Research Analysis: Building Envelope and LEED Credits

Introduction

Green buildings are no longer a new idea and are quickly becoming the trend in the slowly changing industry of building construction. Even though the essence of LEED (Leadership in Energy and Environmental Design) rating systems are understood more universally throughout construction disciplines than a decade ago, the integration of design, engineering, and construction of systems to be "greener" has a ways to go.

LEED rated buildings have numerous advantages over their more traditional counterparts, whether the facility is simply certified or one of the handful of platinum LEED certified projects. The advantages stem from locally used resources, recycled content, and other environmentally friendly applications. Energy consumption utilized for heating and cooling, as well water usage, can be greatly reduced by building with LEED. This can be a large monetary incentive with annual savings ranging from $20,000 - $120,000 for a typical 100,000 square foot commercial building. Air quality and daylight aspects of sustainable designs have been shown to increase productivity in the work force as well as promote learning in classroom environments.

So what is keeping more owners from building with sustainable aspects in mind? The answer is the price tag for the premium designs for the building systems. Redesigning mechanical, structural, lighting, and envelope systems can be tedious and costly. These systems need to be designed congruently to take full advantage of LEED aspects. This allows for systems to be more economical and cost effective to the building owner and possible tenants. The Center for Health Research and Rural Advocacy is also a health care facility which is governed by more stringent regulations than typical commercial construction. Health care operations utilize different ventilation requirements, occupant needs, waste and recycled content removal, and energy usage compared to that of their commercial counterpart. Health care facilities often operate close to full capacity 24 hours the entire year. The energy savings for these facilities can be significant. System efficiency is critical for these facilities not only for cost and maintenance, but for public safety and well-being.

Goal

The research to be employed in this analysis will take an in-depth look at how the selection and design of the building envelope affects the sustainable aspects of the project. Many resources and guides will be utilized to help understand impacts of LEED credits. A review of the LEED-NC for Commercial Construction Version 2.2 and GSA-LEED Cost Study will be compared to determine which credits are affected by the envelope selection and the relative cost of those credits. The Green Guide for Health Care is a new resource being used to help with the design and construction of these LEED rated facilities. This guide will be used to compare findings with the LEED-NC and GSA Cost study data. The goal of this research is to display the monetary and sustainable effects the exterior skin has on projects and to help designers and owners make educated decisions during the skin selection process.

Resource Review and Description

LEED-NC

The first resource used for this research analysis was the LEED-NC for Commercial Buildings Version 2.2. This source outlines the credits and pre-requisites required for attaining LEED certified facilities. The goal for many institutions, including Penn State University, is to construct buildings which are simply LEED certified. By achieving 26 - 32 of the possible 69 points a building will be considered LEED certified. Garnering 33 - 38 points will get a LEED Silver rating and 39 – 51 points equates to a LEED Gold certification. If the building in design and construction earns more than 52 points it achieves the highest rating which is LEED Platinum certification.

GSA LEED® Cost Study

U.S. General Services Administration (GSA) recently published a report outlining cost implications of each of the LEED credits in the LEED-NC guide. This GSA: LEED Cost Study includes credit reviews, calculates individual credit estimates, as well as determines soft costs for LEED credits based on a courthouse and commercial building examples. The credits are broken down according to their related premium costs. Premium cost ratings may range from none ($0)

to high (>$150,000). Once the premium costs are determined, general conditions and soft costs are calculated and added to the credits total expense.

Since the GSA: LEED Cost Study uses courthouses and commercial buildings as examples, an additional resource is needed to compare to health care facilities. The Green Guide for Health Care Construction is a guide being developed by numerous sponsors and organizations. The goal of this pilot document is to provide "A Best Practices Guide for Healthy and Sustainable Building Design, Construction, and Operations". Additional comments and concerns will be raised by this guide in reference to the LEED credits which are seen as affecting the building envelope design.

Analysis Results

Before the resources can be used for comparison and data collection, the LEED credits must be separated into different categories. The following categories will be used to separate the credits into manageable components based on the degree to which they affect the building envelope design and construction.

Directly Affects Building Envelope

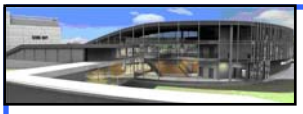
Credit point pertains to one or more of the following:

- The building envelope in reference to its design, construction, and use.
- A system which is contacting the building envelope in regards to structural and mechanical forces. (i.e. mechanical pipes running underneath building skin or supported by structural member)
- Entails day-lighting aspects, UV protection, and other types of solar energy harnessing systems.

In-directly Affects Building Envelope

Credit point does *NOT* directly affect the building envelope and pertains to one or more of the following:

- Pertains to material standards set for the entire project as in terms of locality, made from recycled content, packaging, etc.
- Waste management system for entire project and not just the building envelope.
- Deals with workers, equipment, and materials which will be utilized temporarily for the construction of the building envelope.



Does Not Affect Building Envelope

Credit points which do not directly or in-directly affect the building envelope design, construction, or use.

Since the factors and extents to which the building envelope is affected have been determined, these will be combined with the LEED-NC Version 2.2 for analysis. The following table outlines the LEED credits with a brief description and the category to which it pertains.

LEED Credits

SS: Site Selection		Direct	In-Direct	No-Effect
SS 1	Site Selection: Ecologically sensitive land or prime farmland			x
SS 2	Development Density or Community Connectivity			x
SS 3	Brownfield Redevelopment: Selection of contaminated site			x
SS 4.1	Public Transportation Access			x
SS 4.2	Alternative Transportation: Bicycle rack coverage		x	
SS 4.3	Low Emitting and Fuel Efficient Vehicles			x
SS 4.4	Parking Capacity: Carpool preferred parking			x
SS 5.1	Protect or Restore Habitat			x
SS 5.2	Maximize Open Space			x
SS 6.1	Storm water Design: Quantity Control			x
SS 6.2	Storm water Design: Quality Control		x	
SS 7.1	Heat Island Effect: Non-roof			x
SS 7.2	Heat Island Effect: Roof	x		
SS 8	Light Pollution Reduction		x	

WE: Water Efficiency		Direct	In-Direct	No-Effect
WE 1.1	Water Efficient Landscaping (50%)			x
WE 1.2	Water Efficient Landscaping (No potable water)			x
WE 2	Innovative Wastewater Technologies			x
WE 3.1	Water Use Reduction (20%)			x
WE 3.2	Water Use Reduction (30%)			x

EA: Energy and Atmosphere		Direct	In-Direct	No-Effect
EA 1	Optimize Energy Performance (1-10 pts.)	x		
EA 2	On-Site Renewable Energy (1-3 pts.)	x		
EA 3	Enhanced Commissioning			x
EA 4	Enhanced Refrigerant Management			x
EA 5	Measurement and Verification			x
EA 6	Green Power			x

MR: Materials and Resources

		Direct	In-Direct	No-Effect
MR 1.1	Building Re-Use (Maintain 75% of existing walls, floors, roofs)		x	
MR 1.2	Building Re-Use (Maintain 95% of existing walls, floors, roofs)		x	
MR 1.3	Building Re-Use (Maintain 50% of non-structural interior elements)			x
MR 2.1	Construction Waste Management (50% Diverted)		x	
MR 2.2	Construction Waste Management (75% Diverted)		x	
MR 3.1	Materials Re-Use (5%)	x		
MR 3.2	Materials Re-Use (10%)	x		
MR 4.1	Recycled Content (10%)	x		
MR 4.2	Recycled Content (20%)	x		
MR 5.1	Regional Materials (10% Processed, Manufactured Regionally)		x	
MR 5.2	Regional Materials (20% Processed, Manufactured Regionally)		x	
MR 6	Rapidly Renewable Materials			x
MR 7	Certified Wood			x

EQ: Indoor Environmental Quality

		Direct	In-Direct	No-Effect
EQ 1	Outdoor Air Delivery Monitoring			x
EQ 2	Increased Ventilation			x
EQ 3.1	Construction IAQ Management Plan: During Construction		x	
EQ 3.2	Construction IAQ Management Plan: Before Occupancy			x
EQ 4.1	Low-Emitting Materials: Adhesives & Sealants	x		
EQ 4.2	Low-Emitting Materials: Paints & Coatings	x		
EQ 4.3	Low-Emitting Materials: Carpet Systems			x
EQ 4.4	Low-Emitting Materials: Composite Wood & Agrifiber Products			
EQ 5	Indoor Chemical & Pollutant Source Control	x		
EQ 6.1	Controllability of Systems: Lighting			x
EQ 6.2	Controllability of Systems: Thermal Comfort	x		
EQ 7.1	Thermal Comfort: Design	x		
EQ 7.2	Thermal Comfort: Verification			x
EQ 8.1	Daylight & Views: Daylight 75% of Spaces	x		
EQ 8.2	Daylight & Views: Daylight 90% of Spaces	x		

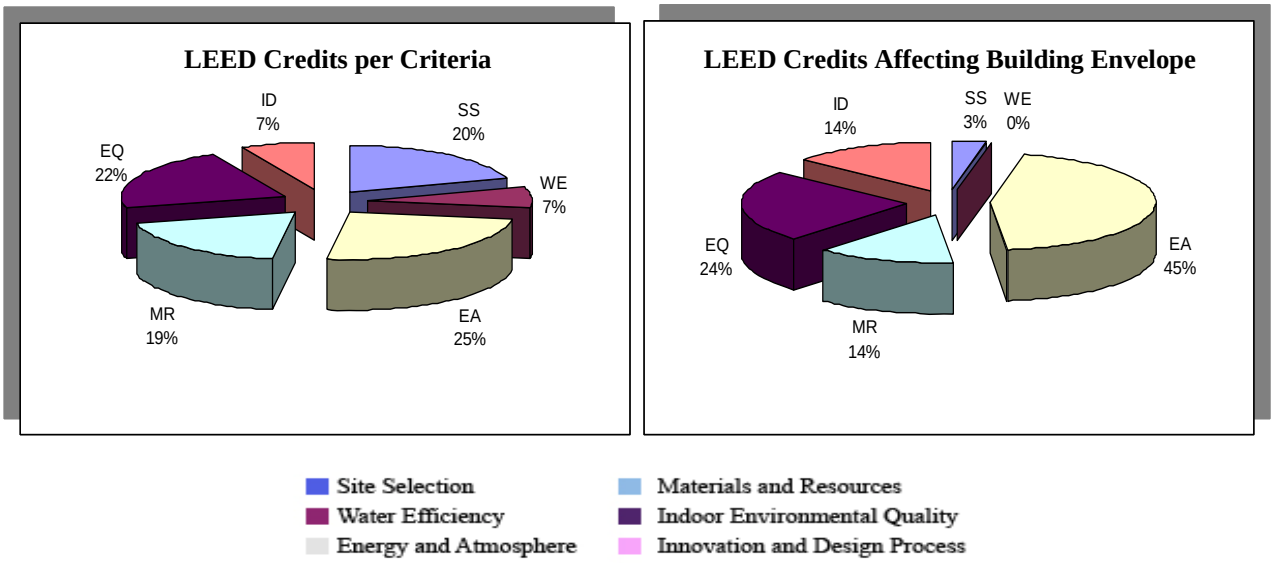
ID: Innovation & Design Process

		Direct	In-Direct	No-Effect
ID 1.1-1.4	Innovation in Design (1-4 pts.)	x		
ID 2	LEED Accredited Professional			x

Summary Table

	# of Credits	SS	WE	EA	MR	EQ	ID
Directly Affect Building Envelope	29	1	0	13	4	7	4
In-Directly Affect Building Envelope	10	3	0	0	6	1	0
No-Effect on Building Envelope	30	10	5	4	3	7	1
Total Credits	**69**	14	5	17	13	15	5

This simple analysis of the LEED credits brings out some interesting insight into the importance the building envelope may play in the design and construction process. 57% of the LEED credits are affected either directly or in-directly by the skin selection and 75% of those credits directly affect the building envelope. The summary table also illustrates the spread of the credits across the various sections of the LEED criterion. The Energy and Atmosphere (EA) section of the LEED-NC is the most critical for exterior systems with 13 of the 17 points being directly affected. The Energy and Atmosphere criterion is one of the most important sustainable aspects of green buildings to most owners and developers. Utility savings in such things as water and electricity can be significant to the everyday operation of certain facilities. Energy efficiency is even more applicable for health care operations which are open 24 hours a day. Building envelope design should be carefully determined for these facilities to maximize owner savings, patient health, and worker productivity. For this and many other reasons the Energy and Atmosphere section of the LEED-NC contains the most possible credit points.



The next most applicable group is the Indoor Environmental Quality (EQ) criterion which determines health aspects for the building occupants. As seen in the Energy and Atmosphere section, the Indoor Environmental Quality is greatly affected by the building envelope design and construction. Of the 15 credit points, 8 are affected by the skin selection. This is attributed to utilizing natural light in facility design as well as thermal comfort controls and design. Exterior systems greatly influence the lighting of spaces as well as the comfort of the occupants. Thermal issues include simple things such as glare protection and cold temperatures near exterior

windows. These issues are amplified in hospitals and health care facilities where patient physical and psychological health is extremely important.

Using the credits which are affected by the building envelope design, a table has been formulated to address cost concerns of pursuing these credit points. Research has shown the positive attributes these additional design considerations have made on other facilities, but owners need to be able to justify the positives outweigh the additional costs accrued. The following table was gathered utilizing the GSA: Cost Study for insight into the premium costs owners could expect if the credit points were pertaining to the building envelope design and construction. Credit points are listed if they are considered directly affecting the envelope system.

Premium Costs

Must Meet by GSA Standards or Mandate	
No Cost Premiums	
Low Cost Premiums (<$50K)	
Moderate Cost Premiums ($50K - $150K)	
Large Cost Premiums (>$150K)	

SS: Site Selection		***$ Impact***
SS 7.2	Heat Island Effect: Roof	*($0)*

EA: Energy and Atmosphere		***$ Impact***
EA 1	Optimize Energy Performance (1-10 pts.)	*(>$150K)*
EA 2	On-Site Renewable Energy (1-3 pts.)	*(>$150K)*

MR: Materials and Resources		***$ Impact***
MR 1.1	Building Re-Use (Maintain 75% of existing walls, floors, roofs)	*($0)*
MR 1.2	Building Re-Use (Maintain 95% of existing walls, floors, roofs)	*($0)*
MR 2.1	Construction Waste Management (50% Diverted)	*(<$50K)*
MR 2.2	Construction Waste Management (75% Diverted)	*($0)*
MR 3.1	Materials Re-Use (5%)	*(<$50K)*
MR 3.2	Materials Re-Use (10%)	*(<$50K)*
MR 4.1	Recycled Content (10%)	*($0)*
MR 4.2	Recycled Content (20%)	*($50K - $150K)*
MR 5.1	Regional Materials (10% Processed, Manufactured Regionally)	*($50K - $150K)*
MR 5.2	Regional Materials (20% Processed, Manufactured Regionally)	*($0)*

EQ: Indoor Environmental Quality		$ Impact
EQ 3.1	Construction IAQ Management Plan: During Construction	*(<$50K)*
EQ 4.1	Low-Emitting Materials: Adhesives & Sealants	*($0)*
EQ 4.2	Low-Emitting Materials: Paints & Coatings	*($0)*
EQ 5	Indoor Chemical & Pollutant Source Control	*(<$50K)*
EQ 6.2	Controllability of Systems: Thermal Comfort	*Mandate*
EQ 7.1	Thermal Comfort: Design	*Mandate*
EQ 8.1	Daylight & Views: Daylight 75% of Spaces	*($0)*
EQ 8.2	Daylight & Views: Daylight 90% of Spaces	*($0)*

ID: Innovation & Design Process		$ Impact
ID 1.1-1.4	Innovation in Design (1-4 pts.)	*(<$50K)*

As was the case with the number of credits in each section pertaining to the exterior skin of a project, the Energy and Atmosphere section requires the most premium dollars to achieve. With the first costs escalating above $150,000 it will be more difficult for owners to justify pursuing these credits. Optimizing energy performance credits can be difficult to achieve depending on whether the efficiency needs to be increased by 10% or 50%. According to the individual credit simulations in the Appendix C of the GSA: Cost Study, achieving 5 credit points (25% cost saving) can be achieved at a premium cost of approximately 0.8% of the overall project cost. However, this value escalates to 3.07% if the goal is to achieve 10 credit points (50% cost savings). The large portion of the costs associated with the additional costs is the HVAC and electrical systems which consist of two-thirds of the overall cost. Façade re-design accounts for only 10% of the premium costs while the additional funds are used for design contingencies, phasing premiums, general conditions, and contractor profit.

The remainder of the sustainable credits relating to exterior skin are relatively inexpensive (less than $50,000) or do not require premium costs at all. This can be attributed to the increasing knowledge of green building construction and increased awareness of recycling and waste management, safer materials, and even government mandates.

Indoor environmental quality is extremely important for health care facilities to keep patients comfortable. These health aspects are fueling major concerns in the health care construction industry which is leading to the development of guides to help designers and construction managers in this challenging field. Facility managers can clearly see that they can achieve these

healthy aspects at minimal costs which will add value to the proposed project. GSA has even deemed some of the indoor environmental quality credits as mandatory to all new government facilities to be constructed.

Many of the indoor environmental quality concerns can be addressed with simple space planning techniques and architectural features which may be determined during conceptual designs. Day-lighting concerns can be alleviated by minimizing the number of enclosed spaces at the perimeter of the building and allow for large open work areas. Even furniture decisions can make an impact by selecting low-height furniture to allow light to travel throughout the various spaces. However, these easy techniques may not be applicable on large hospitals or other health-care facilities where patients need privacy and often isolation.

The Green Guide for Health-Care Construction expands on the day-lighting credits of the LEED-NC Version 2.2. Day-lighting aspects are now worth 5 points in lieu of the 2 credit points in the LEED version. This demonstrates how important natural light is for health care facilities to promote positive psychological and physical health environments. The essence of this new system employs certain percentages of the overall floor plan being located within 15' of the building perimeter. Architects and planners can use these percentages to provide insight into how to achieve properly day-light areas without extensive rework with lighting designers and changes to the original floor plans. This can alleviate cost premiums due to complex designs of the curtain wall and exterior systems which often occur to try to allow natural light into spaces.

Criteria percent of total floor area within 15' of perimeter window by total size					
Point Total	**Below 20,000 sf**	**20,000 to 30,000 sf**	**30,000 to 40,000 sf**	**40,000 to 50,000 sf**	**Above 50,000 sf**
8.1a - 1 point total	48%	44%	40%	37%	34%
8.1b - 2 points total	56%	51%	46%	42%	38%
8.1c - 3 points total	64%	58%	52%	47%	42%

From GGHC Pilot V.2

Proper day-lighting also allows for decreases in energy costs by utilizing solar energy for heat during the winter as well as lessen the heat given off by artificial lights during the summer. Utilizing natural lighting techniques and strategies has been estimated to reduce lighting energy use by 50 to 80% and decrease HVAC loads by 10 to 20%. It is essential for the building envelope to be closely coordinated with the mechanical system designs to take full advantage of these loads to decrease the sizes of HVAC components and relevant costs. The glass and glazing utilized for the exterior skin needs to have the correct design properties in reflectance, transmittance, and UV protection as well as construction issues such as properly caulked connections and joints to ensure the savings in energy consumption and day-lighting aspects are at the estimated levels.

Building Envelope and the Center for Health Research and Rural Advocacy

Since the façade selection is critical for proper utilization of LEED credits and associated costs, it should be taken into account for every project. The Center for Health Research and Rural Advocacy should take careful considerations in selecting the building envelope design and construction. As this is the first LEED certification the Geisinger Health System is pursuing, careful decisions where made when selecting which criteria to achieve. Geisinger Facilities project manager is pursuing 26 of the 69 credits for a LEED sustainable facility. Please reference the figure on the following page which outlines the credits to be garnered.

The building envelope selected for the Center for Health Research and Rural Advocacy is influential in the success of the LEED certification. With cost premiums upwards of $150,000, it is essential that the exterior skin design is closely coordinated with construction processes. Many of these cost premiums were offset by design criteria, locally accessible materials, and proper management. Figure R.1 outlines the challenges associated with the LEED credits and management steps taken.

LEED Credit	*Center for Health Research and Rural Adocacy Checklist*	*Credit Pursuit*		*Envelope Considerations*		*Premium Costs*
SS: Site Selection		*Yes*	*No*	*Yes*	*No*	
SS 4.1	Public Transportation Access	x			x	$0
SS 4.2	Alternative Transportation: Bicycle rack coverage	x			x	$0
SS 5.2	Maximize Open Space	x			x	$0
SS 6.1	Stormwater Design: Quantity Control	x			x	$0
SS 6.2	Stormwater Design: Quality Control	x			x	$0
SS 7.2	Heat Island Effect: Roof	x		x		$0
WE: Water Efficiency						
WE 1.1	Water Efficient Landscaping (50%)	x			x	$0
WE 3.1	Water Use Reduction (20%)	x			x	$0
WE 3.2	Water Use Reduction (30%)	x			x	$0
EA: Energy and Atmosphere						
EA 1	Optimize Energy Performance	x (2)		x		$50,000
EA 5	Measurement and Verification	x			x	$0
MR: Materials and Resources						
MR 1.3	Building Re-Use (Maintain 50% of non-structural interior elements)	x			x	$0
MR 2.1	Construction Waste Management (50% Diverted)	x			x	$0
MR 4.1	Recycled Content (10%)	x		x		$0
MR 5.1	Regional Materials (10% Processed, Manufactured Regionally)	x		x		$50,000-$150,000
MR 5.2	Regional Materials (20% Processed, Manufactured Regionally)	x		x		$0
EQ: Indoor Environmental Quality						
EQ 4.1	Low-Emitting Materials: Adhesives & Sealants	x		x		$0
EQ 4.2	Low-Emitting Materials: Paints & Coatings	x		x		$0
EQ 4.3	Low-Emitting Materials: Carpet Systems	x			x	$0
EQ 6.1	Controllability of Systems: Lighting	x			x	$0
EQ 6.2	Controllability of Systems: Thermal Comfort	x		x		$0
EQ 7.1	Thermal Comfort: Design	x		x		$0
EQ 7.2	Thermal Comfort: Verification	x		x		$0
ID: Innovation & Design Process						
ID 2	LEED Accredited Professional	x			x	$50,000
		Totals 26 Credits		**10**	**16**	**$150,000 - $250,000**

Credit Challenges and Control Methods		
Credit	**Credit Description**	**Control Method**
SS 7.2	Heat Island Effect: Roof	Green/Garden Roof Above Auditorium
EA 1	Optimize Energy Performance	Incorporate MEP Design w/ Weis Research Center Curtain Wall Utilizes Insulating Glass to Minimize Heat Loss
MR 4.1	Recycled Content (10%)	Only Pursue 10% Since Recycling Costs Expensive in Danville
MR 5.1	Regional Materials (10%)	Extruded Aluminum Readily Available
MR 5.2	Regional Materials (20%)	Architectural Pre-cast Contractor Within 10 Mile Radius
EQ 4.1	Low-Emitting Materials: Adhesives & Sealants	Design Selection
EQ 4.2	Low-Emitting Materials: Paints & Coatings	Design Selection
EQ 6.2	Controllability of Systems: Thermal Comfort	Radiant Heaters At Expansive Areas of Glass
EQ 7.1	Thermal Comfort: Design	Minimize Glare With Spandrel Glass in Curtain Wall
EQ 7.2	Thermal Comfort: Verification	Inc. With Design

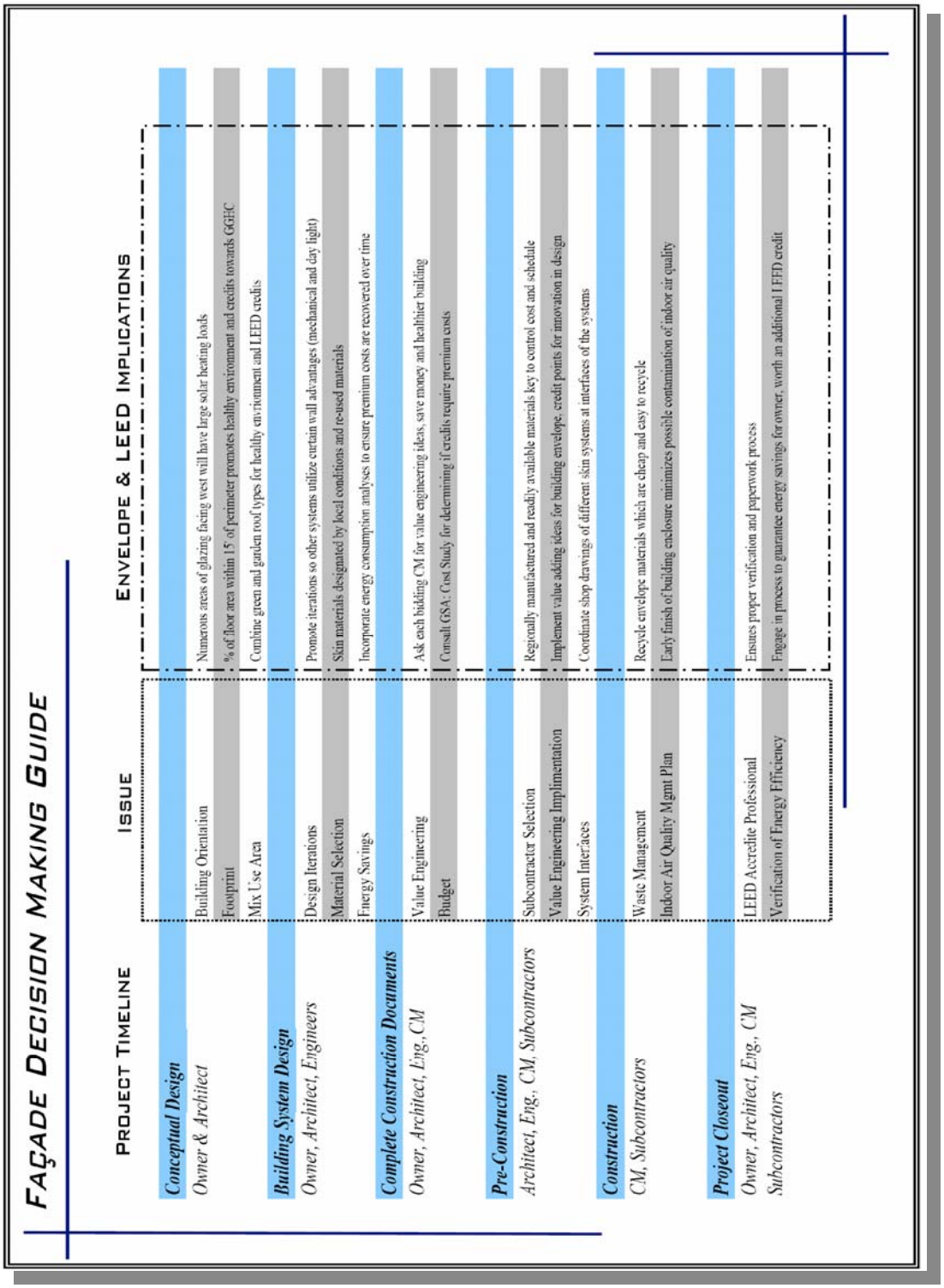
Figure R.1 Credit Challenges and Control Methods

As seen in the above figure, there are many ways that a management team can address the additional costs associated with LEED certification. These range from subcontractor selection to simple decisions based on adding value to the project. For example, the garden roof is used to combat the heat island effect, but since it is incorporated as a garden roof it can be a pleasant place for health care workers and patients to frequent. Another interesting decision was the pursuit of only 10% recycled content in lieu of the 20% for two credits. This is due to the high costs of refuse removal and tipping fees, and by only achieving 10% the workers can recycle the easy and cheap materials and not worry about the difficult ones.

Façade Decision Making Guide

After exploring the implications the building envelope design and construction has on LEED credits and their respective costs, it is easy to see a decision making framework needs to be addressed. Different factors and choices need to be made during certain stages of a projects development. This can range from design development decisions, to 100% contract documents, to project close-out. These choices need to be conducted between multiple entities including but not limited to construction managers, architects, designers, subcontractors, and owners. Flow of information is critical for a successful project and this aspect is even more critical in LEED certified facilities. The guideline can be utilized by project participants to gauge what decisions need to be made regarding façade selection at certain design and construction milestones.

A sample of the guideline is shown below with the remainder in the format of a newsletter in Appendix A.1



Conclusion

After exploring the various dimensions and roles the building exterior plays in health care and sustainable designs, it is easy to see the implications this system has on the success of LEED certified projects. Not only is the façade the barrier between the harsh exterior world and the inner confines of the comfortable health care facility, but it requires thought and consideration for all the design elements. The building envelope affects mechanical loads and system efficiency, structural integrity, day lighting requirements, as well as construction sequencing and building enclosure.

As was seen during the investigation, health care facilities can greatly be affected by the design of the envelope system. Hospitals often operate 24 hours a day the entire year and a rather small decrease in energy efficiency correlates to large savings in operation costs. Patient and worker physical and psychological health is affected by the amounts of natural light and thermal comfort.

The largest LEED aspect which is affected by the façade design is the Energy and Atmosphere criterion, with 45% of the credits residing in the EA section. It is extremely critical to recognize the cost premiums associated with these credits as outlined by the GSA: Cost Study. These costs can be neutralized during conceptual design of the facility by closely coordinating the exterior skin design with the MEP systems and the subsequent savings in energy costs. Health care facilities can take advantage of the Indoor Environmental Quality credits at relevantly low premium costs. These credits which affect day-light and thermal comfort can add significant value to the facility at minimal costs. If the designs are incorporated with energy efficiency of the building envelope, these credits can be achieved simultaneously with the Energy and Atmosphere credits.

LEED certification may be achieved on any construction project with cautious and diligent attention to decision making during the entire construction process. This type of approach is guaranteed to have success with all the resources that are now available.