Duke | FACILITIES MANAGEMENT

HIGH PERFORMANCE BUILDING FRAMEWORK

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Definitions

ANNUAL SUNLIGHT EXPOSURE (ASE)
A metric describing how much of a space receives too much direct sunlight. Measured as the percentage of the floor area that receives over 1000 lux for at least 250 occupied hours per year.

BASIS OF DESIGN (BOD)
A document that records the concepts, calculations, decisions, and product selections used to meet the Owner's Project Requirements and to satisfy applicable regulatory requirements, standards, and guidelines. The document includes narrative descriptions and lists individual items that support the design process.

BUG RATING
A luminaire classification system that classifies luminaires in terms of backlight (B), uplight (U), and glare (G) as defined in the IES/IDA Model Lighting Ordinance.

CHARRETTE
An intensive, multiparty workshop that brings people from different disciplines and backgrounds together to explore, generate, and corroboratively produce design options.

CAPITAL PROJECT COORDINATOR (CPC)
A member of Duke Facilities Management Department (FMD) that is responsible for field quality assurance and quality control during design and construction. Within the scope of this framework, the CPC shall help verify that the construction-related standards are met.

COMMISSIONING (CX)
A quality focused process for enhancing the delivery of a project. The process focuses upon verifying and documenting that all the systems and assemblies are planned, designed, installed, tested, operated and maintained to meet the Owner's Project Requirements.

COMMISSIONING AUTHORITY (CXA)
An entity identified by the owner who leads, plans, schedules, and coordinates the Commissioning Team to implement the Commissioning Process.

DAYLIGHT GLARE PROBABILITY (DGP)
A metric representing the percentage of people disturbed by glare in a given location. Measured as a value between 0 and 1, with values greater than 0.45 representing intolerable glare and values less than 0.35 representing imperceptible glare.

EVAPOTRANSPIRATION
The process by which water is transferred from the land to the atmosphere by evaporation from the soils and other surfaces and by transpiration from plants

ILLUMINANCE
A measure of the total amount of light falling on a given surface. Measured in lux (lumen/m^2) or foot-candles (lumen/ft^2).

LIFE-CYCLE COST ANALYSIS (LCCA)
A analysis method for assessing the most cost-effective design option over the functional life of the building. The scope of LCCA considers all initial and operational costs associated with a design decision over a 20-year period including fuel costs, operation, maintenance, repair costs, replacement costs, and residual values.

NATIVE VEGETATION
An indigenous species that occurs in a particular region, ecosystem, and habitat without direct or indirect human actions.

OWNERS PROJECT REQUIREMENTS (OPR)
A document that details the requirements of a project and the expectations of how it will be used and operated. Includes project goals, measurable performance criteria, benchmarks, success criteria, cost considerations, and supporting information.

POTABLE WATER
Water that meets or exceeds U.S. Environmental Protection Agency drinking water quality standards and is approved for human consumption by the state of North Carolina.

PRE-DESIGN SITE ASSESSMENT
A comprehensive assessment of existing site's soils, vegetation, hydrology, and microclimate conducted prior to a project's development. For detailed requirements please see the design process section of this report.

REGULATED ENERGY USE
Building energy used for heating, cooling, ventilation, lighting, and domestic hot water. Excludes receptacle loads and other building equipment.

R-VALUE
The overall thermal resistance coefficient for a material or assembly in (hr°F ft^2)/BTU. Offers a measure of how well a object resists the conductive flow of heat per a unit area. Higher R-values indicate greater thermal resistance.

REFERENCE SOIL
A soil native to the project site, as described in Natural Resources Conservation Service soil surveys, or undisturbed native soils within the project's region that have native vegetation, topography, and soil textures similar to the project site.

SPATIAL DAYLIGHT AUTONOMY (sDA)
A metric describing how much of a space receives sufficient levels daylight. Measured as the percentage of net floor area that receives at least 300 lux for at least 50% of the annual occupied hours.

SUSTAINABLE BUILDING COORDINATOR (SBC)
A third party consultant hired by Duke FMD responsible for coordinating the design team to ensure that all of Duke's Sustainable Design Standards are implemented in design and construction.

SYSTEMS MANUAL
A document containing the information needed to understand, operate, and maintain a building's systems. The manual will outline the owners project requirements, operation and maintenance manuals, and sequences of operation.

TIER 3 PROJECT
Any capital project at Duke University with a total estimated cost (design and construction) greater than or equal to $10M.

U-VALUE
The overall heat transfer coefficient for a material or assembly in BTU/(hr°F ft^2). Used to describe the how effective a material is as an insulator. Equal to the inverse of an R-value

Abbreviations + Acronyms

AAI	Average annual illuminance
ASHRAE	American Society of Heating, Refrigerating, and Air-Conditioning Engineers
BECx	Building envelope commissioning
CA	Construction administration phase
CARB	California Air Resources Board
CBE	Berkeley Center for the Built Environment
CD	Construction document phase
CDWM	Construction and demolition waste management
CDPH	California Department of Public Health
CFC	Chlorofluorocarbon
CGP	EPA Construction General Permit
CIAQ	Construction indoor air quality
CFM	Cubic feet per minute
CPC	Capital Project Coordinator
CxA	Commissioning authority
DD	Design development phase
DLS	Director of Landscape Services
DUES	Duke Utility and Engineering Services
EEM	Energy efficiency measure
EUI	Energy use intensity (kBTU/ft^2/year)
ESC	Erosion and sedimentation control
FMD	Facilities Management Department
FSC	Forest Stewardship Council
GHG	Greenhouse gas
GPF	Gallons per flush
GPM	Gallons per minute
HPBF	High Performance Building Framework
HVAC+R	Heating, ventilation, air conditioning, and refrigeration
LEED	Leadership in Energy and Environmental Design building rating system
LOW	Limit of work
LPD	Lighting power density (W/ft^2)
MERV	Minimum efficiency reporting value
NC	New construction
NAUF	No added urea formaldehyde
OA	Outdoor air
PIT	Point in time
PM	Project Manager (appointed by Duke FMD)
RFP	Request for proposals
SCAQMD	South Coast Air Quality Management District
SD	Schematic design phase
SHGC	Solar heat gain coefficient
ULA	University Landscape Architect
ULEF	Ultra-low emitting Formaldehyde
VOC	Volatile organic compound

Referenced Standards

AHRI Standard 885- 2008, Procedure for Estimating Occupied Space Sound Levels

ANSI/SMACNA Standard 008-2008, IAQ Guidelines for Occupied buildings Under Construction

ASHRAE Handbook - 2015, HVAC Applications

ASHRAE Guideline 0 - 2013, Commissioning Process for Buildings and Systems

ASHRAE Standard 90.1 - 2016, Energy Standard for Buildings Except Low-Rise Residential

ASHRAE Standard 62.1 -2016, Ventilation for Acceptable Indoor Air Quality

ASHRAE Standard 55 - 2017, Thermal Environmental Conditions for Human Occupancy

ASTM E 1527-05/E 1903-11, Standard Practice for Environmental site Assessments (Phase 1/2)

EPA WaterSense® Water Budget Approach Version 1.02

LEED V4 Reference Guide for Building Design and Construction

SCAQMD Rules 1113 and 1168

Sustainable SITES Initiative v2

National Institute of Standards and Technology (NIST) Handbook 135, Life Cycle Costing Manual

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Introduction

Duke University has established sustainability as a priority across its campus and identified itself as a leader amongst collegiate institutions by setting a goal for carbon neutrality by 2024 in their 2009 Climate Action Plan.

Recognizing that minimizing building energy consumption is a critical step towards achieving this ambitious goal, Duke has institutionalized high performance building design and operation. Starting in 2004, Duke established a goal for all new construction and major renovation projects to achieve LEED Silver certification. As of July 2017, Duke has accrued over 41 building on campus that are LEED certified, representing 31% of the university's total square footage. After over a decade of building to LEED standards, Duke has realized a need to push beyond the current LEED building policy to further the progress towards meeting their sustainability goals.

The purpose of the Duke High Performance Building Framework is to establish green building standards that align with Duke's aggressive sustainability goals and embrace the unique challenges and synergies associated with sustainable building design in Durham, North Carolina. The requirements and processes established in this document build on and rework the core tenants of the LEED rating system to create a design guideline that will guarantee high-performance, sustainable building designs while placing an increased focus on Duke University's priorities: energy and water conservation.

The Duke High Performance Building Framework establishes a process for identifying, implementing, and verifying sustainable design practices in all new construction and major renovation projects at Duke University, and a procedure for monitoring operational building performance. This framework provides project managers with clear requirements, anticipated deliverables, and deadlines that are intended to help facilitate the design and construction of high performance buildings.

Additionally, these documents provide Duke University with a procedure to bring quality assurance to the building design process, and a means of assessing and verifying the operational performance of their building stock. This Standard identifies a minimum level of performance that must be achieved by all building projects while leaving flexibility for project teams to meet project specific goals, maintain budget, and pursue innovative designs.

The Duke High Performance Building Framework holistically addresses all aspects of sustainable building design, construction, and operations, with a focus on reducing energy use and potable water consumption. Also included within the standard are prescriptive and performance-based requirements related to site and landscape, occupant comfort and health, and materials and construction.

INTEGRATED DESIGN AT DUKE UNIVERSITY

This document has been written to encourage an integrated design process for Duke University design teams.

An integrated design process breaks down barriers between the architect, design consultants, and contractor such that all disciplines in a construction project work as one united team. In a conventional design process, information is siloed by each member of the design team resulting in inefficiencies whenever there is handoff between team members. Integrated design aims to eliminate these silos such that there is a fluid exchange of information between team members from project conception through construction. Increased communication is necessary to achieve optimal outcomes in projects with multi-disciplinary objectives such as energy efficiency, carbon reduction, and sustainability.

Rather than each team member focusing exclusively on their scope of work without considering implications to the greater project, the integrated design team works together to accomplish the shared objective of meeting Duke University's Sustainable Design Standards in this report. This collaborative and goal-driven approach is aimed at achieving high-performance project design and widespread buy-in from all parties involved. The Sustainable Design Framework has been written to help facilitate an integrated design process and outlines team workshops and deliverables intended to spur collaborative communication and provide consultants with the information they need to make informed design decisions.

In close collaboration with the Facilities Management Department (FMD) Project Manager, the Sustainable Building Coordinator (SBC) will help enable the integrated process by serving as a knowledge base interconnecting all trades and disciplines. Highly knowledgeable in sustainable design and construction, and with an intimate understanding of Duke University's High Performance Building Framework, the SBC will provide team members with the direction needed to meet the project's sustainability objectives.

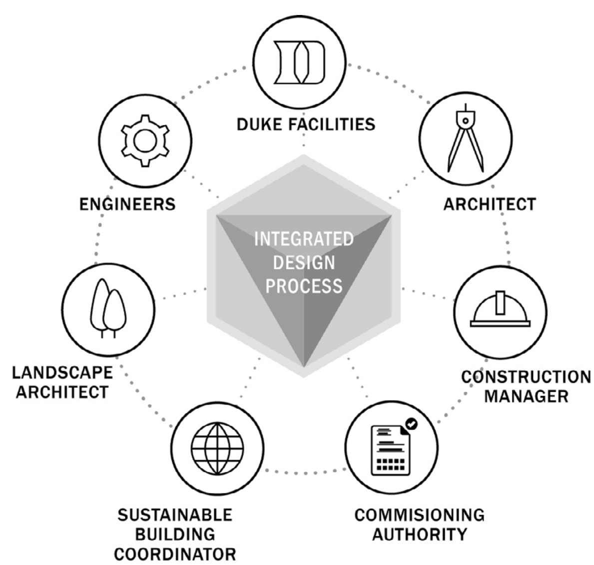
RENEWABLE ENERGY AND THE PATH TO CARBON NEUTRALITY

Duke understands that meeting their goal of carbon neutrality by 2024 will not be met through the design of high-efficiency buildings alone. Systemic changes in campus energy supply and distribution infrastructure will be critical to Duke's success in achieving carbon neutrality. Decarbonizing the University's electricity supply through the use of renewable energy such as solar photovoltaics, wind, or biogas, will be one of the most direct pathways to meeting this target.

Therefore this document does not address renewable energy for individual building projects. This decision has been made with awareness, recognizing the unique constraints of the Durham area grid infrastructure. Due to limitations on net-metering and arduous requirements set forth by the public utility on localized renewable generation, Duke University has steered away from building level renewable energy generation, focusing their efforts on district scale systems instead. By implementing district scale renewable energy generation, Duke University can invest in making a greater impact at a lower cost.

This framework focuses only on improving the site energy efficiency of campus buildings to reduce the overall demand on campus energy supply infrastructure. Improvements in source generation efficiency and the decarbonization of the campus energy supply will be addressed by Duke University elsewhere.

Further information on Duke's progress towards carbon neutrality can be found at https://sustainability.duke.edu/.



INTEGRATED DESIGN TEAM STRUCTURE

How to Use This Document

SCOPE AND APPLICABILITY

The Duke Sustainable Design Framework applies to all Tier 3 new construction and major renovation projects at Duke University. Compliance with the Framework shall be included in all Tier 3 requests for proposals (RFPs) and requests for qualifications (RFQs) issued by the University. The contents of this document apply to all structures and landscape features within a project's limit of work (LOW).

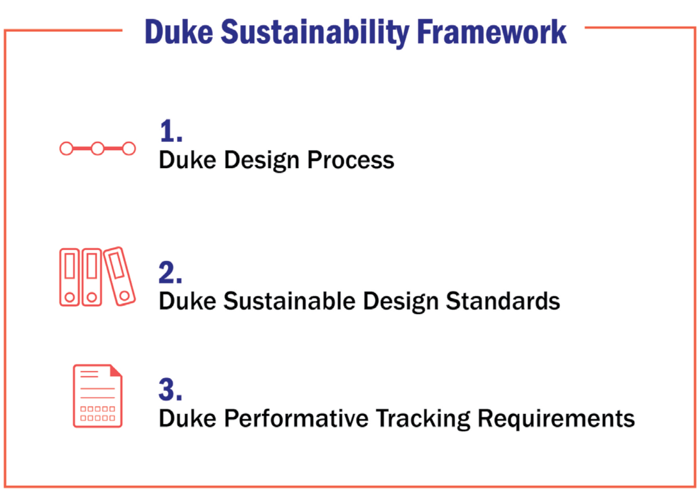
Meeting the goals established in the Framework will require collaboration between all members of the project team, therefore, it is imperative that each member of the project team read and understand all mandatory provisions established in this document as they relate to their scope of work.

All mandatory measures listed in the subsections below must be included in the project design and accounted for at closeout. Deviations from this plan are only permitted upon approval by Duke FMD and must be justified using life-cycle cost analysis (LCCA) or a narrative explaining extenuating circumstances leading to the design decision. Any omission must first be approved by the Project Manager.

OVERVIEW

This framework outlines a process that will facilitate the design, construction, and operation of holistically sustainable buildings. The framework is broken into three parts:

1. Duke Design Process
2. Duke Sustainable Design Standards
3. Duke Performance Tracking Requirements



COMPONENTS OF THE DUKE SUSTAINABILITY FRAMEWORK

In the first part of the Sustainable Design Framework, an integrative design process is established that will enable project teams to make sustainable design decisions. This design process outlines the analysis, meetings, deliverables, and deadlines required for projects at Duke University. The design process has been tailored to allow for feedback and input from Duke FMD, and to gives structure as to when they expect documents from the design team.

The second part of the Framework covers Duke University's Sustainable Design Standards. These Standards address the aspects of sustainable building design most important to Duke University and cement Duke's status as a leader in sustainability amongst peer collegiate institutions. The standards have been specifically tailored to suit the climate and culture of Durham, North Carolina while allowing project teams the flexibility to innovate during the design process. Compliance with these standards will be periodically assessed by the project's Sustainable Building Coordinator (SBC) during the design process to ensure that the project team is on track for meeting each feature. At the end of construction the SBC will review project documentation for compliance with all items included in the Sustainable Design Standards and prepare a summary for Duke FMD review.

The final section sets forth procedures to verify and commission the performance of buildings in operation. This process will recognize high performers, evaluate the effectiveness of Duke's Sustainable Design Standards, and identify buildings that are in need of improvement.

VERIFYING COMPLIANCE HIGH PERFORMANCE BUILDING FRAMEWORK

Compliance with the High Performance Building Framework will be assessed throughout the design phases by the Project Manager and the SBC. Completion of design process milestones including meetings and deliverables will be tracked by the Project Manager using the Design Process Checklist (Appendix H). This completed checklist must be submitted to and approved by Duke FMD prior to project closeout.

The documentation required to prove compliance with each feature is described within the Sustainable Design Standards. Additional guidance on how to document any feature will be provided by the SBC. The SBC will review project documents for compliance with these features throughout design and will perform a final check for prior to project completion. The results of this final assessment will then be turned over to Duke FMD where compliance with the Sustainable Design Standards must be signed off on by the Project Manager and the Sustainable Building Coordinator before a project can be closed out.

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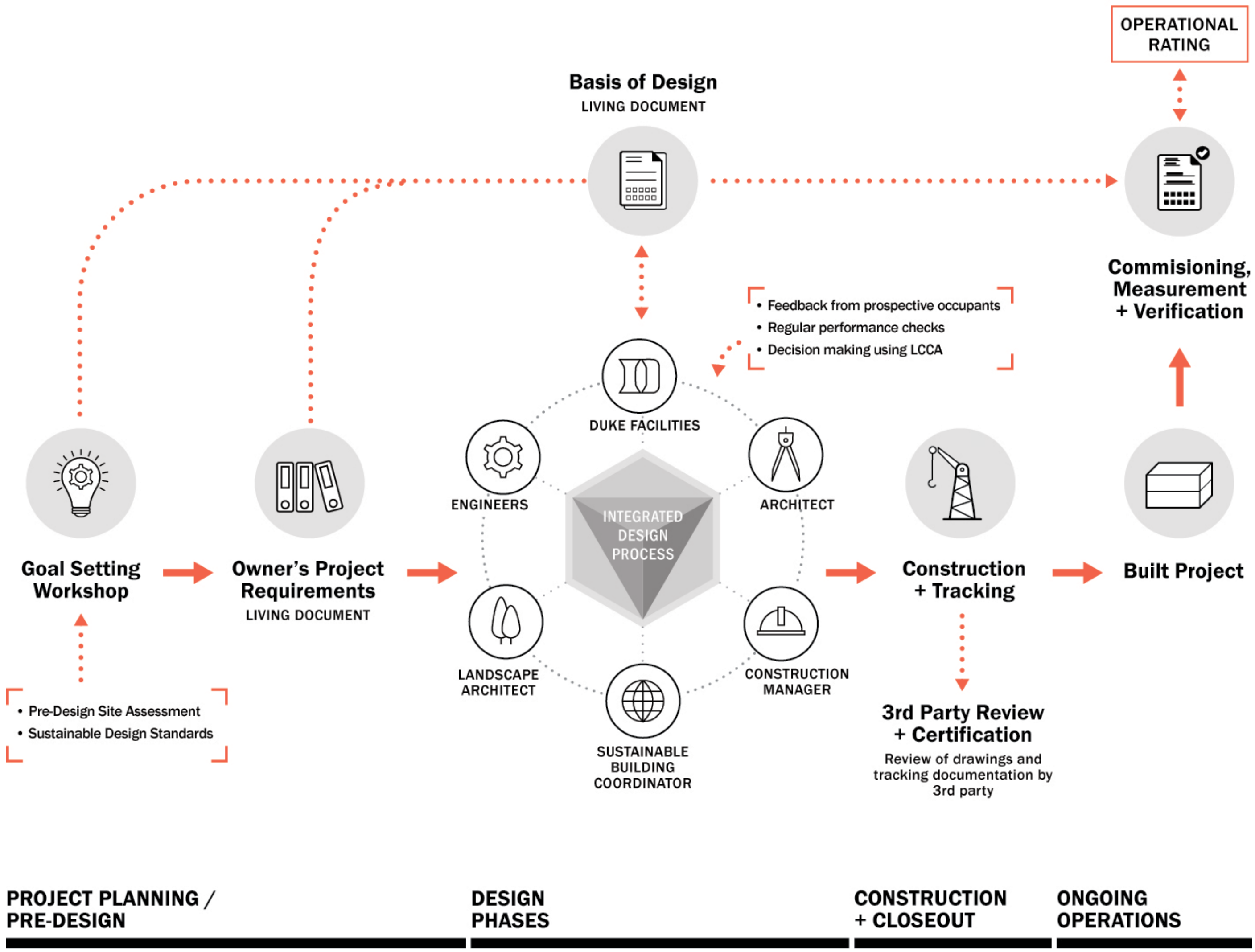
DESIGN PROCESS



FLOWCHART ILLUSTRATING DUKE DESIGN PROCESS

Design Process

The flowchart to the left illustrates the overall design process for projects at Duke University from conception through operation. This process is led and administered by the Project Manager in close coordination with the Duke Sustainable Building Coordinator (SBC). The SBC works closely with both the client and design team to facilitate an integrative process and direct the project team towards meeting Duke University's sustainability goals

VISION AND GOAL SETTING

The process begins before the selection of the design team with goal setting and information gathering exercises. The outcomes of these exercises will be used to help the design team understand the client's aspirations and identify advantages and constraints unique to the project site. Information gathered during these sessions is transcribed to create the Owners Project Requirements (OPR). The OPR establishes the functional requirements of a project and expectations for how it shall be designed and operated. The OPR is a living document and is liable to be updated through the design process as the owner's objectives and criteria are refined. The OPR shall be included as an appendix to the request for proposals (RFP). Throughout the design phases, the OPR will be used by the project team to assess their success in meeting the owner's defined objective and criteria.

INTEGRATED DESIGN PROCESS

When the design team is selected, an iterative and integrated design process is used to respond to the requirements established in the OPR. This response to the OPR is documented in the Basis of Design (BOD). The BOD details the design concepts, calculations, and product selections used to meet the items established in the OPR. This living document is to be updated throughout design and periodically reviewed by the SBC and commissioning authority (CxA) to verify that the design in on track to meet the requirements established in the OPR.

DECISION MAKING AND PERFORMANCE CHECKS

Decision making during the design process is guided by all project stakeholders with decisions justified using quantitative and qualitative analysis. The integrative design team solicits feedback from prospective occupants to understand the needs and desires of the building's end users.

Early phase energy and daylight analysis illuminate sustainable design features to improve building energy performance and occupant experience. Life-cycle cost analysis (LCCA) will be used to justify the financial benefit of implementing these decisions that come at an increased capital cost.

The SBC will perform intermittent reviews of the BOD and project design documents to verify that Duke Sustainable Design Standards are being met. Iterative energy analysis will be used to confirm that a project design will meet the targeted energy performance threshold.

CONSTRUCTION AND VERIFICATION

During the construction phase, the SBC will educate the contractor of the project's sustainability goals and guide them through the material vetting and sustainability submittal process. The project architect will be responsible for confirming that building products meet Duke's material standards. The SBC will guide the architect through this process and provide the information and support necessary to adequately review submittals for sustainability criteria. Any problems with compliance during the construction phase shall be reported to, and resolved by, the Duke Capital Project Coordinator (CPC).

Upon completion, the SBC will assess the completed design to certify that all of Duke's Sustainable Building standards have been met. Both the SBC and the PM must verify that all sustainable design standards have been met before project closeout can occur.

TIMELINE

The following pages contain a project timeline that expand on this design process. The timeline outlines the analysis, meetings, and deliverables required in each phase of design. Detailed requirements on each item listed on the project timeline are expanded upon in the corresponding passages below. All major actions and deliverables are summarized in the Design Process Checklist provided in Appendix H.

Planning / Concept Design

Issue RFP

ACTION

RESPONSIBLE	DELIVERABLE
Duke / Owner	

▶ DEADLINE: N/A

Appoint Sustainable Building Coordinator (SBC)

ACTION

RESPONSIBLE	DELIVERABLE
Duke FMD	

▶ DEADLINE: N/A

Draft OPR

ACTION

RESPONSIBLE	DELIVERABLE
SBC	Owners Project Requirements (OPR)

▶ DEADLINE: N/A

ISSUE RFP

DUKE SUSTAINABLE BUILDING COORDINATOR (SBC)

The Sustainable Building Coordinator is an outside consultant hired by Duke FMD to help the design team comply with Duke's High Performance Building Framework. The SBC will enable an integrated design process by serving as a knowledge base that interconnects all trades and disciplines.

The SBC will serve as the point person between the design team and Duke FMD and will guide the team through the Duke design process. Responsibilities of the SBC include the following:

- Support the preparation of the Owners Project Requirement
- Provide guidance and background information to design team members on items related to the sustainability
- Review Basis of Design for compliance with the Duke Sustainable Design Standards
- Assess design documents to verify project has met all Sustainable Design Standards

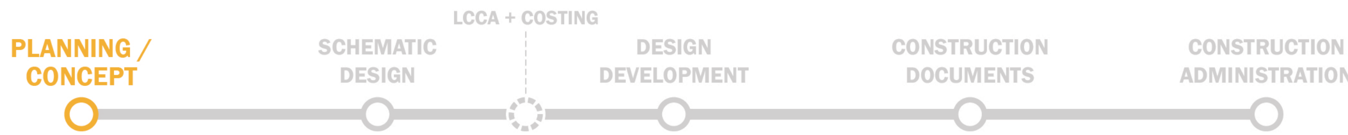
OWNER'S PROJECT REQUIREMENTS (OPR)

The OPR is a document outlining the functional requirements of a project and expectations of how it will be used and operated. Development of the OPR will be coordinated by the SBC with input from Duke University and the Project Manager. The Draft OPR should include a high-level overview of the project's goals and performance criteria. The OPR will include physical properties and target metrics for the project that can be measured to verify the Owner's goals are met.

Additional information on the expected format and content of the OPR can be found in ASHRAE Guideline 0 -2013, Informative Annex J.

The design team will be provided with the OPR at the beginning of the SD phase. Design team members will respond to how they intend to meet each of the Owner's requirements in the Basis of Design (BOD). The OPR and BOD will be compared against each other by the CxA periodically throughout the design process to verify a team's success.

Note that items established in the OPR are liable to change as the design progresses, thus, the OPR should be considered a "living document".



Goal Setting Workshop

MEETING

RESPONSIBLE	DELIVERABLE
Project Manager	Meeting Minutes

DEADLINE: **Start of SD**

Pre-Design Site Assessment

ASSESSMENT

RESPONSIBLE	DELIVERABLE
SBC + ULA	Pre-Design Site Assessment Worksheet

DEADLINE: **Start of SD**

GOAL SETTING/OPR WORKSHOP

The FMD Project Manager will host a workshop with major building stakeholders to assess the project goals and gather the background information required to develop the Owners Project Requirements. Representatives from the owner, Duke FMD, and the SBC will establish the goals and desired outcomes for a project. This workshop will identify goals and priorities for the project in broad and generalized terms without going into technical criteria. Topics of discussion will include general program requirements, project objectives, functional uses, occupancy requirements, budget considerations and performance criteria.

The SBC will use the information gathered during the workshop to develop a set of physical properties and target metrics for the project that can be measured, designed, and documented by the design team to verify the Owner's objectives are met. This information will serve as the body of the Owner's Project Requirements.

Additional guidance on conducting a successful OPR workshop can be found in ASHRAE Guideline 0 -2013, Informative Annex I.

PRE-DESIGN SITE ASSESSMENT

To identify existing natural and infrastructural resources on and around a project's site a pre-design site assessment (Appendix A) will be conducted for each project during planning and pre-concept phases.

The site assessment will be completed by the Project Manger in coordination with the SBC and the University Landscape Architect (ULA) before the Schematic Design Charrette to identify the following items:

- Public transit connections and routes
- Pedestrian flow and access
- Micro-climate factors (solar exposure, etc.)
- View-corridors
- Connections to campus utilities
- Survey of existing trees and vegetation
- Direction of overland water flow
- Vegetation and soils that will be protected throughout construction
- Special status vegetation
- Other unique site considerations

Schematic Design

Solicit Occupant Input

MEETING

RESPONSIBLE	DELIVERABLE
Architect	Meeting Minutes

DEADLINE: **1 week after meeting**

Schematic Design Charrette

MEETING

RESPONSIBLE	DELIVERABLE
Project Manager	Reponsibility Matrix + Basis of Design

DEADLINE: **100% SD**

Block Load Energy Analysis

ANALYSIS

RESPONSIBLE	DELIVERABLE
Energy Analysts	SD EA Report + Duke Energy Modeling Information Form + Potential Energy Efficiency Measures for LCCA

DEADLINE: **100% SD**

SOLICIT OCCUPANT INPUT

During the architectural programming phase, the Project Manager and Design Architect shall hold a sustainability focused meeting with prospective building occupants and the SBC to understand the needs and wishes of the persons who will be using the building. This meeting should cover topics related to sustainable building design such as critical spaces for daylighting, thermal comfort expectations, and expected waste streams.

These desires should be used to influence preliminary program and design goals. Architect to develop meeting minutes outlining the major topics of discussion.

Meeting minutes shall be submitted to Duke FMD upon completion and shared with the design team during the Schematic Design Charrette.

SCHEMATIC DESIGN CHARRETTE

The SD Charrette will be led by the Project Manager with support from the SBC and shall be attended by a representative from each member of the design team and Duke's in-house engineering representative. During this charrette design team members will review the OPR, Pre-Design Site Assessment, and Duke Sustainable Design Standards to gain an understanding of the project context and design requirements.

The SBC will walk the design team through each prescriptive requirement established in the Duke Sustainable Design Standards and assign each item to the appropriate party. The SBC will create a project Responsibility Matrix (Appendix C) outlining which design team member is responsible for each item contained in the Sustainable Design Standards. The Responsibility Matrix will be distributed to Duke FMD and the design team upon completion.

In addition to the Duke Sustainable Design Standards, the design team will review the OPR developed in the pre-design phase. The SBC will introduce the concept of the Basis of Design (BOD) and assign parties responsibility for developing each section of the BOD. Design team members will be responsible for submitting draft BOD sections to the SBC prior to 100% SD.

BLOCK LOAD ENERGY ANALYSIS

In SD, a Block Load Energy Analysis shall be conducted using preliminary design drawings to assess the project's sensitivity to major design options and to determine the project's largest energy end-uses. The project energy analyst will compare the proposed building design to a minimally compliant, ASHRAE 90.1-2016 building to determine the reduction in regulated energy use. Architectural energy efficiency measures such as variations in fenestration ratio, envelope, and orientation should be tested to inform the architectural and mechanical design of the project.

This model will also be used to discuss applicable energy efficiency measures for the project that could be tested for further investigation and life cycle cost analysis (LCCA). The design team, under the direction of the SBC, will select alternative measures to be designed as ad-alternates. These EEMs will be incorporated in 100% SD Phase Energy Analysis and cost estimating to facilitate life cycle cost analysis (LCCA). The design team will complete the LCCA Framing Worksheet and submit it to Duke FMD for review. A list of potential EEMs applicable to major building types can be found in Appendix E.

Exploratory Daylight Analysis

ANALYSIS

RESPONSIBLE	DELIVERABLE
Daylight Analyst	Daylight Analysis Results

▶ DEADLINE: **100% SD**

Basis of Design Review

ASSESSMENT

RESPONSIBLE	DELIVERABLE
SBC	BOD Review comments

▶ DEADLINE: **DD Design Charrette**

The energy analyst will compile the results of the analysis into the SD Energy Analysis Report. This report shall contain the following:

- Energy model assumptions including a completed copy of the Duke Energy Model Inputs worksheet (Appendix F)
- Regulated energy use reduction
- Energy consumption by end-use for baseline and proposed design.
- Additional savings from variations in envelope performance, fenestration ratio, and building orientation, and HVAC system type.
- Identification of potential Energy Efficiency Measures (EEMs) for costing and life cycle cost analysis (LCCA) using the LCCA Framing Worksheet (Appendix G). A

Upon completion, the SD Energy Analysis Report shall be submitted to the SBC and Duke FMD for Review.

EXPLORATORY DAYLIGHT ANALYSIS

During the Schematic Design phase, the party identified as responsible for daylight analysis shall coordinate with the Architect, Project Manager, and SBC to determine no less than two (2) critical spaces for daylight analysis. The analysis should consider annual daylight availability and the risk for visual discomfort and glare. Acceptable analysis metrics include spatial daylight autonomy (sDA), annual average illuminance (AAI), annual sunlight exposure (ASE), point in time illuminance, and daylight glare probability (DGP).

A report shall be developed presenting the results of the daylight analysis and proposing strategies to optimize daylight levels in these spaces. At a minimum, this report should present the following:

- Baseline daylight levels for critical zones
- Potential strategies to improve daylight quality in critical zones

SBC BASIS OF DESIGN REVIEW

The SBC will collect and compile the sections of the BOD from the design team and perform a preliminary review of the content against the OPR and the Duke Sustainable Design Standards.

Review comments will be prepared and distributed to design team members in the early DD Design Coordination meeting.

BASIS OF DESIGN

The Basis of Design (BOD) is a document that records the concepts, calculations, decisions, and product selections used to meet the Owner's Project Requirements and to satisfy applicable regulatory requirements, standards, and guidelines. The design team will respond to each item listed in the OPR with the design decisions made to meet the Owner's criteria and include any assumptions and thought processes behind these decisions in narrative format.

The content of the BOD will be developed and updated incrementally as the design progresses and is therefore considered a 'living document.'

For additional guidance on developing the BOD, please refer to ASHRAE Guideline 0 - 2013, Informative Annex K.

Design Development

LCCA + Costing
AS NEEDED

100% SD Energy Analysis
ANALYSIS

RESPONSIBLE	DELIVERABLE
Energy Analyst	100% EA Report + Duke Energy Modeling Information Form

▶ DEADLINE: **Start of DD**

Costing of EEMs
ACTION

RESPONSIBLE	DELIVERABLE
Cost Estimator	EEM Costing for LCCA

▶ DEADLINE: **Start of DD**

Life Cycle Cost Assessment
ANALYSIS

RESPONSIBLE	DELIVERABLE
Energy Analyst	LCCA Report

▶ DEADLINE: **Start of DD**

100% SD ENERGY ANALYSIS

The block load energy model shall be updated using 100% Schematic Design drawings to assess the level of savings achieved by the current design and the additional reductions possible by implementing up to five (5) additional energy efficiency measures (EEMs). Tested EEMs shall be identified in the block load energy model report and confirmed with the project team. The project energy analyst will compare the proposed building design to a minimally compliant ASHRAE 90.1-2016 building to verify that the building will meet the energy use reduction target established in the Sustainable Design Standards.

The energy analyst will compile the results of the analysis into a report which will be submitted to the Project Manger and the SBC for approval prior to completing the LCCA. This report shall contain the following.

- Energy modeling assumptions, including an updated copy of the Duke Energy Modeling Inputs worksheet (Appendix F)
- Energy use reduction achieved by the proposed design compared to the design target established in the Duke Sustainable Design Standards
- Incremental energy use reductions achieved by each EEM to be used

COSTING OF EEMS

Energy efficiency measures (EEMs) identified in the block load energy model report are to be included in 100% SD documents as ad-alternates and submitted for costing. These cost estimates are prerequisite to completing a LCCA and will be used to evaluate whether or not the design alternatives will be included in the project design.

EEMs and their baseline alternatives should be costed prior to the start of Design Development to allow decisions based on the LCCA to be incorporated in the design.

LIFE CYCLE COST ANALYSIS (LCCA)

To create transparency in the design process and to facilitate effective and efficient design choices, all Duke projects shall utilize LCCA. The scope of the assessment will cover not only the initial capital costs of a building system, but also the long-term costs including utilities, operations, maintenance, and disposal.

LCCA shall be completed by the project energy analyst before the Early-CD Design Coordination Meeting.

Each EEM identified in the Early-DD Design Coordination will need to be analyzed over a 20-year LCCA period. LCCA shall per performed in accordance with the National Institute of Standards and Technology (NIST) Handbook 135, using the latest energy price indices and discount factors.

The energy analyst shall compile the results of the LCCA into a report to be submitted to the Project Manager and SBC. Upon approval from the Project Manager, the report may be distributed to the design team.

DD Coordination Meeting

MEETING

RESPONSIBLE	DELIVERABLE
Project Manager	Update to BOD + Meeting Minutes

DEADLINE: **Before 50% DD**

50% DD Energy Analysis

ANALYSIS

RESPONSIBLE	DELIVERABLE
Energy Analyst	DD EA Report + Duke Energy Modeling Information Form

DEADLINE: **100% DD**

CxA Review of Basis of Design

REVIEW

RESPONSIBLE	DELIVERABLE
CxA	BOD Review Comments

DEADLINE: **100% DD**

EARLY DD COORDINATION MEETING

The Early DD Coordination Meeting will be led by the Project Manager and shall be attended by the SBC and a representative from each member of the design team. The project energy and daylight analysts will present the results of their SD phase analysis and offer an overview of the alternative measures tested. Design team members will review these results and determine what, if any, changes will be incorporated into the design.

If an LCCA was completed, the design team members will review the results of the LCCA assessment to determine which EEMs shall be included in the project design. Any ad-alternate proven to have a lower life-cycle cost over a 20-year period should be selected unless the design team can provide extenuating circumstances precluding the use of the alternate system. The final EEM selection shall be completed by the SBC and the Duke Engineering Representative. The final EEM selection shall be documented by the SBC and reported to the Project Manger.

BOD review comments will be distributed by the SBC. Design team members will respond to any comments received and update the BOD prior to the Commissioning Review of the BOD at 50% DD.

50% DD ENERGY ANALYSIS

Update the latest energy-model based on the 50% Design Development drawing set (or other mid-DD drawing set) to evaluate the design's progress towards meeting the project energy use reduction target. Refine assumptions made in the SD phase model based on the updated drawing set, BOD, and design team discussions.

The project energy analyst shall prepare a summary report including the following items.

- Proposed design energy use reduction compared to ASHRAE 90.1-2016
- Summary of EEMs included in the model and the expected energy use reduction attributed to each.
- Energy modeling assumptions, including an updated copy of the Duke Energy Modeling information form

This report shall be submitted to Project Manager, SBC, and DUES representative for review upon completion.

CXA BOD REVIEW

A detailed review of the BOD will be conducted by the project Commissioning Agent (CxA). This review will check the BOD against the OPR to verify that the system and design choices made by the design team will satisfy the Owner's objectives. The CxA will leverage their expertise in building systems to identify any areas with potential for improvement.

The CxA will issue BOD review comments to the design team prior to 100% DD to be incorporated in the BOD prior to 50% Construction Documents.

For additional guidance on what should be included in a commissioning review, pleaser refer to ASHRAE Guideline 0-2013, Informative Annex N.

Construction Documents

100% DD Document Review

REVIEW

RESPONSIBLE	DELIVERABLE
SBC	BOD Review Comments

▶ DEADLINE: **CD Coordination Meeting**

Early CD Design Coordination Meeting

MEETING

RESPONSIBLE	DELIVERABLE
Project Manager	Response to Document Review

▶ DEADLINE: **1 week after meeting**

Mid CD Document Review

ASSESSMENT

RESPONSIBLE	DELIVERABLE
SBC	Design Review Checklist

▶ DEADLINE: **85% CD**

DD DOCUMENT REVIEW

At 100% Design Development the SBC will conduct a comprehensive review of the project drawings and specifications to verify that each design measure included in the Duke Sustainable Design Standards has been accounted for in the project design.

The SBC will complete a Sustainable Design Standards Review Checklist (Appendix D) noting how each Sustainable Design Standards measure is achieved in the project design and additional action items required by the design team. This Design Review Checklist will be submitted to the Project manger and the design team prior to the start of CD.

EARLY CD COORDINATION MEETING

The Early CD Coordination meeting will be led by the Project Manager and shall be attended by the SBC and a representative from each member of the design team. The SBC shall set the agenda for the meeting based on the results of the DD Document review and will help prepare the Project Manger to lead the discussion. As the project is moving into the CD phase, this meeting will focus on the further refinement of material selection, occupant health and wellness issues, and construction goals that should be addressed in the specifications.

During this meeting, the SBC shall return the review comments from the SBC Document Review and the CxA BOD review. Design team members will be responsible for responding to all of these comments before the subsequent issuance of design drawings.

MID-CD SUSTAINABILITY REVIEW

Upon the issuance of the mid-Construction Document drawing set, the SBC will review the drawings to verify that all comments issued in the DD Document Review were responded to. The SBC will update the Sustainable Design Standards Review Checklist (Appendix D) to indicate the items that have been completed and those pending additional information.

The Design Review Checklist will be submitted to the design team and Project Manager upon completion. The SBC will also prepare a brief report describing the project's compliance with the Sustainable Design Standards and highlighting any shortfalls. This report shall be delivered to the Project Manager and a DUES representative prior to 85% CD. Design team members will be responsible for completing all remaining action items prior to issuing 100% CD drawings.

CxA Document Review

ASSESSMENT

RESPONSIBLE	DELIVERABLE
CxA	Commissioning Review comments

▶ DEADLINE: 85% CD

Bid-Document Energy Analysis

ANALYSIS

RESPONSIBLE	DELIVERABLE
Energy Analyst	Final EA Report + Duke Energy Modeling Information Form

▶ DEADLINE: Immediately after bid-document issue

MID-CD COMMISSIONING REVIEW

To verify that all of the Owner's Project Requirements will be met by the proposed design, the CxA will perform a complete review of the mid-CD design. This review will check the design documents against the OPR to verify that the system and design choices included in the BOD have been included in the design and will meet the Owner's objectives. For additional guidance on what should be included in a commissioning review, pleaser refer to ASHRAE Guideline 0 -2013, Informative Annex N.

During this review the CxA will prepare commissioning review comments to be distributed to the design team and Duke FMD prior to the issuance of project Bid Documents. Design team members must respond to all CxA review comments before drawings are sent out for bid.

BID-DOCUMENT ENERGY ANALYSIS

The final update to the building's energy model will be completed using the project Bid Documents. This modeling update will be used to verify that the project is meeting the energy use reductions required by code and the Duke Sustainable Design Standards.

Modeled energy use intensity (EUI) will be reported to be used as a target for operational building performance. The project energy analyst will prepare a final report including the following items.

- Proposed design energy use reduction compared to ASHRAE 90.1-2016 and code baselines.
- Proposed Design modeled EUI (kBTU/ft^2/yr).
- Summary of EEMs included in the model and the expected energy use reduction attributed to each.
- Energy modeling assumptions, including an updated copy of the Duke Energy Modeling information form.
- Energy modeling output reports.

This report shall be submitted to Project Manager, SBC, and DUES representative for review upon

Construction Administration

CA Kickoff Meeting

MEETING

RESPONSIBLE	DELIVERABLE
Project Manager	CDWM Plan + CIAQ Plan

▶ DEADLINE: **Before CA begins**

Check-in Meetings (Iterative)

MEETING

RESPONSIBLE	DELIVERABLE
Project Manager + Contractor	Updated tracking documents

▶ DEADLINE: **Ongoing**

Submittal Reviews (Continuous)

REVIEW

RESPONSIBLE	DELIVERABLE
Architect	Submittal Review Comments

▶ DEADLINE: **CA, ongoing**

CA KICKOFF MEETING

Before beginning of construction, the Project Manager will hold a construction administration (CA) kick-off meeting with the SBC and the project contractor. This meeting will review the contractor's responsibilities during construction and establish a schedule for subsequent CA check-in meetings.

Topics of discussion at the CA kickoff meeting will include the following:

- The development of construction oversight plans including ESC, CDWM, and CIAQ management
- Construction and demolition waste diversion requirements and tracking procedure
- Sustainable material requirements and tracking procedure
- Low-emitting material requirements and tracking procedure
- Site preservation and restoration requirements
- Submittal review process
- CA check-in schedule

The contractor will be responsible for returning completed copies of the required construction oversight plans prior to the first CA check-in meeting.

CA CHECK-IN MEETINGS

Monthly CA check-in meetings will be held between the contractor and FMD Project Manager to check-in on the submittal review and material tracking process. These meetings will be used to verify that all construction and material-related requirements in the Duke Sustainable Design Standards are being met, and to answer any contractor questions.

Prior to each meeting the contractor will provide the SBC with the following documentation for review:

- Site preservation documentation to show compliance with the goals developed in the Pre-Design Site Assessment
- Two (2) dated and stamped photos documenting that the control measures included in the ESC plan are being implemented on site
- Two (2) date stamped photos documenting the control measures included in the CIAQ plan
- Construction and demolition waste tracking documents
- Low-emitting material tracking documents

The SBC will review these documents and bring info to the Project Manager, the DUES representative and the CPC for action where required.

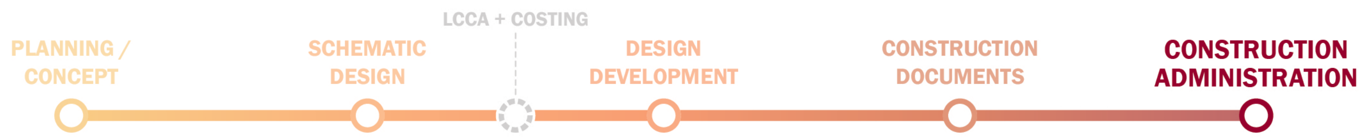
SUBMITTAL REVIEW PROCESS

Throughout construction the architect will review contractor submittals to verify that materials purchased for the project comply with the Duke Sustainable Design standards. All products and materials falling under the following categories must be first approved as complaint with the Sustainable Design Standards before purchase.

- All interior, wet-applied products (paints, coatings, adhesives, and sealants)
- All wood products
- All flooring products
- All materials with mandatory percentages of recycled content

For any product falling within these categories, the contractor shall prepare a Sustainable Materials Reporting Form as part of the submittal package and provide all backup documentation required to prove compliance.

The architect will review all documentation provided and approve or deny the submittal based on its compliance with the Sustainable Design Standards. A log shall be maintained tracking each sustainable material installed in the project and architect's review response for each. Any issues with compliance will be reported to the Project Manager, SBC and the CBC to make a final determination as required.



Final Design Review

REVIEW

RESPONSIBLE	DELIVERABLE
SBC	Review Comments + Report

▶ DEADLINE: **1 mo. after completion**

Project Completion

RESPONSIBLE	DELIVERABLE
SBC	Project Sustainability Summary

Project Handoff

RESPONSIBLE	DELIVERABLE
Project Manager	Duke FMD Process + Documentation of Project Turnover

DESIGN REVIEW VERIFICATION

At the end of construction, all design and construction documentation will undergo a final review for compliance by the project SBC. The SBC will verify that every item included in Duke's Sustainable Design Standards has been successfully achieved.

The SBC will develop a set of review comments outlining any non-compliant items or items that require additional documentation. These review comments will be issued to the Project Manager, a DUES representative and the CBC for further action.

The final review will serve as a means for substantiating Duke's commitment to sustainable building design to external parties. The SBC shall prepare a final review report confirming the project's compliance with the Sustainable Design Standards and outlining key sustainability features. This final report should also outline any project shortfalls and events leading up to them so future project teams can learn from their mistakes. This review report shall be completed within one month of substantial completion.

PROJECT COMPLETION

Only upon verification that the project has successfully met all of Duke's Sustainable Design Standards will a project be considered complete.

If the final review identifies any mandatory provisions that were not included in the project design, the responsible member of the design team will provide explaination as to why he provision could not be achieved by the project.

Upon final certification of a project, the SBC will develop a building summary page highlighting innovative features, sustainability highlights, and lessons learned. These building design summaries will be published for internal and external circulation.

PROJECT HANDOFF

Project turnover to operational personnel shall be completed in accordance with the *Process and Documentation of Project Turnover* developed by Duke FMD.

Please contact Duke Facilities for access to this document.

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SUSTAINABLE DESIGN STANDARDS

Energy

OVERVIEW

As building energy consumption accounts for 64% of overall campus emissions, reducing building energy use is critical to Duke meeting their carbon reduction goal. To effectively do so, projects will need to leverage the expertise of the integrative design team to discover which high performance building strategies are best suited for each project's program and site.

As a campus, Duke has made strides to improve the generation efficiency of the utilities serving university buildings. The campus is conditioned using an efficient district heating and cooling system that supplies chilled water, heating hot water, and high-pressure steam to the majority of Duke buildings. These central plants operate at higher efficiencies than conventional, building-side equipment, and include additional energy conserving measures such as condenser water heat recovery and cogeneration.

Achieving additional energy savings will require campus buildings to lower the demand placed on the already efficient central utilities. Buildings will be required to demonstrate energy use reductions at the site level through the implementation of passive sustainable design strategies and active energy efficiency measures. The energy use reductions mandated in this design standard will push design teams to create highly efficient buildings that align with Duke University's energy conservation goals.

The following section outlines prescriptive requirements related to building energy use that must be incorporated in all new construction and major renovation projects at Duke University.

REQUIRED MEASURES

ENERGY USE REDUCTION

Projects must demonstrate a reduction in regulated building energy use from a baseline building as shown in Table 1. Calculate the baseline building performance in accordance with ASHRAE Standard 90.1–2016, Appendix G.

Regulated energy use includes building energy used for heating, cooling, ventilation, lighting, and domestic hot water, excluding receptacle loads and other building equipment.

Duke central services shall be modeled as purchased utilities such that additional credit is not taken for district energy system efficiencies.

For mixed use buildings, the required energy use reduction may be calculated as the weighted average based on the gross square footage of each typology.

A list of effective EEMS in the Durham climate for each major building typology has been provided in Appendix E of this report to help the design team reach their energy reduction target. Anticipated energy use reductions will be assessed periodically via energy analysis during the design phases.

Documentation Requirements:

- Results summary indicating reduction achieved from ASHRAE 90.1-2016, proposed building EUI, and energy consumption by end use.
- Appendix G energy modeling inputs and assumptions.
- Input and output reports from energy modeling software.
- Exception calculations (if applicable)

TABLE 1: REQUIRED REGULATED ENERGY USE REDUCTIONS

BUILDING TYPOLOGY	NEW CONSTRUCTION	MAJOR RENOVATION
ACADEMIC/OFFICE	20%	Project-specific target to be assigned by Duke Sustainable Building Coordinator
LABORATORY	30%	
DORMITORY	20%	
PUBLIC ASSEMBLY	25%	
FITNESS	30%	
DINING	20%	

Energy

BUILDING ENVELOPE PERFORMANCE

Newly constructed wall, roof and window assemblies must meet or exceed the minimum thermal resistance values for the appropriate building type established for in Tables 2.

Given the stringent code requirements in ASHRAE climate zone 3A (Durham, NC), improvements over the code minimum provide limited benefits. However, modest improvements over code for the wall assembly R-value and window assembly U-value have been shown to benefit energy efficiency and thermal comfort in all building typologies. Recommended targets for new building projects are listed in Table 2.

Documentation Requirements:

- Wall sections and assembly R-value calculations
- Window assembly U-value calculations
- Glazing solar heat gain coefficient (SHGC)

TABLE 2: WALL ROOF + WINDOW ASSEMBLY REQUIREMENTS

ENVELOPE COMPONENT	ASHRAE 90.1-2016 CODE MINIMUM	TARGET
WALL ASSEMBLY (R-VALUE)	R-13	R-16
ROOF ASSEMBLY (R-VALUE)	R-25	R-25
WINDOW ASSEMBLY (U-VALUE)	0.45 (fixed) 0.6 (operable)	0.4 (fixed) 0.5 (operable)
WINDOW SHGC	0.25	0.25

MEP SYSTEM COMMISSIONING

Building mechanical, electrical, and plumbing systems shall be commissioned in accordance with ASHRAE Guideline 0-2013. The CxA should be engaged no later than the Design Development phase to review design documents for compliance with the OPR.

Documentation Requirements:

- Commissioning report
- Systems manual

BUILDING ENVELOPE COMMISSIONING (BECx)

All newly constructed facade are to undergo building envelope commissioning to verify the thermal, hygroscopic, and air infiltration performance of the façade.

The BECxA will follow the commissioning process activities in accordance with the latest version of ASTM E2813.

Documentation Requirements:

- BECx commissioning report

FAULT DETECTION + CONTINUOUS Cx

Building HVAC and BMS systems shall include sensor points and programming required to connect to Duke University's building analytics platform as mandated by the Duke FMD Energy Management Department.

New construction is required to connect to the building analytics program prior to building occupancy.

Documentation Requirements:

- Duke FMD Energy Management continuous Cx requirements.
- Documentation of sensor points and programming included within design

Energy

USE OF CENTRAL SERVICES

Buildings shall be required to connect to Duke University Central Utilities to utilize the source generation efficiencies of the central utility plants. If on-site systems are desired for a project, it must be demonstrated that the source EUI of the project is less than or equal to that of an identical building connected to Duke's central utilities.

ENERGY METERING

Building level energy meters are to be included in all projects to monitor the consumption of all incoming utilities including but not limited to steam, hot water, chilled water, and electricity.

Distribution panel level sub-meters are to be provided to monitor electricity use attributed to equipment, plug loads, lighting, pumps, and fans.

Metering devices must be capable of measuring energy consumption in intervals of one hour or less.

Documentation Requirements:

- Electrical drawings depicting meter locations
- Meter product cut-sheets

REFRIGERANT USE

No on-site HVAC+R equipment shall utilize chlorofluorocarbon (CFC) based refrigerants. Existing equipment containing CFC based refrigerants must be removed as part of the renovation scope.

Documentation Requirements:

- Summary of on-site HVAC+R equipment and refrigerants used for each

DAYLIGHT DIMMING

Perimeter spaces within 15' of the facade will include lighting sensors and luminaires capable of continuous daylight dimming. If permanent partition walls are installed within the 15' building perimeter, only the area between the partition wall and facade must include daylight dimming.

Documentation Requirements:

- Lighting plans highlighting sensor locations
- Lighting control diagrams

OCCUPANCY BASED HVAC SETBACKS

All regularly occupied spaces must be designed to set-back the design heating and cooling temperatures to 65°F and 80°F, respectively, during scheduled unoccupied periods.

During occupied periods, temperatures should be set back by ± 3°F from the set point when a space has been vacant for longer than 15 minutes.

Documentation Requirements:

- Plans indicating regularly occupied spaces and vacancy sensor locations and direction.
- HVAC control diagrams and schedules

OCCUPANCY BASED LIGHTING CONTROLS

Spaces with intermittent occupancy including but not limited to: classrooms, laboratories, offices, conference rooms, rest rooms, corridors, and study rooms, shall include occupancy based lighting controls. Controls may be programmed to either dim or turn-off luminaires at the design teams' discretion.

Documentation Requirements:

- Lighting plans highlighting sensor locations
- Lighting control diagram

LIGHTING POWER DENSITY (LPD) REDUCTION

Projects shall demonstrate a minimum 20% reduction in lighting power density (LPD) from the baseline, space-by-space values defined in ASHRAE 90.1-2016.

Documentation Requirements:

- LPD calculations
- Luminaire cut-sheets highlighting full-load wattage

ALL LED LIGHTING SCHEME

Design new construction projects to utilize an all LED lighting scheme, excluding theatrical and other special purpose lighting. Major renovation projects must include an LED retrofit as a design alternative in LCCA.

Documentation Requirements:

- Lighting schedules

Water

OVERVIEW

Since Durham experienced a historic drought in 2007, reducing campus-wide potable water consumption has become a priority at Duke University. The University has made strides to reduce their water footprint and has achieved a 40% reduction in water consumption per gross square foot since 2006. This reduction has been achieved by retrofitting existing buildings with low-flow fixtures, decreasing the water use of kitchen and laboratory equipment, and reusing captured rainwater and condensate to offset cooling tower water use at the campus chiller plants.

Through implementing water reduction strategies, Duke will build resilience against future water scarcities while reducing their indirect carbon footprint. Potable water is a resource that requires energy to treat and supply, and should be used with intention and care. Reducing water consumption at a campus scale will save considerable amounts of energy by alleviating the burden on municipal water treatment facilities. Additionally, by limiting excessive water use in domestic applications, Duke will reduce the energy attributed to water heating. Water use reductions will achieved by limiting water demand in buildings, and then supplemented by considering opportunities for non-potable water reclamation.

The following section outlines the building-level water reduction strategies to be implemented in all new construction and major renovation projects at Duke University.

REQUIRED MEASURES

FIXTURE WATER USE

All new plumbing fixtures within a building will be specified to meet or exceed the flow-rate requirements established in Table 3.

Documentation Requirements:

- Clearly state flow-rates in the plumbing schedules for each fixture included in the design
- Provide cutsheets for all specified fixtures with flow-rates highlighted

TABLE 3: FIXTURE WATER USE REQUIREMENTS

FIXTURE TYPE	MAXIMUM ALLOWABLE FLOW RATE
TOILETS	1.1 GPF
URINALS	0.125 GPF
PUBLIC LAVATORY FAUCETS	0.35 GPM
PRIVATE LAVATORY FAUCETS	0.5 GPM
KITCHEN FAUCETS	1.5 GPM*
SHOWER HEADS	1.5 GPM

**EXCLUDES FAUCETS USED EXCLUSIVELY FOR FILLING CONTAINERS

APPLIANCE WATER USE

All new appliances specified for the project shall meet the requirements established in Table 4.

Documentation Requirements

- Provide product cut-sheets or other manufacturer data verifying criteria is met for all applicable equipment

TABLE 4: APPLIANCE REQUIREMENTS

EQUIPMENT TYPE	REQUIREMENT
RESIDENTIAL CLOTHES WASHERS	ENERGY STAR CERTIFIED
COMMERCIAL CLOTHES WASHERS	CEE TIER 3A

Water

KITCHEN WATER USE

All new kitchen equipment specified for a project shall meet the requirements defined in Table 5.

Any exceptions to these requirements must be submitted to, and approved by Duke Facilities with an accompanying narrative explaining why the requirement is not feasible for the project.

Documentation Requirements:

- List indicating kitchen equipment included in project scope
- Equipment cut-sheets verifying criteria is met

TABLE 5: KITCHEN EQUIPMENT REQUIREMENTS

EQUIPMENT TYPE	REQUIREMENT
KITCHEN FAUCET*	≤ 1.5 GPM
PRE-RINSE SPRAY VALVES	≤ 1.3 GPM
ICE MACHINES	AIR COOLED OR CLOSED LOOP COOLING
DISHWASHERS (ALL)	ENERGY STAR CERTIFIED
FOOD WASTE DISPOSERS	NOT PERMITTED
FOOD PULPERS	≤ 2.0 GPM MAKEUP WATER
FOOD STEAMERS	CONNECTIONLESS
COMBINATION OVENS	BOILERLESS

WATER METERING

Water metering is required in all projects to track operational water consumption. At a minimum, one building level meter shall track all building side water use. Irrigation meters will be required for all projects that require irrigation beyond a two-year establishment period.

Documentation Requirements:

- Plumbing drawings indicating required water meter

IRRIGATION CONTROLS

Smart irrigation controllers meeting the requirements of the Duke Landscape Services Irrigation Control Standards must be installed for all projects requiring permanent irrigation. Controllers are to be connected to the university weather station to allow for evapotranspiration based irrigation control.

The current approved irrigation controller is the Toro Sentinel with 2-wire valve connections.

Documentation Requirements:

- Irrigation controller cut-sheet confirming compliance

RAINWATER HARVESTING

The potential for roof rainwater collection will be assessed for all projects. Design team members to determine if non-potable demands can be met using harvested rainwater.

Documentation Requirements:

- Monthly rainwater collection potential
- Monthly non-potable water demands
- Report summarizing potential for water reuse and associated systems to be priced

COOLING COIL CONDENSATE COLLECTION

Cooling coil condensate shall be recovered for reuse from all dedicated outdoor air systems or 100% OA units.

Condensate may be sent to the central utility plant to offset cooling tower water demand or used on site for local non-potable demands.

Documentation Requirements:

- List of 100% OA systems included in design
- Condensate collection system schematics

Site + Landscape

OVERVIEW

When designing new buildings at Duke University, project teams should be cognizant of the principles and goals established in the 2012 Campus Master Plan. These include the recognition that Duke is:

- A university in the forest
- A leader in environmental stewardship
- A pedestrian campus
- A historic and dynamic campus
- A community of communities
- A collection of memorable spaces

All of these factors should be considered in the design of new buildings and their surrounding sites.

Projects will demonstrate a commitment to environmental stewardship by protecting and restoring the flora, fauna, and soils native to the site. During the planning and pre-design phases of a project, Duke Landscape Services will survey a project site to identify critical items that must be protected, preserved, or restored during construction. These requirements will be communicated to the design team in the Pre-Design Site Assessment distributed at the beginning of the design process.

The site and landscape requirements established in this section are intended to preserve and strengthen Duke's Identity as a University in the forest while improving occupant experience on the sites. These Design measures begin by identifying natural areas and resources to be preserved and proceed to enhance any blighted areas while also minimizing the environmental impact of new developments.

REQUIRED MEASURES

VEGETATION AND SOIL PROTECTION ZONES

Designate Vegetation and Soil Protection Zones (VSPZs) to prevent damage to vegetation, soil structure, and function during construction. Site elements to be protected within VSPZs will be identified by the University Landscape Architect (ULA) in the Pre-Design Site Assessment and can include existing vegetation, trees, and/or areas of healthy soils to be protected and preserved throughout construction. Soil protection is intended to preserve areas with healthy soil profiles that are suitable for supporting the proposed vegetation in the final landscape design.

Note that not all sites will contain a VSPZ, because VSPZs are based on existing healthy site features deemed worth preserving by the ULA.

Develop a VSPZ Plan to be included within the landscape drawing set. Illustrate the areas of the site designated as VSPZs and detail the protective measures that will be installed to preserve them. VSPZs must be protected using a physical barrier that will protect the areas from construction equipment, parking and traffic, storage of materials, and other construction activities. The required radius of tree protection shall be designated by the ULA or a project arborist.

Documentation Requirements:

- Specification section for VSPZ and tree protection requirements.
- Site plan showing VSPZs and the protective measures that will be installed to preserve them.
- VSPZ Implementation Plan describing the location of VSPZs and the protective measures required
- Photographs showing VSPZ protection measures and signage during construction

Site + Landscape

TREE PRESERVATION AND WOOD USE

In support of Duke's commitment to conserving and enhancing the quality of its woodlands and tree coverage on campus, projects must comply with Duke's Wood Use Policy. All trees removed as part of the project scope must be replaced with new ones such that their is no net loss of trees. If a project takes down more trees than it will replace as a part of the site design, funds equaling the difference between trees owed and trees planted will be transferred from the project into a Tree Replacement Fund.

For every tree at least 6" caliper identified for removal, a new tree must be planted with the project or a payment of $1,000 per tree must be made to the University Tree Replacement Fund, with the exceptions noted below.

1. Specimen trees that have high aesthetic and/or ecological value will be identified and assigned value on a case-by-case basis. Designation and value of the tree will be set by the University Landscape Architect (ULA) and the Director of Landscape Services (DLS).
2. Large projects owing more than fifty (50) replacement trees can negotiate the amount owed to the tree fund. Negotiations will be determined by the ULA, DLS, and the Vice President of Facilities

Locations for replacement trees will be determined by the ULA and DLS to the maximum benefit of the campus.

Documentation Requirements:

- Complete the Duke Wood Use Form

BIRD-SAFE BUILDING DESIGN

Projects with overall fenestration ratios greater than 50% and any uninterrupted glazed segment greater than 50 ft^2 must incorporate bird-safe building design strategies to protect Duke's local and migratory bird populations.

Bird deterrent glazing should have a maximum threat factor of 40 as defined by the American Bird Conservancy.

Documentation Requirements:

- Window-to-wall ratio calculation
- Narrative and drawings demonstrating bird-safe building design strategies, if applicable.

LIGHT POLLUTION REDUCTION

To mitigate light pollution, exterior lighting fixtures shall not exceed the backlight, uplight, and glare (BUG) ratings established below.

- Allowable Backlight Rating: B4
- Allowable Uplight Rating: U2
- Allowable Glare Rating: G2

Documentation Requirements:

- Site lighting plan showing site boundary, fixture location, and applicable measurements
- Luminaire schedule showing uplight, backlight and glare ratings and mounting heights

PARKING FOR ALTERNATIVE TRANSPORTATION

In accordance with Duke University's goal to be a pedestrain and bike-friendly campus, the design of walkways and bike routes for all new buildings and major renovations must support an effective circulation system. Perform a survey of existing parking areas, pathways, and routes for alternative modes of transportation (bicycles, scooters, mopeds, etc.) within a quarter mile radius of the project site. Create a diagram of the location and number of spaces in each parking group and provide results to Duke FMD during the Concept or Schematic Design phase.

Provide additional alternative transportation parking as instructed by Duke FMD. Parking can either be located on site or within an existing parking group located within the quarter mile radius.

Documentation Requirements:

- Plan showing locations of bicycle parking spaces
- Calculations demonstrating that sufficient bicycle parking has been provided for peak building occupants and residents

Occupant Health + Comfort

OVERVIEW

Providing a healthy and comfortable indoor environment is paramount to creating a sustainable and healthy campus. High quality work spaces and learning environments can increase productivity and decrease absenteeism while creating enjoyable spaces for students, faculty, and staff. As the majority of a student's collegiate experience is spent within campus, these spaces should positively contribute to their health and education.

Creating healthy and comfortable indoor environments will be prioritized in the design and construction of all new buildings at Duke University. Interior environments will be designed to provide high indoor air quality, improve thermal comfort, and optimize the use of natural daylight.

The requirements in this section consider indoor air quality and thermal, visual and acoustic comfort. A focus has been placed on eliminating materials known to have detrimental effects on the health of building occupants such as volatile organic compounds (VOCs), formaldehyde, carbon monoxide, and other airborne particulates.

MATERIAL SUBMITTALS

Prior to purchase, the sustainability criteria of all products falling within the recycled content material categories (see Table 11), all wood products, and all low-emitting materials (paints, coatings, adhesives, sealants, flooring, and composite wood), must be first verified by the project architect. Contractors shall complete a copy of the Duke Sustainable Materials Reporting Form (Appendix I) for each product falling within the above noted categories and attach it to the front of each product data submittal packages. All relevant fields in the form must be completed, and back-up documentation must be provided to verify any sustainability claim made in the Reporting Form.

The Architect will review the product submittals and maintain a log of all sustainable materials used in the project and their relevant attributes. These logs will be reviewed by the PM and/or the SBC on a regular basis to verify that the Duke Sustainable Design Standards are being met

REQUIRED MEASURES

OUTSIDE AIR VENTILATION RATE

Provide outdoor airflow (OA) rates for mechanical ventilation systems that meet or exceed the minimum rates determined using the ventilation rate procedure from ASHRAE 90.1-2016.

Meet the minimum requirements of ASHRAE Standard 62.1-2016, Sections 4-7, Ventilation for Acceptable Indoor Air Quality (with errata).

Documentation Requirements:

- Confirmation that project meets minimum requirements of ASHRAE 62.1-2016
- Ventilation rate procedure calculations and assumptions for calculation variables determining minimum required OA rates
- Mechanical schedule demonstrating that designed mechanical ventilation systems meet or exceed minimum required OA rates

NEGATIVE PRESSURIZATION

Sufficiently exhaust each space containing potentially hazardous chemicals, fumes, and particulates, using exhaust rates prescribed by ASHRAE 62.1-2016 or a minimum of 0.5 cfm/ft^2, whichever is higher. For each of these spaces, provide self-closing doors and deck-to-deck partitions or a hard-lid ceiling.

Documentation Requirements:

- List of rooms containing potentially hazardous chemicals, fumes and particulates. Identify their areas, and exhaust rates
- Door hardware schedule showing self-closing door hardware for all doors in spaces containing potentially hazardous chemicals, fumes, and particulates
- Floor plans highlighting partition types for each of these spaces and corresponding partition type sections showing deck-to-deck partitions or hard-lid ceilings

Occupant Health + Comfort

OUTSIDE AIR MONITORING

For all variable air volume (VAV) systems, provide a direct outdoor airflow (OA) measurement device capable of measuring the minimum OA intake rate with an accuracy of +/-10% of the design minimum OA rate. An alarm must alert the BMS if the OA rate varies by 15% or more from the OA set-point.

Documentation Requirements:

- Controls drawing showing OA monitoring devices

OUTSIDE AIR FILTRATION

Provide particle filters with a minimum efficiency reporting value (MERV) of 13 or higher, in accordance with ASHRAE Standard 52.2-2017 for each ventilation system that supplies outdoor air to occupied spaces.

Documentation Requirements:

- Mechanical schedule highlighting MERV 13+ filters for ventilation systems supplying outdoor air to occupied spaces

CARBON DIOXIDE SENSORS

Install CO_2 sensors in all classrooms, auditoriums, public gathering areas, conference rooms, and other spaces with high occupant densities. Determine appropriate design CO_2 set-points using methods established in ASHRAE 62.1-2016, Appendix C. Connect CO_2 sensors to zone HVAC systems and program systems to increase supply airflow when CO_2 concentrations exceed the setpoints by more than 10%.

Documentation Requirements:

- List of all spaces requiring CO_2 monitoring and the space's CO_2 concentration setpoints
- Floor plans showing locations of CO_2 sensors

LOW-EMITTING WET APPLIED PRODUCTS

All wet-applied interior products (paints, coatings, adhesives, and sealants) must meet the VOC limits established by SCAQMD Rule 1168 and 1113. Contractors to keep a log of the VOC content (in g/L) for all applicable materials.

SCAQMD VOC Limits have been provided in Appendix H.

Documentation Requirements:

- Log of all wet-applied interior paints, coatings, adhesives and sealants, and their respective product types, VOC content reported by manufacturer, and maximum allowed VOC content per SCAQMD Rule 1168 and 1113
- Manufacturer backup documentation for all wet-applied interior paints, coatings, adhesives and sealants.

LOW-EMITTING FLOORING PRODUCTS

All finish flooring products shall be inherently non-emitting or shall be tested and determined compliant for VOC emissions in accordance with California Department of Public Health (CDPH) Standard Method v1.1-2010 or later, using the applicable exposure scenario. Table 8 lists some acceptable certifications and programs that meet the CDPH v1.1-2010 testing requirements.

Documentation Requirements:

- Log of all flooring products used in the project
- Manufacturer backup documentation for all flooring products, showing compliance with CDPH v1.1-2010

CARBON MONOXIDE MONITORING

Install CO monitors on each wing or floor of each residential unit.

Documentation Requirements:

- Floor plans highlighting locations of CO monitors

Occupant Health + Comfort

LOW-EMITTING COMPOSITE WOOD

All composite wood must have low formaldehyde emissions that meet the California Air Resources Board (CARB) ATCM requirements for ultra-low-emitting formaldehyde (ULEF) resins or no added formaldehyde (NAF) resins.

Documentation Requirements:

- Log of all interior permanently-installed composite wood
- Manufacturer backup documentation for all composite wood demonstrating compliance with CARB ULEF or NAF requirements

ENTRYWAY SYSTEMS

Provide entryway systems (e.g. floor grilles, grates, walk-off mats) in the primary direction of travel at all high-traffic entrances. If roll-out walk off mats are selected, establish a daily or weekly maintenance plan.

Documentation Requirements:

- Floor plans showing locations and dimensions of entryway systems

TABLE 8: THIRD PARTY CERTIFICATIONS AND PROGRAMS FOR LOW-EMITTING MATERIALS

CERTIFICATION OR PROGRAM	SUBSTITUTABLE FOR
FLOORSCORE	VOC EMISSIONS TESTING (FLOORING)
GREEN LABEL PLUS	VOC EMISSIONS TESTING (FLOORING)
INTERTEK ETL ENVIRONMENTAL VOC+	VOC EMISSIONS TESTING
NSF/ANSI 332	VOC EMISSIONS TESTING
SCS INDOOR ADVANTAGE GOLD	VOC CONTENT AND EMISSIONS TESTING
UL GREENGUARD GOLD	VOC EMISSIONS TESTING
MAS CERTIFIED GREEN	VOC CONTENT TESTING
BERKELEY ANALYTICAL CLEARCHEM	VOC CONTENT AND EMISSIONS TESTING
EMICODE EC1	VOC CONTENT AND EMISSIONS TESTING

HVAC BACKGROUND NOISE

Design to meet criteria for HVAC noise levels resulting from the sound transmission paths listed in ASHRAE 2015 Applications Handbook, Chapter 48, Table 6.

Achieve background noise levels from HVAC systems that do not exceed the maximum levels per ASHRAE 2015 Handbook, HVAC Applications, Chapter 48, Table 1 or AHRI Standard 885-2008, Table 15.

Documentation Requirements:

- Noise reduction narrative demonstrating compliance with ASHRAE design criteria
- Log of calculated or measured sound levels for occupied spaces, and corresponding maximum allowed sound level per ASHRAE criteria.

THERMAL COMFORT

Design HVAC systems and the building envelope to meet the requirements of ASHRAE Standard 55-2017, Thermal Comfort Conditions for Human Occupancy, with errata.

Documentation Requirements:

- ASHRAE 55 compliance documentation
- Outputs from CBE thermal comfort tool for each space type in summer and winter conditions.

Occupant Health + Comfort

INDOOR AIR QUALITY TESTING

After construction ends and prior to occupancy, conduct air quality testing under typical ventilation conditions to demonstrate that contaminants do not exceed the maximum allowable concentrations levels listed in Table 9.

Choose testing locations that are likely to represent the worst-case zones where the highest concentrations of contaminants of concern are likely to occur. Test at least one location per 25,000 ft^2 of gross building area.

Position testing measurement equipment in the breathing zone for all samples, between 3 and 6 feet above the floor; test during normal occupied hours (before occupancy) with the HVAC system delivering the minimum OA rate and starting at the normal daily time; and test using the gravimetric method.

If a given contaminant exceeds the allowable concentration, perform a localized flush-out of the space and redo testing until the test results indicate that the maximum allowable contaminant threshold is met.

Documentation Requirements:

- Air testing report with narrative describing air testing procedures, how testing locations were determined, and dates and results of each test

CHEMICALS OF CONCERN

Limit the use of materials that include any chemicals listed in Table 10. Exceptions are made for the following products without readily available, chemical-free substitutes:

- Structural composite wood may contain Phenol formaldehyde
- Finger joints in structural composite wood may contain Urea formaldehyde
- Composite wood sheet goods may contain Phenol formaldehyde
- Mineral wool insulation may contain Phenol formaldehyde
- Underslab insulation, exterior insulation, and roof insulation may contain halogenated flame retardants when required by code or if necessary to meet required R-value performance

Documentation Requirements:

- Narrative describing strategies taken to limit the use of prohibited materials. Note examples of product substitutions made to reduce toxic chemicals.

TABLE 9: MAXIMUM CONCENTRATION LEVELS

CONTAMINANT	MAXIMUM CONCENTRATION	**ISO TEST METHOD**
FORMALDEHYDE	27 PPB	ISO 16000-3
PARTICULATES (PM10)	50 MICROGRAMS PER CUBIC METER	ISO 7708
TOTAL VOLATILE ORGANIC COMPOUNDS (TVOCS)	500 MICOGRAMS PER CUBIC METER	ISO 16000-6
CARBON MONOXIDE	9 PPM	ISO 4224

TABLE 10: RESTRICTED CHEMICALS

MATERIAL TYPES	**CHEMICALS OF CONCERN**
COMPOSITE WOOD, INSULATION, DOORS AND WINDOWS, DOOR HARDWARE, CONCRETE ADMIXTURES, FINISHES	HALOGENATED FLAME RETARDANTS PVC RECYCLED RUBBER CHROMIUM PLATING SYNTHETIC GYPSUM BOARD LEAD ANTIMICROBIAL COATINGS UREA-FORMALDEHYDE PHTHALATES BISPHENOAL - A
PAINTS, COATINGS, ADHESIVES, OR SEALANTS	NO ADDED METHYLENE CHLORIDE NO ADDED PERCHLOROETHYLENE ALL GENERAL MATERIAL RESTRICTIONS

Materials + Construction

OVERVIEW

The construction process creates a large environmental footprint as equipment, infrastructure, materials, and people are introduced to the site. As the university and design team select materials, special attention should be paid to those which are environmentally preferable. By choosing materials with reduced environmental impact, Duke University will be setting a precedent for a more holistic approach to sustainable building design.

Beyond selection of environmentally preferable materials, projects at Duke will work to reduce landfill waste generated during demolition, construction, and building operation. Comprehensive recycling and waste management programs will reduce environmental impact and provide economic advantage for projects of all types and scales.

Construction related activities can also have a significant impact on the surrounding landscape and the air quality in the finished project. These impacts will be reduced by following best practice construction procedures as thy relate to erosion and sedimentation control and indoor air quality management.

Duke has committed to reducing the environmental impact associated with material production, use, and disposal. The following section establishes required measures that are intended to promote best practice construction, optimize the material supply chain, divert construction and demolition waste, and facilitate ongoing waste management.

MATERIAL SUBMITTALS

Prior to purchase, the sustainability criteria of all products falling within the recycled content material categories (see Table 11), all wood products, and all low-emitting materials (paints, coatings, adhesives, sealants, flooring, and composite wood), must be first verified by the project architect. Contractors shall complete a copy of the Duke Sustainable Materials Reporting Form (Appendix I) for each product falling within the above noted categories and attach it to the front of all product data submittal packages. All relevant fields in the form must be completed, and back-up documentation must be provided to verify any sustainability claim made in the Reporting Form.
The Architect will review the product submittals and shall maintain a log of all sustainable materials used within the project and their relevant attributes. These logs will be reviewed by the PM and/or the SBC on a regular basis to verify that the Duke Sustainable Design Standards are being met.

REQUIRED MEASURES

CONSTRUCTION AND DEMOLITION WASTE MANAGEMENT

Develop and implement a Construction and Demolition Waste Management (CDWM) Plan to divert 90% of construction and demolition waste, by weight or volume. The calculation should exclude hazardous waste.

Documentation Requirements:

- CDWM Plan
- CDWM Tracking documentation including waste hauling tickets.

CONSTRUCTION INDOOR AIR QUALITY (IAQ) MANAGEMENT

Develop and implement a Construction Indoor Air Quality (IAQ) Management Plan to meet or exceed all applicable recommended control measures of the Sheet Metal and Air Conditioning National Contractors Association (SMACNA) IAQ Guidelines for Occupied Buildings under Construction, 2nd edition, 2007, ANSI/SMACNA 008-2008, Chapter 3.

Documentation Requirements:

- Construction IAQ Management Plan
- Photographs and narrative documenting the SMACNA control measures implemented on the construction site
- Cutsheets for filtration media installed on site (must be MERV 8 or greater)

Materials + Construction

RECYCLED CONTENT MATERIALS

Use products that meet the mandatory minimum recycled content percentages for materials in Table 11. Overall recycled content is calculated as post-consumer recycled content plus pre-consumer recycled content.

Documentation Requirements:

- Manufacturer documentation indicating product's recycled content percentage meets criteria established in Table 11.

TABLE 11: MINIMUM RECYCLED CONTENT VALUES

MASTER FORMAT DIVISION	MATERIAL TYPE	MIN. RECYCLED CONTENT %
3	CONCRETE (READY MIXED)	30%
	CONCRETE (CAST-IN-PLACE)	25%
4	BRICK	25%
5	ALUMINUM FABRICATIONS	10%
	STEEL PIPES AND HSS	60%
	HOT ROLLED STRUCTURAL STEEL	90%
	COLD FORMED METAL FRAMING	25%
	METAL DECK	25%
	REBAR	50%
6	COMPOSITE WOOD	95%
7	CELLULOSE INSULATION	75%
	FIBERGLASS INSULATION	25%
	MINERAL WOOL INSULATION	35%
	RIGID INSULATION	10%
9	GYPSUM BOARD	95%
	ACOUSTICAL CEILING TILE	45%
	CARPET	25%
	CARPET PADDING AND CUSHION	40%

RESPONSIBLY-SOURCED WOOD PRODUCTS

Do not use any wood from threatened tree species listed in the International Union for Conservation of Nature (IUCN) "Red List of Threatened Species" as endangered (EN), critically endangered (CR), or extinct in the wild (EW).

For non-threatened wood products, 75% of the all new wood products (by cost) must be FSC certified.

Documentation Requirements:

- Inventory of all new, permanently installed, wood purchased for the project. Indicating species, IUCN classification, FSC certification status, and cost.
- Certificates from the final vendor of each FSC wood product stating the Chain of Custody (CoC) number and the new-wood cost.

WASTE, RECYCLING, AND COMPOSTING FACILITIES

Provide waste storage areas sufficiently sized to hold all the waste, recyclables, and composting that the building occupants will generate until it is collected.

Documentation Requirements:

- Location and area of waste storage area called out on architectural drawings

BUILDING FLUSH OUT

After construction is complete (including finishes and furniture) install new filtration media and then conduct a building flush out to clear out particulates and any off-gassing VOCs.

Supply a total air volume of 14,000 cubic feet of outdoor air (OA) per ft² GFA prior to occupancy, while maintaining an internal temperature of at least 60°F and no higher than 80°F, and relative humidity no higher than 60%.

Documentation Requirements:

- Building flush-out report
- Log indicating dates that new filtration media is installed

WHAT DOCUMENTATION IS REQUIRED

ADHESIVES AND SEALANTS (WET-APPLIED)	Provide manufacturer documentation indicating VOC content. Demonstrate that the value is less than or equal to the VOC limit for the applicable product category established in SCAQMD Rule 1168. **OR** Demonstrate compliance with one of the approved Third-party Certifications for VOC Content.
PAINTS AND COATINGS (WET-APPLIED)	Provide manufacturer documentation indicating VOC content. Demonstrate that the value is less than or equal to the VOC limit for the applicable product category established in SCAQMD Rule 1113. **OR** Demonstrate compliance with one of the approved Third-Party Certifications for VOC Content.
FLOORING	Provide VOC Emissions test results in accordance with CDPH Standard Method v1.1-2010 or later stating the TVOC Range after testing. **OR** Demonstrate compliance with one of the approved Third-party Certifications for VOC Emissions.
COMPOSITE WOOD	Provide manufacturer documentation for all composite wood products used in the project confirming that the product meets the California Air Resource Board (CARB) requirements for ultra-low-emitting formaldehyde (ULEF) resins or no added formal-dehyde (NAF) resins.
WOOD (GENERAL)	State the species name for all wood products used in the project. Provide a summary report from www.wood-database.com or from the www.iucn.org confirming that the species is not listed as endangered, critically endangered, or extinct in wild. **AND** Provide a certificate verifying that
RECYCLED CONTENT MATERIALS	Provide a manufacturer statement disclosing the pre-consumer and post-consumer recycled content of the product in question. Verify that the total recycled content precentage is greater than or equal to the limit established in the Sustainable Design Standards.
PLUMBING FIXTURES	Provide product cut-sheets highlighting the flowrate of each specified fixture addressed in the Sustainable Design Standards (toilets, urnals, lavatories, faucets, showerheads, pre-rinse spray-valves).

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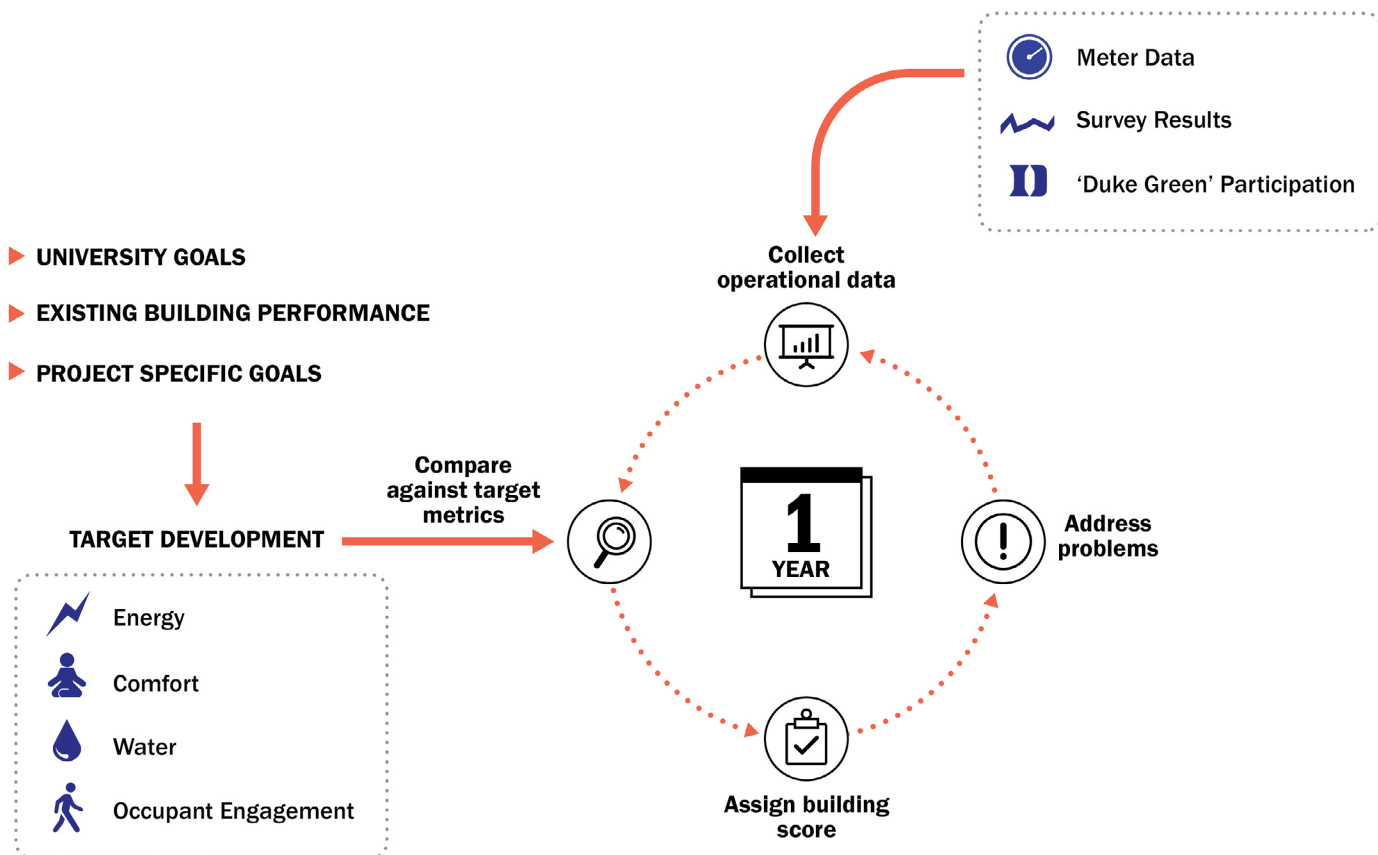
BUILDING TRACKING + RATING



OPERATIONAL ASSESSMENT FLOWCHART

Operational Assessment

OVERVIEW

While the first two sections of the report focused on developing highly sustainable buildings through the design process, this section outlines the procedure to verify and commission the operational environmental performance of Duke's buildings on an annual basis. The operational assessment will substantiate the effectiveness of measures included in the Duke Sustainable Design Standards by measuring each building's operational performance.

Overall building performance is evaluated based on performance in five (5) categories related to sustainable building operation.

1. Energy Use
2. Building Water Consumption
3. Landscape Water Consumption
4. Occupant Comfort
5. Occupant Engagement

This assessment procedure will allow Duke Facilities to monitor the performance of the campus building stock to provide insight on where improvement is possible. The assessment for each category will collect building data such as metered energy and water use, occupant surveys, and occupant participation in the Duke Green Program to assess a building's sustainable performance. Performance in each category will be compared against targets developed by Duke University to create a performance score in each category.

Category scores will be weighted and combined to develop an overall building score that will report the overall sustainable performance of a building. Each of the five categories is weighted differently proportional to Duke's sustainability goals. The final rating will report the holistic operational performance of a building that is reflective of Duke's sustainability priorities.

Building Rating

To verify buildings are operating as intended, metrics evaluating a building's performance in each of the five (5) sustainability categories will be tracked by building operators on an ongoing basis. Scores for each category are updated annually based on the building's performance compared to design targets established by Duke University.

Each category score is adjusted using weighting factors reflective of Duke's over-arching sustainability objectives. A summation of these weighted scores yields the overall building score.

An overview of the tracked metrics, data sources, design targets, and weighting factors for each category are shown in Table 12. Both operational performance targets and weighting factors are liable to be updated over time as Duke's sustainability goals advance.

Operational targets have been developed by the Duke Office of Sustainability and reflect the overall sustainability vision of Duke University.

$$Category\ score\ = \frac{Measured\ performance}{Target\ performance}$$

$$Building\ score\ = \sum(Category\ score \times Weighting\ factor)$$

Targets for operational energy use, building water consumption, and landscape water consumption are based on achieving a set percent reduction from baseline metrics for a building. These baseline metrics will vary depending on the building size, design, and typology.

Standard design targets established for occupant comfort, and occupant engagement are based on Duke's expectations for buildings in operation and remain the same for all projects regardless of size or type.

ENERGY USE

WEIGHTING FACTOR: 40%

To assess building energy performance, the operational EUI (kBTU/ft²/year) will be compared against the modeled building EUI established during the design phase. Achieving an operational EUI better than or within 10% of the modeled value will verify that the building is performing as designed and will earn all points in the Energy Use category. Partial credit will be given for projects based on the following formula:

$$\left(\frac{Operational\ EUI}{Modeled\ EUI} \Big/ 0.9\right) * 0.4$$

TABLE 12: OPERATIONAL ENERGY TARGETS

CATEGORY	METRIC TRACKED	SOURCE OF DATA	OPERATIONAL TARGET	WEIGHTING FACTOR
ENERGY USE	Annual source energy use intensity (EUI) kBTU/ft²/year	Building level utility meters for electricity, hot water, steam, chilled water and natural gas	Operational EUI within 10% of modeled EUI.	40 %
BUILDING WATER CONSUMPTION	Normalized annual building water use Gallons/ft²/year	Duke University Water Use Audit	Reduce indoor water use by 20% from Duke average water use for the building type.	25 %
LANDSCAPE WATER CONSUMPTION	Annual site water use. Gallons/year	Site water meter	75% below baseline water demand determined for site	10 %
OCCUPANT COMFORT	Building comfort score	Annual occupant comfort survey	Average building comfort score ≥ 80%	15 %
OCCUPANT ENGAGEMENT	Percentage of total classrooms, labs, and offices that participate in the Duke Green program	Duke Green Program	All applicable spaces participate in Duke Green Program	10 %

BUILDING WATER CONSUMPTION

WEIGHTING FACTOR: 25%

Unitized operational building water consumption (gallons/ft²/year) will be compared against the baseline value for a given building typology determined using historic water use data collected across campus. Baseline performance will be defined as the average unitized water use for a given building typology on Duke's campus. New construction and major renovation projects are expected to achieve a 20% reduction from these baseline values to earn all points in the Building Water Consumption category.

TABLE 13: OPERATIONAL WATER TARGETS

BUILDING TYPOLOGY	BASELINE WATER USE INTENSITY [GALLON/FT²/YEAR]
ACADEMIC/OFFICE	11
LABORATORY/VIVARIA	34 / 77
DORMITORY	25
PUBLIC ASSEMBLY	14
FITNESS	46
DINING	25

LANDSCAPE WATER CONSUMPTION

WEIGHTING FACTOR: 10%

Water use attributed to irrigation will be compared against the baseline irrigation demand defined for a site. Baseline irrigation demand shall be calculated as 100% of the local evapotranspiration rate during months when irrigation is required.

Annual irrigation water consumption will be compared against the baseline volume to determine the percent reduction achieved by a project. Full points will be granted in the Landscape Water consumption category if an annual water use reduction greater than or equal to 75% is achieved.

OCCUPANT COMFORT

WEIGHTING FACTOR: 15%

To assess occupant comfort in buildings, Duke University will administer an annual Occupant Comfort Survey to regular building users. The survey will assess all factors associated with occupant comfort including thermal comfort, visual comfort, indoor air quality, and cleanliness. The scores of each survey will be averaged to determine overall occupant comfort score.

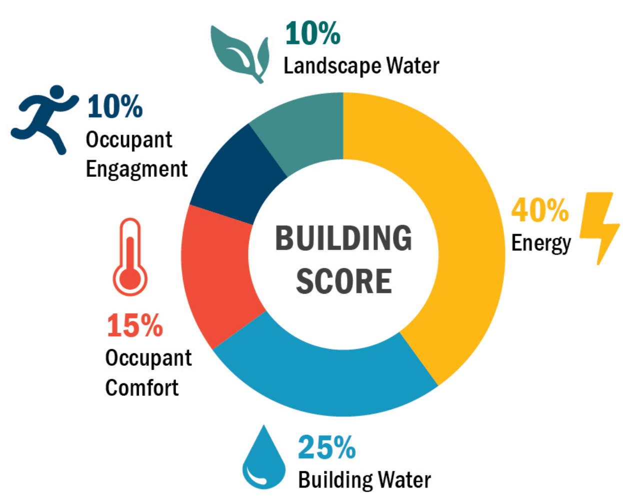
To earn all points in the occupant comfort category, the average occupant comfort score must be greater than or equal to 80%.

OCCUPANT ENGAGEMENT

WEIGHTING FACTOR: 10%

Duke currently has an engagement program for faculty to certify their classrooms, labs, dorms and workplaces through the "Duke Green Certification" program. The occupant engagement portion of the building rating system will be tracked based on the number of eligible spaces in a building that participate in Duke Green Program. The Duke Green Program is applicable to classrooms, labs, and offices and dedicated to promoting sustainable practices.

To earn all points in the occupant engagement category, all applicable spaces must participate in the relevant Duke Green Program.



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APPENDICES

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Appendix A: Pre-Design Site Assessment Worksheet

PRE-DESIGN SITE ASSESSMENT WORKSHEET [FOR REFERENCE ONLY]

DUKE UNIVERSITY PRE DESIGN SITE ASSESSMENT					
Project Name					
Prepared By (LSA)					
Reviewed By (BSC)					
ECOSYSTEMS, SOILS + VEGETATION					
		PROJECT CONTEXT	**COMMENTS**	**REFERNCE REPORTS/DOCUMENTS**	**DESIGN RESPONSIBILITY**
Information Gathering of Existing Site	Identify and/or Map	Forests, woodlands, streams, lakes, riparian buffers, wetlands, etc., noting ecosystem condition and health			
		Habitats for endangered or threatened species			
		Areas of healthy soils			
		Areas of soils disturbed by previous development			
		Total existing vegetated area			
		Invasive plants on site			
		Native plants and native plant communities on site			
		Special status vegetation and Duke Forest			
		Tree inventory, noting species, diameter at breast height, and tree health			
Establish Project Criteria	Identify and/or Map	Healthy ecosystems, soils, and/or vegetation on site that should be classified as Vegetation and Soil Protection Zones (VSPZ) and protected throughout construction and operation.			
		Ecosystems, soils, and/or vegetation on site that should be restored as part of the project scope.			
	Provide a Narrative	Establish reference soil conditions (based on test results or verified allowable ranges) and soil restoration criteria for the project site. Reference soils conditions shall include: a. Organic matter b. Compaction or infiltration c. Soil chemical characteristics or soil biological function			
WATER					
		PROJECT CONTEXT	**COMMENTS**	**REFERNCE REPORTS/DOCUMENTS**	**DESIGN RESPONSIBILITY**
Information Gathering of Existing Site	Identify and/or Map	Limits of 10-year and 100-year flood plain (if applicable)			
		Overland water flow on site: determine topography, direction, and effects on the watershed, including natural rates of erosion.			
		Campus stormwater management infrastructure that will serve project site			
		Pollution Sources: Existing and potential sources, point and nonpoint sourcs, health hazards, both on-site and in adjacent areas			
	Provide a Narrative	Water shed conditions a.Common stormwater pollutants b. Specific pollutants of concern c. Local, regional, or state watershed plans d. Artificial modification of natural hydrology			
		Precipitation a. Average annual precipitation b. Average monthly precipitation c. Precipitation events (every 5th percentile rainfall event) d. Mid- and end-of-century precipitation projections			
		Water sources a. Potable and non-potable water sources for the site b. Opportunities to capture, treat, and reuse rainwater and graywater			
Establish Project Criteria	Provide a Narrative	Establish project-specific requirements and/or recommendations for stormwater management and water reuse			
SITE CONNECTIVITY					
		PROJECT CONTEXT	**COMMENTS**	**REFERNCE REPORTS/DOCUMENTS**	**DESIGN RESPONSIBILITY**
Information Gathering of Existing Site	Identify and/or Map	Pedestrian routes and flows, including points of entry			
		Accessibility and ADA requriements			
		Bicycle paths and number of existing bicycle parking spaces			
		Public and Univsiery transit stops and routes located within 1/2 mile of the project site			
		Vehicular routes and through-traffic			
		Adjacent parking areas			
		Special view corridors			
		Historic or significant structures and landscapes			
Establish Project Criteria	Provide a Narrative	For pedestrian access idententify requirements for accessibility (ADA), safety (natural surveillance, adequate lighting, variety of access), and wayfinding (clear entrances, sightlights, landmarks, orientation devicies) that should be included in the site design			
		Establish bicycle ridership numbers and number of bicycle parking spaces			
		Identify required connections to transit and bicycle networks			
		Identify preservation requirements for historic structures and/or landscapes and view corridors			

Appendix B: Design Process Checklist

DESIGN PROCESS CHECKLIST [FOR REFERENCE ONLY]

DUKE DESIGN PROCESS CHECKLIST

Item	Task	Type	Deliverable(s)	Complete by	Responsible	Date Completed	PM Sign-off
Planning / Concept Design							
PC-1	Draft Owners Project Requirements (OPR)	Document	• Draft OPR	Goal Setting Workshop	SBC		
PC-2	Complete Pre-Design Site Assessment	Document	• PDSA worksheet	SD Charrette	SBC / ULA		
PC-3	Goal Setting Workshop	Meeting	• Meeting minutes	Schematic Design	PM		
Schematic Design							
SD-1	Occupant Input Meeting	Meeting	• Meeting minutes	SD Charrette	PM/Architect		
SD-2	Schematic Design Charrette	Meeting	• Meeting minutes	One week from date of SD Charrette	PM		
SD-3	Responsibility Matrix	Document	• Completed Responsibility Matrix	One week from date of SD Charrette	SBC		
SD-4	Compile Basis of Design	Document	• Compiled BOD including sections from each relevant dicipline	100% SD	SBC		
SD-5	SD Energy Analysis	Analysis	• SD energy analysis report • Duke Energy Model Information form • List of potential EEMs for LCCA	100% SD	Energy Analyst		
SD-6	Exploratory Daylight Analysis	Analysis	• Daylight analysis report	100% SD	Daylight analyst		
SD-7	SBC Basis of Design Review	Review	• BOD review comments	DD Design Charrette	SBC		
LCCA + Costing [as needed]							
LC-1	LCCA Framing Worksheet	Document	• Completed LCCA Framing Worksheet	Prior to starting LCCA	Energy Analyst		
LC-2	LCCA Energy Analysis	Analysis	• Energy model report listing energy savings attributed to EEMs for LCCA	Start of DD	Energy Analyst		
LC-3	EEM Cost Estimate	Document	• Estimate of additional cost attributed to EEMs	Start of DD	Cost Estimator		
LC-4	Life Cycle Cost Analysis	Analysis	• LCCA results and report	Start of DD	Energy Analyst		

DESIGN PROCESS CHECKLIST [FOR REFERENCE ONLY]

DUKE DESIGN PROCESS CHECKLIST							
Item	**Task**	**Type**	**Deliverable(s)**	**Complete by**	**Responsible**	**Date Completed**	**PM Sign-off**
Design Development							
DD-1	DD Coordination Meeting	Meeting	• Meeting minutes	One week from date of meeting	PM		
DD-2	EEM Selection	Document	• List of EEMs that will be included in the project	50% DD	SBC		
DD-3	BOD Update	Document Update	• Updated BOD with added EEMs	50% DD	SBC		
DD-4	50% DD Energy Analysis	Analysis	• Energy analysis report • Duke Energy Model Information form	100% DD	Energy Analyst		
DD-5	CxA BOD Review	Review	• BOD Review Comments	100% DD	Commissioning Agent		
DD-6	100% DD Document Review	Review	• Design Review Checklist	100% DD	SBC		
Construction Documents							
CD-1	CD Coordination Meeting	Meeting	• Meeting minutes	One week from date of meeting	PM		
CD-2	Respond to DD Document Review Comments	Review Response	• Updated drawing set addressing pertinant review comments	50% CD	Design Team		
CD-3	50% CD Sustainability Review	Review	• Design Review Checklist	85% CD	SBC		
CD-4	Mid-CD Commissioning Review	Review	• Commissioning review comments	85% CD	Commissioning Agent		
CD-5	Bid document energy analysis	Analysis	• Final energy analysis report • Duke Energy Model Information form	85% CD	Energy Analyst		
CD-6	Bid document energy analysis	Analysis	• Final energy analysis report • Duke Energy Model Information form	85% CD	Energy Analyst		
Construction Administration							
CA-1	CA Kickoff Meeting	Meeting	• Meeting minutes	One week from date of meeting	PM		
CA-2	CA Check-in Meetings (throughout construction)	Meetings	• Record of meeting minutes	End of Construction	SBC		
CA-3	Submittal Review Summary	Document	• Copy of submittal log confirming material compliance	End of Construction	Architect		
CA-4	Construction Waste Summary	Report	• Summary of project's construction waste diversion rate	End of Construction	Contractor		
CA-5	Final Project Review	Review	• Design Review Checklist	End of Construction	SBC		
CA-6	Sustainability Summary Report	Report	• Report outlining sustainability features	Project Close-out	SBC		
CA-7	Project Turnover documentation	Document	• Complete steps outlined in Duke Process for Documentation of Project Turnover	Project Close-out	Project Manager		

Appendix C: Responsibility Matrix

SUSTAINABLE DESIGN STANDARDS RESPONSIBILITY MATRIX [FOR REFERENCE ONLY]

DUKE SUSTAINABLE DESIGN RESPONSIBILITY MATRIX

Project Name

	ENERGY		RESPONSIBLE	REQUIREMENT	DOCUMENTATION REQUIRED
Energy	Feature 1	**Energy Use Reduction**		Demonstrate a __% reduction in regulated building energy use from an ASHRAE 90.1-2016 Baseline following the Appendix G modeling approach.	Energy model results summary, modeling input and assumptions, input and output reports from energy modeling software, and exception calculations (if applicable).
Energy	Feature 2	**Building Envelope Performance**		Meet or exceed the envelope performance requirements established for the project type.	Wall sections, assembly R- or U- value calculations, glazing cutsheets.
Energy	Feature 3	**MEP System Commissioning**		Commission mechanical, electrical, and plumbing systems in accordance with ASHRAE Guideline 0-2013.	Building commissioning report and systems manual.
Energy	Feature 4	**Building Envelope Commissioning**		Commission newly constructed façade areas in accordance with the latest version of ASTM E2813 to verify the thermal, hygroscopic, and air infiltration performance of the façade.	Building envelope commissioning report.
Energy	Feature 5	**Fault Detection + Continuous Commissioning**		Provide sensor points and programing required to connect to Duke Universities building analytics platform as mandated by the Sustainable Buildings Coordinator.	Summary of sensor point locations in building commissioning report.
Energy	Feature 6	**Use of Central Services**		Connect to Duke University Central Utilities OR demonstrate a comparable source EUI if using on-site boilers,/chillers.	Utility supply plan AND/OR source EUI calculations.
Energy	Feature 7	**Energy Metering**		Meter all incoming utilities at the building level and submeter energy use attributed to equipment, plug loads, lightings, pumps, and fans at the distribution panel level.	Electrical drawings depicting meter locations and product cut-sheets.
Energy	Feature 8	**Refrigerant Use**		Use no HVAC+R requirement that utilizes chlorofluorocarbon-based refrigerants.	Summary of on-site HVAC+R equipment and refrigerants used.
Energy	Feature 9	**Daylight Dimming**		Include daylight dimming within 15' of the façade in all perimeter spaces.	Lighting plans and control diagrams.
Energy	Feature 10	**Occupancy Based HVAC Setbacks**		Set-back the design heating and cooling temperatures to 65°F and 80°F, respectively during scheduled unoccupied periods.	Plans indicating regularly occupied spaces and vacancy sensor locations and HVAC control diagrams.
Energy	Feature 11	**Occupancy Based Lighting Controls**		Provide occupancy based lighting controls in all spaces with intermittent occupancies.	Lighting plans and control diagrams highlighting sensor locations and control logic.
Energy	Feature 12	**Lighting Power Density (LPD) Reduction**		Reduce lighting power density by 20% from baseline space-by-space LPD allowance.	Lighting power density calculations and fixture cutsheets.
Energy	Feature 13	**All LED Lighting Scheme**		Design new construction projects with an all LED lighting scheme.	Lighting fixture schedules showing all LED lamps.

	WATER		RESPONSIBLE	REQUIREMENT	DOCUMENTATION REQUIRED
Water	Feature 1	**Fixture Water Use**		Meet maximum allowable flowrates established in the sustainable design standards.	Plumbing fixture schedule and cutsheets indicating flowrates.
Water	Feature 2	**Appliance Water Use**		Meet appliance water use requirements for all applicable equipment included in the project scope.	Appliance cutsheets.
Water	Feature 3	**Kitchen Water Use**		Meet kitchen equipment requirements for all applicable equipment included in the project scope.	Kitchen equipment cutsheets and manufacturer documentation.
Water	Feature 4	**Water Metering**		Provide building level water meters to monitor the consumption of domestic water and irrigation water.	Plumbing plans indicating meter locations and meter cutsheets.
Water	Feature 5	**Irrigation Controls**		Provide smart controllers capable of varying irrigation rates based on weather and evapotranspiration as required by Duke Landscape Services	Controller cut-sheets.
Water	Feature 6	**Rainwater Harvesting**		Assess the potential for rainwater collection in the schematic design phase.	Report summarizing monthly rainwater collection potential, non-potable water demands, and associated re-use systems for pricing.
Water	Feature 7	**Cooling Coil Condensate Collection**		Collect and reuse condensate from all dedicated outdoor air systems and 100% outdoor air units.	Ventilation systems summary showing OA percentage and condensate collection system schematics.

	SITE + LANDSCAPE		RESPONSIBLE	REQUIREMENT	DOCUMENTATION REQUIRED
Site + Landscape	Feature 1	**Vegetation and Soil Protection Zones**		Designate VSPZs as identified in the Predesign Site Assessment.	Specifications section for VSPZs and tree protection, site map showing VSPZs, and VSPZ plan describing the protective measures required.
Site + Landscape	Feature 2	**Tree Preservation and Wood Use**		Comply with Duke's Wood Use Policy such that there is no net-loss of trees on site as the result of a new construction project. If adequate trees cannot be maintained, pay the required donation to the University Tree Replacement Fund.	Complete Duke Wood Use Form
Site + Landscape	Feature 3	**Light Pollution Reduction**		Do not exceed allowable backlight, uplight, and glare (BUG) ratings for exterior lighting fixtures (B4, U2, G2).	Site lighting plan and luminaire schedule showing BUG ratings.
Site + Landscape	Feature 4	**Parking for Alternative Transportation**		Provide bicycle parking for a minimum of 5% of building occupants AND/OR 40% of residents.	Building occupancy calculations and site plan showing bicycle parking locations.
Site + Landscape	Feature 5	**Bird-Safe Building Design**		Incorporate bird safe building strategies with a maximum threat factor of 40 in all projects with a window to wall ratio greater than 50% and all uninterrupted glazed segments greater than 50ft².	Window-to-wall ratio calculation, and window schedule showing areas. Provide narrative and drawings demonstrating bird-safe design strategies.

	OCCUPANT HEALTH + COMFORT		RESPONSIBLE	REQUIREMENT	DOCUMENTATION REQUIRED
Health + Comfort	Feature 1	**Outside Air Ventilation Rate**		Meet or exceed minimum OA ventilation rates determined using the ventilation rate procedure outlined in ASHRAE 62.1-2016.	Ventilation rate calculations and mechanical schedules showing design system airflow.
Health + Comfort	Feature 2	**Negative Pressurization**		For spaces where hazardous chemicals may be present, create negative pressurization using the exhaust rates prescribed by ASHRAE 62.1-2016 or 0.5 CFM/ft², whichever is higher. Use deck-to-deck partitions and self closing door hardware to prevent cross contamination.	Plan markup of rooms with hazardous chemicals or gasses, mechanical schedules highlighting required exhaust rates, and documentation depicting self-closing door hardware and deck-to-deck partitions.
Health + Comfort	Feature 3	**Outside Air Monitoring**		Monitor OA delivery using a measuring device capable of triggering an alarm if the OA rate varies by more than 15% from the setpoint.	Mechanical control drawings illustrating compliance.
Health + Comfort	Feature 4	**Outside Air Filtration**		Provide MERV 13 or higher filters for each ventilation system supplying OA to occupied spaces.	Mechanical schedule highlighting filter MERV rating.
Health + Comfort	Feature 5	**Carbon Dioxide Sensors**		Install CO2 sensors in all classrooms, public gathering areas, conference rooms, and other spaces with high occupant densities. Program HVAC systems to increase supply airflow when concentrations exceed	List of all spaces requiring CO2 monitoring and the corresponding CO2 concentration set point and mechanical control drawings depicting CO2 sensors.
Health + Comfort	Feature 6	**Carbon Monoxide Monitoring**		Provide CO monitors on each flor of each residential unit.	Floor plans highlighting the location of each CO monitor.
Health + Comfort	Feature 7	**Low-Emitting Wet Applied Products**		Meet VOC limits for wet-applied paints, coatings, adhesives, and sealants established by SCAQMD Rule 1168 and 1113.	Log of all wet applied products listing VOC content and SCAQMD VOC limits with manufacturers documentation verifying product VOC content.
Health + Comfort	Feature 8	**Low-Emitting Flooring Products**		Demonstrate compliance with a general emissions evaluation (GEE) in accordance with CDPH Standard Method v1.1-2010 (or provide accepted third-party certification) for all finish flooring products used in the	Log of all flooring products and GEE test results from the manufacturer for each.
Health + Comfort	Feature 9	**Low-Emitting Composite Wood**		Meet California Air Resources Board (CARB) ATCM requirements for ultra-low-emitting formaldehyde (ULEF) resins or no added formaldehyde (NAF resins).	Log of all composite wood products and manufacturer documentation verifying CARB compliance.
Health + Comfort	Feature 10	**Entryway Systems**		Provide entryway systems (floor grilles, grates, or walk off mats) extending 10' in the direction of primary travel at all high-traffic entrances.	Floorplans showing locations and dimensions of all walk-off systems.
Health + Comfort	Feature 11	**HVAC Background Noise**		Design to meet criteria for HVAC noise levels resulting from the sound transmission paths listed in ASHRAE 2015 Applications Handbook, Chapter 48, Table 6. Achieve background noise levels from HVAC systems	Noise reduction narrative and calculations demonstrating compliance with ASHRAE design criteria.
Health + Comfort	Feature 12	**Thermal Comfort**		Design HVAC systems to meet the requirements of ASHRAE 55-2017.	ASHRAE 55 compliance documentation and outputs from the CBE thermal comfort tool for each space type in summer and winter conditions.
Health + Comfort	Feature 13	**Indoor Air Quality Testing**		Conduct indoor air quality testing after construction ends and prior to occupancy demonstrating that maximum contaminant concentrations are not exceeded.	Air testing report and narrative describing testing procedures and measured concentrations.
Health + Comfort	Feature 14	**Chemicals of Concern**		Avoid using materials that contain the chemicals of concerns listed in the Duke Sustainable Design Standards.	Narrative describing design strategies taken to limit the use of products containing chemcials of concern in the project.

	MATERIALS + CONSTRUCTION		RESPONSIBLE	REQUIREMENT	DOCUMENTATION REQUIRED
Materials + Construction	Feature 1	**Construction and Demolition Waste Management (CDWM)**		Divert 90% of construction and demolition waste from disposal.	Log of construction waste tracking receipts calculating overall project diversion rate.
Materials + Construction	Feature 2	**Construction Indoor Air Quality (CIAQ) Management**		Develop an CIAQ plan that meets or e exceeds all recommended control measures of the SMACNA IAQ Guidelines for Occupied Buildings Under Construction.	CIAQ Plan, photographs of control measures during construction, and specifications or cutsheets demonstrating the use of MERV 8+ filters used during construction.
Materials + Construction	Feature 3	**Recycled Content Materials**		Use products with the minimum recycled content percentages established in the Duke Sustainable Design Standards.	Log of all applicable materials with manufactures documentation verifying recycled content.
Materials + Construction	Feature 4	**Responsibly Sourced Wood Products**		Do not use wood from any threatened tree species listed in the IUCN Red List as endangered, critically endangered, or extinct in the wild. For non-threatened new wood products, ensure 75 % of wood (by cost)	Inventory of all new wood purchased for the project indicating species, IUCN classification, FSC certification status, and cost.
Materials + Construction	Feature 5	**Waste, Recycling, and Composing Facilities**		Provide a centralized storage area(s) sufficiently sized to hold all building waste, recyclables, and compost that occupants will generate between collection intervals.	Plan markup showing locations of storage rooms.
Materials + Construction	Feature 6	**Building Flush out**		Flush out buildings using 14,000 ft^3 of outside air per square foot of building area after construction but prior to occupancy.	Flush out duration calculations and proof of execution.

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Appendix D: Sustainable Design Standards Review

SUSTAINABLE DESIGN STANDARD REVIEW CHECKLIST [FOR REFERENCE ONLY]

DUKE UNIVERSITY DESIGN REVIEW CHECKLIST

Project Name ______________________

Document Set ______________________

Reviewed By (SBC) ______________________

Approved By (FMD) ______________________

Complete Y/N		ENERGY		REVIEW COMMENTS	RESONSIBLE PARTY
	Energy	Feature 1	Energy Use Reduction		
	Energy	Feature 2	Building Envelope Performance		
	Energy	Feature 3	MEP System Commissioning		
	Energy	Feature 4	Building Envelope Commissioning		
	Energy	Feature 5	Fault Detection + Continuous Commissioning		
	Energy	Feature 6	Use of Central Services		
	Energy	Feature 7	Energy Metering		
	Energy	Feature 8	Refrigerant Use		
	Energy	Feature 9	Daylight Dimming		
	Energy	Feature 10	Occupancy Based HVAC Setbacks		
	Energy	Feature 11	Occupancy Based Lighting Controls		
	Energy	Feature 12	Lighting Power Density (LPD) Reduction		
	Energy	Feature 13	All LED Lighting Scheme		

Complete Y/N		WATER		REVIEW COMMENTS	RESONSIBLE PARTY
	Water	Feature 1	Fixture Water Use		
	Water	Feature 2	Appliance Water Use		
	Water	Feature 3	Kitchen Water Use		
	Water	Feature 4	Water Metering		
	Water	Feature 5	Irrigation Controls		
	Water	Feature 6	Rainwater Harvesting		
	Water	Feature 7	Cooling Coil Condensate Collection		

Complete Y/N		SITE + LANDSCAPE		REVIEW COMMENTS	RESONSIBLE PARTY
	Site + Landscape	Feature 1	Vegetation and Soil Protection Zones		
	Site + Landscape	Feature 2	Tree Preservation and Wood Use		
	Site + Landscape	Feature 3	Light Pollution Reduction		
	Site + Landscape	Feature 4	Parking for Alternative Transportation		
	Site + Landscape	Feature 5	Bird-Safe Building Design		

Complete Y/N		OCCUPANT HEALTH + COMFORT		REVIEW COMMENTS	RESONSIBLE PARTY
	Health + Comfort	Feature 1	Outside Air Ventilation Rate		
	Health + Comfort	Feature 2	Negative Pressurization		
	Health + Comfort	Feature 3	Outside Air Monitoring		
	Health + Comfort	Feature 4	Outside Air Filtration		
	Health + Comfort	Feature 5	Carbon Dioxide Sensors		
	Health + Comfort	Feature 6	Carbon Monoxide Monitoring		
	Health + Comfort	Feature 7	Low-Emitting Wet Applied Products		
	Health + Comfort	Feature 8	Low-Emitting Flooring Products		
	Health + Comfort	Feature 9	Low-Emitting Composite Wood		
	Health + Comfort	Feature 10	Entryway Systems		
	Health + Comfort	Feature 11	HVAC Background Noise		
	Health + Comfort	Feature 12	Thermal Comfort		
	Health + Comfort	Feature 13	Indoor Air Quality Testing		
	Health + Comfort	Feature 14	Chemicals of Concern		

Complete Y/N		MATERIALS + CONSTRUCTION		REVIEW COMMENTS	RESONSIBLE PARTY
	Materials + Construction	Feature 1	Construction and Demolition Waste Management (CDWM)		
	Materials + Construction	Feature 2	Construction Indoor Air Quality (CIAQ) Management		
	Materials + Construction	Feature 3	Recycled Content Materials		
	Materials + Construction	Feature 4	Responsibly Sourced Wood Products		

Appendix E: Applicable EEMs by Building Typology

OVERVIEW

The following energy efficiency measures (EEMs) will help project teams achieve the targeted energy use reductions outlined in this standard. Arranged into various groups based on building typology, these EEMs have been optimized for the Durham, NC climate.

The EEMs for each building type have been arranged into three categories: best practice, high-performance, and exemplary performance. Best practice measures are relatively low-impact and should be implemented by most designs. Other EEMs may be more cost intensive to implement and should be evaluated on a case-by-base basis using life cycle cost assessment.

Design teams should review these EEMs in the Schematic Design phase to determine which measures can be included in the base design, and others that will be further vetted using a life-cycle cost assessment.

LABORATORY

Best Practice:

- Low SHGC glazing
- 20% LPD reduction over ASHRAE 90.1-2013 in all spaces
- Exhaust air sensible heat recovery system
- Transfer air from non-lab to lab spaces
- Night time lab air change rate set-back
- Low-flow fixtures to reduce DHW energy

High Performance:

- Optimized exterior shades to reduce solar heat gain
- 30% LPD reduction over ASHRAE 90.1-2013 in all spaces
- Decoupled systems in internal load driven labs
- Low pressure drop fan system design
- Laboratory exhaust fans with VFDs and variable speed operation
- Automatic fume hood exhaust set-back controls based on zone occupancy sensors
- Dual wheel/wrap around coils to reduce reheat and cooling load in ventilation driven labs.

Exemplary Performance:

- Low-flow fume hoods
- Automatic lab air change rate set-backs using occupancy sensors / Aircuity type controls

ACADEMIC

Best Practice:

- Low SHGC glazing
- 20% LPD reduction over ASHRAE 90.1-2013 in all spaces
- Low-flow fixtures to reduce DHW energy
- Demand control ventilation

High Performance:

- Optimized exterior shades to reduce solar heat gain
- 30% LPD reduction over ASHRAE 90.1-2013 in all spaces
- Displacement ventilation in large lecture halls and auditoriums
- Low pressure drop fan system design

Exemplary Performance:

- Occupancy sensor based VAV and thermostat set-backs in classrooms and private offices
- 40% LPD reduction over ASHRAE 90.1-2013

DINING HALL

Best Practice:

- Low SHGC glazing
- 20% LPD reduction over ASHRAE 90.1-2013 in all spaces
- Low-flow fixtures to reduce DHW energy
- Air-side economizing
- ENERGY STAR appliances
- Transfer air from dining to kitchen
- Separate kitchen make-up air unit to provide partially conditioned air to kitchen hoods

High Performance:

- Optimized exterior shades to reduce solar heat gain
- 30% LPD reduction over ASHRAE 90.1-2013 in all spaces
- Low pressure drop fan system design
- VAV kitchen hood exhaust
- General exhaust air heat recovery

Exemplary Performance:

- 40% LPD reduction over ASHRAE 90.1-2013
- Water-cooled refrigeration equipment to reduce space cooling loads
- Domestic hot water heat recovery
- Kitchen exhaust air heat recovery

GENERAL ASSEMBLY

Best Practice:

- Low SHGC glazing
- 20% LPD reduction over ASHRAE 90.1-2013 in all spaces
- Low-flow fixtures to reduce DHW energy
- Air-side economizing
- Demand control ventilation

High Performance:

- Optimized exterior shades to reduce solar heat gain
- 30% LPD reduction over ASHRAE 90.1-2013 in all spaces
- Displacement ventilation in high volume areas
- Low pressure drop fan system design
- Perimeter FCUs and baseboard heaters in highly glazed areas
- Dual wheel heat recovery or wrap around coils to reduce reheat

Exemplary Performance:

- 40% LPD reduction over ASHRAE 90.1-2013
- Optimized HVAC zoning to use occupancy based VAV and thermostat set-backs
- Relaxed temperature set-points with natural ventilation and ceiling fans in large open assembly areas

FITNESS CENTER

Best Practice:

- Low SHGC glazing
- 20% LPD reduction over ASHRAE 90.1-2013 in all spaces
- Low-flow fixtures to reduce DHW energy
- Air-side economizing
- Demand control ventilation

High Performance:

- Optimized exterior shades to reduce solar heat gain
- 30% LPD reduction over ASHRAE 90.1-2013 in all spaces
- Displacement ventilation in high volume areas
- Low pressure drop fan system design
- Dual wheel heat recovery or wrap around coils to reduce reheat

Exemplary Performance:

- 40% LPD reduction over ASHRAE 90.1-2013
- Optimized HVAC zoning to use occupancy based VAV and thermostat set-backs
- Relaxed temperature set-points with natural ventilation and ceiling fans in large open assembly areas
- Heat recovery from shower waste water for DHW preheat

Appendix F: Energy Model Information Form

DUKE ENERGY MODEL INFORMATION FORM [FOR REFERENCE ONLY]

PLEASE PROVIDE INFORMATION REQUESTED BELOW AND ATTACH SUPPORTING DOCUMENTATION. PLEASE PROVIDE COMPLETED MODELING SOFTWARE FILE AS WELL AS REPORTING INPUT/OUTPUT FORMS FROM SOFTWARE AS PART OF THIS SUBMISSION.	
Project/Building Name:	**Building Area, GSF:**
Assumed # Bldg Occupants:	**Modeler Name:**
Firm/Company Name:	**Simulation Software Used:**
Design Phase Used for Model: ☐ SD ☐ DD ☐ 90% CD ☐ 100% CD	**Issue Date of Drawing Set Used for Model:**

UTILITY INFORMATION[1]		
CONSULTANTS SHOULD USE INFORMATION BELOW IN DEVELOPMENT OF BUILDING ENERGY SIMULATION MODELS		
Which Utility Services are provided to the project?: ☐ Steam ☐ Chilled Water ☐ Electrical ☐ District Hot Water ☐ Natural Gas ☐ Water		
Utility	Cost Information	Energy Conversions
Steam:	$18.57 per 1000 lbs	950 Btu/lbm
Chilled Water:	$0.1596 per ton-hour	2730 Btu/ton-hr
Electrical: $19.44 per 1000	$0.0724 per kWh	3412 Btu/kWh
$0.1702 per Water: $0.0744 per kWh	$10.96 per CCF	N/A
District Hot Water: $13.49 per CCF	Calculate as Equivalent to Steam Energy Cost	Calculate as Equivalent to Steam Energy Cost
Natural Gas:	*see PSNC Rate Schedule 125	1000 Btu/CF

MODEL INPUT SUMMARY		
Basic Architecture		
Item	Baseline Building	Proposed Design
Area, GSF	Same as Proposed	
Overall Height	Same as Proposed	
# floors above grade	Same as Proposed	
# floors below grade	Same as Proposed	
Roof area, GSF	Same as Proposed	
Building Envelope		
Item	Baseline Building	Proposed Design
Typical Wall R-value		
Typical Roof R-value		
Fenestration U-val/ SHGC		
% of Wall Area Fenestration		
Does this project include any of the following features? ☐ Solar PV ☐ Solar Thermal ☐ Non-pot. water reclaim ☐ Green Roof		
Internal Loads		

DUKE ENERGY MODEL INFORMATION FORM [FOR REFERENCE ONLY]

Lighting Power Density, W/sq.ft.		
Plug Load, W/space or W/sq.ft.		
Operable Windows?		

HVAC Systems		
Item	Baseline Building	Proposed Design
System Type		
Heating Temp. Occ/Unocc Set-points		
Cooling Temp. Occ/Unocc Set-point		
HVAC Equipment Schedules		

MODEL OUTPUT SUMMARY		
Energy Consumption		
Item	Baseline Building	Proposed Design
Annual Steam consumption, lbs		
Annual CHW consumption, ton-hrs		
Annual Electricity consumption, kWh		
Annual water consumption, gal or CCF (may be taken from sources not related to energy model)		
Energy Demand - *note: provide model results, not values from equipment schedules/ construction documents		
Item	Baseline Building	Proposed Design
Peak Steam demand, lbm/hr, & time/day of year		
Peak CHW demand, tons, & time/day of year		
Peak Electrical demand, kW, & time/day of year		
Peak water usage, gal/day (may be taken from sources not related to energy model)		
Metrics		
Item	Baseline Building	Proposed Design
EUI (kBtu/GSF/yr) **use energy conversion factors shown on page 1, "utility information" section	Aggregate value: % Steam: % CHW: % Elec: % Gas:	Aggregate value: % Steam: % CHW % Elec % Gas:
Usage Profile (kBtu/yr)	% Lighting % HVAC % Service Water % Plug Load % Other	% Lighting % HVAC % Service Water % Plug Load % Other

DUKE FMD REVIEW			
ACCEPTANCE OF CONSTRUCTION DOCUMENT SUBMITTAL IS DEPENDENT ON FMD APPROVAL			
NAME	**TITLE**	**SIGNATURE**	**DATE**

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Appendix G: LCCA Framing Worksheet

DUKE LCCA FRAMING WORKSHEET - FOR REFERENCE ONLY

DUKE UNIVERSITY LCCA FRAMING WORKSHEET

Project Name

Prepared By

Approved By

BLOCK LOAD ENERGY ANALYSIS SUMMARY

Proposed Design EUI kBTU/ft²/yr

Regulated Energy Use Reduction from Baseline %

Targeted Reduction ______________ %

Energy Distribution by End Use

Space Heating	%
Space Cooling	%
Pumps + Fans	%
Lighting	%
Domestic HW	%
Misc. Equipment	%

APPLICABLE ENERGY EFFICIENCY MEASURES

 # EEMS REQUIRED Number of EEMs to be determined by Duke SBC

	Baseline System	Alternate System for LCCA
1		
2		
3		
4		
5		
6		

LCCA ASSUMPTIONS

Study Period 20 Years

Discount Rate ______________ %

Escalation and Current Utility Rates

Electricity	______ %	______ $/kWh
Natural Gas	______ %	______ $/Therm
Chilled Water	______ %	______ $/Ton-hrs
Steam	______ %	______ $/MMBtu
Fuel Oils	______ %	______ $/Gallon
Maintenance + Labor	______ %	______ $/Hour

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Appendix H: SCAQMD VOC LIMITS

PAINTS AND COATINGS	g/L
Architectural Coatings	50
Bond Breakers	350
Building Envelope Coatings	50
Concrete-Curing Compounds	100
Concrete Surface Retarder	50
Default	50
Driveway Sealer	50
Dry-Fog Coatings	50
Faux Finishing Coatings	
Clear Topcoat	100
Decorative Coatings	350
Glazes	350
Japan	350
Trowel Applied Coatings	50
Fire-Proofing Coatings	150
Flats	50
Floor Coatings	50
Form Release Compound	100
Graphic Arts (Sign) Coatings	200
Industrial Maintenance (IM) Coatings	100
Color Indicating Safety Coatings	480
High Temperature IM Coatings	420
Non-Sacrificial Anti-Graffiti Coatings	100
Zinc-Rich IM Primers	100
Magnesite Cement Coatings	450
Mastic Coatings	100
Metallic Pigmented Coatings	150
Multi-Color Coatings	250
Nonflat Coatings	50
Pre-Treatment Wash Primers	420
Primers, Sealers, and Undercoaters	100
Reactive Penetrating Sealers	350
Recycled Coatings	150
Roof Coatings	50
Roof Coatings, Aluminum	100
Roof Primers, Bituminous	350
Rust Preventative Coatings	100
Sacrificial Anti-Graffiti Coatings	50
Shellac	
Clear	750
Pigmented	550
Specialty Primers	100
Stains	100
Stains, Interior	250
Stone Consolidants	450
Swimming Pool Coatings	340
Tile and Stone Sealers	100
Tub and Tile Refinishing Coatings	420
Waterproofing Sealers	100
Waterproofing Concrete/Masonry Sealers	100
Wood Coatings	275
Varnish	275
Sanding Sealers	275
Lacquer	275
Wood Conditioners	100
Below-Ground Wood Preservative	350
Other Coatings	350

ADHESIVES	g/L
Building Envelope Membrane Adhesive	250
Carpet Pad Adhesive	50
Ceramic Glass, Porcelain, & Stone Tile Adhesive	65
Cove Base Adhesive	50
Dry Wall and Panel Adhesive	50
Multi-Purpose Construction Adhesives	70
Roofing	
Single Ply Roof Membrane Adhesive	200
All Other Roof Adhesives	200
Rubber Floor Adhesive	60
Structural Glazing Adhesive	100
Structural Wood Member Adhesive	140
Subfloor Adhesive	50
VCT and Asphalt Tile Adhesive	50
Wood Flooring Adhesive	20
All Other Indoor Floor Covering Adhesives	50
All Other Outdoor Floor Covering Adhesives	50
Contact Adhesive	80
Edge Glue Adhesive	250
Plastic Welding Cement	
ABS Welding Cement	325
ABS to PVC Transition Cement	425
CPVC Welding Cement	400
PVC Welding Cement	425
All Other Plastic Welding Cements	100
Rubber Vulcanization Adhesive	250
Special Purpose Contact Adhesive	250
Thin Metal Laminating Adhesive	780
Top and Trim Adhesive	250
Waterproof Resorcinol Glue	170
All Other Adhesives	250
Substrate Specific Adhesives	
Metal	30
Plastic Foams	50
Porous Material (except wood)	50
Wood	30
Fiberglass	80
Reinforced Plastic Composite	200

SEALANTS	g/L
Clear, Paintable, and Water-Resistant Sealant	250
Foam Insulation	250
Foam Sealant	250
Grout	65
Roadway Sealant	250
Non-Staining Plumbing Putty	150
Potable Water Sealant	100
Roofing	
Single Ply Roof Membrane Sealant	250
All Other Roof Sealants	250
All Other Architectural Sealants	50

ADHESIVE PRIMERS	g/L
Plastic	550
Pressure Sensitive	250
All Other Adhesive Primers	250

SEALANT PRIMERS	g/L
Plastic	550
Pressure Sensitive	250
All Other Adhesive Primers	250

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Appendix I: Duke Sustainable Material Reporting Form

SUSTAINABLE MATERIAL REPORTING FORM - FOR REFERENCE ONLY

Duke Sustainable Material Reporting Form

Please complete this form for all permanently installed products within the product categories noted below. Check boxes for the appropriate product type and complete all fields as indicated. **Provide backup documentation for each environmental claim.**

Submittal Number : ____________________ Product Name or Model # : ____________________

Submittal Name : ____________________ Manufacturer : ____________________

____________________ Location of Product : (Relative to weatherproofing membrane) Interior ☐ Exterior ☐

Paints / Coatings / Adhesives / Sealants

Product VOC content (grams/Liter): ____________ g/L

SCAQMD Product Category: ____________________

SCAQMD VOC Limit: ____________ g/L *table of SCAQMD VOC categoreies and limits provided on reverse*

Type of documentation:

Manufacturer Statement ☐ *or* 3rd Party Certificate (specify) ☐ ____________________

Flooring

General Emissions Evaluation Provided: Y☐ N☐ *GEE must be in compliance with CDPH Standard Method v1.1 or later*

Type of documentation:

Testing Report ☐ *or* 3rd Party Certificate (specify) ☐ ____________________

TVOC range:

<0.5 mg/m^3 ☐ 0.5-5.0 mg/m^3 ☐ >5.0 mg/m^3 ☐

Wood

Composite Wood Product:

If yes, Confirm CARB compliance with one of the following:

ULEF ☐ *or* NAF ☐ *or* CARB Exempt ☐

All Wood Products:

Cost of New Wood (w/o site labor/equip) : ____________

Wood Species : ____________________

IUCN Designation : ____________________ *see www.icun.org or www.wood-database.com*

FSC Certified Y☐ N☐ _____%

- COC# ____________

Recycled Content Materials

Product Category ____________________ *table of tracked categories and minimum recycled value provided on reverse*

Minimum Required Recycled Content _____%

Product Recycled Content _____% *pre-consumer + post-consumer*

Manufacturer Documentation Provided: Y☐ N☐

Contractor Certification:

I ____________________ a duly authorized representative of ____________________ hereby certify that the material information contained herein is an accurate representation of the material qualifications to be provided by us, as components of the final building construction. Furthermore, I understand that any change in such qualification during the purchasing period will require prior written approval from the Construction Manager and Owner.

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