Paint	High-zinc-dust-content paint complying with SSPC-Paint 20 and compatible with paints specified to be used over it.
	Shop Primer for Galvanized Steel	Water based galvanized metal primer complying with MPI#134
	Bituminous Paint	Cold-applied asphalt emulsion complying with ASTM D 1187
	Nonshrink, Nonmetallic Grout	Factory-packaged, nonstaining, noncorrosive, nongaseous grout complying with ASTM C 1107. Provide grout specifically recommended by manufacturer for interior and exterior applications.

Appendix RR-Product List-Steel-Decorative Metal Railings-1

Section 05	7300 Decorative Metal Railings	
1	Manufacturers	Subject to compliance with requirements, provide products by one of the following:
		1. Stainless-Steel Decorative Railings:
		a. Blum, Julius & Co., Inc.
		b. Blumcraft of Pittsburgh.
		c. CraneVeyor Corp.
		d. Wagner, R & B, Inc.; a division of the Wagner Companies.
		2. Glass-Supported Railings:
		a. Blum, Julius & Co., Inc.
		b. Blumcraft of Pittsburgh.
		c. CraneVeyor Corp.
2	Metals, General	
	Metal Surfaces, General	Provide materials with smooth surfaces, without seam marks, roller marks, rolled trade names, stains, discolorations, or blemishes.
	Brackets, Flanges, and Anchors	Same metal and finish as supported rails unless otherwise indicated.
3	Stainless Steel	
	Tubing	ASTM A 554, Grade MT 304
	Pipe	ASTM A 312/A 312M, Grade TP 304
	Castings	ASTM A 743/A 743M, Grade CF 8 or CF 20
	Sheet, Strip, Plate and Flat Bar	ASTM A 666, Type 304
	Bars and Shapes	ASTM A 276, Type 304

Appendix SS-Product List-Steel-Decorative Metal Railings-2

4	Glass and Glazing Materials			
	Tempered Glass			ASTM C 1048, Kind FT (fully tempered), Condition A (uncoated), Type 1 (transparent flat glass), Quality-Q3. Provide products that have been tested for surface and edge compression according to ASTM C 1048 and for impact strength according to 16 CFR 1201 for Category II materials.
				1. Glass Color: Clear.
				2. Thickness for Structural Glass Balusters: 19.0 mm, unless otherwise indicated on Drawings.
				3. Thickness for Structural Glass Balusters: As required by structural loads, but not less than 19.0 mm.
	Laminated Glass			ASTM C 1172, Condition A (uncoated), Type I (transparent flat glass),
				Quality-Q3 with two plies of glass and polyvinyl butyral interlayer not less than 0.060 inch (1.52
				mm) thick.
				1. Kind: LT (laminated tempered) .
				2. Glass Color: Clear.
				3. Interlayer Color: Clear.
				4. Glass Plies for Structural Glass Balusters: Thickness required by structural loads, but not less than 8.0 mm thick, each.
				5. Glass Plies for Glass Infill Panels: Thickness required by structural loads, but not less than 5.0 mm, each.
	Glazing Cement and Accessories for Structural Glazing			Glazing cement, setting blocks, shims, and related accessories as recommended or supplied by railing manufacturer for installing structural glazing in metal subrails.
				1. Glazing Cement: Non-shrinking organic cement designed for curing by passing an electric current through metal subrail holding glass panel, as standard with manufacturer.

Appendix TT-Product List-Steel-Decorative Metal Railings-3

5	Fasteners	
	Fastener Materials	Unless otherwise indicated, provide the following:
		1. Stainless-Steel Components: Type 304 stainless-steel
		2. Dissimilar Metals: Type 304 stainless-steel fasteners.
	Fasteners for Anchoring to Other Construction	Select fasteners of type, grade, and class required to produce connections suitable for anchoring railings to other types of construction indicated
		Provide concealed fasteners for interconnecting railing components and for attaching railings to other work unless otherwise indicated.
	Anchors, General	Anchors capable of sustaining, without failure, a load equal to six times the load imposed when installed in unit masonry and four times the load imposed when installed in concrete, as determined by testing according to ASTM E 488, conducted by a qualified independent testing agency.
	Post-Installed Anchors	Torque-controlled expansion anchors.
		1. Material for Interior Locations: Carbon-steel components zinc plated to comply with
		ASTM B 633 or ASTM F 1941 (ASTM F 1941M), Class Fe/Zn 5, unless otherwise indicated
6	Miscellaneous Materials	
	Wood Rails	Clear, straight-grained hardwood rails secured to metal
		1. Species: Maple, unless otherwise indicated on Drawings.
		2. Finish: Manufacturer's standard.
		3. Staining: As selected by Architect from manufacturer's full range.
		4. Profile: As indicated.
	Welding Robs and Bare Electrodes	Select according to AWS specifications for metal alloy welded
	Non-Shrink, Non-Metallic Grout	Factory-packaged, non-staining, non-corrosive, non-gaseous grout complying with ASTM C 1107. Provide grout specifically recommended by manufacturer for interior and exterior applications.

Appendix UU-Product List-Wood-Miscellaneous Rough Carpentry-1

Wood			
Section 06	**1053**	**Miscellaneous Rough Carpentry**	
1	Wood Products, General		
	Certified Wood		Lumber and plywood shall be produced from wood obtained from forests certified by an FSC-accredited certification body to comply with FSC STD-01-001, "FSC Principles and Criteria for Forest Stewardship."
	Lumber		DOC PS 20 and applicable rules of grading agencies indicated. If no grading agency is indicated, provide lumber that complies with the applicable rules of any rules-writing agency certified by the ALSC Board of Review. Provide lumber graded by an agency certified by the ALSC Board of Review to inspect and grade lumber under the rules indicated.
			1. Factory mark each piece of lumber with grade stamp of grading agency.
			2. Where nominal sizes are indicated, provide actual sizes required by DOC PS 20 for moisture content specified. Where actual sizes are indicated, they are minimum dressed sizes for dry lumber.
			3. Provide dressed lumber, S4S, unless otherwise indicated
	Maximum Moisture Content of Lumber		19 percent unless otherwise indicated

Appendix VV-Product List-Wood-Miscellaneous Rough Carpentry-2

2	Wood-Preservative-Treated Materials	
	Preservative Treatment by Pressure Process	AWPA U1; Use Category UC2 for interior construction not in contact with the ground, Use Category UC3b for exterior construction not in contact with the ground, and Use Category UC4a for items in contact with the ground.
		1. Preservative Chemicals: Acceptable to authorities having jurisdiction and containing no arsenic or chromium. Do not use inorganic boron (SBX) for sill plates.
	Kiln-Dry Lumber	Kiln-dry lumber after treatment to a maximum moisture content of 19 percent. Do not use material that is warped or does not comply with requirements for untreated material.
	Mark Lumber	Mark lumber with treatment quality mark of an inspection agency approved by the ALSC Board of Review
	Application	Treat items indicated on Drawings, and the following:
		1. Wood cants, nailers, curbs, equipment support bases, blocking, stripping, and similar members in connection with roofing, flashing, vapor barriers, and waterproofing.
		2. Wood sills, sleepers, blocking, furring, and similar concealed members in contact with masonry or concrete.

Appendix WW-Product List-Wood-Miscellaneous Rough Carpentry-3

3	Fire-Retardant-Treated Materials				
	General			Use materials complying with requirements in this article, that are acceptable to authorities having jurisdiction, and with fire-test-response characteristics specified as determined by testing identical products per test method indicated by a qualified testing agency.	
	Fire-Retardant-Treated Lumber and Plywood by Pressure Process			Products with a flame spread index of 25 or less when tested according to ASTM E 84, and with no evidence of significant progressive combustion when the test is extended an additional 20 minutes, and with the flame front not extending more than 10.5 feet (3.2 m) beyond the centerline of the burners at any time during the test.	
				1. Use treatment that does not promote corrosion of metal fasteners.	
				2. Exterior Type: Treated materials shall comply with requirements specified above for fire-retardant-treated lumber and plywood by pressure process after being subjected to accelerated weathering according to ASTM D 2898. Use for exterior locations and where indicated.	

Appendix XX-Product List-Wood-Miscellaneous Rough Carpentry-4

				3. Interior Type A: Treated materials shall have a moisture content of 28 percent or less when tested according to ASTM D 3201 at 92 percent relative humidity. Use where exterior type is not indicated.	
	Kiln-Dry Lumber			Kiln-dry lumber after treatment to a maximum moisture content of 19 percent. Kiln-dry plywood after treatment to a maximum moisture content of 15 percent.	
	Identify Fire-Retardant-Treated Wood			Identify fire-retardant-treated wood with appropriate classification marking of testing and inspecting agency acceptable to authorities having jurisdiction.	
	Application			Treat items indicated on Drawings, and the following:	
				1. Concealed blocking.	
				2. Wood cants, nailers, curbs, equipment support bases, blocking, and similar members in connection with roofing.	
				3. Plywood backing panels.	

Appendix YY-Product List-Wood-Miscellaneous Rough Carpentry-5

4	Miscellaneous Lumber				
	A General			Provide miscellaneous lumber indicated and lumber for support or attachment of other construction, including the following:	
				1. Blocking.	
				2. Nailers.	
				3. Rooftop equipment bases and support curbs.	
				4. Cants.	
				5. Furring.	
	B			For items of dimension lumber size, provide Construction or No. 2 grade lumber of any species.	
				1. Hem-fir (north); NLGA.	
				2. Mixed southern pine; SPIB.	
				3. Spruce-pine-fir; NLGA.	
				4. Hem-fir; WCLIB or WWPA.	
				5. Spruce-pine-fir (south); NeLMA, WCLIB, or WWPA.	
	C			For concealed boards, provide lumber with 19 percent maximum moisture content and any of the following species and grades:	
				1. Mixed southern pine, No. 2 grade; SPIB.	
				2. Hem-fir or hem-fir (north), Construction or No. 2 Common grade; NLGA, WCLIB, or WWPA.	
				3. Spruce-pine-fir (south) or spruce-pine-fir, Construction or No. 2 Common grade; NeLMA, NLGA, WCLIB, or WWPA.	

Appendix ZZ-Product List-Wood-Miscellaneous Rough Carpentry-6

	D			For blocking not used for attachment of other construction, Utility, Stud, or No. 3 grade lumber of any species may be used provided that it is cut and selected to eliminate defects that will interfere with its attachment and purpose	
	E			For blocking and nailers used for attachment of other construction, select and cut lumber to eliminate knots and other defects that will interfere with attachment of other work	
5	Plywood Backing Panels				
	Equipment Backing Panels			DOC PS 1, Exterior, AC, fire-retardant treated, in thickness indicated or, if not indicated, not less than 3/4-inch (19-mm) nominal thickness.	
6	Fasteners				
	General			Provide fasteners of size and type indicated that comply with requirements specified in this article for material and manufacture.	
				1. Where carpentry is exposed to weather, in ground contact, pressure-preservative treated, or in area of high relative humidity, provide fasteners with hot-dip zinc coating complying with ASTM A 153/A 153M	
	Nails, Brads, and Staples			ASTM F 1667	
	Wood Screws			ASME B18.6.1	
	Screws for Fastening to Metal Framing			ASTM C 1002 or ASTM C 954 as applicable, length as recommended by screw manufacturer for material being fastened	

Appendix AAA-Product List-Wood-Miscellaneous Rough Carpentry-7

	Lag Bolts			ASME B18.2.1 (ASME B18.2.3.8M).	
	Bolts			Steel bolts complying with ASTM A 307, Grade A (ASTM F 568M, Property Class 4.6); with ASTM A 563 (ASTM A 563M) hex nuts and, where indicated, flat washers	
	Expansion Anchors			Anchor bolt and sleeve assembly of material indicated below with capability to sustain, without failure, a load equal to 6 times the load imposed when installed in unit masonry assemblies and equal to 4 times the load imposed when installed in concrete as determined by testing per ASTM E 488 conducted by a qualified independent testing and inspecting agency.	
				1. Material: Carbon-steel components, zinc plated to comply with ASTM B 633, Class Fe/Zn	
7	Miscellaneous Materials				
	Adhesives for Gluing Furring to Concrete or Masonry			Formulation complying with ASTM D 3498 that is approved for use indicated by adhesive manufacturer.	
				1. Adhesives shall have a VOC content of 70 g/L or less when calculated according to 40	
				CFR 59, Subpart D (EPA Method 24).	

Appendix BBB-Product List-Wood-Sheathing-1

Section 06	**1600 Sheathing**	
1	Performance Requirements	
	Fire-Test-Response Characteristics	For assemblies with fire-resistance ratings, provide materials and construction identical to those of assemblies tested for fire resistance per ASTM
		E 119 by a testing and inspecting agency acceptable to authorities having jurisdiction.
		1. Fire-Resistance Ratings: Indicated by design designations from UL's "Fire Resistance Directory."
2	Wall Sheathing	
	Glass-Mat Gypsum Wall Sheathing	ASTM C 1177/1177M
		1. Products: Subject to compliance with requirements, provide the following:
		a. CertainTeed Corporation; "GlasRoc."
		b. G-P Gypsum Corporation; "Dens-Glass Gold."
		c. United States Gypsum Co.; "Securock."
		2. Type and Thickness: Type X, 5/8 inch (15.9 mm) thick.
		3. Size: Not less than 48 by 96 inches (1219 by 2438 mm) for vertical installation.

Appendix CCC-Product List-Wood-Sheathing-2

3	Fasteners				
	General			Provide fasteners of size and type indicated that comply with requirements specified in this article for material and manufacture.	
				1. For sheathing, provide fasteners with hot-dip zinc coating complying with ASTM A 153/A	
				153M.	
	Nails, Brads, and Staples			ASTM F 1667	
	Screws for Fastening Sheathing to Cold-Formed Metal Framing:			Steel drill screws, in length recommended by sheathing manufacturer for thickness of sheathing to be attached, with organic-polymer or other corrosion-protective coating having a salt-spray resistance of more than 800 hours according to ASTM B 117.	
				1. For steel framing from 0.033 to 0.112 inch (0.84 to 2.84 mm) thick, use screws that comply with ASTM C 954.	
4	Sheathing Joint-and-Penetration Treatment Materials				
	Sheathing Tape			Self-adhering glass-fiber tape, minimum 2 inches (50 mm) wide, 10 by 10 or	
				10 by 20 threads/inch (390 by 390 or 390 by 780 threads/m), of type recommended by sheathing and tape manufacturers for use with silicone emulsion sealant in sealing joints in	
				1. Glass-mat gypsum sheathing and with a history of successful in-service use.	

Appendix DDD-Product List-Wood-Interior Architectural Woodwork-1

Section 06	4023	Interior Architectural Woodwork			
1	Materials				
	General			Provide materials that comply with requirements of AWI's quality standard for each type of woodwork and quality grade specified, unless otherwise indicated	
	Wood Species and Cut for Transparent Finish (WD-2)			Bamboo Moso (Phyllostachys Pubescens); cut as indicated in Finish Legend.	
	Wood Products			Comply with the following:	
				1. Recycled Content of Medium-Density Fiberboard and Particleboard: Provide products with an average recycled content so postconsumer recycled content plus one-half of preconsumer recycled content is not less than 20 percent.	
				2. Hardboard: AHA A135.4.	
				3. Medium-Density Fiberboard: ANSI A208.2, Grade MD, made with binder containing no urea formaldehyde.	
				4. Particleboard: ANSI A208.1, Grade M-2-Exterior Glue.	
				5. Particleboard: Straw-based particleboard complying with requirements in ANSI A208.1, Grade M-2, except for density.	
				6. Softwood Plywood: DOC PS 1, Medium Density Overlay.	

Appendix EEE-Product List-Wood-Interior Architectural Woodwork-2

				6. Softwood Plywood: DOC PS 1, Medium Density Overlay.	
				7. Veneer-Faced Panel Products (Hardwood Plywood): HPVA HP-1, made with adhesive containing no urea formaldehyde.	
	High-Pressure Decorative Laminate (PL-1 through PL-6)			NEMA LD 3, grades as indicated or, if not indicated, as required by woodwork quality standard.	
				1. Manufacturer: Subject to compliance with requirements, provide high-pressure decorative laminates by one of the following:	
				a. Formica Corporation.	
				b. Lamin-Art, Inc.	
				c. Nevamar Company, LLC; Decorative Products Div.	
				d. Panolam Industries International	
				e. Westinghouse Electric Corp.; Specialty Products Div.	
				f. Wilsonart International; Div. of Premark International, Inc.	
	Solid-Surfacing Material (SS-1):			Homogeneous solid sheets of filled plastic resin complying with ISSFA-2.	
				1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:	

				a. Avonite, Inc.
				b. E. I. du Pont de Nemours and Company.
				c. Formica Corporation.
				d. LG Chemical, Ltd.
				e. Meganite Inc.; a division of the Pyrochem Group.
				f. Nevamar Company, LLC; Decorative Products Div.
				g. Samsung; Cheil Industries Inc.
				h. Swan Corporation (The).
				i. Transolid, Inc.
				j. Wilsonart International; Div. of Premark International, Inc.
				2. Type: Standard type or Veneer type made from material complying with requirements for
				Standard type, as indicated, unless Special Purpose type is indicated.
				3. Colors and Patterns: As indicated by manufacturer's designations in Finish Legend .
	Recycled Glass Solid Surfacing (SS-2)			85 percent recycled glass with Portland cement, water and proprietary inert ingredients such as minerals, pigments and other non-VOC substances.
				1. Basis-of-Design Product: Subject to compliance with requirements, provide " Vetrazzo Surfacing" by Vetrazzo or an
				2. Style and Color: As indicated in Room Finish Legend.
				3. Recycled Glass Content: 100 percent post-consumer.

Appendix GGG-Product List-Wood-Interior Architectural Woodwork-4

	Resin Panels (RP-1 and RP-2)			Acrylic panels in thickness and dimensions as indicated on Drawings.	
				1. Basis-of-Design Product: "Acrylic Lightblocks" by MB Wellington Studio, Inc.	
				2. Color and Pattern: As indicated in Finish Legend on Drawings.	
2	Fire-Retardant-Treated Materials				
	General			Where fire-retardant-treated materials are indicated, use materials complying with requirements in this Article that are acceptable to authorities having jurisdiction, and with firetest- response characteristics specified.	
				1. Do not use treated materials that do not comply with requirements of referenced woodworking standard or that are warped, discolored, or otherwise defective.	
				2. Use fire-retardant-treatment formulations that do not bleed through or otherwise adversely affect finishes. Do not use colorants to distinguish treated materials from untreated materials.	
				3. Identify fire-retardant-treated materials with appropriate classification marking of UL, U.S.	
				Testing, Timber Products Inspection, or another testing and inspecting agency acceptable to authorities having jurisdiction.	

	Fire-Retardant-Treated Lumber and Plywood by Pressure Process			Comply with performance requirements of AWPA C20 (lumber) and AWPA C27 (plywood). Use the following treatment type:	
				1. Exterior Type: Organic-resin-based formulation thermally set in wood by kiln	
				2. Interior Type A: Low-hygroscopic formulation.	
				3. Mill lumber after treatment within limits set for wood removal that do not affect listed firetest-response characteristics, using a woodworking plant certified by testing and inspecting agency.	
				4. Mill lumber before treatment and implement special procedures during treatment and drying processes that prevent lumber from warping and developing discolorations from drying sticks or other causes, marring, and other defects affecting appearance of treated	
				5. Kiln-dry materials before and after treatment to levels required for untreated materials.	
	Fire-Retardant Particleboard			Panels complying with the following requirements, made from softwood particles and fire-retardant chemicals mixed together at time of panel manufacture to achieve flame-spread index of 25 or less and smoke-developed index of 25 or less per ASTM E 84.	

Appendix III-Product List-Wood-Interior Architectural Woodwork-6

				1. For panels 3/4 inch (19 mm) thick and less, comply with ANSI A208.1 for Grade M-2 except for the following minimum properties: modulus of rupture, 1600 psi (11 MPa); modulus of elasticity, 300,000 psi (2070 MPa); internal bond, 80 psi (550 kPa); and screw-holding capacity on face and edge, 250 and 225 lbf (1100 and 1000 N), respectively.
				2. For panels 13/16 to 1-1/4 inches (20 to 32 mm) thick, comply with ANSI A208.1 for
				Grade M-1 except for the following minimum properties: modulus of rupture, 1300 psi (9 MPa); modulus of elasticity, 250,000 psi (1720 MPa); linear expansion, 0.50 percent; and screw-holding capacity on face and edge, 250 and 175 lbf (1100 and 780 N), respectively.
				3. Product: Subject to compliance with requirements, provide "Duraflake FR" by Weyerhaeuser.
3	Cabinet Hardware and Accessories			
	Butt Hinges			2-3/4-inch (70-mm), 5-knuckle steel hinges made from 0.095-inch- (2.4-mm-) thick metal, and as follows:
				1. Semiconcealed Hinges for Flush Doors: BHMA A156.9, B01361.
				2. Semiconcealed Hinges for Overlay Doors: BHMA A156.9, B01521.

Appendix JJJ-Product List-Wood-Interior Architectural Woodwork-7

				a. Basis-of-Design Product: "No. 1592-4 Interleaf Casework Hinge" by Stanley	
				Hardware, or approved equal.	
	Wire Pulls			Back mounted, solid brass, 4 inches (100 mm) long, 5/16 inch (8 mm) in diameter	
				1. Available Products:	
				a. No. 4484 by Stanley Hardware.	
				b. No. MC-4024 by Epco Hardware.	
				c. No. 6208 by National Lock and Cabinet Hardware.	
	Catches			Magnetic catches, BHMA A156.9, B03141, Grade 1, with clear anodized aluminum case and impregnated floating rubber magnet, zinc plated strike, slotted screw holes in case and off-center hole in strike.	
				1. Basis-of-Design Product: "No. SP41" or "No. SP45" by Stanley Hardware.	
	Adjustable Shelf Standards and Supports			End-Mounted Cabinet Shelving: BHMA A156.9, B04071; with shelf rests, B04081	
				a. Basis-of-Design Product: "No. 255-256" by Knape and Vogt Manufacturing Co.	
				2. Back-Mounted Wall Shelving - Heavy Duty: BHMA A156.9, B04102; with shelf brackets,	
				B04112.	
				a. Basis-of-Design Product: "No. 87-187" with " No. 104-103 Series Back and Front Shelf Rests" at each bracket by Knape and Vogt	
	Shelf Rests			BHMA A156.9, B04013; metal	

Appendix KKK-Product List-Wood-Interior Architectural Woodwork-8

	Counter Support Brackets			6063 T6 "T" shaped extruded aluminum bracket with MIG welding across 45-degree miters and back.
				1. Load Capacity: 450 pounds per bracket minimum.
				2. Finish: Custom powder coat finish as selected by Architect from manufacturer's full
				3. Basis-of-Design Product: "Rakks Counter Support Bracket" by the Rangine Corporation.
	Drawer Slides			BHMA A156.9, B05091.
				1. Standard Duty (Grade 1, Grade 2, and Grade 3): Side mounted; full-extension type; zincplated steel with polymer rollers.
				a. Drawers 6-inches (152mm) or less in depth and up to 16-inches (406mm) in width:
				100 lb./pr. (45kg) load rating, telescoping, self-closing movement
				1) Basis-of-Design Product: "Model 3832SC" by Accuride International.
				b. Drawers 6-inches (152 mm) or less in depth and up to 24-inches (610 mm) in width: 100 lb./pr. (45kg) load rating, progressive movement
				1) Basis-of-Design Product: "Model 7432" by Accuride International.
				2. Heavy Duty (Grade 1HD-100 and Grade 1HD-200): Side mounted; full-extension type; zinc-plated steel ball-bearing slides.

Appendix LLL-Product List-Wood-Interior Architectural Woodwork-9

				a. Drawers over 6-inches (152mm) in depth and up to 42-inches (1067mm) in width: 200lb./pr. (90 kg) load rating, sequential movement	
				1) Basis-of-Design Product: "Model 3640" by Accuride International.	
				3. Box Drawer Slides: Grade 1HD-100; for drawers not more than 6 inches 150 mm high and 24 inches 600 mm wide.	
				4. File Drawer Slides: Grade 1HD-100; for drawers more than 6 inches 150 mm high or 24 inches 600 mm wide.	
				5. Keyboard Slides: Grade 1; for computer keyboard shelves.	
	Exposed Hardware Finishes			For exposed hardware, provide finish that complies with	
				BHMA A156.18 for BHMA finish number	
				1. Satin Chromium Plated: BHMA 626 for brass or bronze base; BHMA 652 for steel base.	
				For concealed hardware, provide manufacturer's standard finish that complies with product class requirements in BHMA A156.9, unless otherwise indicated	

Appendix MMM-Product List-Wood-Interior Architectural Woodwork-10

4	Miscellaneous Materials		
	Anchors		Select material, type, size, and finish required for each substrate for secure anchorage. Provide nonferrous-metal or hot-dip galvanized anchors and inserts on inside face of exterior walls and elsewhere as required for corrosion resistance. Provide toothed-steel or lead expansion sleeves for drilled-in-place anchors.
	Adhesives, General		Do not use adhesives that contain urea formaldehyde.
	VOC Limits for Installation Adhesives and Glues		Use installation adhesives that comply with the following limits for VOC content when calculated according to 40 CFR 59, Subpart D
			Method 24):
			1. Wood Glues: 30 g/L.
			2. Contact Adhesive: 250 g/L.
	Adhesive for Bonding Plastic Laminate		Unpigmented contact cement .
			1. Adhesive for Bonding Edges: Hot-melt adhesive or adhesive specified above for faces.
5	Fabrication, General		
6	Wood Cabinets for Transparent Finiah		
	Grade		Custom
	AWI Type of Cabinet Construction		Flush overlay, unless otherwise indicated on Drawings.
	Wood Species and Cut for Exposed		As indicated in Finish Legend.

Appendix NNN-Product List-Wood-Interior Architectural Woodwork-11

				1. Grain Direction: Vertically for drawer fronts, doors, and fixed panels, unless otherwise indicated on Drawings.	
				2. Matching of Veneer Leaves: Book match.	
				3. Vertical Matching of Veneer Leaves: End	
	Semiexposed Surfaces			Provide surface materials indicated below:	
				1. Surfaces Other Than Drawer Bodies: Same species and cut indicated for exposed surfaces.	
				2. Drawer Sides and Backs: Solid-hardwood lumber.	
				3. Drawer Bottoms: Hardwood plywood	
7	Plastic-Laminate Cabinets				
	Grade			Custom	
	AWI Type of Cabinet Construction			Flush overlay, unless otherwise indicated on Drawings .	
	Laminate Cladding for Exposed Surfaces			High-pressure decorative laminate complying with the following requirements:	
				1. Horizontal Surfaces Other Than Tops: Grade HGS.	
				2. Postformed Surfaces: Grade HGP.	
				3. Vertical Surfaces: Grade HGS.	
				4. Edges: Grade HGS .	
	Materials for Semiexposed Surfaces			Surfaces Other Than Drawer Bodies: High-pressure decorative laminate, Grade VGS .	
				a. Edges of Plastic-Laminate Shelves: PVC tape, 0.018-inch (0.460-mm) minimum thickness, matching laminate in color, pattern, and finish.	

				b. For semiexposed backs of panels with exposed plastic-laminate surfaces, provide surface of high-pressure decorative laminate,	
				2. Drawer Sides and Backs: Solid-hardwood lumber.	
				3. Drawer Bottoms: Hardwood plywood.	
	Concealed Backs of Panels with Exposed Plastic Laminate Surfaces			High-pressure decorative laminate, Grade BKL.	
				Colors, Patterns, and Finishes: Provide materials and products that result in colors and textures of exposed laminate surfaces complying with the following requirements:	
				As indicated by laminate manufacturer's designations.	
8	Wood Countertops				
	Grade			Custom	
	Type of Top			Solid wood for transparent finish, edge glued, with crown direction reversed in adjacent boards, to produce widths indicated. Select boards for similarity of color and grain and arrange boards for optimum match between adjacent boards. Species and cut as follows:	
				1. Wood Species and Cut: As indicated in Finish Legend or on Drawings.	

Appendix PPP-Product List-Wood-Interior Architectural Woodwork-13

9	Solid-Surfacing-Material Countertops	
	Grade	Custom
	Solid-Surfacing-Material Thickness	3/4 inch (19 mm), unless otherwise indicated on Drawings.
	Colors, Patterns, and Finishes	Provide materials and products that result in colors of solid surfacing material complying with the following requirements:
		1. As indicated by manufacturer's designations in Finish Legend.
	Fabricate Tops	Fabricate tops in one piece, unless otherwise indicated. Comply with solid-surfacing-material manufacturer's written recommendations for adhesives, sealers, fabrication, and finishing.
		1. Fabricate tops with shop-applied edges of materials and configuration indicated.
		2. Fabricate tops with shop-applied
	Sink Bowls	Install integral sink bowls in countertops in
	Holes in Countertops	Drill holes in countertops for plumbing fittings and soap dispensers in shop
10	Shop Finishing	
	Grade	Provide finishes of same grades as items to be finished.
	General	Finish architectural woodwork at fabrication shop as specified in this Section. Defer only final touchup, cleaning, and polishing until after installation.

	Shop Priming			Shop apply the prime coat including back priming, if any, for transparent-finished items specified to be field finished. Refer to Division 09 painting Sections for material and application requirements.	
	Preparation for Finishing			Comply with referenced quality standard for sanding, filling countersunk fasteners, sealing concealed surfaces, and similar preparations for finishing architectural woodwork, as applicable to each unit of work.	
				1. Back priming: Apply one coat of sealer or primer, compatible with finish coats, to concealed surfaces of woodwork. Apply two coats to back of paneling and to end-grain surfaces. Concealed surfaces of plastic-laminate-clad woodwork do not require back priming when surfaced with plastic laminate, backing paper, or thermoset decorative panels.	
	Transparent Finish			1. Grade: Custom.	
				2. AWI Finish System: Catalyzed lacquer.	
				3. AWI Finish System: Conversion varnish.	
				4. Staining: Match approved sample for color.	
				5. Wash Coat for Stained Finish: Apply wash-coat sealer to woodwork made from closedgrain wood before staining and	
				6. Open Finish for Open-Grain Woods: Do not apply filler to open-grain woods.	

Appendix RRR-Product List-Wood-Interior Architectural Woodwork-15

				7. Filled Finish for Open-Grain Woods: After staining (if any), apply paste wood filler to open-grain woods and wipe off excess. Tint filler to match stained wood.
				a. Apply wash-coat sealer after staining and before filling.
				8. Sheen: Satin, 31-45 gloss units measured on 60-degree gloss meter per ASTM D 523.
11	Lighting for Architectural Woodwork			
	Fluorescent Under-Shelf / Under-Cabinet Lighting			1. Products: Subject to compliance with requirements, provide one of the following products:
				a. "Little Inch SFHP Series" by Alkco.
				b. "Spectra SF Series" by Healthcare Lighting.
				c. "UCSL Series" by Kenall.
				d. "TSF Series" by Lightolier.
				e. "1SF Series" by Williams.
				2. Description
				a. Size: Not greater than 1-1/8-inch by 5-inches (28 by 127 mm) in cross section; provide length required for applications indicated on
				b. Lamping: T5 lamps of length and wattage required.
				c. Housing: Cold rolled steel, formed to specified size and shape, solid metal front, concealed knockouts.

	d. Finish: White polyester powder coat.
	e. Lens: Clear lay-in prismatic acrylic.
	f. Ballast: Electronic T5.
	3. Accessories
	a. Integral ON/OFF rocker style switch.
	b. 6-foot long, 3-wire cord and plug, white.
	c. Integral 3-wire single receptacle.
	4. Provide individual single unit luminaires or multiple ganged luminaires as required to provide a continuous, uniformly lighted element within the woodwork.
	a. Short woodwork dimensions corresponding to a standard lamp length dimension (nominal 2 foot, 3 foot, or 4 foot) provided with single luminaires of applicable length.
	b. Woodwork dimensions not corresponding to standard lamp length dimension provided with multiple luminaires, installed end-to-end along entire length of lighted woodwork application. Provide fewer luminaires of longer lamp length rather than more luminaires of shorter lamp length.

Appendix TTT-Product List-Wood-Wood Paneling -1

Section 06	4200 Wood Paneling			
1	Materials			
	General			Provide materials that comply with requirements of AWI's quality standard for quality grade specified, unless otherwise
	Wood Products			Comply with the following:
				1. Medium-Density Fiberboard: ANSI A208.2, Grade MD, made with binder containing no urea formaldehyde.
				2. Particleboard: ANSI A208.1, Grade M-2-Exterior Glue.
				3. Bamboo: Moso (Phyllostachys Pubescens).
				4. Softwood Plywood: DOC PS 1, Medium Density Overlay.
	Adhesives			Do not use adhesives that contain urea formaldehyde.
	VOC Limits for installation Adhesives and Glues			Use installation adhesives that comply with the following limits for VOC content when calculated according to 40 CFR 59, Subpart D
				Method 24):
				1. Wood Glues: 30 g/L.
				2. Panel Adhesives: 50 g/L.
				3. Contact Adhesive: 80 g/L.
				4. Special Purpose Contact Adhesive (contact adhesive that is used to bond melamine covered board, metal, unsupported vinyl, Teflon, ultra-high molecular weight polyethylene, rubber or wood veneer 1/16 inch or less in thickness to any surface): 250 g/L.

Appendix UUU-Product List-Wood-Wood Paneling -2

2	Fire-Retardant-Treated Materials				
	General			Where fire-retardant-treated materials are indicated, use materials that are acceptable to authorities having jurisdiction and that comply with requirements in this Article and with fire-test-response characteristics specified.	
				1. Do not use treated materials that do not comply with requirements of referenced woodworking standard or that are warped, discolored, or otherwise defective.	
				2. Use fire-retardant-treatment formulations that do not bleed through or otherwise adversely affect finishes. Do not use colorants to distinguish treated materials from untreated materials.	
				3. Identify fire-retardant-treated materials with appropriate classification marking of UL, U.S.	
				Testing, Timber Products Inspection, or another testing and inspecting agency acceptable to authorities having jurisdiction.	
	Fire-Retardant Particleboard			Panels complying with the following requirements, made from softwood particles and fire-retardant chemicals mixed together at time of panel manufacture to achieve flame-spread index of 25 or less and smoke-developed index of 25 or less per ASTM E84	

Appendix VVV-Product List-Wood-Wood Paneling -3

				1. For panels 3/4 inch (19 mm) thick and less, comply with ANSI A208.1 for Grade M-2 except for the following minimum properties: modulus of rupture, 1600 psi (11 MPa); modulus of elasticity, 300,000 psi (2070 MPa); internal bond, 80 psi (550 kPa); and screw-holding capacity on face and edge, 250 and 225 lbf (1110 and 1000 N), respectively.	
				2. For panels 13/16 to 1-1/4 inches (20 to 32 mm) thick, comply with ANSI A208.1 for Grade	
				M-1 except for the following minimum properties: modulus of rupture, 1300 psi (9 MPa); modulus of elasticity, 250,000 psi (1720 MPa); linear expansion, 0.50 percent; and screw-holding capacity on face and edge, 250 and 175 lbf (1110 and 780 N), respectively.	
				3. Product: Subject to compliance with requirements, provide "Duraflake FR" by Weyerhaeuser.	
	Fire-Retardant Fiberboard			Medium-density fiberboard panels complying with ANSI A208.2, made from softwood fibers, synthetic resins, and fire-retardant chemicals mixed together at time of panel manufacture to achieve flame-spread index of 25 or less and smoke-developed index of 200 or less per ASTM E 84.	
				1. Product: Subject to compliance with requirements, provide "Medite FR" by	
				Ltd.; Medite Div.	

Appendix WWW-Product List-Wood-Wood Paneling -4

3	Installation Materials				
	Anchors			Select material, type, size, and finish required for each substrate for secure anchorage. Provide nonferrous-metal or hot-dip galvanized anchors and inserts on inside face of exterior walls and elsewhere as required for corrosion resistance. Provide toothed-steel or lead expansion sleeves for drilled-in-place anchors.	
4	Fabrication, General				
	Paneling Grade			Provide Custom grade paneling complying with referenced quality standard.	
				Complete fabrication, including assembly and finishing, to maximum extent possible, before shipment to Project site. Disassemble components only as necessary for shipment and installation. Where necessary for fitting at site, provide ample allowance for scribing, trimming, and fitting.	
				Shop cut openings, to maximum extent possible, to receive hardware, appliances, plumbing fixtures, electrical work, and similar items. Locate openings accurately and use templates or roughing-in diagrams to produce accurately sized and shaped openings. Sand edges of cutouts to remove splinters and burrs	

Appendix XXX-Product List-Wood-Wood Paneling -5

5	Flush Wood Paneling for Transparent Finish (WD-3)				
	Grade			Custom	
	Wood Species and Cut			Bamboo	
	Panel Construction			Edge grain, 5/8 inch solid plank flooring (standard size 5/8-inch by 3 3/4-inch by 76-1/4-inch), prefinished, urea formaldehyde-free.	
	Basis-of-Design			"Plyboo Bamboo Flooring, Amber Edge Grain," by Smith & Fong Company.	
	Matching within Panel Face			Running match	
	Panel-Matching Method			Premanufactured sets used full width within each separate area.	
				Provide paneling of thickness shown or, if not shown, 3/4-inch (19-mm) minimum thickness.	
				Assemble by gluing and concealed fastening.	

Appendix YYY-Product List-Roofing-EPDM Roofing-1

Roofing				
Section	**07-5323**	**Ethylene-Propylene-Diene-Monomer EPDM Roofing**		
PART 2 - PRODUCTS				
2.1 EPDM MEMBRANE ROOFING				
	A. EPDM: ASTM D 4637, Type I, non-reinforced, uniform, flexible EPDM sheet.		EPDM Membrane, 60mils, white on black	
		1. Manufacturers: Subject to compliance with requirements, provide products		Roof Envelope
		by one of the following:		
		a. Carlisle SynTec Incorporated.GeoEPDM Pond Liner		
		b. Firestone Building Products. EcoWhite EPDM		
		c. Johns Manville.JM Nonreinforced EPDM		
		2. Thickness: 60 mils (1.5 mm), nominal.		
		3. Exposed Face Color: White on black.		
2.2 AUXILIARY MEMBRANE ROOFING MATERIALS				
	A. General: Auxiliary membrane roofing materials recommended by roofing system manufacturer			
	for intended use and compatible with membrane roofing.			
		1. Liquid-type auxiliary materials shall comply with VOC limits of authorities having jurisdiction.		
		2. Adhesives and sealants that are not on the exterior side of weather barrier shall comply		

Appendix ZZZ-Product List-Roofing-EPDM Roofing-2

with the following limits for VOC content when calculated according to 40 CFR 59, Subpart D (EPA Method 24):

a. Plastic Foam Adhesives: 50 g/L.

b. Gypsum Board and Panel Adhesives: 50 g/L.

c. Multipurpose Construction Adhesives: 70 g/L.

d. Fiberglass Adhesives: 80 g/L.

e. Contact Adhesive: 80 g/L.

f. Single-Ply Roof Membrane Sealants: 450 g/L.

g. Nonmembrane Roof Sealants: 300 g/L.

h. Sealant Primers for Nonporous Substrates: 250 g/L.

i. Sealant Primers for Porous Substrates: 775 g/L.

j. Other Adhesives and Sealants: 250 g/L.

B. Sheet Flashing: 60-mil- (1.5-mm-) thick EPDM, partially cured or cured, according to application.

C. Protection Sheet: Epichlorohydrin or neoprene non-reinforced flexible sheet, 55- to 60-mil- (1.4- to 1.5-mm-) thick, recommended by EPDM manufacturer for resistance to hydrocarbons, non-aromatic solvents, grease, and oil.

D. Bonding Adhesive: Manufacturer's standard, water based or solvent based materials as recommended for particular use. .

E. Seaming Material: Manufacturer's standard, synthetic-rubber polymer primer and 3-inch- (75-mm-) wide minimum, butyl splice tape with release film.

F. Lap Sealant: Manufacturer's standard, single-component sealant, colored to match membrane roofing.

G. Water Cutoff Mastic: Manufacturer's standard butyl mastic sealant.

H. Metal Termination Bars: Manufacturer's standard, predrilled stainless-steel or aluminum bars, approximately 1 by 1/8 inch (25 by 3 mm) thick; with anchors.

I. Miscellaneous Accessories: Provide pourable sealers, preformed cone and vent sheet flashings, preformed inside and outside corner sheet flashings, reinforced EPDM securement strips, T-joint covers, in-seam sealants, termination reglets, cover strips, and other accessories.

J. Night Seal: Manufacturer’s standard products compatible with membrane materials.

K. Solvent Cleaners: Liquid cleaner(s) to be used to remove contaminants from membrane seam and flashing areas prior to application of splice tape or adhesive.

Appendix AAAA-Product List-Roofing-EPDM Roofing-3

2.3 SUBSTRATE BOARDS								
	A. Substrate Board: ASTM C 1177/C 1177M, glass-mat, water-resistant gypsum substrate, Type X, 5/8 inch (16 mm) thick.					Gypsum Board, X, 5/8 inch		
		1. Products: Subject to compliance with requirements, provide the following or an acceptable equivalent product:						
			a. Georgia-Pacific Corporation; "Dens Deck."					
	B. Fasteners: Factory-coated steel fasteners and metal or plastic plates complying with corrosion-resistance provisions in FM Approvals 4470, designed for fastening substrate panel to roof deck.							
2.4 VAPOR RETARDER								
	A. Laminated Sheet: Kraft paper, two layers, laminated with asphalt and edge woven fiberglass yarn with maximum permeance rating of 0.50 perm (29 ng/Pa x s x sq. m) and with manufacturer's standard adhesive.					Polypropylene Scrim Kraft-PSK PSK Vapour Barrier		
2.5 ROOF INSULATION								
	A. General: Preformed roof insulation boards manufactured or approved by EPDM membrane roofing manufacturer, selected from manufacturer's standard sizes suitable for application, of thicknesses indicated and that produce FM Approvals-approved roof insulation.						FM Approvals	
	B. Extruded-Polystyrene Board Insulation: ASTM C 578, Type IV, 1.6-lb/cu. ft. (26-kg/cu. m) minimum density, square edged.						Insulation thickness unknown assumed to be 2 inches(51mm) to provide R 10	XPS
	C. Polyisocyanurate Board Insulation: ASTM C 1289, Type II, Class 1, Grade 2, felt or glass-fiber mat facer on both major surfaces.						Insulation thickness unknown assumed to be 2 inches to provide R 12	
		1. Provide insulation with a minimum compressive strength of 20 psi and minimum density of 1.5 pcf.						
	D. Tapered Insulation: Provide factory-tapered insulation boards fabricated to slope of 1/4 inch per 12 inches (1:48) unless otherwise indicated.							
		1. Thickness: As required to obtain an overall average "R" value specified under the Performance Requirement paragraph.						
		2. Factory pre-cut boards not to exceed 4-inches by 4-inches with top surface cut to provide a continuous slope indicated on Drawings.						
		3. Tapered insulation exceeding 4 inches shall be in two layers, to include starter and filler blocks fabricated to assure staggering of all vertical joints both ways between layers.						
		4. All miters shall be factory cut, consisting of two diagonally cut abutting blocks with matching edges and thickness.						
	E. Provide preformed saddles, crickets, tapered edge strips, and other insulation shapes where indicated for sloping to drain. Fabricate to slopes indicated.							

Appendix BBBB-Product List-Roofing-EPDM Roofing-4

2.6 INSULATION ACCESSORIES						
	A. General: Furnish roof insulation accessories recommended by insulation manufacturer for intended use and compatibility with membrane roofing.					
	B. Fasteners: Factory-coated steel fasteners and metal or plastic plates complying with corrosion-resistance provisions in FM Approvals 4470, designed for fastening roof insulation and cover boards to substrate, and acceptable to roofing system manufacturer.					
	C. Cover Board: ASTM C 1177/C 1177M, glass-mat, water-resistant gypsum substrate, 5/8 inch (16 mm) thick, factory primed.					Gypsum Board
		1. Products: Subject to compliance with requirements, provide the following or an acceptable equivalent product:				
			a. Georgia-Pacific Corporation; "Dens Deck."			
2.7 WALKWAYS						
	A. Flexible Walkways: Factory-formed, nonporous, heavy-duty, solid-rubber, slip-resisting, surface-textured walkway pads, approximately 3/16 inch (5 mm) thick, and acceptable to membrane roofing system manufacturer.					

Appendix CCCC-Product List-Roofing-PVC Roofing-1

Section	**07-5429**	**Polyvinyl-Chloride PVC Roofing**		
PART 2 - PRODUCTS				
2.1 PVC MEMBRANE ROOFING				
	A. PVC Sheet: ASTM D 4434, Type II, Grade I, glass fiber reinforced, felt backed.			PVC Membrane, 48 mils
		1. Products: Subject to compliance with requirements, provide the following:		Roof Envelope
			a. Sarnafil Inc.; "Sarnafil G410."	
		2. Thickness: 48 mils (1.2 mm), minimum.		
		3. Exposed Face Color: As selected by Architect from manufacturer's available selection.		
2.2 AUXILIARY MEMBRANE ROOFING MATERIALS				
	A. General: Auxiliary membrane roofing materials recommended by roofing system manufacturer for intended use, and compatible with membrane roofing.			
		1. Liquid-type auxiliary materials shall comply with VOC limits of authorities having jurisdiction.		
		2. Adhesives and sealants that are not on the exterior side of weather barrier shall comply with the following limits for VOC content when calculated according to 40 CFR 59, Subpart D (EPA Method 24):		
			a. Plastic Foam Adhesives: 50 g/L.	
			b. Gypsum Board and Panel Adhesives: 50 g/L.	
			c. Multipurpose Construction Adhesives: 70 g/L.	
			d. Fiberglass Adhesives: 80 g/L.	
			e. Contact Adhesive: 80 g/L.	
			f. Other Adhesives: 250 g/L.	
			g. PVC Welding Compounds: 510 g/L.	
			h. Adhesive Primer for Plastic: 650 g/L	
			i. Single-Ply Roof Membrane Sealants: 450 g/L.	
			j. Nonmembrane Roof Sealants: 300 g/L.	
			k. Sealant Primers for Nonporous Substrates: 250 g/L.	
			l. Sealant Primers for Porous Substrates: 775 g/L.	

Appendix DDDD-Product List-Roofing-PVC Roofing-2

B. Sheet Flashing: Manufacturer's standard sheet flashing of same material, type, reinforcement, thickness, and color as PVC sheet membrane.

C. Bonding Adhesive: Manufacturer's standard, water based or solvent based.

D. Slip Sheet: Manufacturer's standard, of thickness required for application.

E. Metal Components: 0.020-inch thick PVC membrane laminated to 25 gauge galvanized sheet metal; "Sarnaclad" by Sarnafil.

F. Non-Asphaltic Polyester Felt: Use as asphalt barrier and leveling layer.

1. Products: Subject to compliance with requirements, provide one of the following:

a. Saranfil; "Sarnafelt."

G. Solvent cleaner: For removal of adhesives or other contaminants from exposed membrane

1. Products: Subject to compliance with requirements, provide one of the following:

a. Saranfil; "Sarnasolv."

H. Metal Termination Bars: Manufacturer's standard, predrilled stainless-steel or aluminum bars, approximately 1 by 1/8 inch (25 by 3 mm) thick; with anchors.

1. Products: Subject to compliance with requirements, provide one of the following:

a. Saranfil; "Sarnabar."

I. Metal Battens: Manufacturer's standard, aluminum-zinc-alloy-coated or zinc-coated steel sheet, approximately 1 inch wide by 0.05 inch (25 mm wide by 1.3 mm) thick, prepunched.

1. Products: Subject to compliance with requirements, provide one of the following:

a. Saranfil; "Sarnastop."

J. Fasteners: Factory-coated steel fasteners and metal or plastic plates complying with corrosion-resistance provisions in FM Approvals 4470, designed for fastening membrane to substrate, and acceptable to membrane roofing system manufacturer.

K. Expansion Joints: Prefabricated expansion joint made with Sarnafil S327 polyester-reinforced membrane, neoprene foam and galvanized metal flanges and welding flaps.

1. Products: Subject to compliance with requirements, provide one of the following:

a. Saranfil; "Sarnaflash."

L. Miscellaneous Accessories: Provide pourable sealers, preformed cone and vent sheet flashings, preformed inside and outside corner sheet flashings, T-joint covers, lap sealants, termination reglets, and other accessories.

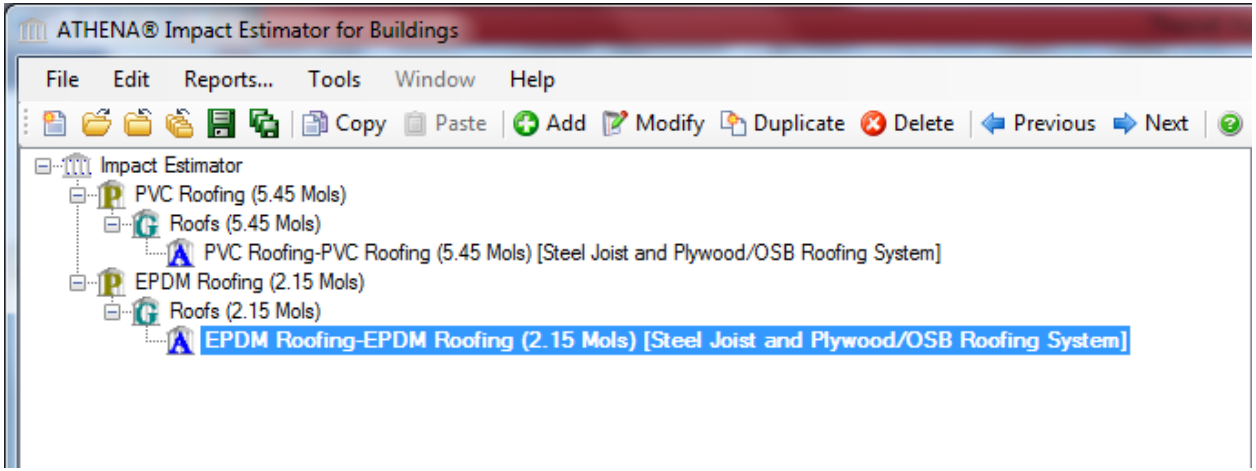
Appendix EEEE-Product List-Roofing-PVC Roofing-3

	M. Water Cut-Off Mastic: Compatible with membrane materials as recommended by Sarnafil.	
	N. Night Seal: Compatible with membrane materials as recommended by Sarnafil.	
2.3 SUBSTRATE BOARDS		
	A. Substrate Board: ASTM C 1177/C 1177M, glass-mat, water-resistant gypsum substrate,	Gypsum Board, X, 5/8 inch
	Type X, 5/8 inch (16 mm) thick.	
	1. Products: Subject to compliance with requirements, provide the following or an	
	acceptable equivalent product:	
	a. Georgia-Pacific Corporation; "Dens Deck."	
	B. Fasteners: Factory-coated steel fasteners and metal or plastic plates complying with	
	corrosion-resistance provisions in FM Approvals 4470, designed for fastening substrate board	
	to roof deck.	
2.4 VAPOR RETARDER		
	A. Laminated Sheet: Kraft paper, two layers, laminated with asphalt and edge	Polypropylene Scrim Kraft-PSK
	reinforced with woven fiberglass yarn with maximum permeance rating of	PSK Vapour Barrier
	0.50 perm (29 ng/Pa x s x sq. m) and with manufacturer's standard adhesive.	
2.5 ROOF INSULATION		
	A. General: Preformed roof insulation boards manufactured or approved by PVC membrane	
	roofing manufacturer, selected from manufacturer's standard sizes suitable for application, of	
	thicknesses indicated and that produce FM Approvals-approved roof insulation.	
	B. Polyisocyanurate Board Insulation: ASTM C 1289, Type II, Class 1, Grade 2,	Insulation
	felt or glass-fiber mat facer on both major surfaces.	R-20.4 with 83mm thickness.
	1. Products: Subject to compliance with requirements, provide one of the following:	
	a. Saranfil; "Sarnatherm."	
	C. Provide preformed saddles, crickets, tapered edge strips, and other insulation shapes where	
	indicated for sloping to drain. Fabricate to slopes indicated.	

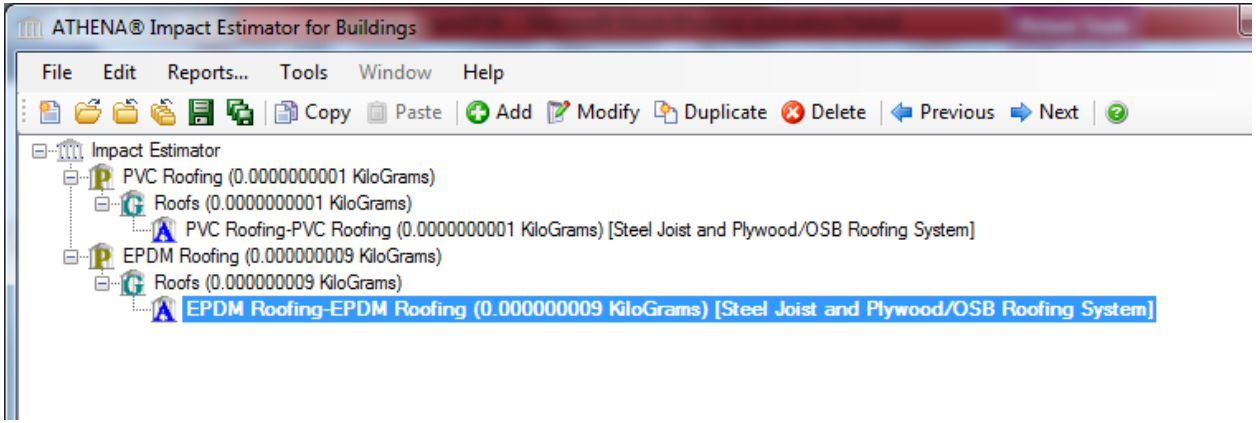
Appendix FFFF-Product List-Roofing-PVC Roofing-4

2.6 INSULATION ACCESSORIES						
	A. General: Furnish roof insulation accessories recommended by insulation manufacturer for intended use and compatibility with membrane roofing.					
	B. Fasteners: Factory-coated steel fasteners and metal or plastic plates complying with corrosion-resistance provisions in FM Approvals 4470, designed for fastening roof insulation and cover boards to substrate, and acceptable to roofing system manufacturer.					
	C. Full-Spread Applied Insulation Adhesive: Insulation manufacturer's recommended spray-applied, low-rise, two-component urethane adhesive formulated to attach roof insulation to substrate or to another insulation layer.					
	D. Cover Board: ASTM C 1177/C 1177M, glass-mat, water-resistant gypsum substrate, 5/8 inch (16 mm) thick, factory primed.					Gypsum Board
		1. Products: Subject to compliance with requirements, provide the following:				
			a. Georgia-Pacific Corporation; "Dens Deck."			
2.7 WALKWAYS						
	A. Flexible Walkways: Factory-formed, nonporous, heavy-duty, slip-resisting, surface-textured walkway pads or rolls, approximately 3/16 inch (5 mm) thick, and acceptable to membrane roofing system manufacturer.					

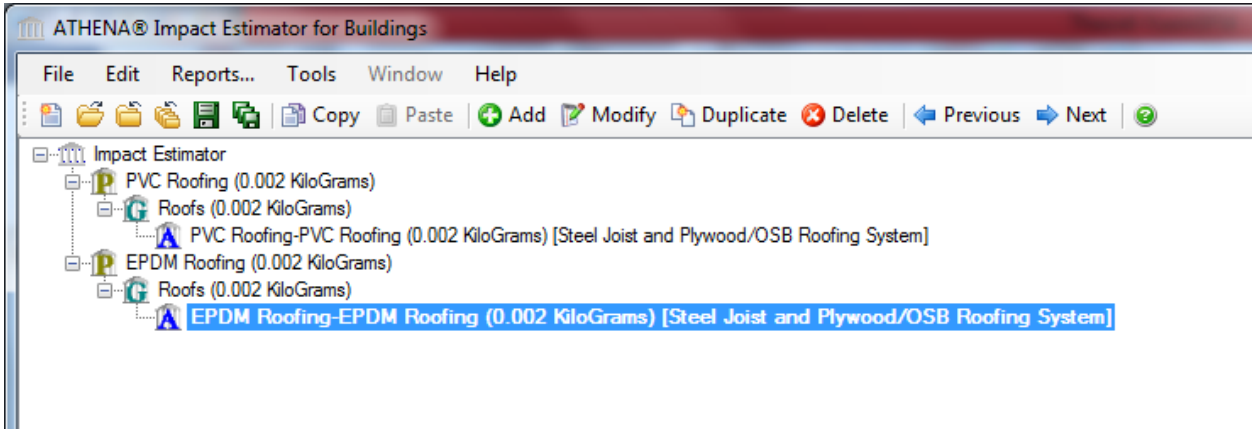
Appendix GGGG-Acidification Consumption of EPDM and PVC



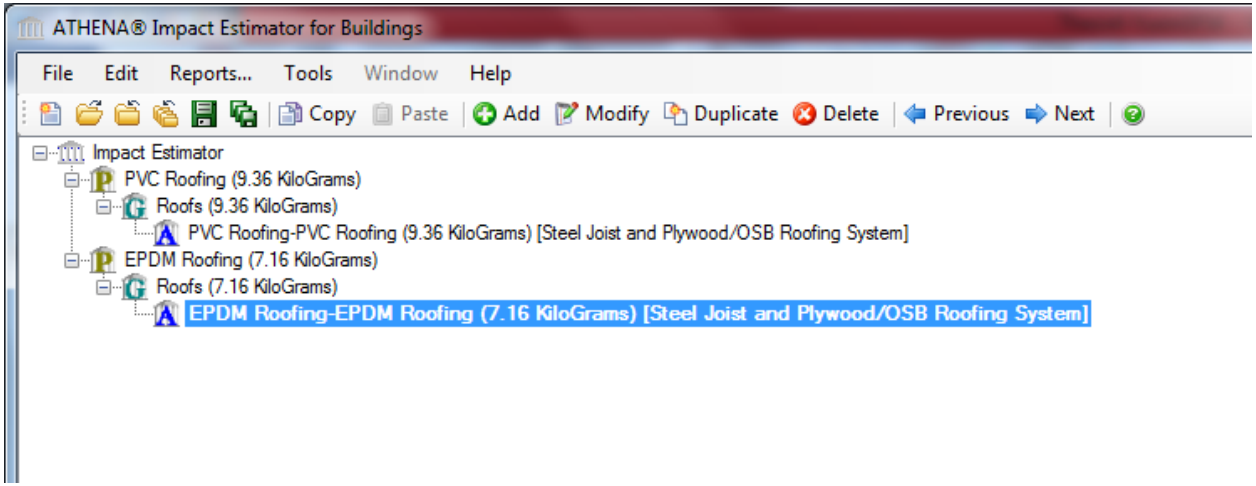
Appendix HHHH-Ozone Depletion Potential of EPDM and PVC



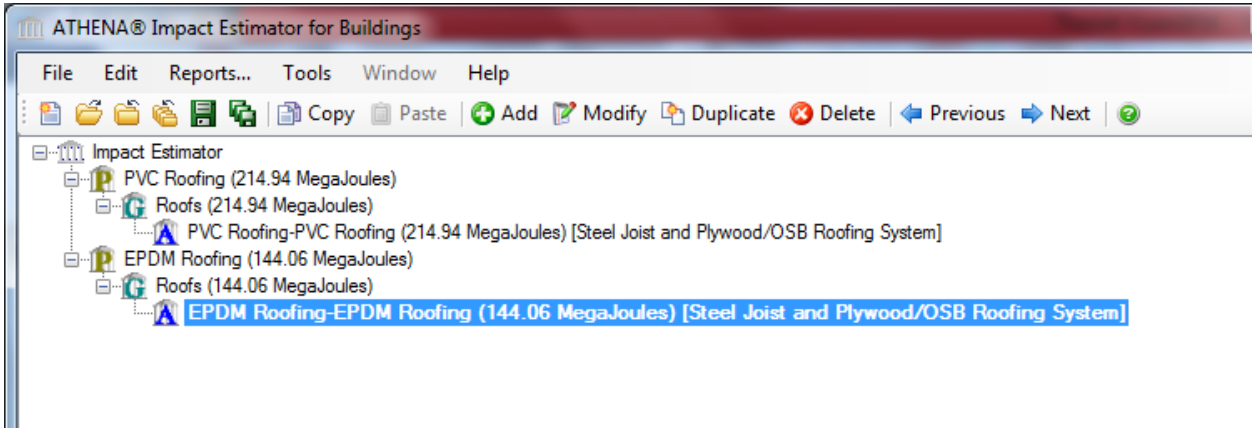
Appendix IIII-Eutrophication Potential of EPDM and PVC



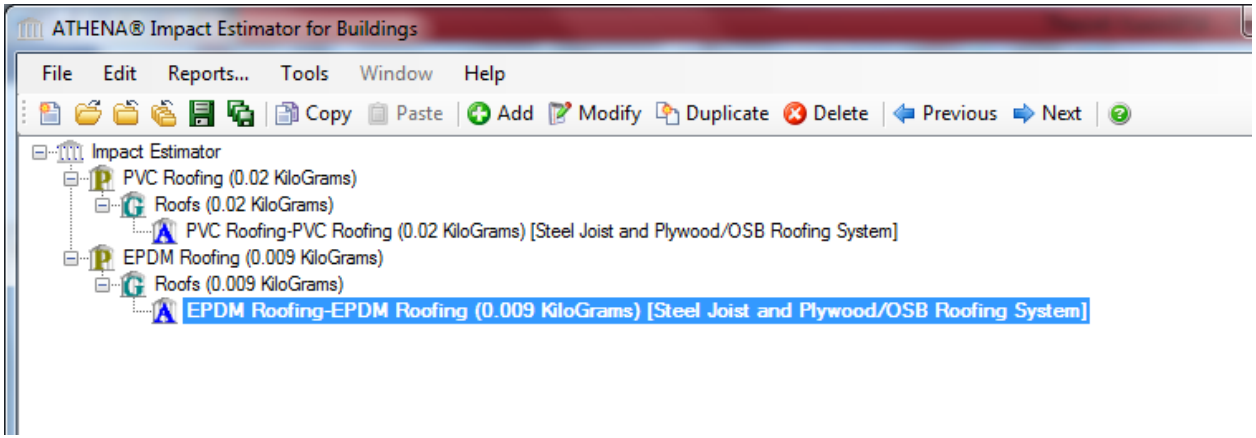
Appendix JJJJ-Global Warming Potential of EPDM and PVC



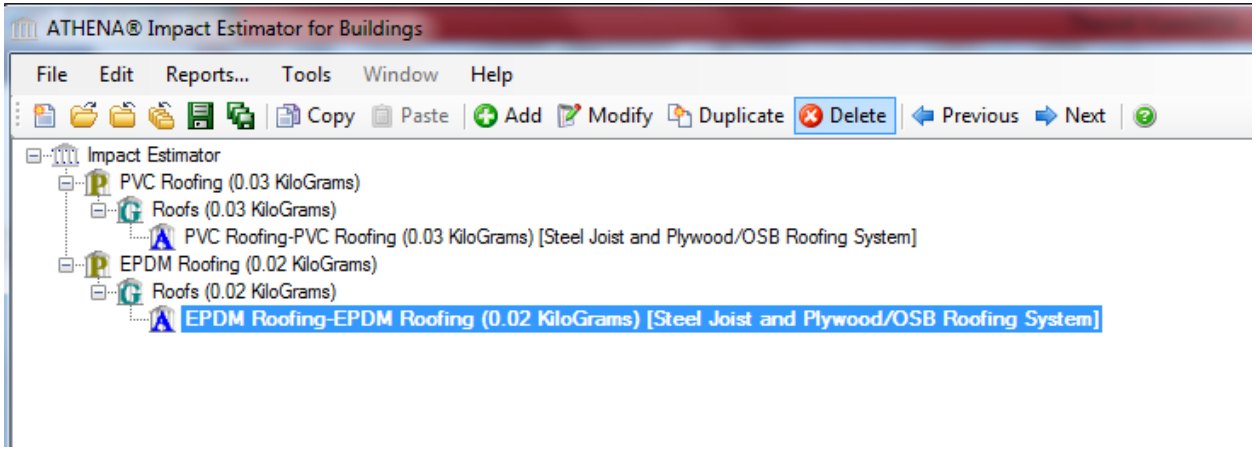
Appendix KKKK-Fossil Fuel Consumption of EPDM and PVC



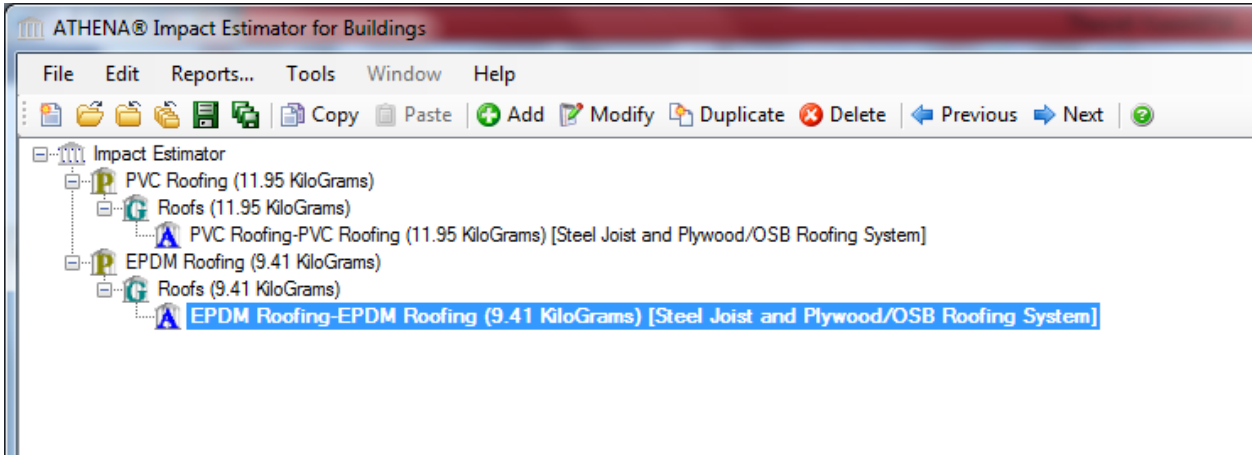
Appendix LLLL-Human Health Respiratory Effects Potential of EPDM and PVC



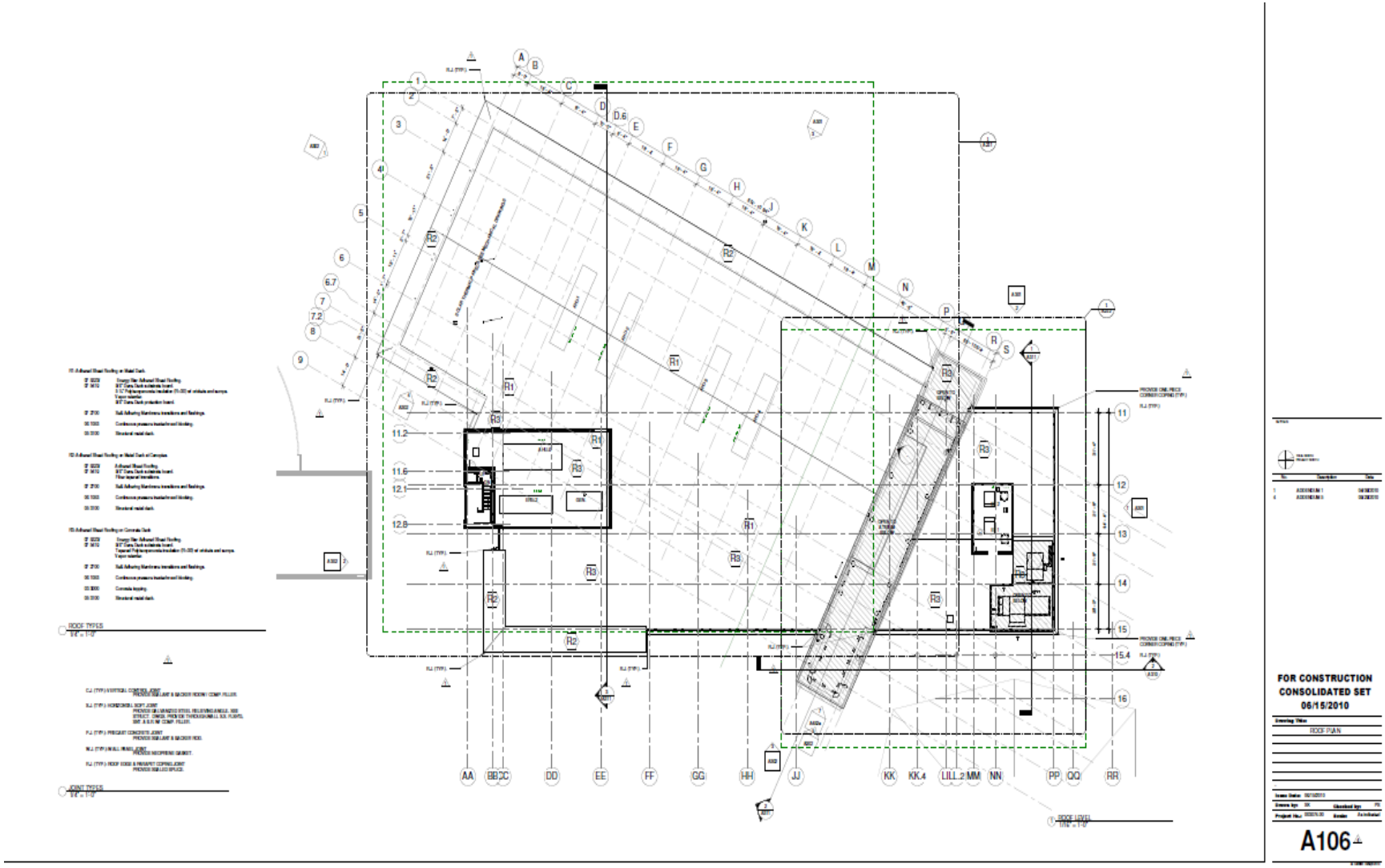
Appendix MMMM-Smog Potential of EPDM and PVC



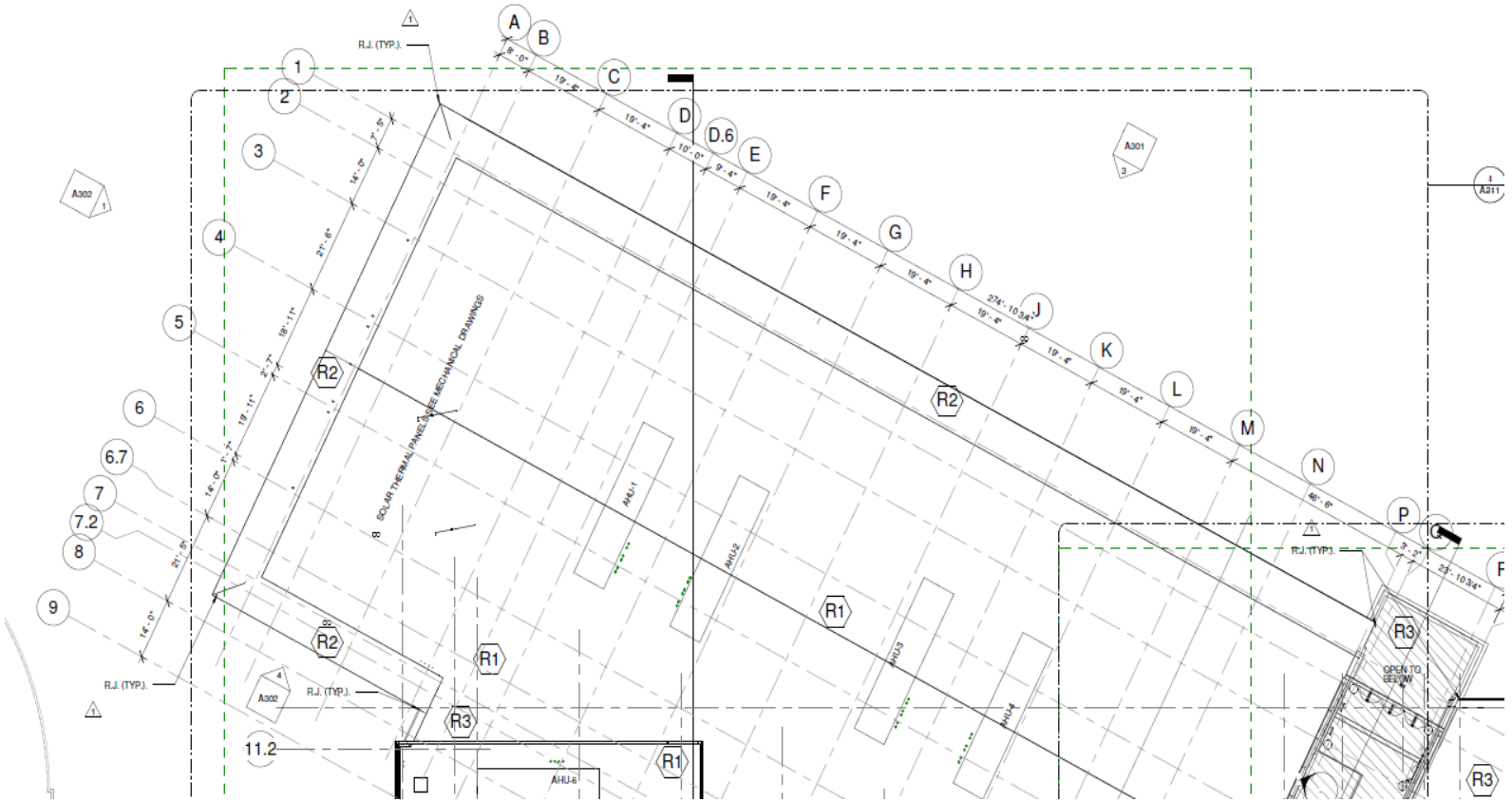
Appendix NNNN-Weighted Resources of EPDM and PVC



Appendix OOOO-Roof Plan of Rec. Center



Appendix PPPP-Detailed Dimensions of Roof



Appendix QQQQ-Energy Savings of EPDM and PVC

Roof dimensions: 107 x 248 # ft. (numbers only)

Insulation thickness: 3.3" ISO (20-R value)

Relative Roof Difficulty: Simple (Few Pipe Penetration)

Tear off existing roof: NO

Sky-lights: 0

Chimney: 0

Parapet Wall (# ft): 0

Roof Slope: (Metal Roofs only) Low slope (3)

Roof slope selector is used to calculate Metal Roofing prices or if you have a slope on your flat roof. Select 1/2" fan-fold roof insulation' when calculating Metal Roofing prices.

Calculate Roof Price – Roof price will appear below

Material Type:	Price:	Energy Saving in MA	Expected Roof Life
IB Roof 50-mil	$236436	$4,641.15	30+ years
IB 80-mil White	$265625	$4,641.15	30+ years
IB 80-mil Color	$277301	$4,057.35	30+ years
IB Traditions	$251031	$4,057.35	30+ years
EPDM (Black Rubber)	$180976	$0.00	10-15 years *
Tar & Gravel/BUR	$198489	$0.00	20 years
TPO Roof 45-mil	$192651	$4,641.15	7-12 years **
Metal Shingles Roof	$281680	$4,057.35	50-100 years

Appendix RRRR-Inflation Rate Data[3]

InflationData.com **Current Annual Inflation Rate**

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ave
2012	2.93%	2.87%	2.65%	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2011	1.63%	2.11%	2.68%	3.16%	3.57%	3.56%	3.63%	3.77%	3.87%	3.53%	3.39%	2.96%	3.16%
2010	2.63%	2.14%	2.31%	2.24%	2.02%	1.05%	1.24%	1.15%	1.14%	1.17%	1.14%	1.50%	1.64%
2009	0.03%	0.24%	-0.38%	-0.74%	-1.28%	-1.43%	-2.10%	-1.48%	-1.29%	-0.18%	1.84%	2.72%	-0.34%
2008	4.28%	4.03%	3.98%	3.94%	4.18%	5.02%	5.60%	5.37%	4.94%	3.66%	1.07%	0.09%	3.85%
2007	2.08%	2.42%	2.78%	2.57%	2.69%	2.69%	2.36%	1.97%	2.76%	3.54%	4.31%	4.08%	2.85%
2006	3.99%	3.60%	3.36%	3.55%	4.17%	4.32%	4.15%	3.82%	2.06%	1.31%	1.97%	2.54%	3.24%
2005	2.97%	3.01%	3.15%	3.51%	2.80%	2.53%	3.17%	3.64%	4.69%	4.35%	3.46%	3.42%	3.39%
2004	1.93%	1.69%	1.74%	2.29%	3.05%	3.27%	2.99%	2.65%	2.54%	3.19%	3.52%	3.26%	2.68%
2003	2.60%	2.98%	3.02%	2.22%	2.06%	2.11%	2.11%	2.16%	2.32%	2.04%	1.77%	1.88%	2.27%
2002	1.14%	1.14%	1.48%	1.64%	1.18%	1.07%	1.46%	1.80%	1.51%	2.03%	2.20%	2.38%	1.59%
2001	3.73%	3.53%	2.92%	3.27%	3.62%	3.25%	2.72%	2.72%	2.65%	2.13%	1.90%	1.55%	2.83%
2000	2.74%	3.22%	3.76%	3.07%	3.19%	3.73%	3.66%	3.41%	3.45%	3.45%	3.45%	3.39%	3.38%

Note: Red indicates Deflation, NA indicates data not yet released.

Get more Historical Data from InflationData.com Web Masters: Get This Widget

To calculate inflation from a month and year to a later month and year, Try our Inflation calculator

[3] Source from InflationData.com, http://inflationdata.com/inflation/inflation_rate/currentinflation.asp

Appendix SSSS-Inflation Rate Calculation

Inflation Rate	
Year	Avg
2012	NA
2011	3.16%
2010	1.64%
2009	-0.34%
2008	3.85%
2007	2.85%
2006	3.24%
2005	3.39%
2004	2.68%
2003	2.27%
2002	1.59%
2001	2.83%
2000	3.38%
i	2.55%

Appendix TTTT-EPA Method 24

2.2 AUXILIARY MEMBRANE ROOFING MATERIALS

A. General: Auxiliary membrane roofing materials recommended by roofing system manufacturer for intended use and compatible with membrane roofing.

1. Liquid-type auxiliary materials shall comply with VOC limits of authorities having jurisdiction.
2. Adhesives and sealants that are not on the exterior side of weather barrier shall comply with the following limits for VOC content when calculated according to 40 CFR 59, Subpart D (EPA Method 24):

a. Plastic Foam Adhesives: 50 g/L.
b. Gypsum Board and Panel Adhesives: 50 g/L.
c. Multipurpose Construction Adhesives: 70 g/L.
d. Fiberglass Adhesives: 80 g/L.
e. Contact Adhesive: 80 g/L.
f. Single-Ply Roof Membrane Sealants: 450 g/L.
g. Nonmembrane Roof Sealants: 300 g/L.
h. Sealant Primers for Nonporous Substrates: 250 g/L.
i. Sealant Primers for Porous Substrates: 775 g/L.
j. Other Adhesives and Sealants: 250 g/L.

Appendix UUUU-Weighted Performance of EPDM Roof Membrane

Firestone Building Products: EcoWhite EPDM Roof Membrane

Environmental Weighted Performance				
Item	*Item Weight*	*Unit of Measurement*	*Performance Rating*	*Weighted Performance*
A. Ozone Depletion Potential	9	g	2.64558E-08	0.0000002
B. Eutrophication Potential	9	g	0.001040897	0.0092937
C. Global Warming Potential	29	g	0.002798773	0.0799649
D. Fossil fuel Consumption	9	MJ	0.040799796	0.3642839
E. Human Health Respiratory Effects Potential	20	g	5.66862E-07	0.0000111
F. Smog Potential	11	g	0.001320132	0.0141443
G. Weighted Resource Use	5	g	0.000177561	0.0009512
H. Acidification	9	millimoles	2.75634E-05	0.0002461
TOTAL PERFORMANCE				**0.468896**

Economic Weighted Performance				
Item	*Item Weight*	*Unit of Measurement*	*Performance Rating*	*Weighted Performance*
A.First Cost	50	$/sf	1	50
B. Future Cost	50	$/sf	1	50
TOTAL PERFORMANCE				**100**

Building Weighted Performance				
Item	*Item Weight*	*Unit of Measurement*	*Performance Rating*	*Weighted Performance*
A. Aesthetic Aspect	6	Availability	10	63
B. Energy Efficiency	31	$/sf	10	313
C. Indoor Air Quality	25	Qualification	0	0
D. Thermal Comfort	19	R Value	8	150
E. Lighting Comfort	13	Qualification	0	0
F. Acoustic Comfort	6	Qualification	0	0
TOTAL PERFORMANCE				**525**

Material Credits-LEED Weighted Performance				
Item	*Item Weight*	*Unit of Measurement*	*Performance Rating*	*Weighted Performance*
A. Heat Island Effects	6	SRI Value	1	6
B. Recycled Content	25	%	10	250
C. Regional Materials	19	miles	10	188
D. FSC Certified Wood	19	Qualification	0	0
E. Low Emitting Materials	25	Qualification	0	0
F. Rapidly Renewable Materials	6	Qualification	0	0
TOTAL PERFORMANCE				**444**

Appendix VVVV-Product Total Performance of EPDM Roof Membrane

Firestone Building Products: EcoWhite EPDM Roof Membrane

Product Total Performance			
Section	*Raw Score*	*Section Weight*	*Section Total Performance*
A. Environmental Performance	1	14	0.468896
B. Economic Performance	3	43	100
C. Building Performance	1	14	525
D. Material Credits-LEED	2	29	444
PRODUCT TOTAL PERFORMANCE			**244.71**

Appendix WWWW-Weighted Performance of PVC Roof Membrane

Sarnafil Inc.: "Sarnafil G410."PVC Roof Membrane

Environmental Weighted Performance				
Item	*Item Weight*	*Unit of Measurement*	*Performance Rating*	*Weighted Performance*
A. Ozone Depletion Potential	9	g	2.93953E-10	0.000000
B. Eutrophication Potential	9	g	0.001040897	0.009294
C. Global Warming Potential	29	g	0.003658731	0.104535
D. Fossil fuel Consumption	9	MJ	0.060873998	0.543518
E. Human Health Respiratory Effects Potentia	20	g	1.25969E-06	0.000025
F. Smog Potential	11	g	0.001980198	0.021216
G. Weighted Resource Use	5	g	0.00022549	0.001208
H. Acidification	9	millimoles	6.987E-05	0.000624
TOTAL PERFORMANCE				**0.680420**

Economic Weighted Performance				
Item	*Item Weight*	*Unit of Measurement*	*Performance Rating*	*Weighted Performance*
A.First Cost	50	$/sf	1	50
B. Future Cost	50	$/sf	1	50
TOTAL PERFORMANCE				**100**

Building Weighted Performance				
Item	*Item Weight*	*Unit of Measurement*	*Performance Rating*	*Weighted Performance*
A. Aesthetic Aspect	6	Availability	7	44
B. Energy Efficiency	31	$/sf	10	313
C. Indoor Air Quality	25	Qualification	0	0
D. Thermal Comfort	19	R Value	8	150
E. Lighting Comfort	13	Qualification	0	0
F. Acoustic Comfort	6	Qualification	0	0
TOTAL PERFORMANCE				**506**

Material Credits-LEED Weighted Performance				
Item	*Item Weight*	*Unit of Measurement*	*Performance Rating*	*Weighted Performance*
A. Heat Island Effects	6	SRI Value	1	6
B. Recycled Content	25	%	10	250
C. Regional Materials	19	miles	1	19
D. FSC Certified Wood	19	Qualification	0	0
E. Low Emitting Materials	25	Qualification	0	0
F. Rapidly Renewable Materials	6	Qualification	0	0
TOTAL PERFORMANCE				**275**

Appendix XXXX-Product Total Performance of PVC Roof Membrane

Sarnafil Inc.: "Sarnafil G410."PVC Roof Membrane

Product Total Performance			
Section	*Raw Score*	*Section Weight*	*Section Total Performance*
A. Environmental Performance	1	14	0.680420
B. Economic Performance	3	43	100
C. Building Performance	1	14	506
D. Material Credits-LEED	2	29	275
PRODUCT TOTAL PERFORMANCE			**193.85**

Appendix YYYY-Weighted Performance of OSB Sheathing

Georgia-Pacific: Blue Ribbon® OSB Rated Sheathing

Environmental Weighted Performance				
Item	*Item Weight*	*Unit of Measurement*	*Performance Rating*	*Weighted Performance*
A. Ozone Depletion Potential	9	g	0.000000	0.000000
B. Eutrophication Potential	9	g	0.000862	0.007698
C. Global Warming Potential	29	g	0.000331	0.009451
D. Fossil fuel Consumption	9	MJ	0.000263	0.002345
E. Human Health Respiratory Effects Potential	20	g	0.000104	0.002040
F. Smog Potential	11	g	0.002418	0.025908
G. Weighted Resource Use	5	g	0.000033	0.000176
H. Acidification	9	millimoles	0.000002	0.000014
TOTAL PERFORMANCE				**0.047633**

Economic Weighted Performance				
Item	*Item Weight*	*Unit of Measurement*	*Performance Rating*	*Weighted Performance*
A.First Cost	50	$/sf	1	50
B. Future Cost	50	$/sf	1	50
TOTAL PERFORMANCE				**100**

Building Weighted Performance				
Item	*Item Weight*	*Unit of Measurement*	*Performance Rating*	*Weighted Performance*
A. Aesthetic Aspect	6	Availability	10	63
B. Energy Efficiency	31	$/sf	0	0
C. Indoor Air Quality	25	Qualification	1	25
D. Thermal Comfort	19	R Value	0	0
E. Lighting Comfort	13	Qualification	0	0
F. Acoustic Comfort	6	Qualification	0	0
TOTAL PERFORMANCE				**88**

Material Credits-LEED Weighted Performance				
Item	*Item Weight*	*Unit of Measurement*	*Performance Rating*	*Weighted Performance*
A. Heat Island Effects	6	SRI Value	0	0
B. Recycled Content	25	%	10	250
C. Regional Materials	19	miles	8	150
D. FSC Certified Wood	19	Qualification	1	19
E. Low Emitting Materials	25	Qualification	1	25
F. Rapidly Renewable Materials	6	Qualification	0	0
TOTAL PERFORMANCE				**444**

Appendix ZZZZ-Product Total Performance of OSB Sheathing

Georgia-Pacific: Blue Ribbon® OSB Rated Sheathing

Product Total Performance			
Section	*Raw Score*	*Section Weight*	*Section Total Performance*
A. Environmental Performance	1	14	0.047633
B. Economic Performance	3	43	100
C. Building Performance	1	14	88
D. Material Credits-LEED	2	29	444
PRODUCT TOTAL PERFORMANCE			**182.15**

Appendix AAAAA-Weighted Performance of Plywood Sheathing

Georgia-Pacific: Plytanium® Plywood

Environmental Weighted Performance				
Item	*Item Weight*	*Unit of Measurement*	*Performance Rating*	*Weighted Performance*
A. Ozone Depletion Potential	9	g	0.000000	0.000000
B. Eutrophication Potential	9	g	0.000109	0.000974
C. Global Warming Potential	29	g	0.000164	0.004699
D. Fossil fuel Consumption	9	MJ	0.000101	0.000899
E. Human Health Respiratory Effects Potential	20	g	0.000072	0.001424
F. Smog Potential	11	g	0.000140	0.001505
G. Weighted Resource Use	5	g	0.000005	0.000025
H. Acidification	9	millimoles	0.000000	0.000001
TOTAL PERFORMANCE				**0.009526**

Economic Weighted Performance				
Item	*Item Weight*	*Unit of Measurement*	*Performance Rating*	*Weighted Performance*
A.First Cost	50	$/sf	1	50
B. Future Cost	50	$/sf	1	50
TOTAL PERFORMANCE				**100**

Building Weighted Performance				
Item	*Item Weight*	*Unit of Measurement*	*Performance Rating*	*Weighted Performance*
A. Aesthetic Aspect	6	Availability	10	63
B. Energy Efficiency	31	$/sf	0	0
C. Indoor Air Quality	25	Qualification	1	25
D. Thermal Comfort	19	R Value	0	0
E. Lighting Comfort	13	Qualification	0	0
F. Acoustic Comfort	6	Qualification	0	0
TOTAL PERFORMANCE				**88**

Material Credits-LEED Weighted Performance				
Item	*Item Weight*	*Unit of Measurement*	*Performance Rating*	*Weighted Performance*
A. Heat Island Effects	6	SRI Value	0	0
B. Recycled Content	25	%	10	250
C. Regional Materials	19	miles	5	94
D. FSC Certified Wood	19	Qualification	10	188
E. Low Emitting Materials	25	Qualification	1	25
F. Rapidly Renewable Materials	6	Qualification	0	0
TOTAL PERFORMANCE				**556**

Appendix BBBBB-Product Total Performance of Plywood Sheathing

Georgia-Pacific: Plytanium® Plywood			
Product Total Performance			
Section	*Raw Score*	*Section Weight*	*Section Total Performance*
A. Environmental Performance	1	14	0.009526
B. Economic Performance	3	43	100
C. Building Performance	1	14	88
D. Material Credits-LEED	2	29	556
PRODUCT TOTAL PERFORMANCE			**214.29**

Appendix CCCCC-Weighted Performance of Steel Framing

CEMCO: Cold-Formed Steel Framing(load bearing)

Environmental Weighted Performance				
Item	*Item Weight*	*Unit of Measurement*	*Performance Rating*	*Weighted Performance*
A. Ozone Depletion Potential	9	g	0.000000	0.000000
B. Eutrophication Potential	9	g	0.000072	0.000639
C. Global Warming Potential	29	g	0.000220	0.006279
D. Fossil fuel Consumption	9	MJ	0.000170	0.001521
E. Human Health Respiratory Effects Potential	20	g	0.001649	0.032397
F. Smog Potential	11	g	0.000122	0.001312
G. Weighted Resource Use	5	g	0.000082	0.000441
H. Acidification	9	millimoles	0.000000	0.000002
TOTAL PERFORMANCE				**0.042590**

Economic Weighted Performance				
Item	*Item Weight*	*Unit of Measurement*	*Performance Rating*	*Weighted Performance*
A.First Cost	50	$/sf	6	300
B. Future Cost	50	$/sf	1	50
TOTAL PERFORMANCE				**350**

Building Weighted Performance				
Item	*Item Weight*	*Unit of Measurement*	*Performance Rating*	*Weighted Performance*
A. Aesthetic Aspect	6	Availability	6	38
B. Energy Efficiency	31	$/sf	10	313
C. Indoor Air Quality	25	Qualification	0	0
D. Thermal Comfort	19	R Value	0	0
E. Lighting Comfort	13	Qualification	0	0
F. Acoustic Comfort	6	Qualification	0	0
TOTAL PERFORMANCE				**350**

Material Credits-LEED Weighted Performance				
Item	*Item Weight*	*Unit of Measurement*	*Performance Rating*	*Weighted Performance*
A. Heat Island Effects	6	SRI Value	0	0
B. Recycled Content	25	%	7	175
C. Regional Materials	19	miles	5	94
D. FSC Certified Wood	19	Qualification	0	0
E. Low Emitting Materials	25	Qualification	0	0
F. Rapidly Renewable Materials	6	Qualification	0	0
TOTAL PERFORMANCE				**269**

Appendix DDDDD-Product Total Performance of Steel Framing

CEMCO: Cold-Formed Steel Framing(load bearing)			
Product Total Performance			
Section	*Raw Score*	*Section Weight*	*Section Total Performance*
A. Environmental Performance	1	14	0.042590
B. Economic Performance	3	43	350
C. Building Performance	1	14	350
D. Material Credits-LEED	2	29	269
PRODUCT TOTAL PERFORMANCE			**276.79**

Appendix EEEEE-Weighted Performance of Wood Framing

Georgia-Pacific: Wood Framing

Environmental Weighted Performance				
Item	*Item Weight*	*Unit of Measurement*	*Performance Rating*	*Weighted Performance*
A. Ozone Depletion Potential	9	g	0.000000	0.000000
B. Eutrophication Potential	9	g	0.000087	0.000774
C. Global Warming Potential	29	g	0.000124	0.003548
D. Fossil fuel Consumption	9	MJ	0.000083	0.000744
E. Human Health Respiratory Effects Potential	20	g	0.000192	0.003776
F. Smog Potential	11	g	0.000104	0.001113
G. Weighted Resource Use	5	g	0.000013	0.000069
H. Acidification	9	millimoles	0.000000	0.000002
TOTAL PERFORMANCE				**0.010026**

Economic Weighted Performance				
Item	*Item Weight*	*Unit of Measurement*	*Performance Rating*	*Weighted Performance*
A.First Cost	50	$/sf	2	100
B. Future Cost	50	$/sf	1	50
TOTAL PERFORMANCE				**150**

Building Weighted Performance				
Item	*Item Weight*	*Unit of Measurement*	*Performance Rating*	*Weighted Performance*
A. Aesthetic Aspect	6	Availability	4	25
B. Energy Efficiency	31	$/sf	10	313
C. Indoor Air Quality	25	Qualification	0	0
D. Thermal Comfort	19	R Value	0	0
E. Lighting Comfort	13	Qualification	0	0
F. Acoustic Comfort	6	Qualification	0	0
TOTAL PERFORMANCE				**338**

Material Credits-LEED Weighted Performance				
Item	*Item Weight*	*Unit of Measurement*	*Performance Rating*	*Weighted Performance*
A. Heat Island Effects	6	SRI Value	0	0
B. Recycled Content	25	%	10	250
C. Regional Materials	19	miles	2	38
D. FSC Certified Wood	19	Qualification	0	0
E. Low Emitting Materials	25	Qualification	0	0
F. Rapidly Renewable Materials	6	Qualification	0	0
TOTAL PERFORMANCE				**288**

Appendix FFFFF-Product Total Performance of Wood Framing

Georgia-Pacific: Wood Framing

Product Total Performance			
Section	*Raw Score*	*Section Weight*	*Section Total Performance*
A. Environmental Performance	1	14	0.010026
B. Economic Performance	3	43	150
C. Building Performance	1	14	338
D. Material Credits-LEED	2	29	288
PRODUCT TOTAL PERFORMANCE			**194.64**

Appendix GGGGG-Weighted Performance of Fired Clay Brick

Fired Clay Brick

Environmental Weighted Performance				
Item	*Item Weight*	*Unit of Measurement*	*Performance Rating*	*Weighted Performance*
A. Ozone Depletion Potential	9	g	0.000000	0.000000
B. Eutrophication Potential	9	g	0.000457	0.004079
C. Global Warming Potential	29	g	0.001764	0.050404
D. Fossil fuel Consumption	9	MJ	0.002256	0.020145
E. Human Health Respiratory Effects Potential	20	g	0.000010	0.000192
F. Smog Potential	11	g	0.001495	0.016015
G. Weighted Resource Use	5	g	0.000085	0.000455
H. Acidification	9	millimoles	0.000002	0.000021
TOTAL PERFORMANCE				**0.091311**

Economic Weighted Performance				
Item	*Item Weight*	*Unit of Measurement*	*Performance Rating*	*Weighted Performance*
A.First Cost	50	$/sf	2	100
B. Future Cost	50	$/sf	1	50
TOTAL PERFORMANCE				**150**

Building Weighted Performance				
Item	*Item Weight*	*Unit of Measurement*	*Performance Rating*	*Weighted Performance*
A. Aesthetic Aspect	6	Availability	10	63
B. Energy Efficiency	31	$/sf	10	313
C. Indoor Air Quality	25	Qualification	0	0
D. Thermal Comfort	19	R Value	0	0
E. Lighting Comfort	13	Qualification	0	0
F. Acoustic Comfort	6	Qualification	0	0
TOTAL PERFORMANCE				**375**

Material Credits-LEED Weighted Performance				
Item	*Item Weight*	*Unit of Measurement*	*Performance Rating*	*Weighted Performance*
A. Heat Island Effects	6	SRI Value	0	0
B. Recycled Content	25	%	10	250
C. Regional Materials	19	miles	1	19
D. FSC Certified Wood	19	Qualification	0	0
E. Low Emitting Materials	25	Qualification	0	0
F. Rapidly Renewable Materials	6	Qualification	0	0
TOTAL PERFORMANCE				**269**

Appendix HHHHH-Product Total Performance of Fired Clay Brick

Fired Clay Brick			
Product Total Performance			
Section	*Raw Score*	*Section Weight*	*Section Total Performance*
A. Environmental Performance	1	14	0.091311
B. Economic Performance	3	43	150
C. Building Performance	1	14	375
D. Material Credits-LEED	2	29	269
PRODUCT TOTAL PERFORMANCE			**194.66**

Appendix IIIII-Weighted Performance of Stucco

New England Stucco and Weatherization, Inc. : Cement Stucco

Environmental Weighted Performance				
Item	*Item Weight*	*Unit of Measurement*	*Performance Rating*	*Weighted Performance*
A. Ozone Depletion Potential	9	g	0.000000	0.000000
B. Eutrophication Potential	9	g	0.000155	0.001383
C. Global Warming Potential	29	g	0.000570	0.016274
D. Fossil fuel Consumption	9	MJ	0.000343	0.003058
E. Human Health Respiratory Effects Potential	20	g	0.010394	0.204160
F. Smog Potential	11	g	0.000531	0.005695
G. Weighted Resource Use	5	g	0.000030	0.000161
H. Acidification	9	millimoles	0.000001	0.000005
TOTAL PERFORMANCE				**0.230737**

Economic Weighted Performance				
Item	*Item Weight*	*Unit of Measurement*	*Performance Rating*	*Weighted Performance*
A.First Cost	50	$/sf	1	50
B. Future Cost	50	$/sf	1	50
TOTAL PERFORMANCE				**100**

Building Weighted Performance				
Item	*Item Weight*	*Unit of Measurement*	*Performance Rating*	*Weighted Performance*
A. Aesthetic Aspect	6	Availability	8	50
B. Energy Efficiency	31	$/sf	10	313
C. Indoor Air Quality	25	Qualification	0	0
D. Thermal Comfort	19	R Value	0	0
E. Lighting Comfort	13	Qualification	0	0
F. Acoustic Comfort	6	Qualification	0	0
TOTAL PERFORMANCE				**363**

Material Credits-LEED Weighted Performance				
Item	*Item Weight*	*Unit of Measurement*	*Performance Rating*	*Weighted Performance*
A. Heat Island Effects	6	SRI Value	0	0
B. Recycled Content	25	%	10	250
C. Regional Materials	19	miles	1	19
D. FSC Certified Wood	19	Qualification	0	0
E. Low Emitting Materials	25	Qualification	0	0
F. Rapidly Renewable Materials	6	Qualification	0	0
TOTAL PERFORMANCE				**269**

Appendix JJJJJ-Product Total Performance of Stucco

New England Stucco and Weatherization, Inc. : Cement Stucco

Product Total Performance			
Section	*Raw Score*	*Section Weight*	*Section Total Performance*
A. Environmental Performance	1	14	0.230737
B. Economic Performance	3	43	100
C. Building Performance	1	14	363
D. Material Credits-LEED	2	29	269
PRODUCT TOTAL PERFORMANCE			**171.46**

Appendix KKKKK-Weighted Performance of Aluminum Siding

Rollex®: Aluminum Siding Double 4 in.

Environmental Weighted Performance				
Item	*Item Weight*	*Unit of Measurement*	*Performance Rating*	*Weighted Performance*
A. Ozone Depletion Potential	9	g	0.000488	0.004357
B. Eutrophication Potential	9	g	0.000092	0.000819
C. Global Warming Potential	29	g	0.000601	0.017177
D. Fossil fuel Consumption	9	MJ	0.000488	0.004360
E. Human Health Respiratory Effects Potential	20	g	0.000692	0.013590
F. Smog Potential	11	g	0.000309	0.003312
G. Weighted Resource Use	5	g	0.000003	0.000018
H. Acidification	9	millimoles	0.000001	0.000006
TOTAL PERFORMANCE				**0.043639**

Economic Weighted Performance				
Item	*Item Weight*	*Unit of Measurement*	*Performance Rating*	*Weighted Performance*
A.First Cost	50	$/sf	1	50
B. Future Cost	50	$/sf	1	50
TOTAL PERFORMANCE				**100**

Building Weighted Performance				
Item	*Item Weight*	*Unit of Measurement*	*Performance Rating*	*Weighted Performance*
A. Aesthetic Aspect	6	Availability	10	63
B. Energy Efficiency	31	$/sf	10	313
C. Indoor Air Quality	25	Qualification	0	0
D. Thermal Comfort	19	R Value	0	0
E. Lighting Comfort	13	Qualification	0	0
F. Acoustic Comfort	6	Qualification	0	0
TOTAL PERFORMANCE				**375**

Material Credits-LEED Weighted Performance				
Item	*Item Weight*	*Unit of Measurement*	*Performance Rating*	*Weighted Performance*
A. Heat Island Effects	6	SRI Value	0	0
B. Recycled Content	25	%	10	250
C. Regional Materials	19	miles	3	56
D. FSC Certified Wood	19	Qualification	0	0
E. Low Emitting Materials	25	Qualification	1	25
F. Rapidly Renewable Materials	6	Qualification	0	0
TOTAL PERFORMANCE				**331**

Appendix LLLLL-Product Total Performance of Aluminum Siding

Rollex®: Aluminum Siding Double 4 in.			
Product Total Performance			
Section	*Raw Score*	*Section Weight*	*Section Total Performance*
A. Environmental Performance	1	14	0.043639
B. Economic Performance	3	43	100
C. Building Performance	1	14	375
D. Material Credits-LEED	2	29	331
PRODUCT TOTAL PERFORMANCE			**191.08**

Appendix MMMMM-Weighted Performance of 15% Fly Ash Cement

Cemex: 15% Fly Ash Cement

Environmental Weighted Performance				
Item	*Item Weight*	*Unit of Measurement*	*Performance Rating*	*Weighted Performance*
A. Ozone Depletion Potential	9	g	0.000000	0.000000
B. Eutrophication Potential	9	g	0.000625	0.005579
C. Global Warming Potential	29	g	0.001547	0.044208
D. Fossil fuel Consumption	9	MJ	0.000780	0.006967
E. Human Health Respiratory Effects Potential	20	g	0.039988	0.785479
F. Smog Potential	11	g	0.001342	0.014379
G. Weighted Resource Use	5	g	0.000105	0.000565
H. Acidification	9	millimoles	0.000001	0.000013
TOTAL PERFORMANCE				**0.857189**

Economic Weighted Performance				
Item	*Item Weight*	*Unit of Measurement*	*Performance Rating*	*Weighted Performance*
A.First Cost	50	$/CY	10	500
B. Future Cost	50	$/CY	1	50
TOTAL PERFORMANCE				**550**

Building Weighted Performance				
Item	*Item Weight*	*Unit of Measurement*	*Performance Rating*	*Weighted Performance*
A. Aesthetic Aspect	6	Availability	10	63
B. Energy Efficiency	31	$/CY	10	313
C. Indoor Air Quality	25	Qualification	0	0
D. Thermal Comfort	19	R Value	0	0
E. Lighting Comfort	13	Qualification	0	0
F. Acoustic Comfort	6	Qualification	0	0
TOTAL PERFORMANCE				**375**

Material Credits-LEED Weighted Performance				
Item	*Item Weight*	*Unit of Measurement*	*Performance Rating*	*Weighted Performance*
A. Heat Island Effects	6	SRI Value	0	0
B. Recycled Content	25	%	9	225
C. Regional Materials	19	miles	2	38
D. FSC Certified Wood	19	Qualification	0	0
E. Low Emitting Materials	25	Qualification	0	0
F. Rapidly Renewable Materials	6	Qualification	0	0
TOTAL PERFORMANCE				**263**

Appendix NNNNN-Product Total Performance of 15% Fly Ash Cement

Cemex: 15% Fly Ash Cement			
Product Total Performance			
Section	*Raw Score*	*Section Weight*	*Section Total Performance*
A. Environmental Performance	1	14	0.857189
B. Economic Performance	3	43	550
C. Building Performance	1	14	375
D. Material Credits-LEED	2	29	263
PRODUCT TOTAL PERFORMANCE			**364.41**

Appendix OOOOO-Weighted Performance of 20% Fly Ash Cement

Cemex: 20% Fly Ash Cement

Environmental Weighted Performance				
Item	*Item Weight*	*Unit of Measurement*	*Performance Rating*	*Weighted Performance*
A. Ozone Depletion Potential	9	g	0.000000	0.000000
B. Eutrophication Potential	9	g	0.000617	0.005513
C. Global Warming Potential	29	g	0.001503	0.042954
D. Fossil fuel Consumption	9	MJ	0.000772	0.006889
E. Human Health Respiratory Effects Potential	20	g	0.037651	0.739580
F. Smog Potential	11	g	0.001315	0.014094
G. Weighted Resource Use	5	g	0.000104	0.000556
H. Acidification	9	millimoles	0.000001	0.000012
TOTAL PERFORMANCE				**0.809599**

Economic Weighted Performance				
Item	*Item Weight*	*Unit of Measurement*	*Performance Rating*	*Weighted Performance*
A.First Cost	50	$/CY	10	500
B. Future Cost	50	$/CY	1	50
TOTAL PERFORMANCE				**550**

Building Weighted Performance				
Item	*Item Weight*	*Unit of Measurement*	*Performance Rating*	*Weighted Performance*
A. Aesthetic Aspect	6	Availability	10	63
B. Energy Efficiency	31	$/CY	10	313
C. Indoor Air Quality	25	Qualification	0	0
D. Thermal Comfort	19	R Value	0	0
E. Lighting Comfort	13	Qualification	0	0
F. Acoustic Comfort	6	Qualification	0	0
TOTAL PERFORMANCE				**375**

Material Credits-LEED Weighted Performance				
Item	*Item Weight*	*Unit of Measurement*	*Performance Rating*	*Weighted Performance*
A. Heat Island Effects	6	SRI Value	0	0
B. Recycled Content	25	%	8	200
C. Regional Materials	19	miles	2	38
D. FSC Certified Wood	19	Qualification	0	0
E. Low Emitting Materials	25	Qualification	0	0
F. Rapidly Renewable Materials	6	Qualification	0	0
TOTAL PERFORMANCE				**238**

Appendix PPPPP-Product Total Performance of 20% Fly Ash Cement

Cemex: 20% Fly Ash Cement			
Product Total Performance			
Section	*Raw Score*	*Section Weight*	*Section Total Performance*
A. Environmental Performance	1	14	0.809599
B. Economic Performance	3	43	550
C. Building Performance	1	14	375
D. Material Credits-LEED	2	29	238
PRODUCT TOTAL PERFORMANCE			**357.26**

Appendix QQQQQ-Weighted Performance of Ceramic Tile

American Olean Tile Co.:Ceramic Tile

Environmental Weighted Performance				
Item	*Item Weight*	*Unit of Measurement*	*Performance Rating*	*Weighted Performance*
A. Ozone Depletion Potential	9	g	0.000000	0.000000
B. Eutrophication Potential	9	g	0.000229	0.002045
C. Global Warming Potential	29	g	0.001009	0.028816
D. Fossil fuel Consumption	9	MJ	0.001187	0.010594
E. Human Health Respiratory Effects Potential	20	g	0.004616	0.090663
F. Smog Potential	11	g	0.000863	0.009249
G. Weighted Resource Use	5	g	0.000285	0.001526
H. Acidification	9	millimoles	0.000001	0.000011
TOTAL PERFORMANCE				**0.142904**

Economic Weighted Performance				
Item	*Item Weight*	*Unit of Measurement*	*Performance Rating*	*Weighted Performance*
A.First Cost	50	$/sf	1	50
B. Future Cost	50	$/sf	1	50
TOTAL PERFORMANCE				**100**

Building Weighted Performance				
Item	*Item Weight*	*Unit of Measurement*	*Performance Rating*	*Weighted Performance*
A. Aesthetic Aspect	6	Availability	1	6
B. Energy Efficiency	31	$/sf	10	313
C. Indoor Air Quality	25	Qualification	0	0
D. Thermal Comfort	19	R Value	0	0
E. Lighting Comfort	13	Qualification	0	0
F. Acoustic Comfort	6	Qualification	0	0
TOTAL PERFORMANCE				**319**

Material Credits-LEED Weighted Performance				
Item	*Item Weight*	*Unit of Measurement*	*Performance Rating*	*Weighted Performance*
A. Heat Island Effects	6	SRI Value	0	0
B. Recycled Content	25	%	3	75
C. Regional Materials	19	miles	3	56
D. FSC Certified Wood	19	Qualification	0	0
E. Low Emitting Materials	25	Qualification	1	25
F. Rapidly Renewable Materials	6	Qualification	10	63
TOTAL PERFORMANCE				**219**

Appendix RRRRR-Product Total Performance of Ceramic Tile

American Olean Tile Co.:Ceramic Tile			
Product Total Performance			
Section	*Raw Score*	*Section Weight*	*Section Total Performance*
A. Environmental Performance	1	14	0.142904
B. Economic Performance	3	43	100
C. Building Performance	1	14	319
D. Material Credits-LEED	2	29	219
PRODUCT TOTAL PERFORMANCE			**150.91**

Appendix SSSSS-Weighted Performance of Wool Carpet Tile

Flor®: Wool Carpet Tile

Environmental Weighted Performance				
Item	*Item Weight*	*Unit of Measurement*	*Performance Rating*	*Weighted Performance*
A. Ozone Depletion Potential	9	g	0.000003	0.000026
B. Eutrophication Potential	9	g	0.179727	1.604706
C. Global Warming Potential	29	g	0.014598	0.417079
D. Fossil fuel Consumption	9	MJ	0.003217	0.028726
E. Human Health Respiratory Effects Potential	20	g	0.001687	0.033144
F. Smog Potential	11	g	0.029620	0.317360
G. Weighted Resource Use	5	g	0.006599	0.035350
H. Acidification	9	millimoles	0.000037	0.000327
TOTAL PERFORMANCE				**2.436718**

Economic Weighted Performance				
Item	*Item Weight*	*Unit of Measurement*	*Performance Rating*	*Weighted Performance*
A. First Cost	50	$/sf	2	100
B. Future Cost	50	$/sf	1	50
TOTAL PERFORMANCE				**150**

Building Weighted Performance				
Item	*Item Weight*	*Unit of Measurement*	*Performance Rating*	*Weighted Performance*
A. Aesthetic Aspect	6	Availability	1	6
B. Energy Efficiency	31	$/sf	10	313
C. Indoor Air Quality	25	Qualification	0	0
D. Thermal Comfort	19	R Value	0	0
E. Lighting Comfort	13	Qualification	0	0
F. Acoustic Comfort	6	Qualification	0	0
TOTAL PERFORMANCE				**319**

Material Credits-LEED Weighted Performance				
Item	*Item Weight*	*Unit of Measurement*	*Performance Rating*	*Weighted Performance*
A. Heat Island Effects	6	SRI Value	0	0
B. Recycled Content	25	%	7	175
C. Regional Materials	19	miles	9	169
D. FSC Certified Wood	19	Qualification	0	0
E. Low Emitting Materials	25	Qualification	1	25
F. Rapidly Renewable Materials	6	Qualification	1	6
TOTAL PERFORMANCE				**375**

Appendix TTTTT-Product Total Performance of Wool Carpet Tile

Flor®: Wool Carpet Tile			
Product Total Performance			
Section	*Raw Score*	*Section Weight*	*Section Total Performance*
A. Environmental Performance	1	14	2.436718
B. Economic Performance	3	43	150
C. Building Performance	1	14	319
D. Material Credits-LEED	2	29	375
PRODUCT TOTAL PERFORMANCE			**217.31**

Appendix UUUUU-Weighted Performance of Linoleum Flooring

Armstrong®: Linoleum NATURCote

Environmental Weighted Performance				
Item	*Item Weight*	*Unit of Measurement*	*Performance Rating*	*Weighted Performance*
A. Ozone Depletion Potential	9	g	0.000000	0.000000
B. Eutrophication Potential	9	g	0.001129	0.010084
C. Global Warming Potential	29	g	0.000364	0.010391
D. Fossil fuel Consumption	9	MJ	0.000686	0.006127
E. Human Health Respiratory Effects Potential	20	g	0.000111	0.002187
F. Smog Potential	11	g	0.000789	0.008449
G. Weighted Resource Use	5	g	0.000842	0.004512
H. Acidification	9	millimoles	0.000001	0.000007
TOTAL PERFORMANCE				**0.041756**

Economic Weighted Performance				
Item	*Item Weight*	*Unit of Measurement*	*Performance Rating*	*Weighted Performance*
A.First Cost	50	$/sf	1	50
B. Future Cost	50	$/sf	1	50
TOTAL PERFORMANCE				**100**

Building Weighted Performance				
Item	*Item Weight*	*Unit of Measurement*	*Performance Rating*	*Weighted Performance*
A. Aesthetic Aspect	6	Availability	1	6
B. Energy Efficiency	31	$/sf	10	313
C. Indoor Air Quality	25	Qualification	0	0
D. Thermal Comfort	19	R Value	0	0
E. Lighting Comfort	13	Qualification	0	0
F. Acoustic Comfort	6	Qualification	0	0
TOTAL PERFORMANCE				**319**

Material Credits-LEED Weighted Performance				
Item	*Item Weight*	*Unit of Measurement*	*Performance Rating*	*Weighted Performance*
A. Heat Island Effects	6	SRI Value	0	0
B. Recycled Content	25	%	8	200
C. Regional Materials	19	miles	10	188
D. FSC Certified Wood	19	Qualification	0	0
E. Low Emitting Materials	25	Qualification	1	25
F. Rapidly Renewable Materials	6	Qualification	1	6
TOTAL PERFORMANCE				**419**

Appendix VVVVV-Product Total Performance of Linoleum Flooring

Armstrong®: Linoleum NATURCote			
Product Total Performance			
Section	*Raw Score*	*Section Weight*	*Section Total Performance*
A. Environmental Performance	1	14	0.041756
B. Economic Performance	3	43	100
C. Building Performance	1	14	319
D. Material Credits-LEED	2	29	419
PRODUCT TOTAL PERFORMANCE			**208.04**