# GREEN BUILDING: THE INTEGRATION OF LEED v2009 CRITERIA IN THE BIM ENVIRONMENT

*Jakob Lawman*

Graduate Student / North Dakota State University / jakob.lawman@my.ndsu.edu

Building Information Modeling, or BIM, is the best way to manage every aspect of a building project. The only aspect that is missing is sustainability. While it may be apparent, it is not easily managed my most programs under the BIM envelope. LEED is the prominent resource for managing sustainable criteria for a building project, with incentive to award a building certification for being green. There is currently no easy or well-defined way to incorporate LEED criteria with the BIM environment. This research explores the fusion of LEED and BIM using Autodesk Revit as the central management system for a building project. The core methods in this fusion include creating a LEED template for Revit to manage supplementary documentation and using Revit parameters to define critical green building criteria for a project.

## INTRODUCTION

LEED has gained a lot of momentum in the past several years, with over 52,000 projects and 833.6 million square meters (8.9 billion square feet) becoming LEED certified space around the world. More and more companies are striving to become more sustainable, and LEED certification is one way of making sure all of the key components of green building are addressed. The USGBC (United States Green Building Council) and the GBCI (Green Building Certification Institute) have set up LEED Online, a website used to register a project, upload required information, and ultimately grant LEED certification.

LEED Online is a great way to manage LEED certification, but it could be better. BIM (Building Information Modeling) is the best way to manage an entire building project throughout all phases of design, focusing on every aspect and system of a building and their integration with one another. Integrating the LEED certification process with BIM software would be ideal. All of the required statistics and intricate details involved in the LEED certification process could be implemented in a BIM management program—Autodesk Revit, for example—in the form of a plug-in that could export data directly to LEED Online, streamlining the process of submitting information to the USGBC and GBCI.

Currently, all information must be submitted manually via the LEED Online website. This system works, but it could definitely be improved upon through software integration as mentioned above. The research documented in this article studies the current ability of these two entities—BIM and LEED—to integrate with one another. Different methods of integration are attempted and discussed and solutions to problem are suggested.

**RESEARCH METHODOLOGY**

How can LEED criteria be implemented into the BIM practices used in an architecture firm? Initial research on this topic turned up empty. There were a few results, but instead of talking about the actual process of implementing LEED, they just discussed possibilities. The USGBC website and their resources for the LEED certification process became the primary source of information. The LEED Handbook for New Construction and Major Renovations and LEED Online became the two most valuable sources informing the research.

The first endeavor attempted was translating LEED Online into an Excel workbook that could be managed offline throughout the entire design process (which later proved to be an unproductive tactic to mesh BIM and LEED). The idea was this: parameters pertaining to the LEED certification process could be defined in Autodesk Revit, exported to a Microsoft Excel workbook via IFC (Industry Foundation Classes), and linked to a master LEED Excel workbook. The master Excel workbook was divided into sheets based on each LEED prerequisite and credit in the LEED Handbook for New Construction and Major Renovations. Each sheet had cells with different criteria that could be entered manually or linked to a Revit-exported Excel workbook containing the appropriate values. The entire Excel workbook was formatted with radio buttons, check boxes, and formulas to automate as many of the calculations and options as possible.

The first step in the process was to create a list of shared parameters that could be applied to a project in Revit. These shared parameters were divided into groups based on the LEED credit categories— Sustainable Sites, Water Efficiency, Energy & Atmosphere, Materials & Resources, Indoor Environmental Quality—and general project information required for LEED calculations. This list of parameters originally included criteria such as "Percent Salvaged/Reused Material," "Fixture Flow Rate," and even "Project Zip Code." These values were then exported from Revit as an IFC file.

SimpleBIM, an advanced IFC management program used to examine, filter, and export IFC properties, was used to open the IFC file. Using this program, it became possible to exclude Revit parameters that are

irrelevant to the LEED certification process.  Once the specified criteria were selected, they were exported to an Excel workbook.  Fields from this Excel workbook were then linked to the master LEED Excel workbook, containing all of the fields pertinent to the LEED prerequisites and credits.  All of the values not contained in the IFC-exported Excel workbook would then be entered manually until all of the cells were full.

## RESEARCH PRODUCTS

There were three main deliverables produced from the research.  The first was an Excel spreadsheet mimicking the functionality of LEED Online, the second a template file for Revit, and the third a Revit shared parameter file.

The Excel spreadsheet was discussed above, and was subsequently dropped from the research after determining it was unnecessary (see Project Limitations).  To replace the goal that the Excel spreadsheet was attempting to achieve, a LEED-based template file was created for Revit.  This template is set up with sheets pertaining to some of the supplementary documentation that must be uploaded to LEED Online for certification.  These sheets include floor plans, site plans, sections, elevations, plumbing schedules, mechanical schedules, and other drawings that Revit is capable of producing.  Other supplementary documents not included in the Revit template are excerpts from employee handbooks, photographs, and legal documents, which are more easily produced using other means.

The other deliverable is a shared parameter file containing LEED criteria that can be assigned to different components in Revit.  These parameters include properties like baseline and installed flush and flow rates, types of refrigerant used in HVAC systems, and the percentage of recycled or salvaged material in a project. While the main goal of these parameters is to define LEED criteria directly in the Revit model, they also define sustainable properties of project components right from the start, instead of making it an after-thought.

**LEED FOR NEW CONSTRUCTION AND MAJOR RENOVATIONS v2009 CHECKLIST**

The following pages contain a list of all the prerequisites and credits for the LEED for New Construction and Major Renovations v2009 checklist.  Listed for each prerequisite and credit is their relationship to the LEED Template and LEED Parameters, specifying which relevant supplementary documentation is possible within Revit and what parameters would be helpful in informing LEED Online.  The format is as follows:

## NAME OF CREDIT CATEGORY

### Name and Number of Prerequisite/Credit
**TEMPLATE.** *The following supplementary documents can be fulfilled in the Revit LEED Template:*
- Ø   AAc1. Description of the supplementary document.

**PARAMETERS.** *The following parameters pertain to this credit*
- Ø   LEED Parameter Name

### Credit Category Parameters

| PARAMETER NAME | TYPE |
|---|---|
| Ø   LEED Parameter Name | Parameter Type |

*Description of what parameter is used for.*
Applies to the following Revit Categories:
- ø   List of Revit categories that would be checked when making a project parameter

## SUSTAINABLE SITES

### Prerequisite 1. Construction Activity Pollution Prevention
*LEED Template and LEED Parameters are not applicable.*

### Credit 1: Site Selection
*LEED Template and LEED Parameters are not applicable.*

### Credit 2: Development Density & Community Connectivity
**TEMPLATE.** *The following supplementary documents can be fulfilled in the Revit LEED Template:*
- Ø   SSc2-1. Area plan, which includes the development density radius, property identifiers, and a scale

Ø   SSc2-2. Area plan showing the ½ mile radius of the surrounding area or neighborhood with an average density of at least 10 units per acre, at least 10 basic services with pedestrian access, and a scale

**Credit 3: Brownfield Development**

*LEED Template and LEED Parameters are not applicable.*

**Credit 4.1: Alternative Transportation – Public Transportation Access**

TEMPLATE. *The following supplementary documents can be fulfilled in the Revit LEED Template:*

Ø   SSc4.1-2. Site plan with scale, showing the walking path from the project building main entrance to the rail stop

Ø   SSc4.1-3. Site plan with scale, showing the walking path from the project building main entrance to bus stops

**Credit 4.2: Alternative Transportation – Bicycle Storage & Changing Rooms**

TEMPLATE. *The following supplementary documents can be fulfilled in the Revit LEED Template:*

Ø   SSc4.2-1. Site plan identifying the location of the bicycle racks and/or storage facilities

**Credit 4.3: Alternative Transportation – Low-Emitting and Fuel-Efficient Vehicles**

TEMPLATE. *The following supplementary documents can be fulfilled in the Revit LEED Template:*

Ø   SSc4.3-1. Site plan showing all parking areas, highlighting any preferred parking, including signage details

Ø   SSc4.3-3. Site plan showing the alternative-fuel fueling stations

Ø   SSc4.3-6. Site plan identifying low-emitting/fuel-efficient parking area (which is the nearest available spaces in the nearest available parking area), highlights the walking path from low-emitting/fuel-efficient vehicle parking area to the project site, and notes the distance between parking area and project building.

PARAMETERS. *The following parameters pertain to this credit:*

Ø   LEED Customer Parking

Ø   LEED Employee Parking

Ø   LEED Preferred Parking

**Credit 4.4: Alternative Transportation – Parking Capacity**

PARAMETERS. *The following parameters pertain to this credit:*

Ø   LEED Customer Parking

Ø   LEED Employee Parking

Ø   LEED Preferred Parking

**Credit 5.1: Site Development – Protect or Restore Habitat**

*LEED Template and LEED Parameters are not applicable.*

**Credit 5.2: Site Development – Maximize Open Space**

**TEMPLATE.** *The following supplementary documents can be fulfilled in the Revit LEED Template:*

- Ø SSc5.2. Site plan showing the project site boundaries and highlights all open space and/or pedestrian-oriented hardscape areas contributing to credit achievement

### Credit 6.1: Stormwater Design – Quantity Control

*LEED Template and LEED Parameters are not applicable.*

### Credit 6.2: Stormwater Design – Quality Control

*LEED Template and LEED Parameters are not applicable.*

### Credit 7.1: Heat Island Effect – Nonroof

**TEMPLATE.** *The following supplementary documents can be fulfilled in the Revit LEED Template:*

- Ø SSc7.1. Site plan identifying all hardscape and parking areas at the project site

### Credit 7.2: Heat Island Effect – Roof

**TEMPLATE.** *The following supplementary documents can be fulfilled in the Revit LEED Template:*

- Ø SSc7.2. Project roof plan(s) or drawing(s) depicting the project roof area and highlighting the location and quantity of specific roofing materials areas and/or vegetated roofing systems if applicable

### Credit 8: Light Pollution Reduction

**TEMPLATE.** *The following supplementary documents can be fulfilled in the Revit LEED Template:*

- Ø SSc8-1. Documentation (such as plans or drawings) showing the location of automatic lighting controls
- Ø SSc8-3. Drawings illustrating the location of automatic shading devices
- Ø SSc8-6. Exterior photometric site plan showing the LEED project boundary and point-by-point candle levels 10 feet beyond for LZ2 and 15 feet beyond for LZ3 and LZ4.

### Sustainable Sites Parameters

| PARAMETER NAME | TYPE |
|---|---|
| Ø LEED Customer Parking | Yes/No |

*Specifies whether or not parking space is for customer use.*

Applies to the following Revit Categories:

- ø Parking

| | |
|---|---|
| Ø LEED Employee Parking | Yes/No |

*Specifies whether or not parking space is for employee use.*

Applies to the following Revit Categories:

- ø Parking

| | |
|---|---|
| Ø LEED Preferred Parking | Yes/No |

*Specifies whether or not parking space is for use by low-emitting or fuel-efficient vehicles.*

Applies to the following Revit Categories:

ø    Parking

**WATER EFFICIENCY**

**Prerequisite 1: Water Use Reduction**

    **TEMPLATE.** *The following supplementary documents can be fulfilled in the Revit LEED Template:*

        Ø    WEp1-1. Plumbing fixture and fitting schedule highlighting flush and flow rates for all applicable plumbing fixtures and fittings within the project building

    **PARAMETERS.** *The following parameters pertain to this credit*

| | |
|---|---|
| Ø    LEED Baseline Flush Rate (gpf) | Ø    LEED Installed Flush Rate (gpf) |
| Ø    LEED Baseline Flow Rate (gpm) | Ø    LEED Installed Flow Rate (gpm) |

**Credit 1: Water Efficient Landscaping**

    **TEMPLATE.** *The following supplementary documents can be fulfilled in the Revit LEED Template:*

        Ø    WEc1-1. Site plan showing the landscaped areas

**Credit 2: Innovative Wastewater Technology**

    *LEED Template and LEED Parameters are not applicable.*

**Credit 3: Water Use Reduction**

    *LEED Template and LEED Parameters are not applicable.*

**Water Efficiency Parameters**

| PARAMETER NAME | TYPE |
|---|---|
| Ø    LEED Baseline Flush Rate (gpf) | Number |

*The baseline flush rate for a fixture as specified by EP Act 1992*

Applies to the following Revit Categories:

    ø    Plumbing Fixtures

| | |
|---|---|
| Ø    LEED Baseline Flow Rate (gpf) | Number |

*The baseline flow rate for a fixture as specified by EP Act 1992*

Applies to the following Revit Categories:

    ø    Plumbing Fixtures

| | |
|---|---|
| Ø    LEED Installed Flush Rate (gpf) | Number |

*The installed flush rate for a fixture as specified by the product manufacturer*

Applies to the following Revit Categories:

    ø    Plumbing Fixtures

| | |
|---|---|
| Ø    LEED Installed Flow Rate (gpf) | Number |

*The installed flow rate for a fixture as specified by the product manufacturer*

Applies to the following Revit Categories:

    ø    Plumbing Fixtures

**ENERGY & ATMOSPHERE**

**Prerequisite 1: Fundamental Commissioning of Building Energy Systems**

TEMPLATE. *The following supplementary documents can be fulfilled in the Revit LEED Template:*

- Ø EAp2-1. Floor plan(s) indicating the location of CO2 sensors installed as part of the demand control ventilation system

**Prerequisite 2: Minimum Energy Performance**

*LEED Template and LEED Parameters are not applicable.*

**Prerequisite 3: Fundamental Refrigerant Management**

PARAMETERS. *The following parameters pertain to this credit:*

- Ø LEED Refrigerant Used

**Credit 1: Optimize Energy Performance**

TEMPLATE. *The following supplementary documents can be fulfilled in the Revit LEED Template:*

- Ø EAc1-1. Cutsheets or other documentation indicating the daylight controls installed or specified in the project
- Ø EAc1-2. Drawings indicating daylight areas
- Ø EAc1-3. Summary calculations confirming at least 40% reduction in connected lighting load for the project building
- Ø EAc1-4. Cut sheets, summary calculations, or other documentation demonstrating that all commercial refrigeration and ice-making equipment is in compliance

**Credit 2: On-Site Renewable Energy**

*LEED Template and LEED Parameters are not applicable.*

**Credit 3: Enhanced Commissioning**

*LEED Template and LEED Parameters are not applicable.*

**Credit 4: Enhanced Refrigerant Management**

PARAMETERS. *The following parameters pertain to this credit:*

- Ø LEED Refrigerant Used
- Ø LEED Use of Refrigerant

**Credit 5: Measurement & Verification**

*LEED Template and LEED Parameters are not applicable.*

**Credit 6: Green Power**

*LEED Template and LEED Parameters are not applicable*

**Energy & Atmosphere Parameters**

| PARAMETER NAME | TYPE |
|---|---|

Ø   LEED Refrigerant Used                                    Text

*Used to specify the type of refrigerant used in a component (CFC-11, HFC-23, Ammonia, etc.)*

Applies to the following Revit Categories:

   ø   Mechanical Equipment

Ø   LEED Use of Refrigerant                                  Yes/No

*Used to specify whether or not a component uses refrigerants*

Applies to the following Revit Categories:

   ø   Mechanical Equipment


## MATERIALS & RESOURCES

### Prerequisite 1: Storage and Collection of Recyclables

**TEMPLATE.** *The following supplementary documents can be fulfilled in the Revit LEED Template:*

Ø   MRp1-2. Floor plan highlighting the recycling storage areas in the project

### Credit 1.1: Building Reuse – Maintain Existing Walls, Floors, and Roof

*LEED Template and LEED Parameters are not applicable.*

### Credit 1.2: Building Reuse – Maintain Interior Nonstructural Elements

*LEED Template and LEED Parameters are not applicable.*

### Credit 2: Construction Waste Management

*LEED Template and LEED Parameters are not applicable.*

### Credit 3: Materials Reuse

**PARAMETERS.** *The following parameters pertain to this credit:*

Ø   LEED CSI Division                    Ø   LEED Material Cost

Ø   LEED Description of Material          Ø   LEED Percent Salvaged/Reused

Ø   LEED Manufacturer/Vendor

### Credit 4: Recycled Content

**PARAMETERS.** *The following parameters pertain to this credit:*

Ø   LEED CSI Division                    Ø   LEED Percent Pre-Consumer Recycled

Ø   LEED Description of Material              Content

Ø   LEED Manufacturer/Vendor             Ø   LEED Percent Post-Consumer Recycled

Ø   LEED Material Cost                       Content

### Credit 5: Regional Materials

**TEMPLATE.** *The following supplementary documents can be fulfilled in the Revit LEED Template:*

Ø   MRc5-1. Cutsheets for 20% of the materials (by cost) to support regional material claims

**PARAMETERS.** *The following parameters pertain to this credit:*

Ø LEED CSI Division | Ø LEED Manufacture Distance (mi)

Ø LEED Description of Material | Ø LEED Extraction Distance (mi)

Ø LEED Manufacturer/Vendor | Ø LEED Percent Regional

Ø LEED Material Cost

## Credit 6: Rapidly Renewable Materials

**TEMPLATE.** *The following supplementary documents can be fulfilled in the Revit LEED Template:*

Ø MRc6-1. Cutsheets for 20% of the materials (by cost) to support rapidly renewable material claims

**PARAMETERS.** *The following parameters pertain to this credit:*

Ø LEED CSI Division | Ø LEED Material Cost

Ø LEED Description of Material | Ø LEED Renewable Material Type

Ø LEED Manufacturer/Vendor | Ø LEED Percent Rapidly Renewable

## Credit 7: Certified Wood

**PARAMETERS.** *The following parameters pertain to this credit:*

Ø LEED CSI Division | Ø LEED Percent New Wood

Ø LEED Description of Material | Ø LEED Percent New Wood that is FSC

Ø LEED Manufacturer/Vendor |    Certified

Ø LEED Material Cost

## Materials & Resources Parameters

| PARAMETER NAME | TYPE |
| --- | --- |

Ø LEED CSI Division     Text

*Used to specify the CSI Division of the material*

Applies to the following Revit Categories:

    ø *See appended list: LEED Materials & Resources Revit Parameter Categories*

Ø LEED Description of Material     Text

*Used to provide a short description of the material*

Applies to the following Revit Categories:

    ø *See appended list: LEED Materials & Resources Revit Parameter Categories*

Ø LEED Manufacturer/Vendor     Text

*Used to specify the manufacturer or vendor of the material*

Applies to the following Revit Categories:

    ø *See appended list: LEED Materials & Resources Revit Parameter Categories*

Ø LEED Material Cost     Currency

*Used to specify the cost of the material*

Applies to the following Revit Categories:

    ø *See appended list: LEED Materials & Resources Revit Parameter Categories*

Ø LEED Extraction Distance   (mi)                                    Length

*Used to specify the distance from the project site that the material was extracted*

Applies to the following Revit Categories:

    ø   *See appended list: LEED Materials & Resources Revit Parameter Categories*

Ø LEED Manufacture Distance (mi)                                    Length

*Used to specify the distance from the project site that the material was manufactured*

Applies to the following Revit Categories:

    ø   *See appended list: LEED Materials & Resources Revit Parameter Categories*

Ø LEED Percent New Wood                                             Number

*Used to specify the percentage of new wood in a component*

Applies to the following Revit Categories:

    ø   *See appended list: LEED Materials & Resources Revit Parameter Categories*

Ø LEED Percent New Wood that is FSC Certified          Number

*Used to specify the percentage of new wood in a component that is FSC certified*

Applies to the following Revit Categories:

    ø   *See appended list: LEED Materials & Resources Revit Parameter Categories*

Ø LEED Percent Post-Consumer Recycled Content          Number

*Used to specify the percentage of post-consumer recycled content contained in a component*

Applies to the following Revit Categories:

    ø   *See appended list: LEED Materials & Resources Revit Parameter Categories*

Ø LEED Percent Pre-Consumer Recycled Content          Number

*Used to specify the percentage of pre-consumer recycled content contained in a component*

Applies to the following Revit Categories:

    ø   *See appended list: LEED Materials & Resources Revit Parameter Categories*

Ø LEED Percent Rapidly Renewable                             Number

*Used to specify the percentage of rapidly renewable materials in a component*

Applies to the following Revit Categories:

    ø   *See appended list: LEED Materials & Resources Revit Parameter Categories*

Ø LEED Percent Regional                                             Number

*Used to specify the percentage of materials considered "regional" by LEED standards*

Applies to the following Revit Categories:

    ø   *See appended list: LEED Materials & Resources Revit Parameter Categories*

Ø LEED Percent Salvaged/Reused                             Number

*Used to specify the percentage of salvaged or reused material in a component*

Applies to the following Revit Categories:

    ø   *See appended list: LEED Materials & Resources Revit Parameter Categories*

Ø  LEED Renewable Material Type                    Text

*Used to specify the type of rapidly renewable material used in a component*

Applies to the following Revit Categories:

      *ø  See appended list: LEED Materials & Resources Revit Parameter Categories*

Ø  Appended List: LEED Materials & Resources Revit Parameter Categories

| | |
|---|---|
| ø  Casework | ø  Roofs |
| ø  Ceilings | ø  Stairs |
| ø  Columns | ø  Structural Beam Systems |
| ø  Doors | ø  Structural Columns |
| ø  Floors | ø  Structural Foundations |
| ø  Furniture | ø  Structural Framing |
| ø  Furniture Systems | ø  Walls |
| ø  Railings | ø  Windows |

## INDOOR ENVIRONMENTAL QUALITY (15)

### Prerequisite 1: Minimum Indoor Air Quality Performance

*LEED Template and LEED Parameters are not applicable.*

### Prerequisite 2: Environmental Tobacco Smoke (ETS) Control

**TEMPLATE.** *The following supplementary documents can be fulfilled in the Revit LEED Template:*

Ø  IEQp2-4. Drawing(s) or photo(s) documenting signage communicating the interior smoking policy.

### Credit 1: Outdoor Air Delivery Monitoring

**TEMPLATE.** *The following supplementary documents can be fulfilled in the Revit LEED Template:*

Ø  IEQc1-1. A controls drawing sample showing outdoor airflow measurement devices that serve non-densely occupied spaces.

Ø  IEQc1-2. Floor plan highlighting the location of CO2 sensors

Ø  IEQc1-3. Floor plan highlighting the location and size of naturally ventilated zones and associated windows, as well as the locations of CO2 sensors

### Credit 2: Increased Ventilation

**TEMPLATE.** *The following supplementary documents can be fulfilled in the Revit LEED Template:*

Ø  IEQc2-1. Documentation demonstrating the flow diagram process in Figure 2.8 of the CIBSE Application Manual 10: 2005, Natural Ventilation in Non-domestic Buildings was used to determine that natural ventilation is an effective strategy for this project

Ø IEQc2-2. Diagrams and calculations demonstrating the design of the natural ventilation systems meets the recommendations set forth in the CIBSE Applications Manual 10: 2005, Natural Ventilation in Non-domestic Buildings

Ø IEQc2-3. Documentation demonstrating the design of the natural ventilation systems meets the recommendations set forth in the CIBSE Applications Manual 13: 2000, Mixed Mode Ventilation

**Credit 3.1: Construction Indoor Air Quality Management Plan – During Construction**

*LEED Template and LEED Parameters are not applicable.*

**Credit 3.2: Construction Indoor Air Quality Management Plan – Before Occupancy**

*LEED Template and LEED Parameters are not applicable.*

**Credit 4.1: Low-Emitting Materials – Adhesives and Sealants**

**PARAMETERS.** *The following parameters pertain to this credit:*

Ø LEED Allowable VOC Content

Ø LEED Actual VOC Content

**Credit 4.2: Low-Emitting Materials – Paints and Coatings**

**PARAMETERS.** *The following parameters pertain to this credit:*

Ø LEED Allowable VOC Content

Ø LEED Actual VOC Content

**Credit 4.3: Low-Emitting Materials – Flooring Systems**

**PARAMETERS.** *The following parameters pertain to this credit:*

Ø LEED Allowable VOC Content

Ø LEED Actual VOC Content

**Credit 4.4: Low-Emitting Materials – Composite Wood and Agrifiber Products**

**PARAMETERS.** *The following parameters pertain to this credit:*

Ø LEED Urea-Formaldehyde

**Credit 5: Indoor Chemical and Pollutant Source Control**

**TEMPLATE.** *The following supplementary documents can be fulfilled in the Revit LEED Template:*

Ø IEQc5-1. Floor plan(s) showing entryway location(s) and measurement(s)

Ø IEQc5-2. Mechanical drawing(s) highlighting the location of chemical/hazardous gas usage areas, room separations, and associated exhaust systems

Ø IEQc5-3. Mechanical schedule(s) (or similar documentation) listing the filter rating for all air handling units installed in the project

**Credit 6.1: Controllability of Systems – Lighting**

**TEMPLATE.** *The following supplementary documents can be fulfilled in the Revit LEED Template:*

Ø IEQc6.1-1. Drawings/floor plans identifying the lighting controls declared in Tables IEQ6-1 and IEQ6-2 on LEED Online

### Credit 6.2: Controllability of Systems – Thermal Comfort

**TEMPLATE.** *The following supplementary documents can be fulfilled in the Revit LEED Template:*

Ø IEQc6.2-1. Drawings/floor plans identifying the thermal comfort controls declared in Tables IEQ6-1 and IEQ6-2 on LEED Online

### Credit 7.1: Thermal Comfort – Design

*LEED Template and LEED Parameters are not applicable.*

### Credit 7.2: Thermal Comfort – Verification

*LEED Template and LEED Parameters are not applicable.*

### Credit 8.1: Daylight & Views – Daylight

**TEMPLATE.** *The following supplementary documents can be fulfilled in the Revit LEED Template:*

Ø IEQc8.1-1. Floor plan highlighting regularly occupied space and daylighted areas/zones

Ø IEQc8.1-3. Project drawing(s) with the recorded daily measurements

### Credit 8.2: Daylight & Views – Views

**TEMPLATE.** *The following supplementary documents can be fulfilled in the Revit LEED Template:*

Ø IEQc8.2-1. Plan view drawings, floor plans, photographs, or other documentation demonstrating line of sight from interior spaces through exterior windows

Ø IEQc8.2-2. Sections or interior elevations with glazing elements and sight lines, drawn from typical seated height, for the areas claimed in the views section of Upload L-8.

### Indoor Environmental Quality Parameters

| PARAMETER NAME | TYPE |
|---|---|
| Ø LEED Allowable VOC Content | Text |

*Used to specify the allowable levels of VOCs in a component as specified by the LEED for New Construction & Major Renovations Handbook*

| Ø LEED Actual VOC Content | Text |
|---|---|

*Used to specify the actual levels of VOCs in a component*

| Ø LEED Urea-Formaldehyde | Yes/No |
|---|---|

*Used to specify whether or not a component uses Urea-Formaldehyde*

## INNOVATION IN DESIGN

### Credit 1: Innovation in Design

*LEED Template and LEED Parameters are not applicable.*

### Credit 2: LEED Accredited Professional

*LEED Template and LEED Parameters are not applicable.*

## REGIONAL PRIORITY

### Credit 1: Regional Priority
*LEED Template and LEED Parameters are not applicable.*

## MISCELLANEOUS LEED TEMPLATE ITEMS

- Ø  L-1. Floor plans for the project building
- Ø  L-1.1. Floor plan for the project building indicating the areas served by a combination of natural and mechanical ventilation or conditioning systems
- Ø  L-2. Site plan identifying the LEED project boundary
- Ø  L-3. Mechanical schedules
- Ø  L-4. Mechanical plans and/or drawings
- Ø  L-5. Section and/or elevation supporting the window areas claimed in the sidelighting section of Upload L-8
- Ø  L-9. Sections or interior elevations including gazing elements and sight lines, drawn from typical seated height, for the areas claimed in the views section of Upload L-8
- Ø  L-14. Graphic and numeric summary of the airflow analysis performed, including the boundary conditions used for analysis, simulation algorithm, solution variables, temperatures, airflow volumes, and mean age of air for the spaces modeled
- Ø  Plf4-3. Project building section(s)/elevation(s).

## PROJECT LIMITATIONS

LEED and BIM are still a long way from working coherently.  The findings documented in the research determine that Revit, the main component of BIM software the research was conducted with, is not green building friendly.  LEED exists within its own environment, separate from BIM.  There is software available that will simulate components of sustainable design and LEED criteria.  For this research, Revit was the centerpiece of the research conducted and the main tool for managing the Revit project.

The first limitation encountered by the research was the inability to directly facilitate the export of LEED criteria from Revit to LEED Online.  Several processes were attempted, as noted in the research documentation.  The problem with all of the different approaches was how redundant many of the steps were and how backwards-thinking it all was.  What is the reason for an Excel workbook that is nearly identical to the web forms on LEED Online?  The process created one extra, unnecessary step that could easily be avoided by entering the information on LEED Online in the first place, rather than going through the tedious process of exporting parameters from Revit, filtering them with third-party software, exporting them to one Excel file, linking them to a master Excel workbook, and using a third-party program to code the transfer of information from an Excel workbook to a complex set of web forms (LEED Online).

The other limitations relate directly to the Excel workbook.  LEED Online uses checkboxes, radio buttons, and drop-down menus with very specific values.  To ensure that all the LEED criteria would be transferred properly from Revit to the LEED Online web forms, the parameter values would need to be entered in Revit the same way they appear on LEED Online.  This would pose a problem for project teams having to reference the way a value is formatted on LEED Online while making the Revit model.  It is possible; it is just more tedious than is necessary.

Excel also managed checkboxes and radio buttons in a way that hindered the performance and ease-of-use for the spreadsheets.  It became very difficult to make the workbook user-friendly simply because there was so much information presented at once.  There is the ability to hide and show cells based on the selection of a radio button, which will allow you to see only the relevant information to the design choices you are making in relation to the LEED checklist, but its functionality was restricted and did not allow for nested check boxes and radio buttons in more complex series of decision making.  Cells collapse and expand, but radio buttons and checkboxes contained within those collapsed cells remain unhidden.  A solution to this problem was not addressed in the time spent creating the LEED Excel workbook.  It was determined infeasible partway through the research due to its redundant nature, as stated in the first limitation.

**PROJECTION OF FINDINGS INTO PRACTICE**


The two main deliverables that made it to the end of the research – the LEED Revit template and LEED parameters – are the beginning of a fusion between LEED and BIM.  For managing LEED Online uploads, the Revit template becomes a useful tool.  The LEED parameters serve the function of implementing green building design into components to make the Revit user more aware of the sustainable properties contained by a component.


There are several supplementary documents that must be given attention and uploaded to LEED Online.  For some documents, such as floor plans, site plans, sections, elevations, and schedules, the easiest way to complete them would be in Revit.  Other documents, like employee handbooks and legal forms, are best completed using other software or resources produced outside of the program.


The USGBC lists several criteria for each prerequisite and credit that it evaluates to determine LEED certification.  Many of these do not show up in Revit anywhere, so a shared parameter file will incorporate green building and LEED-related parameters to Revit components, such as the installed flush and flow rates for water closets or refrigerants used in mechanical systems.  These criteria are things that show up somewhere while working on a project, but now they will be in the project right from the start, at the heart of BIM as part of the central building model.


To improve the relationship between LEED and the BIM environment, the world of software has several obstacles to overcome.  First, LEED Online is its own separate entity – a web form that must be manually filled out based on information from a myriad of sources.  An ideal solution would be the integration of the LEED certification process with software, such as Revit, in the form of a plug-in from the USGBC (or a third party associated with LEED).  There are several tables and charts on LEED Online with values that could be filled out as parameters in Revit and then exported via an (imagined) "Export to LEED Online" button in Revit,

and the values would then be uploaded to the LEED Online cloud of information.  Supplementary documentation could be uploaded this way as well via an "Export Sheet to LEED Online" option.

The integration between BIM and LEED has a long way to go.  Ultimately, "green building" and "sustainable design" will evolve into simply "building" and "design," doing away with the need to specify that sustainability is being addressed by each, but is instead the new standard.  When this day comes, green building criteria will be at the core of the BIM environment.

**CONCLUSION**

The relationship between LEED and BIM is a complex one.  There are many areas in which BIM excels, and green building design is currently not one of those areas.  The green building criteria of the LEED rating system can be integrated with BIM, but not without a complicated setup and delivery method.  Using Revit sheets, Revit parameters, and fields exported to Excel can be tedious and is not the ideal way to handle criteria for LEED.  Integrating one with the other needs to be easier.  There is no longer a divide between sustainable design and design – there is only how sustainable as design is.  Since sustainability and LEED have become so commonplace, companies involved in the development in BIM software need to work with the USGBC's LEED standards and criteria in order to improve the relationship between the two.  Only then will LEED and BIM coexist with one goal in mind: delivering a sustainable, LEED certified building using the best software and delivery methods possible.