1. Introduction

One of the University's Guiding Principles for Future Expansion, as articulated by the Administration in 2003, is to "build in an environmentally responsible manner - a manner which is sensitive to geography, sensitive to energy and resource consumption and works to sustain strong community relations."

These Guidelines are intended to provide direction and resources for the sustainable design and construction of new buildings and the comprehensive renewal of existing buildings for capital projects at Princeton, in support of the Guiding Principle. The requirements of this process are described in this Section of the PUDS, which is intended to complement other Sections which contain requirements particular to specific building programs or systems. These Sustainable Building Guidelines are summarized as follows:

1. Set goals and benchmarks for each project.
2. Model alternative methods of meeting goals and benchmarks and use results to make decisions.
3. Repeat the modeling and analysis as the design is developed to refine decisions.
4. Review and monitor the expected outcome during documentation and construction.
5. Measure the outcome to determine success, and to establish benchmarks for future projects.

Using Life-Cycle Cost Analysis, described in Section 1.2 (6), and Social and Environmental Impact Assessment, described in Section 1.2 (7), an iterative process of recommendation, comparative modeling, decision-making and refinement is intended to enable the University to make better-informed choices regarding expenditures of resources.

These general Sustainability Guidelines describe a process that is intended to be implemented along with the requirements of the Energy Guidelines found in Section 3.3 of the PUDS. Many of the Life-Cycle Comparative Studies described in more detail in Section 1.2 (5) will draw on data and analyses conducted in response to the Energy Guidelines.

The sustainability process is applicable to projects of all sizes. However, for small scale renovation projects with existing envelopes, and predetermined HVAC system selections, a shortened version of this Life-Cycle Comparative Studies approach is appropriate. On these small scale projects, the Project Manager will assist in determining the limits of the LCCS to apply to the project.

2. Contacts

A. The Project Manager (in Office of Design and Construction, the Engineering Department, Grounds and Building Maintenance, the Construction Office, or as applicable)

B. Program Manager for Standards — MacMillan Building, 609-258-1330

C. Director of Facilities Engineering — MacMillan Building, 609-258-5472

3. Index of References http://facilities.princeton.edu/PhysicalPlanning/DesignStandards/

		PDF	MS Word	MS Excel
A	Funding Opportunities for Sustainability	Appendix 1.2-1		
B	Relevant Sustainable Building Guidelines	Appendix 1.2-1		
C	Web Resources for Sustainability	Appendix 1.2-1		
D	Waste Management Resources	Appendix 1.2-1		
E	Life-Cycle Resources	Appendix 1.2-2		
F	Cost Components of Life-Cycle Cost Analysis	Appendix 1.2-3		
G	Building Component Useful Life Data	Appendix 1.2-4		
H	Sample Life-Cycle Cost Analysis Comparative Studies	Appendix 1.2-5		Appendix 1.2-5
I	Commissioning Process (Cx)	Appendix 3.3-3	Appendix 3.3-3	
J	Outline of MEP Design Intent (Commissioning)	Appendix 3.3-4	Appendix 3.3-4	
K	MEP Basis of Design (Commissioning)	Appendix 3.3-5	Appendix 3.3-5	
L	Final Commissioning Report	Appendix 3.3-6	Appendix 3.3-6	
M	Index of MEP Prefunctional Tests (Commissioning)	Appendix 3.3-7	Appendix 3.3-7	
N	Index of MEP Functional Tests (Commissioning)	Appendix 3.3-8	Appendix 3.3-8	
O	Index of Commissioning Specifications	Appendix 3.3-9	Appendix 3.3-9	
P	Sample of High-Performance Systems Matrix	Appendix 3.3-10		

4. Outline of Process

A. Integrated Design

Buildings are networks of complex systems. Building in a sustainable manner requires consideration of the network as well as the individual systems through an integrated design process. The Project Team will be defined specifically at the outset of each project, and will include university representatives for the client/user, the Facilities Project Manager, the Design Team, and the Construction Manager. The Design Team will be comprised of all of the project design consultants including the architect, civil, structural and building systems engineers, the landscape architect, and any specialized consultants. All of the members of the Project Team must collaborate to find the beneficial relationships among site and building systems that result in an environmentally sustainable outcome in support of the program. The Design Team must be committed to working through a collaborative process to learn new ways of considering these systems.

B. Organizational Meetings

In order to work collaboratively as a Project Team, the Design Team will plan and facilitate workshops and meetings with university representatives specifically to further the integrated design process:

1. **Sustainability Charrette:** During the Pre-Schematic Design phases (Scoping / Feasibility / Programming) the Project Team will meet to establish goals and objectives with respect to sustainable building design, benchmarking and metrics. Ideally this will be done as part of a broader agenda focused on overall project goals including program, campus planning and project-budgeting. If those goals have already been set, a meeting focusing specifically on sustainable design objectives which are mutually supportive of other project goals will be conducted.

2. **Life-Cycle Comparative Study (LCCS) Workshop**: During the Pre-Schematic Design phases, after the Sustainability Charrette, the Project Team will hold an LCCS Workshop. While the Sustainability Charrette will set project intentions and outcome, the LCCS Workshop begins to set focus on the specific paths to those outcomes. The intent of this workshop is for the Design Team to identify the study categories recommended for LCCS, the method(s) of analysis proposed, the social and environmental impacts proposed for evaluation in conjunction with the Life Cycle Cost Analysis (LCCA), and to confirm project parameters and data, including that required to be provided by Princeton. The LCCS Workshop must occur after the Sustainability Charrette in order for the Design Team to make recommendations in support of the Project Sustainability Goals.

3. **Life-Cycle Comparative Study (LCCS) Reviews**: During Schematic Design the Project Team will meet to review the initial findings of the Life Cycle Comparative Studies. The Design Team will prepare the analysis to compare alternatives. The purpose of the review is to enable the Project Team to make decisions based on the Project Sustainability Goals. This process will be repeated before the conclusion of Design Development.

4. **Construction Meetings**: During the Pre-Bid meeting, the Facilities PM and the Design Team will convey project sustainability objectives to bidders. Requirements will be reviewed again at the Pre-Construction meeting and at Pre-Installations meetings for relevant trades.

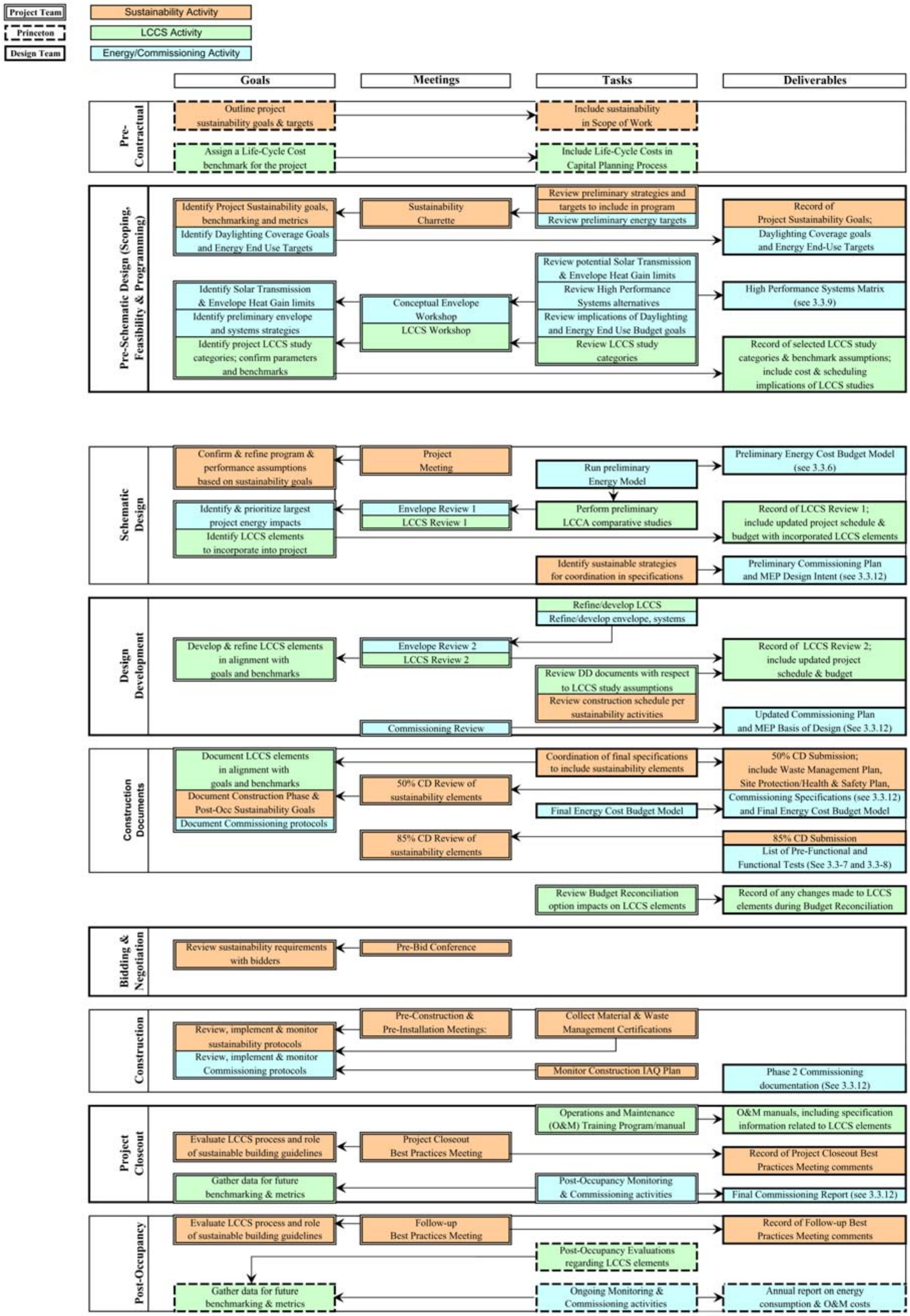
5. **Best Practices Meetings**: At the conclusion of the project the Project Team will conduct a Best Practices meeting in order to evaluate the process and the initial outcome. A follow-up meeting of the Project Team will be scheduled after one year of occupancy. Subsequent follow-up will be conducted by the university, with other members of the Project Team participating on an as-needed basis.

C. Required Documentation

Following is a summary of documentation requirements for the sustainable design and Life-Cycle Comparative Studies (LCCS) process:

1. Record of Project Sustainability Goals from the Sustainability Charrette, including benchmarking objectives and metrics. Include in the project Scoping, Programming or Feasibility Study Report as required.
2. Record of Life-Cycle Comparative Study (LCCS) categories selected, including social and environmental impacts, project parameters and data. Refer to Section 1.2 (5. Life-Cycle Comparative Studies) for LCCS study requirements. Include in the project Scoping, Programming or Feasibility Study Report as required.
3. Record of largest energy impacts & priorities based on preliminary energy model in conjunction with the MEP Design Intent document. Refer to Appendix 3.3-4 for MEP Design Intent documentation requirements.
4. Record of the initial LCCS results in a format as outlined in Appendix 1.2-5 (Sample Life-Cycle Cost Analysis Comparative Studies) in conjunction with the MEP Design Intent document submitted at the conclusion of Schematic Design. Refer to Appendix 3.3-4 for MEP Design Intent documentation requirements.
5. Updated project budget and schedule with LCCS elements incorporated.
6. Record of the refined LCCS results in a format as outlined in Appendix 1.2-5 (Sample Life-Cycle Cost Analysis Comparative Studies) in conjunction with the MEP Basis of Design document submitted at the conclusion of Design Development. Refer to Appendix 3.3-5 for MEP Basis of Design documentation requirements.
7. Final Energy Model report.
8. Records of the Pre-Bid, Pre-Construction and Pre-Installation meetings to be included in minutes or reports of those sessions.
9. Operations & Maintenance manuals, including specification information related to LCCS elements, in conjunction with the Final Commissioning Report. Refer to Appendix 3.3-3 for an overview of the Building Commissioning Process and Appendices 3.3-4 through 3.3-9 for specific documentation requirements for Commissioning.
10. Record of Best Practices meetings recording the discussion and recommending improvements for future projects and processes.

The Sustainable Building Design Process



5. Life-Cycle Comparative Studies (LCCS)

LCCS Process / Procedural Guidelines

The primary method of Life-Cycle Comparative Studies (LCCS) will be a comparison between two or more alternatives for each of the topics identified for study during the LCCS Workshop. The alternatives should be viable options under consideration for the project. The tools identified in Appendix 1.2-2 (Life-Cycle Resources) may be used to conduct the comparative studies.

Life-Cycle Comparative Studies (LCCS) will be formally documented and reviewed twice during the design process, in the Schematic Design and Design Development phases. However, the principles and knowledge gained by these studies are applicable at any stage in the design process. The Project Team will work together in the preliminary design stages to lay out the schedule and study categories to maximize the value of these studies for each specific project.

Project Benchmarking

As part of the sustainable design process, the Project Team will establish the performance of other University projects as benchmarks against which to measure the subject project. The outcome of the LCCS will be compared against these benchmarks. Over time, these performance benchmarks will establish a broad basis of comparison for new work.

Study Categories

The following building systems shall serve as the basis for the selection of the comparative studies:

1. Energy Systems
2. Electrical Systems
3. Building Envelope
4. Siting / Massing Strategies
5. Structural Systems
6. Mechanical Systems
7. Water Systems
8. Interior Systems

Six (6) or more Life-Cycle Comparative Studies are required at both the Schematic Design and Design Development phases. At least one (1) of these studies shall be within the Building Envelope category and one (1) within the Energy Systems category. No more than three (3) of the studies shall be conducted within a single study category.

Certain study categories may be more relevant to particular building types or projects and project-specific priorities will be established at the initial LCCS Workshop in the Pre-Schematic Design phase. However, the above study categories/ building systems do not operate in isolation. The energy model and Life-Cycle Comparative Studies shall be developed with an understanding and acknowledgement of the inter-relationship of building systems on the life-cycle costs and impacts of the project.

Energy Modeling and Design Tools

Energy modeling is a prerequisite to conducting the Life-Cycle Cost Analysis (LCCA) component of the comparative studies. A preliminary energy model will be developed in the Schematic Design phase in order to identify and document the largest energy impacts of the project. Refer to Appendix 3.3-5 (MEP Basis of Design). The energy model will also serve as the platform from which to analyze energy consumption rates of the alternate options in both the Schematic and Design Development phases. The energy model will continue to be refined throughout the design phases. A final run of the model incorporating the selected LCCS elements will be performed and documented prior to the conclusion of Construction Documentation phase.

6. Life-Cycle Cost Analysis (LCCA)

In adopting Life-Cycle Cost Analysis (LCCA) as part of a process of sustainable design and construction, Princeton establishes the life-cycle cost of a building element or system as a unit of measure for decision-making. LCCA requires that the Project Team consider not only the initial construction costs of a building system, but also the long-term costs including utilities, operations and maintenance and, ultimately, disposal or re-use. This methodology takes into account the University's role as the owner of buildings in addition to its role as builder.

The primary goal of implementing this approach is to create transparency in the design and decision-making process so that decisions are made in an informed manner about the whole life-cycle implications of a project. Cost-effective solutions are not inherently sustainable solutions, but decisions based on an understanding of economic performance, when considered in conjunction with social and environmental performance, will result in effective and efficient choices of the greatest value to the University.

In conjunction with Life-Cycle Cost Analysis (LCCA), it is the obligation of the Project Team to explore and highlight the social and environmental impacts of the design strategies that are being analyzed, so that the appropriate balance of these factors, along with economic objectives, can be discussed. The process and documentation procedure for these studies is described in Section 1.2 (7. Social and Environmental Impact Assessment).

LCCA Data and Parameters

Princeton University Standards and Metrics have been established for use in Life-Cycle Cost Analysis. The utilization of these standards is critical to ensure that there is consistency and comparability of life-cycle data across projects as well as to inform decision-making in future projects. Standard cost information, including utility costs, maintenance costs and building components for use in the LCCA studies is included in Appendix 1.2-3 (Cost Components of Life-Cycle Cost Analysis) for this data.

7. Social and Environmental Impact Assessment

Life-Cycle Cost Analysis (LCCA) does not directly address the social and environmental life-cycle impacts of design alternatives. These costs and benefits should be presented and evaluated in conjunction with the results of the LCCA studies performed. While tools are available to assist the Project Team in conducting this analysis, it is ultimately up to the Project Team to determine the method of assessment most compatible with project objectives. Below is a list of considerations for social and environmental impact assessment. This list is not intended to be all-inclusive, but to highlight anticipated issues for review and discussion:

Land Use, Water and Ecosystem Quality

Retain open space
Optimize program and development density
- Reduce site disturbance
- Reduce building footprint

Increase flexibility / adaptive reuse potential
Optimize building orientation
- Utilize passive design strategies
- Employ natural ventilation strategies

Reduce heat island effects
- Provide adequate shade coverage
- Select high albedo / light-colored materials
- Select high-reflectance, high-emissivity roofing materials

Reduce automobile use
Promote efficient transportation alternatives
Optimize parking lot location and design
Maximize water use efficiency

- Reduce Potable water use
- Use captured or recycled water
- Employ sustainable landscaping strategies

Minimize Stormwater runoff
- Select permeable paving materials

Increase on-site stormwater filtration
Reduce stormwater contaminants
Employ restorative design strategies

Social & Programmatic Factors

Improve building safety and security
Improve site security
Improve interior acoustic control
Reduce exterior noise pollution
Reduce exterior light pollution
Improve Operational Efficiency
Provide Flexibility of Systems

Materials and Waste

Reduce Solid Waste generation
- Enforce Construction/Demolition Waste Management plan
- Promote existing building reuse
- Select Reused and salvaged materials
- Select Recycled content materials
- Reduce non-renewable resource selection
- Maximize storage/ collection of recyclables

Select rapidly renewable resource materials
Select low-embodied energy materials

Indoor Environmental Quality

Optimize ventilation effectiveness
Employ natural ventilation strategies
Minimize indoor and chemical pollutants
- Select low-emitting materials
- Encourage non-toxic maintenance protocols
- Design separation from exterior pollutants

Provide Carbon dioxide monitoring
Enforce Construction IAQ management
Increase thermal comfort
Improve controllability of systems
Optimize natural daylight & views

Energy and Atmosphere

Reduce fossil fuel depletion
Use Renewable energy sources
Reduce energy-related emissions
- Reduce greenhouse gas emissions
- Reduce ozone-depleting emissions
- Maximize envelope thermal performance
- Integrate daylight/electric lighting controls
- Improve Mechanical systems performance
- Eliminate equipment use of CFC's

Building component and materials options can be assessed using environmental performance database tools such as *Building for Environmental Sustainability* (BEES) and the *ATHENA Environmental Impact Estimator (ATHENA EIE).* Additional database resources for materials selection, such as the *GreenSpec Product Directory*, are listed in Appendix 1.2-3 (Life Cycle Resources).

Life-Cycle Cost Analysis (LCCA) information shall be presented in conjunction with social and environmental impacts to facilitate decision-making. An example of this format is illustrated in Appendix 1.2-5 (Sample Life-Cycle Comparative Studies).

8. Materials and Waste Management

Conscientious design is the first step towards controlling the generation of solid waste on a building project. Effective design-stage waste reduction strategies include existing building reuse, optimization of building program, envelope and systems energy efficiency, the use of alternative building materials (salvaged, recycled content and rapidly renewable materials), detailing and dimensioning to limit material waste, proper planning for the storage and collection of recyclables, and sustainability-oriented design specification language and contractor requirements.

Materials Selection
Durability, maintenance and aesthetics are the primary criteria for materials selection. Over its history, Princeton has developed a number of materials standards which can be referenced throughout the pertinent sections of the *Princeton University Design Standards Manual*. These standards have been developed based on a material's proven ability to meet the programmatic, maintenance and aesthetic performance goals of the University through the test of time and use.

Changing technologies have resulted in a wealth of new materials on the market and the potential for their application in Princeton building projects is encouraged provided adequate evaluation of the primary criteria cited above. Where identified as critical to the support of project goals and objectives, a Life-Cycle Comparative Study (LCCS) of a newly proposed material (in comparison to an existing material standard or precedent) may serve as the basis of this evaluation. Evaluation of the life cycle cost implications of any suggested new material is recommended when not specifically identified for evaluation through the LCCS process or on small-scale projects. The social and environmental impacts of proposed materials selection should also be included in this evaluation. Refer to Section 1.2 (7. Social and Environmental Impact Assessment) for a selected list of potential criteria. Please note that pertinent criteria for materials selection are cited under the Materials and Waste subtitle and the other subtitles of section 1.2.7, such as reduction of heat island effects through the selection of high-reflectance, high-emissivity roofing materials listed under Land Use, Water and Ecosystem Quality.

Design Specifications and Construction Waste Management

According to the EPA, construction, demolition and land-clearing debris combined comprises at least 24% percent of municipal solid waste. Establishing waste reduction goals and implementing cot-effective Construction Waste Management techniques can significantly reduce this impact and provide economic advantages for projects of all types and scales.

Project specifications shall require the contractor to submit a Construction & Demolition Waste Management Plan for approval by the University at the beginning of the submittal and review period (or earlier when applicable). This plan must include but is not limited to:

- Analysis of the proposed job site waste to be generated, including the types of recyclable and waste materials generated (by volume or weight).
- A list of each material proposed to be salvaged, reused, or recycled during the Project
- An outline of proposed Project Waste Management meetings (At a minimum, waste management goals and issues shall be discussed at the Pre-bid meeting, Pre-construction meeting and regular jobsite meetings).
- Materials Handling Procedures for removal, separation, storage, and transportation.
- a Communication Plan for informing subcontractors and crews about the Waste Management Plan, establishing job-site instruction, notification and signage procedures for waste management and providing a methodology for documenting and reporting quantities and types of materials reused, salvaged, recycled, and disposed.

Other effective specification waste-reduction strategies include the use of bid alternates for undertaking specific recycling measures, the use of language that requires waste reduction, reuse, and recycling to the fullest extent possible and the requirement for an independent on-site waste manager hired to handle all waste recycling and disposal. Useful waste management references for both designers and contractors, including sample specification language, waste management plans and contractor's checklists can be found in Appendix 1.2-1 (Sustainability Resources).

9. Site Planning

A new campus master planning effort has been initiated in the fall of 2005 and is currently investigating both campus-wide and neighborhood-specific strategies for

- utility distribution
- stormwater management
- energy efficiency goals/targets
- sustainable landscape strategies and planting materials
- paving materials
- exterior lighting plan
- transportation & parking plan
- potable water use plan

A significant percentage of exterior site work on campus is associated with capital projects. Design teams are thus encouraged to select Life-Cycle Comparative Studies (LCCS) that are both appropriate to project specific goals and might contribute to the overall development of the Campus Plan.

The design team shall coordinate with the Master Planning team to identify potential studies and for updated information on the progress of the Campus Plan through the Office of the University Architect.

The greatest potential for understanding and managing the environmental impacts of a project is through early and multi-disciplinary consideration of site selection criteria, building siting, orientation and massing, water usage, stormwater management and landscaping strategies The Sustainability Charrette (to be conducted during the Pre-Schematic phases) and the Life-Cycle Comparative Studies (LCCS) process are intended to ensure that these critical issues are addressed by the design team in a timely and holistic manner (Refer to Section 1.2.4 Outline of Process).