POLITECNICO DI MILANO

Dipartimento A:B.C.

Dipartimento di Architettura, Ingegneria delle Costruzioni e Ambiente costruito

Department Architecture, Built environment and Construction engineering. ABC

DOTTORATO DI RICERCA TEPAC

TECNOLOGIA e PROGETTO DELL'AMBIENTE COSTRUITO
25 ciclo

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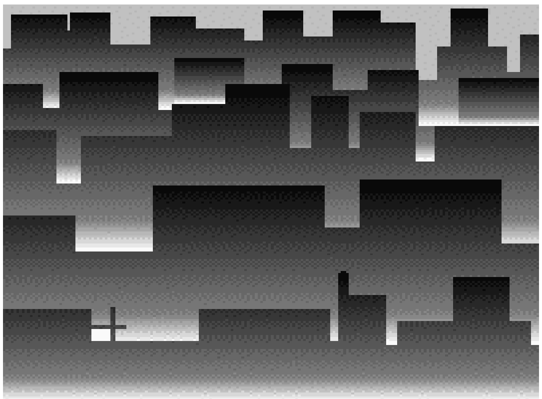
Matricolo: 756123

Developing a Systemic framework for Applying LEED System

Managing Energy and Materials Credits



Tutor: Prof.ssa Anna Mangiarotti

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Dottorando/a :

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ABSTRACT

LEED system is one of the mostly diffused Green Building Rating systems, yet there is no defined framework on how to apply LEED system along the building process- as a Mean Not as an End itself. Hence, the research defines and develops the scopes and limits of operation of the LEED system establishing a proposed systemic framework for practitioners to apply LEED through an integrated process as well as individual practices- focusing on environmental considerations. The proposed framework is based on differentiating between two interrelated mechanisms of operation of Green Building Rating systems; 'Rating' and 'Certification' mechanisms; the Rating Mechanism, which includes acting as a (Guideline and Decision making support tool) covers organizational and operational aspects to achieve sustainable building process and as a (Measurement and Benchmarking tool) to assess sustainable building performance. Then, it discusses LEED system's verification and certification mechanism, which includes quality assurance methods provided by the system to verify sustainable building performance, e.g. Commissioning, Measurement and Verification, Post Occupancy Evaluation and Life Cycle Assessment- providing for the quality, which factors in the system's certification and market performance, hence determines the value and sets the price of LEED certified projects. Each scope represents a distinct role played by LEED system in the building process, and the contribution of each scope is what constitutes the whole system thinking. All four scopes should be applied in a systemic iterative manner within the correct timeframe, to support the decision making process and reach optimized management process. The framework was applied on both energy and materials credits- which represent almost half the total weight assigned for LEED credits and main source of criticism for the system. The research applies the proposed systemic framework along different project stages, to present a 'Know how' for practitioners. Then the research tests and validates the proposed framework for some of the *Materials and Resources* and *Energy and Atmosphere* credits, using two case studies: one is a new construction project (Science Museum in Trento), and the other is a major renovation project (Palazzo Ricordi Berchet) to explore the effect of using the suggested framework on different building types and contexts, as well as using different LEED rating systems and versions on the management process. Then a final step of adjustments is presented for the proposed research framework based on findings from the testing step.

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AKNOWLEDGEMENT

I thank holly merciful god for granting me all his blessings…I thank him for giving me the strength and wisdom to conduct this research work inspite of all difficulties, and to him I dedicate my work...may he accept with blessings.

Also, I dedicate my work to my family, my mother whose support, encouragement and greatest sacrifice were the main motives for my success; to her I owe my love to life, knowledge and my continuous search to reach higher goals, to my father-unc. Mohamed - whose prayers were the light on my way. A special dedication must be granted to my dear sister Doaa, who is closer to me than my soul. To my husband for his sacrifice and support, and above all to my little sons, who have filled my life with infinite love and happiness.

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ABBREVIATIONS AND NOTATIONS

ASHRAE: American Society of Heating, Refrigerating and Air-Conditioning Engineers

BAS: Building Automation System

BOD: Basis of design

C(x): Credit number

Cx: Commissioning

CxA: Commissioning authority

CD: Construction drawings

CER: Catalogo Europeo dei Rifiuti (European Waste code)

C&D WM: Construction and demolition waste management

CWM plan: Construction Waste Management plan

DD: Design drawings

DFD: Design for disassembly

DFDD: Design for disassembly and deconstruction

EA: Energy and atmosphere

EC: Embodied Carbon

ECMs: Energy conservation measures

EE: Embodied energy

EOL: End of Life

EPA: U.S. Environmental Protection Agency

EPD: Environmental Product Declarations

EQ: Environmental Quality

ESCO(s): Energy Service Companies

EBCx: Existing building commissioning

FSC: Forest Stewardship Council

GBCI: Green Building Council Institute

GBRS: Green Building Rating system(s)

G.C.: General Contractor

HVAC: Heating, Ventilation and Air Conditioning

IAQ: Indoor Environmental Quality

ID: Innovation in design

IPMVP: International Performance Measurement and Verification Protocol

ISO: International Organization of Standards documents

LCA; Life Cycle Assessment approach

LCC: Life Cycle Costing

LCI Life Cycle Inventory

LCIA Life Cycle Impact Assessment

LEED: Leadership in Energy and Environmental Design

LEED V(x): LEED version (x)

LEED AP: LEED Accredited Professional
LEED EB: LEED for Existing Building
LEED CI: LEED for Commercial Interior
LEED CS: LEED for Core and Shell
LEED NC: LEED for New construction and major renovations
LEED ND: LEED for Neighborhood Development
M&V process: Measurement and Verification Process
MOU; Memorandum Of Understanding
MPR: Minimum Program Requirement
MR: Materials and resources
O&M: Operation and Maintenance
OPR: Owner project requirement
PEFC: Programme for the Endorsement of Forest Certification
PV: Photo Voltaic
POE: Post Occupancy Evaluation
Pre(x): prerequisite number
R-value: Thermal resistance
R & id: Research and identify
RP: Regional priority
SS: Sustainable Sites
TRACI: Tool for the Reduction and Assessment of Chemical and Other Environmental Impacts
USGBC: United States Green Building Council
VOC(s): Volatile Organic Compound(s)
WE: Water Efficiency
NFRC; the National Fenestration Rating Council
LBNL: Lawrence Berkeley National Laboratory
VRF units: Variable refrigerant flow – a technology for heating and cooling

DEFINITION OF TERMS

Adaptability: for the purpose of the research, the term was used to indicate the potentials of Green building rating systems to cope with various contexts.
Applicability: for the purpose of the research, the term was used to indicate the potentials of Green building rating systems to cope with various building types.
Basis of Design (BOD): This step is performed by design team and it is important to take place prior to contractors' submittals of any commissioned equipment or systems. CxA review BOD to ensure it reflects OPR. It includes narrative for the design of the systems to be commissioned and any design assumptions including: a) *Primary design assumptions:* (space use, redundancy, diversity, climatic design conditions, zoning, occupancy, operation and space environmental requirements), b) *Standards* (including

codes, guidelines and regulations), c) *Narrative:* for performance criteria of HVAC&R systems, lighting, hot water systems and onsite power systems (LEED NC reference guide, 2009).

Benchmarking; is the process of comparing sustainable building performance to other similar buildings and to the building itself (BCA, 2008) to determine improvement, optimization, and saving potentials (AIA, 2010).

Building codes; they are enforceable body of rules that govern the design, construction, alteration, and repair of buildings, whereas standards outline a series of options for performance of building systems and assemblies and are often referenced by codes but are not alone enforceable, unless adopted as part of a code (AIA, 2010)

Commissioning; is a systematic process of verifying and documenting that a building and all of its systems and assemblies are planned, designed, installed, tested, operated, and maintained to meet the owner's project requirements (OPR), Basis of design (BOD) and design requirements.

'Design Charrettes': It is an intensely focused workshop in which participants with a wide range of backgrounds and expertise are brought together to collaborate on a design problem. it is recommended to start early in the pre-schematic phase to set project's goals, define the scope and establish preliminary project schedules and budgets, and continues along the whole building process to generate a series of ideas, resolve conflicts and provide for fast feedback. The scope, focus and timing of design charrettes are estimated case by case (Yudelson, 2006 p.21), (Green Buildings BC, GVRD and NRCan), (Yellamraju, 2011 p.206)

Design for Disassembly: it is the deliberate effort during design to maximize the potential for disassembly, as opposed to demolishing the building totally or partially, to allow the recovery of components for reuse and materials for recycling long term waste generation (Kibert, 2005).

Embodied Energy; it is the sum of energy input during material manufacturing and construction phases of a building.

Existing building commissioning (EBCx): it is a systematic process for investigating, analysing, and optimizing the performance of building systems through the identification and implementation of low/no cost and capital intensive facility Improvement Measures and ensuring their continued performance (BCA, 2008). The goal of EBCx is to make building systems perform interactively and provide the tools to support the continuous improvement of system performance over time (The Building Commissioning Association (BCA)).

Fuel-mix for Energy Generation; it can be described as a breakdown, typically expressed in percentages as a ratio of the overall electricity generation, of the contribution of each renewable and non-renewable source in the production of energy for a specific region.

Functional unit; it is a description of the product or system being assessed, so that the resulting LCA can be compared to the LCA of a similar product or system, thus to ensure that the function which products are designed for is comparable in terms of quantity, quality and timescale need to be considered. Thus, it provides an equivalent level of function or service (Publications Office of the European Union, 2010) and (AIA, 2010). Final score is expressed as 'points per functional unit' representing the use of the product- or in other terms (Utility) (Vezzoli et al,2010) (Howard,2005)

Global Warming Potential (GWP); this phenomenon characterizes the change in the greenhouse effect due to emissions and absorptions attributable to humans. The unit for measurement is grams equivalent of CO2 per functional unit.

Green leasing; is defined by the 'California Sustainability Alliance', and 'The Building Owners and Managers Association (BOMA)'. It dictates that building performance becomes transparent to all parties involved in the lease transaction, including (HVAC, plumbing, lighting, etc.)

Greenwashing: It is a term that indicates faulty claims of sustainability.

Impact Category: it is a class representing environmental issues of concern to which LCI results may be assigned.

Life Cycle: Consecutive and interlinked stages of a product system, from raw material acquisition or generation of natural resources to final disposal.

Life Cycle Assessment (LCA): A process of compilation and evaluation of the inputs, outputs, and potential environmental impacts of a product system throughout its life cycle.

International Performance Measurement & Verification Protocol (IPMVP): Volume III Concepts and Options for Determining Energy Savings in New Construction, April 2003. It is a guidance document that addresses determining and documenting savings resulting from energy-efficiency projects. It provides a framework and four measurement and verification (M&V) options for how savings can be transparently, reliably and consistently determined in a manner that enables independent verification.

Measurement and Verification process; it comprises a set of complex procedures and testing methods proposed by some standards, citing the IPMVP standard, to allow a user to compare the performance of a particular system or building to the performance of the same system or building at an earlier time, or to the performance predicted by a simulation, or to the performance of other systems or buildings, but basically it should be developed to allow for sub metering of energy and water use to facilitate data collection (Green Building Finance Consortium, 2010) , (Mendler et al,2nd edition p.46). It uses on-going BAS trending, portable data loggers, spot measurements, and functional testing to measure the efficacy of systems/components, and verify its proper implementation (BCA, 2008).

MOU; they refer to common measurement metrics between similar rating systems.

Normalization: A technique for changing impact indicator values with differing units into a common, unit-less format. This is achieved by dividing the impact category value by a selected reference quantity.

Operational Energy: Energy used in buildings during their operational phase, including energy consumption due to HVAC system, lighting, service hot water, etc.

OPR: it details the functional requirement of the project and expectations of building's use and operation, and it addresses: a) Owner and user requirement (primary purposes, program, use, future expansion, flexibility, quality of materials, construction and operational costs), b) Environment and sustainability goals, c) Energy efficient goals, d) Indoor environmental quality requirements, e) Equipment and system expectation (including the desired level of quality, reliability, automation, flexibility and maintenance-commissioning requirements- technologies and manufacturers), f) Building occupants and O&M personnel requirements (LEED NC reference guide, 2009).

Postconsumer material; according to LEED reference guide, it is defined as waste material generated by households or by commercial, industrial and institutional facilities in their role as end-users of the product, which can no longer be used for its intended purpose.

Pre-consumer material; according to LEED reference guide, it is defined as material diverted from the waste stream during the manufacturing process. Reutilization of materials (i.e. rework, regrind or scrap generated in a process and capable of being reclaimed within the same process that generated it.

Primary energy; it is measured in Mega-joules (MJ), and includes all non-renewable energy, direct and indirect, used to transform or transport raw materials into products and buildings, including inherent energy contained in raw or feedstock materials that are also used as common energy sources (AIA, 2010).

Post Occupancy Evaluation (POE); It is a detailed assessment used to determine a completed building's overall performance (or key goals) relative to a set of established goals, through engaging appropriate participants.

Quality assurance (**QA**): it refers to the engineering activities implemented in a quality system so that requirements for a product or service will be fulfilled. It is the systematic measurement, comparison with a standard, monitoring of processes and an associated feedback loop that confers error prevention. This can be contrasted with quality control, which is focused on process outputs. http://en.wikipedia.org/wiki/Quality_assurance

Rapidly renewable; LEED V3.0 requires that building materials and products are made from plants that are typically harvested within a 10-year or shorter cycle, e.g. bamboo, wool, cotton insulation, agrifiber, linoleum, wheat board, strawboard and cork.

Rating; is the evaluation or assessment of something, in terms of quality, quantity, or some combination of both. It is different than ranking because the latter is a relationship between a set of items such that they either rank; higher, lower or equal even though they may be different. Nevertheless, both methods are used to evaluate complex information according to predefined criteria, (source: http://en.wikipedia.org/wiki/Rating, http://en.wikipedia.org/wiki/Ranking)

Recycling; is when a material is recovered and used to manufacture a new product. It should be noted that 'Upcycling' is reusing a material for a higher-grade application than its current use, while its contrary is 'Downcycling' which is not considered true recycling, (Kane, 2010 p. 24-26)

Regional materials; LEED V3.0 requires that the material be extracted, harvested or recovered, and manufactured within 500 miles of the project site

Reuse; is when a material or item is to be used again in its current form, with or without a small amount of repair (Kane, 2010 p. 24-26)

Source energy (primary energy): it represents the total amount of raw fuel that is required to operate the building. It incorporates all transmission, delivery, and production losses, thereby enabling a complete assessment of energy efficiency in a building (Green Building Finance Consortium, 2010).

Site energy (secondary energy) :it is the amount of heat and electricity created from source energy such as electricity purchased from the grid or heat received from a district steam system, consumed by a building as reflected in utility bills (Green Building Finance Consortium, 2010).

Sustainable Adaptive reuse/ refurbishment: It can be regarded as a compromise between historic preservation and demolition. It refers to the process of reusing an existing building for a purpose other than which it was built or designed for, it also describes working on existing buildings to improve their environmental performance using sustainable methods and materials, though the principles are very similar to those used on new buildings, the practice and details appropriate for the wide range of situations found in old buildings has required development of specific solutions and guidance to optimise the process and avoid subsequent problems.

System boundary*;* it is defined as an interface between a product system and the environment or other product systems. It defines the activities and processes that will be included in each life-cycle stage for the LCA analysis and those that will be excluded. It dictates the breadth and depth of the proposed LCA. If a comparative LCA is anticipated, then it is critical that the system boundary be established in the same way for the systems being compared (AIA, 2010).

Weighting; is one of the methods used for decision making process. It is usually performed based on numeric techniques, investigating a discrete set of alternatives and their variants, to enable decision makers reach an understanding of their comparative value. This is achieved on the basis of the impact of the alternatives on certain criteria and thereby on the overall utility of the decision maker(s).

CH ONE

1

1.1. INTRODUCTION

Green buildings require adopting a conscious long term approach covering not only individual practices, but the process as a whole. Moreover, the sustainable building industry demands are rising; from simply requiring guidelines to support a sustainable building process, to the need of measuring/ quantifying building performance, and additionally, the need of providing means to verify this performance, and provide a business case to support green investments. Hence, the scientific community has been attempting to provide means for assessing sustainable building performance, which was also encouraged by the real estate market demand for standardization of measurement metrics, differentiation of sustainable building performance, and branding for certified buildings.

The research discusses the application of LEED *Green Building* rating system being one of the most well known, and greatly adopted international rating system. The discussion reveals that there are mainly two approaches to apply the LEED rating system; first; to use it to gain points- which is one mean or another of 'Green washing'- or to properly use it to achieve the true sense of sustainability, and this requires additional effort from project team members; primariliy to explore LEED system's potentials on one hand and its gaps and limitations on the other hand. The two approaches of applying the LEED system reflect significantly on the management process and accordingly on the decison making process- where it act as a guideline tool to achieve a sustainable building process, and provide better means of measuring and verifying sustainable building process, and how it influences and it is influenced by the market potentials.

Hence, the research expands the existing literature by defining and developing the scopes and limits of operation of the LEED system along the building process, and explores its potentials and drawbacks when applied for different building types or contexts. Then, the research develops a framework to apply the LEED system classifying the use of the LEED system into its main targets based on profound understanding for credits' intent, its contribution in the building process, and how each credit acts integrally as a part of a whole sum. Hence, it investigates LEED system's requirements in the form of guidelines, measurement metrics, verification and certification requirements, and indicates means of applying them along different phases of the building process in an integrated and iterative manner when required to support an in-sighted decision making process. This presents a '*know how*' to use the system for sustainable project management, exploring opportunities to exceed LEED system's requirements, so that LEED is applied as a mean not as an end by itself.

1.2. DELIMITATIONS

This study discusses LEED-New Construction due to the reason that it is one of the mostly adopted certification programs for new buildings in the world, and unless otherwise noted, this review focused on LEED-NC Version 3.0 - focusing on non-domestic dwellings. It is worth noting that the main discussion revolves around environmental performance (some economic aspects shall be highlighted only which serve the main discussion about environmental performance). The study does not cover the entire LEED categories, but focus on energy and materials credit categories (except EA Pr 3 and EA C4, discussing refrigerant management- which discuss different areas of concern other than the research focus), and it is mainly the logic behind credits' intent that shall be mostly highlighted rather than individual credits' weighting because credits' weighting continuously change with versions, hence it was more important to set the general framework for applying the LEED system which may constitutes current as well as future LEED versions.

This research is undergoing after the recent introduction of LEED V3.0 system to the Italian context [2010] and in parallel with the current development process for the new version 4.0 of LEED system [expected to be activated at the end of 2013]. Thus, the research focus was mainly on LEED version 3.0 along with the expected updates of version 4.0 which represent the major milestone developments of the LEED system.

1.3. DEFINING THE RESEARCH PROBLEM & RESEARCH OBJECTIVES

Sustainable management process is very important to the overall impact of the building process, though they are more difficult to integrate into a rating tool. This is evident in the case of the LEED system, because there is no defined methodology or roadmap available for applying LEED system along the sustainable project management processes. It is true there is guidance for sustainable management practices but it lacks in sights for integrating the whole process- this makes it a tool to be used, and it depends on the way team members may use it to achieve the true sense of sustainability. This is why the research followed the following steps; Analysis, Evaluation, Proposal, Testing and Adjustments. Hence, the research presents an integrated framework for applying the LEED system that could be properly employed for sustainable project management. The framework is discussed along all project management phases to draw a step by step guide tool for practitioners on how to apply LEED system along the building process- exploring how the design choice can be influenced by the scope of applying the LEED system. Hence, the research was developed, primarily to address practitioners- in order to better define and develop the role of LEED system to achieve green buildings. It aims at highlighting some of its critical aspects, opportunities and drawbacks, and discusses the way the LEED system may be applied along the management process, and how it may significantly change the whole design approach, the building process in whole or in part.

The result of the Analysis and Evaluation step shows that the required methodology should take into consideration integrating LCA to improve LEED system's environmental assessment, as well as considerations for applying the system for different building types and contexts with particular concern for energy and materials credits because according to international studies, they are considered the most challenging sustainable criteria for practitioners.

The suggested framework is applied on energy and materials credits to highlight potentials and drawbacks of using the system as guideline and decision making supporting tool, measurement and benchmarking tool for sustainable building performance, and verification tool to act as a quality assurance and quality control mechanism, as well as exploring the role played by LEED certification system for real estate market transformation and how this affects the design decision. This may better explain how the LEED system can perform according to each scope, and how they can be integrated together to provide a 'Know how' for applying the LEED system indicating areas of precedence and/or concern, when applying the system for different building types and contexts.

1.4. Research Assumptions

The research assumes a dual mechanism for LEED system's operation. The first one identifies LEED's Rating Mechanism- divided into LEED's role as guidelines and Decision Making support tool for sustainable building process, and LEED as a Measurement and Benchmarking tool for sustainable building performance. While, the second one identifies LEED's Verification and Certification Mechanism- divided into LEED's role as verification tool for sustainable building performance, and market tool to support and promote sustainable real estate market transformation. The research found this differentiation between its two mechanisms of operation useful for assessing and developing the LEED system.

1.5. Methodology

The research is divided into five main chapters that cover the main steps; Analysis, Evaluation, Proposal, Testing and Adjustments. It starts with investigating the state of the art discussing green buildings and means of measuring their environmental performance, through *Green Building* rating systems, highlighting promising role for integrating LCA to support the environmental assessment (chapter 2). The research focuses on the LEED system- indicating its potentials and drawbacks, along with highlighting its future development course.

The following chapter (chapter 3) discusses the specificity of the LEED rating system. The analysis is based on both theoretical and practical basis through; analytical comparison to other *Green Building* rating systems, and conducting questionnaires and interviews among practitioners in the Italian context (where afterwards, the two case studies are discussed). The analysis discusses the status of the LEED system considering integrating LCA, as well as the adaptability and applicability of the LEED system to different building types and contexts- this concerns highlighting LEED categories and more specifically LEED credits that are mostly adopted by practitioners and the reason behind that, as well as defining any critical aspects related to the management process under LEED certification.

The results of the Analysis and Evaluation steps mainly revolve around two main issues; the first, is the lack of proper guidance on how to apply the LEED system for sustainable project management especially with the wide variations of building types and contexts, along with doubts about the robustness and reliability of its environmental evaluation method.

Hence, in the following chapter (chapter 4), the research proposes a comprehensive framework for applying LEED system based on differentiating between its dual mechanisms of operation; rating and certification mechanisms, which are consequently divided into four scopes. Each scope is further elaborated expanding the discussion to reveal its potentials, synergies and trade-offs with other scopes. The thesis explores how the design choice can be influenced by the scope of applying the LEED system, emphasizing individual credits.

Moreover, in (chapter 5), the research proposes a systemic approach of applying the four scopes in a step by step project management framework for LEED energy and materials credits, covering all phases of the building process, along with discussing other management practices, like choosing the project delivery method, material selection and procurement methods, as well as specification and documentation practices.

In the final chapter (chapter 6), the research tests the suggested framework on two different case studies; new construction and major renovation projects, highlighting challenges in managing projects under LEED certification system in the Italian context, having different building types and conditions, and using different LEED rating systems with two sequential versions, in order to test all variables that may affect the project management process. Then a Validation and Adjustment step was carried on the proposed research framework according to findings from the Testing step.

C H T W O

2 STATE OF THE ART OF THE RESEARCH

This chapter sets the core understanding of the research theme; discussing Green buildings and GBRS focusing on the LEED system-defining its main targets, critical aspects, as well as its future development. This highlights the main research arguments discussing the application of the LEED system in the project management process; incorporating LCA to support its environmental assessment method, and other concerns for its applicability and adaptability to different building types and contexts which shall be analyzed in the following chapters.

2.1. Introduction

The global world faces drastic environmental problems. The rising concern of the building sector is due to its share of energy consumption and Greenhouse gas emissions which is estimated to be around 30 and 40% in developed countries (IPCC, 2007), putting them among the largest end-use sectors and the biggest contributors to carbon emission. However, according to IPCC[1] (2007) and the International Energy Agency (IEA), the building sector is one of the most cost-effective sectors with the highest energy saving and pollution reduction potential and can play a critical role in achieving the transition to a low-carbon economy. This enhanced rapid and profound change in the construction sector towards a sustainable building process. Nevertheless, a 'business as usual' approach for project management will not be efficient to achieve sustainable goals if it continues to account for short term savings and lower capital cost. Hence, Green building principles have risen as a response of the building industry to the environmental and resource impacts of the built environment- this leads to a huge leap towards sustainable building practices considering the three dimensions of sustainability in project design and construction, and along the whole project phases, as well as continuous follow up and management to material and energy flows (Berardi, 2011) and (Mateus, 2011).

[1] Intergovernmental Panel on Climate Change

2.2. Green Buildings

2.2.1. Green buildings' Evolution & Definitions

According to previous studies, building codes have been slow to promote sustainable development; this explains the rise of *Green Building* rating systems (GBRS) as a mechanism to regulate impacts caused by the building industry and to channel construction in a sustainable direction (Mateus, 2011) and (McManus, 2010). The evolution of green buildings can be represented in the following diagram.

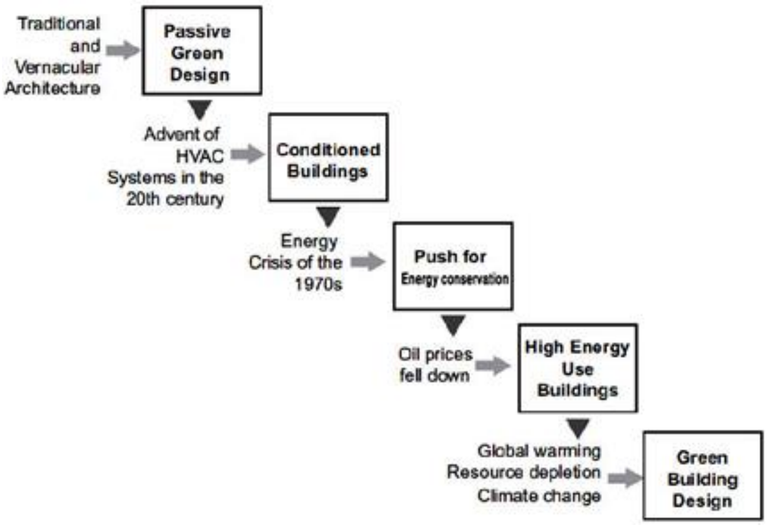

Figure 1: Evolution of green buildings[1]

In general, green buildings might best be characterized as 'integrated building practices' that significantly reduce the environmental footprint of buildings in comparison to standard practices. The term is often used interchangeably with *sustainable building* or High Performance buildings (Fischer,2010).

Other definitions for the term were provided by;

Environmental Protection Agency:

Green building is the practice of creating structures and using processes that are environmentally responsible and resource efficient throughout a building's life-cycle from siting to design, construction, operation, maintenance, renovation and deconstruction. This practice expands and complements the classical building design concerns of economy, utility, durability, and comfort.

Building Science Corporation:

'Green building' is a label for the process of design and construction which aims to produce buildings that are less damaging to the environment—and the people that use

[1] Source: (Yellamraju, 2011 p.5)

them—than most buildings currently built today. [It] focuses on incremental steps to solve known and measurable problems with ... current practice.

Thus, it can be concluded that currently there exists no common consensus regarding the term ‘green’ or “sustainable” building in the building sector, but generally it can be defined as follows[1];

‘Green Building is a concept or an approach that revolves around resource efficiency, life-cycle approach and building performance, as well as enhanced management and occupant satisfaction. Its main aim is to reduce the negative human impacts on the natural surroundings; materials, assets, and promotes a procedure that prevails nature. They provide financial benefits due to cost savings from reduced energy and water consumption, reducing waste output, less maintenance procedure and improved occupants productivity, and health.’

These definitions give important indications for the area of *Green Building* research. It indicates that *green* is a comparatively relative concept, it is not limited to only one factor, but involves integration across several sustainable criteria, it covers not only single practices, but the whole process as well, in an integrated manner and along the building life cycle. It acts on an incremental approach to sustainability covering known and measurable problems, and from here originates the importance of the measurement criteria for green buildings and indicates their continuous evolution to provide more stringent requirements for sustainability, and finally, it acts as a complementary to classical building design concerns.

It is also related to the term ‘Smart Buildings’[2]; which is based on achieving an integrated building technology (Energy and sustainability, 2010), to reach almost the same green goals. Both ‘Green buildings’ and ‘Smart buildings’ have a common area of interest as can be seen from the figure- that aim at maximizing energy savings through using more comprehensive monitoring and control-system integration to deliver the financial and conservation benefits of energy management. According to (Energy and sustainability, 2010), *Smart buildings are part of green buildings and greatly support and affect Green Building certification.* This leads to the conclusion that some of the qualifications required to obtain special Green features relies on employing smart technologies but not all Smart buildings can be considered Green buildings.

[1] The author’s elaboration citing; (Wu et al, 2010),(Energy and sustainability, 2010), (McManus, 2010), and (Rahardjati et al, 2011)

[2] The Smart Buildings Institute describes a certified smart building as one that, “1. Provides actionable information regarding the performance of building systems and facilities; 2. Proactively monitors and detects errors or deficiencies in building systems; 3. Integrates systems to an enterprise business level for real-time reporting and management utilisation of operations, energy and occupant comfort; 4. Incorporates the tools, technologies, resources and practices to contribute to energy conservation and environmental sustainability.”, source: http://www.greenbang.com/from-inspired-to-awful-8-definitions-of-smart-buildings_18078.html

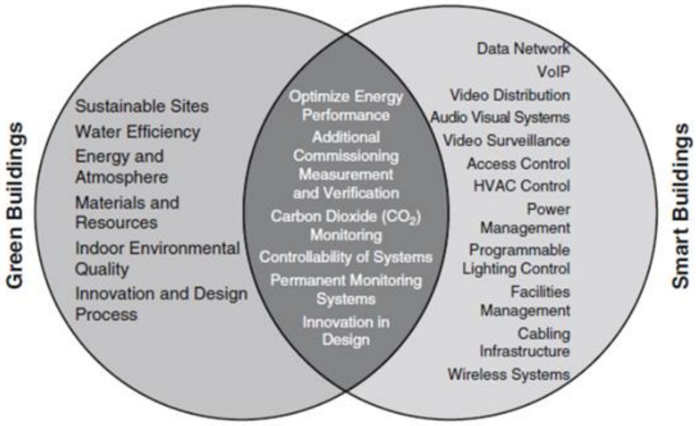

Figure 2: Commonality of ‘Smart’ and ‘Green’ buildings, source (Energy and sustainability, 2010)

Some of the commonality of ‘Smart’ and ‘Green’ buildings may exist in; energy efficiency, monitoring, and controllability of systems as shown in the figure above (Energy and sustainability, 2010).[1]

Green buildings typically optimize most or all of the following areas (McManus, 2010), (Understanding LEED Version 3, 2009), (Rockingham Planning Commission), (Vijayan et al, 2005):

☐ Management of a sustainable building process

☐ Site: carbon footprint, Land use and ecology; surrounding environment

☐ Indoor Environment: Health and well-being, comfort

☐ Resource Depletion: Water, energy, materials and wastes

☐ Innovative System Openness: Innovation in design, eco-education

☐ Environmental Loadings: Impact on the environment, waste and pollution

☐ Socio-economic aspects and community outreach.

☐ Market position and shareholders’ value.

This analysis is useful to capture the sense of the research argument concerning; applicability and integration, comparability, and improvement as well as identifying areas of concern of green buildings.

2.2.2. Green buildings’ potentials and challenges

Many studies have discussed the different potentials of green buildings and how to properly assess them in order to estimate the value gain in the sustainable marketplace. Their benefits were mainly divided into environmental, economic and public benefits (Understanding LEED Version 3, 2009), (Vijayan et al, 2005), (Fischer,2010) (Green Building Finance Consortium, 2010) and (Rockingham Planning Commission). These factors have to be taken into consideration, exploring both tangible and intangible benefits, cost and payback time needed to repay for investments paid for *Green Building* features in order to properly assess their business performance as will be referred to in

[1]This categorization is harmonized to the LEED rating system sustainability and credits as will be explained in detail later in the research.

chapter four. Green buildings differ from conventional buildings, however, in that many of the financial benefits will be realized over the long-term life of the building ranging from 3-5 years of building and recovering up to 10 times of its cost premium (Rockingham Planning Commission), (Lacouture et al, 2008)[1] . This has to be taken into consideration when estimating the profitability of any green investment.

Green building profitability for commercial real estate shall bring increases in occupancy rate, tenant retention, tenant satisfaction, asset value and shareholder value while driving down operating costs. Estimated increases are as follows: 3% Rent ratio increase, 3.5% Occupancy ratio increase, 6.6% Return On Investment, 7.5% Building Value Increase, and 9% Operating Cost decrease (Veritas , 2009). Nevertheless, it should be noted that cost barriers to the use of *Green Building* may decrease as the practice becomes more widespread, also, financial incentives may change in response to increasing demand (Fischer,2010).

Yet, the main current challenges of the widespread adoption of *Green Building* approaches are; lack of awareness regarding benefits, and lack of interest in life-cycle cost assessment- which causes perceived higher costs and extra time, lack of market acceptance, lack of information to make informed decisions along with immature markets and supply chains causing materials, technology and sustainable energy to be of limited supply, expensive, or of poor quality - thus creating uncertainty about the size and type of Green building benefits, and this leads to stakeholders' resistance to pay for green investments (Yudelson, 2006 p.13), (Kane, 2010 p. 32,33,138), (Issa et al, 2010), (Lovea et al, 2002). This is mostly pronounced in the issue of *Split Incentives* (Yellamraju, 2011), (Fischer,2010). This is shown in figure (3) where different involved parties have different interests, for example; the benefit of operational efficiency is realized by the tenants and not necessarily by the developers, while actually the key influencer on the building specification is the investor, who, has minimum interest in economic burdens unless it is provided by some means of assessment of investment risks (Yates, 2001).

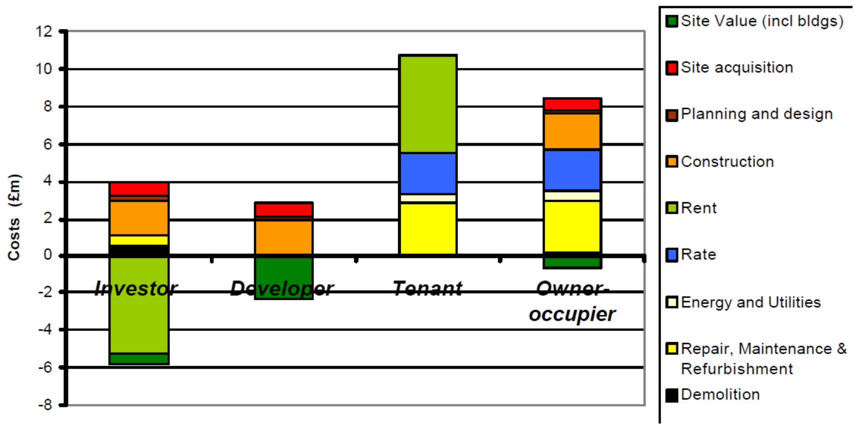

Figure 3: Stakeholder burdens, BRECSU (Yates, 2001)2

[1] Source: (Lacouture et al, 2008): Ross B, Lopez-Alcala M, Small III AA. Modeling the private financial returns from green building investments. Journal of Green Building 2006;2(1):97–105, as well as Edwards B, editor. Green buildings pay. 2nd ed. London; New York: Spon Press; 2003, and Kats G. The cost and financial benefits of green buildings: a report to California's sustainable building task force. Sacramento, CA: Sustainable Building Task Force; 2003.

[2] key groups of decision makers were classified in the study as follows (Yates, 2001):

Recent changes such as *Procure and Operate* packages, as well as several new leasing models referred to as *Green* Leases are currently under development to address this issue. It is true that currently they represent a minor part of the market, but it presents an opportunity particularly if they operate integrally and in parallel for both operation and management practices (Yates, 2001), (Yellamraju, 2011 p.213).

The previously discussed issues share the need to introduce proper methods for how to best measure, document, and quantify benefits of green buildings, and this leads to the introduction of Green Building Assessment methods.

2.2.3. Green Building Assessment

The market requires a standard way to differentiate *Green Buildings* from traditional buildings through the use of standard, transparent, objective, and verifiable measures of green building performance, which assure that the minimum green requirements have been reached (Lacouture et al, 2008). This calls to the introduction of Green Building Rating Systems, which are sometimes called *Total Quality Assessment systems* (*TQA)*; they are multi-dimensional systems based on the triple bottom line approach to sustainability. They include environmental, social and economic parameters; hence they combine both quantitative and qualitative sustainable criteria, example, BREEAM, LEED, GreenStar, and many others. They are generally simple in use and easy to understand, where each criterion has an assigned weight, and summing the total weight obtained through fulfilling the requirements of the rating system represents the perceived sustainable performance level of the building. Yet, a critical aspect of this type of assessment is their additional structure (Hahn, 2008), selection of criteria and weighting assigned to each of them, which has received a lot of criticism in the scientific research community (Berardi, 2011).

This is why efforts from the scientific community call for introducing the Life Cycle Assessment method (LCA) to support the environmental assessment method of GBRS concerning quantitative sustainable building criteria, where it measures the impact of the building on the environment by assessing the emission of one or more chemical substances related to the building construction and operation- hence making use of the robustness and reliability of LCA in quantifying environmental impact, and the ease of use and comprehensiveness of GBRS (Berardi, 2011), (Howard,2005).

Investors: Responsible for providing funding and concerned with investment returns, rental yields and intrinsic value only.
Developers: Responsible for upfront costs of providing the product in the first place. This places the emphasis on the attractiveness of the product and so concentrates on image issues.
Tenant : Responsible for all operational costs. Image is also important as it effects profile
Owner /Occupier :Responsible for both the development and operating costs. Thus, they are more likely to take life-cycle costs into consideration when making decisions on property

2.3. Green Building Rating and Certification system

Green building rating systems are designed to assess and evaluate the performance of either the whole building or a specific division of the building from planning, designing, construction, and operation (Wu et al,2010). They provide a framework to design, build, and operate green buildings based on common set of criteria and targets to provide a verifiable measurement and benchmarking method for key sustainability standards and set credible standards by which buildings can be judged objectively**,** aiming to increase standards exceeding building codes and regulations, and transforming the building industry (Fowler et al,2006), (Reed et al, 2011), (AIA, 2010), (Yellamraju, 2011 p. 4 ,5).

Green Buildings are based on a triple bottom line strategy. It is at the intersection of economic, environmental and social performance that sustainability occurs (Understanding LEED Version 3, 2009), and attempting to balance all three dimensions of sustainability can create the difference between GBRS regarding their; assessment methods, criteria, weighting and accordingly the results obtained, and although there is a general consensus on the range of environmental outcomes that a sustainable building should strive for, yet, there is no consensus on how such outcomes should be achieved, measured, certified, or valued (Green Building Finance Consortium, 2010). Hence, little is known about the equivalence and comparative uptake of the tools used internationally (McManus, 2010) which shall be discussed next chapter. But for now, the research differentiates between two interrelated mechanisms; the mechanism for 'Rating' Green Buildings and another for 'Certifying' Green buildings, pointing out that not all rating systems provide certification, e.g. GBTool, and the focus of the research will be on systems that provide both rating and certification mechanisms.

2.3.1. Rating Scheme

Rating mechanism aims at assessing green building performance which is considered an essential prerequisite to its promotion. Measuring/evaluating[1] sustainable building performance is considered a comparison based management tool that can be used to help gain competitive advantage[2]- yet, it is considered one of the biggest challenges in real estate market, providing measurement metrics, tools, methods, and benchmarks matching with the nature of each sustainable criterion to reach a unified rating, and at the same time establishing common sustainable metrics to allow for comparability between green certified projects, and also considering the building from a whole system thinking perspective[3].

[1] For the research purpose; the term 'Measurement' was dedicated for quantitative sustainable criteria, e.g. energy, water, materials and resources, while the term 'Evaluation' was dedicated for qualitative sustainable criteria, e.g. indoor environmental quality and sustainable sites.
[2] The study conducted by (Emmitt, 2007, p.192), pointed out that measurement metrics are used to obtain competitive market advantage in the real estate market place.
[3] The author's elaboration from; (Reed et al, 2011),and (Wu et al, 2010).

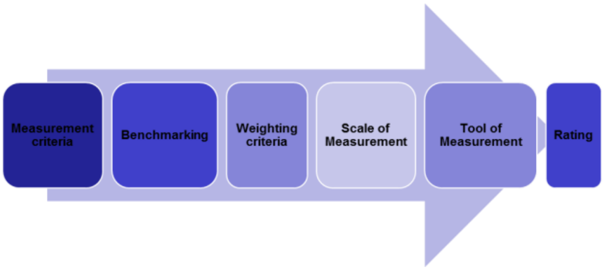

Figure 4: Rating criteria

Defining the rating mechanism can be derived from several studies as follows[1];

'It is a set of design checklist and credit rating calculators structured within the overall building process to guide the decision making process. It is based on multicriteria triple bottom line approach, considering that each aspect has different units of measurement and applies at different physical and global scales. They evaluate the performance of the building compared to present benchmark performance and give rating award as shown in figure (4), which may be used in marketing purposes.

The issues covered include those relating to the global, local and internal environments. Each rating mechanism features a suite of tools developed for different building types (Reed et al, 2011). Nevertheless, evaluating sustainability is a different and complex process, this requires a number of variables and any evaluation will be reducing and abstracting the reality. Thus, all indicators are considered reducing and simplifying, this can create distortion and can be manifested in the multiplicity of instruments and indicators dealing with some problems and neglecting others, and this is creating confusion in the sustainable real estate market. Yet, as a general rule; the use of one instrument/tool has to be applied synergistically and integrally in order to obtain the optimum results (Lavagna, 2008 p.48).

2.3.2. Certification Mechanism

Certification mechanism delivers the results of the rating mechanism to interested parties. It may be used as a national and/or global policy tool (e.g. to channel the building sector into sustainable development, hence, help achieve the national target for energy efficiency and emission reduction), and above all as a marketing purpose to remove some of the uncertainty perceived primarily for sustainable building performance, so, it is useful for tenants and occupiers, and secondly, for green investments, so, it is useful for investors and developers as previously discussed[2]- providing sustainable buildings with signalling factors to gain a competitive market advantage and a tool to be communicated to various parties in the market. In addition, a key lesson for applying certification scheme is the need to ensure that they are adaptable enough to evolve with expected and unanticipated developments in the future.

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[1] The author's elaboration citing: (Rahardjati et al, 2011), (Fowler et al,2006), (Wu et al, 2010), (Mateus et al, 2011) (Kibert, 2005) and (Reed et al, 2011).

[2] The author's elaboration from (OECD/IEA, 2010), (Understanding LEED Version 3, 2009), and (Yates, 2001).

Certificates can be performed for the whole building rating, or for individual sustainability parameter- specifically for energy performance. Also, they may be used voluntary, or imposed by some mean of national policy. Both means can affect the sustainable real estate market in different means (OECD/IEA, 2010) and (McManus, 2010);

Mandatory certification scheme; this type of certification schemes has the greatest potential for market impact and can result in the largest savings, thus it can be seen as an important policy intervention that can help raise awareness of sustainability ethics and at the same time address market failure.

Voluntary certification mechanism; this type of certification mechanism is basically motivated by signalling market factor[1]. It is used as a tool to stimulate the market for more environmentally responsible process and providing branding for sustainable buildings as a form of market incentives, verifying that a building is sustainable usually by a third party, providing information about building sustainability performance and sometimes providing recommendation for improved building efficiency.

Voluntary certification mechanisms bring more incentives to exceed benchmarks in a free competing market place, hence they prove to be the most efficient but relies greatly on availability, transparency and reliability of information, while mandatory mechanisms probably result in satisfying minimum building requirements to be eligible for certification. This difference shall be indicated in chapter six when comparing the two case studies.

From here comes the importance of sustainable certification system and how it is becoming a tool for market competition between operators, but the existing problem is the role of verification and control to guarantee a correct competition. Also certification is a decision tool for evaluating environmental impact and determine in a scientific manner the level of sustainability of alternatives, but it is different to manage these instruments as a result of the wideness and fragmentation of the information sources and specification (Lavagna, 2008 p. 47)

2.3.3. Potentials and Problems of GBRS

Green Building rating systems may provide useful information on the good practices and measures to achieve green objectives. In fact, each rating system provides a certain level of information that can help project managers to create a certain balance between the process and the practice (Wu et al,2010). Yet, it is important to remain focused on the *objectives* of *Green Building* design keeping in mind that GBRS cover a few of the initiatives that result in sustainable development- citing the trajectory of integrative thinking model presented by Reed, pointing out that *Green Building* rating system are still on the way of promoting high performance design (Boecker et al,2009)[2].

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[1] Mlecnik et al., 2010, found in (OECD/IEA, 2010)

[2] The study stated that there are four sequential levels of a sustainable building performance, they are from lower to upper as follows; the Conventional design- Green high performance design (encouraged by GBRS) - Sustainability/ Conserving design- Restorative design - Regenerative design

Literature review reveals numerous types of problems facing *Green Building* rating systems. The research classifies them into; limits within the structure of the rating system, and limits concerning the application of the rating system.

a. *Structure of the rating system*

Structure of the rating system is criticized in relation to the choice of criteria and weighting method. Some of the available multi-criterion systems are accused of a lack of completeness neglecting economic and social dimensions [1], on the other hand, its environmental assessment is not always based on reliable methods (Berardi, 2011), and moreover, measuring qualitative type of sustainable criteria relies on subjective means. In addition to the consequent problems arising from using a 'Single-score' rating , which is mostly based on subjective judgment to the weighting of individual issues, and hence, reduces the amount of information presented on sustainable building performance, which may provide misleading indications (Inbuilt, 2010), (www.bdcnetwork.com).

Other criticism has been directed stating that GBRS are not sufficiently integrative, they do not provide sufficient integration across elements or stages in the building's life cycle—or that they are too incremental in scope arguing that mere mitigation of environmental impacts is not sustainable, and that new approaches are preferable based on ecosystem efficiency[2].

b. *Application of the rating system;*

Applying point based rating system may lead to a risk, if design professionals get caught up in scoring easily obtained credits (in terms of cost and effort) even if with less environmental value (DeStefano,2005), (Wu et al,2010), (Eijadi et al, 2002), (Schendler at al, 2005), (Stein et al, 2004) (Rumsey and McLellan 2005, Schendler and Udall 2005) (Smith et al,2006) , focusing on minimizing short-term costs without fully considering and assessing the impact of doing so upon the long-term environmental and economic performance of buildings (Eijadi et al, 2002), thus raising the risk of Green washing (Schendler at al, 2005).

Additionally, the study conducted by (Reed et al, 2011), discussed the adaptability of the rating system to foreign contexts. This opens the discussion regarding possible regional adaptations in assessment criteria .However, local aspects, priorities and benchmarks are complex to establish, especially when it is necessary to manage weights and optimal performance values as in multi-criterion systems (Berardi, 2011). This has created complications for the global real estate market and necessitated a better understanding of the differences between markets.

[1] Ding, 2008, found in (Wu et al, 2010)

[2] Found in (Fischer,2010): Anya Kamenetz, "The Green Standard?," Fast Company, December 19, 2007, http://www.fastcompany.com/
magazine/119/the-green-standard.html, and Victor Olgyay and Julee Herdt, "The application of ecosystems services criteria for green building assessment," Solar Energy 77 (February 26, 2004): 389-398.

2.3.4. Future development of GBRS

Efforts to develop GBRS are mainly going into two directions: improving the performance of individual buildings- ultimately achieving *zero energy* buildings[1], as well as developing and harmonizing *Green Building* Rating and Certification system.

The first direction is concerned about the following points;

☐ Increasing the building performance through providing better guidelines for sustainable building performance, continuous refinement of the metrics and methods of assessment (Howard,2005), and continuous credit weighting adjustment, and more stringent requirements.

☐ Better evaluation and verification mechanism; assessment methods should rely more on 'performance' rather than 'prescriptive' based metrics (Howard,2005), employing new tools and methods, e.g. commissioning (Cx), Measurement and Verification process (M&V), Post Occupancy Evaluation (POE), and Life Cycle Assessment (LCA), to be employed along the building process, and particularly in critical stages of building life cycle- to obtain reliable results and support decision making process.

While the second direction is concerned about the; Transparency, comparability and communicability of results, and for this concern it is important to link the certification mechanism to other sustainable national and international bodies, develop more adaptable versions to be better applied to foreign contexts, in addition to develop common metrics and performance standards to support harmonization, for example; in Europe (through the European Committee for Standardization [CEN]) and in North America through the Residential Energy Services Network (RESNET) programme. These programmes also reflect international standards contained in the International Energy Conservation Code (IECC), those of the American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) and those developed by the International Organisation for Standardisation (ISO) (OECD/IEA, 2010), and the creation of the Sustainable Building Alliance in order to establish common evaluation categories and to improve comparability among systems for sustainable assessment (Berardi, 2011). Also, the development of the International Green Construction Code (IGCC) is considered a significant step in the direction of making *Green Building* designs a code requirement.

[1] They are buildings that have zero net energy consumption annually. However, technologies and systems required to achieve this outcome require significant upfront investment, and establishing sustainable interrelationships between buildings and their communities on a community/neighborhood scale.

2.3.5. LEED Green Building Rating System

2.3.5.1. Introduction and definition to the LEED system

LEED is an abbreviation for '*Leadership in Energy and Environmental Design' Green Building* rating system. It was developed by the U.S. *Green Building* Council (USGBC) in 1998.[1]LEED is a consensus-driven *Green Building* rating system. It is a registered trademark and a brand name, and represents part of a keen commercial mind-set at the USGBC- which is a national non-profit membership body including corporations, governmental agencies, non-profit organizations and others from throughout the country (Inbuilt, 2010).

According to the USGBC statements;

'*LEED was developed primarily to be applied in the real estate market. It offers a set of concise framework for Green Building process that aims at supporting the decision making process and improving the quality of the built environment on the widest possible scale promoting new green innovative practices and allowing for Research and development transfer'* (USGBC 2009)

Literature review presents several definitions for the LEED system with various perspectives (Rahardjati et al,2011), (Berardi, 2011), (Sleeuw, 2011)[2]. Analysing various targets of the LEED system is helpful to draw a scheme about the different scopes defining its limits of operation in the building process.

Scope (1) Design and Construction Guidelines

- ☐ Sustainable building industry needed a system to define and measure "green buildings" providing a definitive standard for what constitutes a *Green Building* in design, construction, and operation (LEED NC reference guide, 2009).
- ☐ The system is a how-to guide for professionals new to green construction… It is a design process that should, in theory, produce sustainable buildings (Schendler at al, 2005).
- ☐ It was designed to promote and encourage the adoption of sustainable *Green Building* practices (Rahardjati et al,2011), (Issa et al, 2010)
- ☐ It encourages development teams to incorporate sustainable design techniques and strategies for the benefit of society, the environment, and the economy (Winefsky et al, Taking the LEED)
- ☐ It was created to provide the industry with ''consistent credible standards of what constitutes a green building''- as a benchmark for sustainable building practices in itself (Energy and sustainability, 2010), (Issa et al, 2010). It is based on a holistic vision of sustainability to present a set of concise framework for identifying and implementing practical and measurable *Green Building* design, construction (Best practices), operations and maintenance solutions (Issa et al, 2010).

[1] GBCI are currently responsible for the LEED system. Project teams interact with the Green Building Certification Institute (GBCI) for project registration and certification. GBCI was established in 2008 as a separately incorporated entity with the support of the U.S. Green Building Council. GBCI administers credentialing and certification programs related to Green Building practice.

[2]Official website: (www.usgbc.org), also http://www.awc.org/pdf/TheImpactofLEED.pdf

- ☐ LEED was created to define “green building”, promote integrated, whole-building design practices, recognize environmental leadership in the building industry, stimulate green competition, raise consumer awareness of *Green Building* benefits, and contribute to a growing *Green Building* knowledge base (The New Zealand Green Building Council, 2006).
- ☐ LEED system is an effective tool to transform the construction industry and guide decisions to designs that most effectively mitigate environmental impact (Eijadi et al, 2002).

Scope (2) Measurement metrics

- ☐ It is a measurement system for key areas of real estate performance (Energy and sustainability, 2010), (Understanding LEED Version 3, 2009), (www.beaulieu-usa.com), (The New Zealand Green Building Council, 2006)
- ☐ It is a point-based rating process that classifies design and construction projects as environmentally sustainable. Credits are awarded based on compliance with a set of standardized and measurable criteria (Lacroix,2010)
- ☐ LEED evaluates environmental performance from a whole building perspective over a building’s life cycle (LEED NC reference guide, 2009).

Scope (3) Verification method

- ☐ It provides third-party verification that a building or community was designed and built using strategies aimed at improving building performance from a sustainability perspective (McManus, 2010)
- ☐ It demonstrates that a building is truly “green”, provides independent, third-party verification that a building /project meets the highest level of *Green Building* and performance measurements (www.beaulieu-usa.com), (The New Zealand Green Building Council, 2006)

Scope (4) Certification and marketing tool

- ☐ It provides an internationally recognized *Green Building* certification system created to encourage market transformation toward sustainable design (www.beaulieu-usa.com), (Energy and sustainability, 2010).
- ☐ The LEED *Green Building* rating systems are voluntary, consensus-based, driven and targeted for real estate market. “It is based on existing and proven technology for energy and environmental principles and strike a balance between known, established practices and emerging concepts” (LEED NC reference guide, 2009).

Hence, the research attempts to provide a combined definition that forms the basis of the forthcoming analysis:

LEED is a Green building rating and certification system. It attempts to provide a suite of standards for environmentally sustainable building practices, thus acting on four parallel directions; Guideline- Measurement and Benchmarking, Verification, Certification and Market tool. The system aims at promoting the way *projects are managed incorporating an Integrated design approach, considering the whole life cycle of the building, and various levels of complexity of the building process, along with sub processes related to the choice of green materials, products, technologies, systems and services.*

The research articulates based on this defined system's targets, as shall be discussed in the following chapters.

LEED is considered one of the multicriteria TQA methods. It is comprised of checklist framework, and covering both global and local or regional environmental issues- comprising 'Prerequisites' and 'Credits'. Credit categories discuss ;Sustainable Sites (SS), Water Efficiency (WE),Energy and Atmosphere (EA), Materials and Resources (MR), Innovation in Design Process (ID) and Regional Priority (RP). Earning LEED certification requires the fulfilment of all Minimum Program Requirement (MPR)[1] and the satisfaction of mandatory prerequisites and the accumulation of optional credits in the building categories listed above.

In LEED 2009 there are 100 possible base points plus an additional 6 points for Innovation in Design and 4 points for Regional Priority. The allocation of points between credits is based on the potential environmental impacts and human benefits of each credit with respect to a set of impact categories. The impacts are defined as the environmental or human effect of the design, construction, operation, and maintenance of the building. Finally, the assessment method is performed in a numerical way, where 'points' specific to 'green building' attributes are assigned for each 'LEED Credit' according to compliance with credit requirements, then obtain their total sum which determine the certification level expected or achieved[2].

It is also important to note that LEED has a fixed number of credits that does not vary according to the situation of the project, even if some credits where inapplicable due to project situation, they are still represented in the overall weighting. Credit weightings process is re-evaluated over time to incorporate changes in values ascribed to different building impacts and building types, based on both market reality and evolving building scientific knowledge (LEED NC reference guide, 2009) . All LEED systems use the same credit/point ratings for the purpose of maintaining consistency and usability across rating systems (LEED NC reference guide, 2009), (McManus, 2010). It also uses the same representation which makes it easy to compare the relative achievement of different projects and building types (Fowler et al,2006).

There are four levels of LEED certification: according to LEED 2009 for New Construction and Major Renovations (NC) certifications are awarded according to the following scale: Certified- Silver- Gold and Platinum. LEED rating system is currently

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[1] Minimum Program Requirements (MPRs) were introduced in LEED V3.0 and they define the minimum characteristics that a project must possess in order to be eligible for LEED certification: 1. Must Comply with Environmental Laws, 2. Must be a Complete, Permanent Building or Space, 3. Must Use a Reasonable Site Boundary, 4. Must Comply with Minimum Floor Area Requirements, 5. Must Comply with Minimum Occupancy Rates, 6. Must Commit to Sharing Whole-Building Energy and Water Usage Date, and 7. Must Comply with a Minimum Building Area to Site Area Ratio

[2] http://www.awc.org/pdf/TheImpactofLEED.pdf

applicable to many building typologies including; offices, retail and service establishments, institutional buildings (e.g., libraries, schools, museums and religious institutions), hotels, and residential buildings of four or more habitable stories (Berardi, 2011), (McManus, 2010).

There exist five overarching categories corresponding to the specialties available under the LEED Accredited Professional program and six different USGBC LEED rating systems addressing various categories of building development; New construction and major renovations (NC), Core and Shell (CS), Commercial interiors (CI), Existing buildings and Operation and Maintenance (EBOM), Neighbourhood development (ND), and Homes construction.

The LEED rating system is considered among the top widely adapted Green building rating systems. There are many countries which have adopted the LEED rating system (Fowler et al,2006). Some have even developed their own versions, while others are currently working on local adaptations of the USGBC LEED program.

2.3.5.2. Criticism against LEED system

LEED system has been criticised in a number of studies. Most of the criticism is general or in other words discusses basic characteristics in the LEED system, while others were more related to specific versions; this is why it is useful to relate the study to its corresponding LEED version; starting with (Eijadi et al, 2002) discussing LEED V 2.0, then (Pitts, 2004), (Stein et al, 2004)[1] discussing LEED V 2.1, followed by (Wu et al,2010), (Smith et al,2006), (Baird,2009), (Schendler at al, 2005)[2] discussing LEED V 2.2, ending with the recent studies by (McManus, 2010), (AIA, 2010), (Green Building Finance Consortium, 2010), (Yellamraju, 2011), (Gauthier et al,2011), discussing LEED V 3.0. Another recent study by (Issa et al, 2010), discusses LEED NC Canada V1.0 (2010) - highlighting points related to the contextual adaptation of the LEED system in the Canadian context. Yet, it can be concluded that most of the criticism revolve around the system’s point structure, assessment method, measurement metrics, credit weighting, benchmarking, cost and time of certification procedures…etc.

The research shall focus on the following areas of concern;

a) There is no defined methodology or roadmap available for applying LEED system in sustainable project management processes (Wu et al,2010), (AIA, 2010), (Yellamraju, 2011 p.17, 19). It is true there is guidance for sustainable management practices but it lacks in sights for the whole process (Wu et al,2010). Some criticism has revolved around the system’s guidelines for sustainable building performance (AIA, 2010), (Stein et al, 2004), (www.bdcnetwork.com), measurement and benchmarking criteria (Stein et al, 2004), (McManus, 2010), (Baird,2009), (Green

[1] Also, http://www.awc.org/pdf/TheImpactofLEED.pdf
[2] The LEED version for both (Baird,2009), (Schendler et al, 2005) is not defined but the time of publishing indicates that they may have discussed LEED V 2.2 or 3.0

Building Finance Consortium, 2010), verification method(s) (The New Zealand Green Building Council, 2006), as well as other drawbacks related to exploring its certification performance and value (Green Building Finance Consortium, 2010), (Baird,2009). The study performed by (Eijadi et al, 2002) pointed out an important risk resulting from the dominance of the point system and certification prestige.

This indicates that primarily there could be two approaches of applying the LEED system; the first one depends on 'point chasing' – which is basically concerned about achieving LEED credits' requirements to obtain the desired level of LEED certification, and another approach which is more concerned about how to properly apply the LEED system as a tool to achieve the true sense of sustainable building process; this requires additional effort from project team members to plan for how to use the LEED system in a way that allows for exploring its potentials on one hand, as well as exceeding its gaps and limitations on the other hand. The first approach basically defines LEED certification level as a target, while the second approach uses the LEED as a tool- or as a base not as a ceiling. The two approaches significantly reflect on the management process as shall be discussed later in detail.

b) The necessity of integrating LCA in LEED system's environmental assessment (the new introduction in LEED V4.0) (Smith et al,2006), (Schendler at al, 2005), (Eijadi et al, 2002), and a robust mean for economic valuation (Schendler at al, 2005), (Stein et al, 2004), (Gauthier et al, 2011) (Thilakaratnea et al, 2011)

c) The adaptability of applying the LEED system to other contexts, and its applicability to other building types and scales (Stein et al, 2004).

d) Particular concern is paid for applying energy and materials credits (Lavy et al,2009), (Berardi, 2011), citing the 2008 NBI study, which concluded that LEED certified buildings on average use 25-30% less energy than non-LEED buildings. An initial follow-up study refining the NBI data and analysis concluded that energy savings were as low as 18%, ranging from 18% to 39%, but that 28% to 35% of the LEED buildings actually used more energy than similar conventional buildings. A second follow-up study reported its main conclusion that LEED office buildings on average used 17% less site energy, but total source energy for LEED buildings was actually higher than the corresponding average for similar commercial stock[1].

2.3.5.3. Development of LEED system

Development of LEED system is based on using a consensus based approach in order to cope with the continuous evolution of new technologies and advancements in building science, technology and operation (Energy and sustainability, 2010), (LEED NC reference guide, 2009). It is important for the USGBC to balance continuous updates in

[1] NBI, 2008 found in (Green Building Finance Consortium, 2010). Yet it should be noted that this kind of study was performed on older versions. This cannot be taken for granted regarding the following LEED versions.

the certification system with stability and consistency in certified buildings under various versions in the marketplace.

This section discusses the two main milestone changes; LEED V3.0 in 2009 and expected future version LEED V4.0 at the end of 2013, because they indicate a major leap for the system's future development as shown in figure (5).

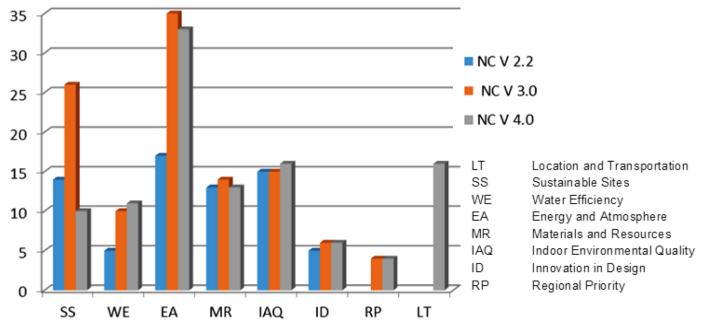

Figure 5: Comparing the weight assigned for each LEED category along the latest LEED version development

The figure shows that LEED system is continuously adjusting its weighting process and introducing new credit categories, but it is noticeable that weighting assigned for Energy and atmosphere category is the highest among all other categories- which indicates great concern about energy efficiency.

a. Development from LEED V2.2 to LEED V3.0- 2009

The USGBC appointed an independent, non-profit organization, the Green Building Certification Institute (GBCI), to help improve performance and to make the process more third party, and merged the different rating systems into three main categories: Green Building Design & Construction (BD&C), Green Interior Design and Construction (ID&C), and Green Buildings Operations & Maintenance (O&M)- yet, all LEED rating categories have a total of 100 possible points and a consistent set of points.

LEED NC	Version 2.2	Version 3.0/ V4.0
Certified	26-32 points	40-49 points
Silver	33-38 points	50-59 points
Gold	39-51 points	60-79 points
Platinum	52-69 points	80 + points

Table 1: LEED certification levels for different versions

This milestone was characterized by upgrading both the rating and certification process towards a better modified point system, changing credit weighting as shown in table (1), and streamlined user friendly online submission process (Understanding LEED Version 3, 2009), (Energy and sustainability, 2010). In addition to changes in prerequisite & credit alignment to emphasize operational performance rather than design intent (Eijadi et al, 2002), (Energy and sustainability, 2010), especially for reducing energy use and carbon dioxide emissions- using the target finder[1] to determine the energy requirement, considering the building's location, size, occupancy, as well as other applicable parameters (Advanced Energy Modelling for LEED Technical Manual, USGBC, 2011). MR category witnessed some important development as well using TRACI as a preliminary step for integrating LCA. Also, the development process incorporated regional differences through adding the new category of Regional Priority Credits (RPCs)[2]. Moreover, it provided for new functionality; to sort and group multiple projects in order to streamline the certification process (LEED Application Guide for Multiple Buildings and On-Campus Building Projects) (Understanding LEED Version 3, 2009).

b. Development from LEED V3.0 to LEED V4.0- 2013

The development process shall continue to outweigh performance rather than prescriptive requirements- thus a credit reweighting is performed to encourage implementing an Integrated Design Process, as well as introducing LCA as a mean to quantify environmental assessment- as an option for Materials and Resources category, which had changed dramatically in LEED V4.0 than previous LEED versions as shall be explained in the following section. In addition to adding other credits and prerequisites that aim at increasing the sustainability bar for LEED certified projects.

2.3.6. Environmental Assessment using LCA

Environmental evaluation has been greatly criticised in LEED system because it lacks scientific base for assessment. Several tools and systems have been developed for the environmental assessment breaking down products and process into elementary parts (www.bdcnetwork.com), and Life Cycle approach is the most commonly used type of environmental assessment (Berardi, 2011). This is why the next LEED version 4.0 is expected to include LCA in LEED Materials and Resources category.

2.3.6.1. LCA Definition and Methods

The International Organization for Standardization (ISO) defines life cycle assessment (LCA) as;

"Compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product or system throughout its life cycle" (ISO 14040: 1997)[3]

Hence, LCA quantifies all physical exchanges with the environment as shown in figure (6), whether these are inputs in the form of natural resources, land use and energy, or outputs in the form of emissions to air, water and soil, thus profiling all environmental

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[1] Target Finder is a web-based tool created by EPA, to provide the mechanism to determine the energy requirement to meet the Governor's Energy Efficient Green Building Executive Order. The tool accesses the DOE - Environmental impact assessment CBECS database of energy consumption by building type. http://www.energystar.gov/index.cfm?c=new_bldg_design.bus_target_finder .

[2] When a project is registered with LEED, it is automatically assigned extra credit opportunities based on the project zip code- offering extra incentive for project teams to address environmental issues that are identified as local/regional priorities by USGBC's regional councils, chapters and affiliates (Understanding LEED Version 3, 2009).

3 ISO 14040:1997, Environmental Management: Life Cycle Assessment– Principles and framework, International Organisation for Standardization.

impacts arising from a product/process-called 'environmental footprint' (www.bdcnetwork.com).

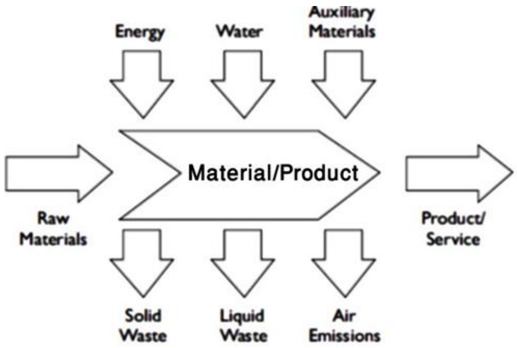

Figure 6: Profiling environmental impact[1]

According to ISO 14040, the framework for LCA consists of four iterative phases as shown in figure (7)[2]:

1) *Goal and Scope Definition*: to clarify the questions to be answered and determine how much precision, detail, and reliability are needed to answer those questions. It requires defining a functional unit to determine the type of analysis performed, impact categories and data that need to be collected (AIA, 2010).

2) *Inventory Analysis*: the energy and raw materials used and the emissions defined within the system boundary are quantified for each step in the process, then combined in the process flow chart and related back to the functional unit.

3) *Impact Assessment*: Data from the inventory analysis (Step 2) is attributed to appropriate impact category defined in scoping (Step 1). They can be thought of as a class of environmental issues of concern to which Life Cycle Inventory (LCI) results may be assigned. There is no dominant impact framework and they vary from system to system.

4) *Interpretation*: In which the results are compared with the goal of the study. They are often presented in the form of tables or graphs, which is especially helpful in comparison. The overall result of a LCA study can either be presented for different impact categories or a single value result can be obtained by applying weights. The outcome of this step is directly useful in decision making process as shall be explained later in chapter six.

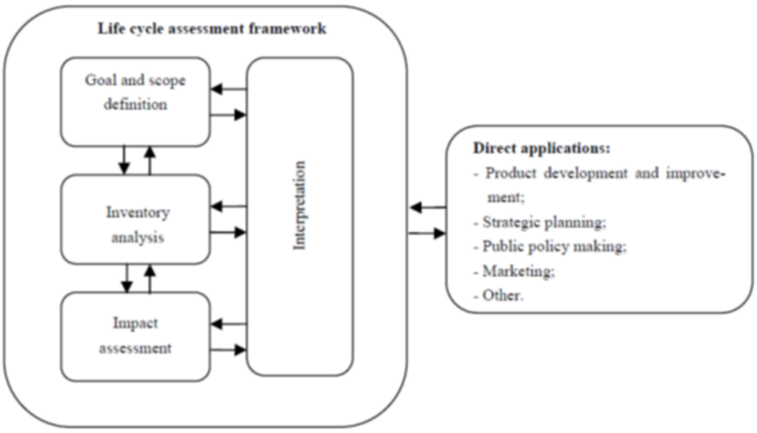

Figure 7: Stages of LCA in ISO 14040:2006

[1] The author's elaboration from (Kane, 2010 p. 10)

[2] ISO 14040:1997, Goal and Scope; ISO14041 (1998), Life Cycle Inventory Analysis; ISO14042 (2000), Life Cycle Impact Assessment; ISO14043 (2000), Life Cycle Interpretation; ISO14048 (2002), Environmental Management: Life Cycle Assessment – Data documentation format, International Organization for Standardization.

2.3.6.2. Development of LCA in the building sector

Sustainable development in the construction sector has been subject to a lot of concern both on the international level (ISO TC 59 technical committee that has elaborated ISO 21930; ISO 15392) and on the European level (CEN TC 350 technical committee) (FCE, 2011). In order to standardize and facilitate the interpretation of results and comparison between different building sustainability assessment methods, (CEN/TC 350) and “Sustainability of Construction Works”, developed voluntary standardization of methods for the assessment of the sustainability aspects of new and existing construction works and standards for the environmental product declarations (EPD)[1] of construction products (CEN, 2010).

This can enforce global market structure coherency for environmental assessment and support obtained results. In addition, there are several international as well as national/regional legislations and directives, that attempts to incentivize the use of LCA in building industry as a step so that it would later be mandated. This may explain why the current trend for many GBRS is to incorporate LCA as a base for their environmental assessment framework to maintain its competitive advantage in the global marketplace.

2.3.6.3. Potentials and Problems for using LCA

Differentiation based on environmental characteristics is an increasingly powerful tool in the sustainable real estate market, it could provide a competitive advantage and increase the market value (Publications Office of the European Union, 2010), (AIA, 2010). Some future incentives for using the LCA methodology are possible if the release of emissions is taxed or limited in some way, also owing to the evolution of current rating systems and the emergence of *Green Building* codes, e.g. ASHRAE 189.1[2], Carbon Cap-and-Trade Bill and IgCC[3] (Howard,2005), (AIA, 2010), (www.bdcnetwork.com), (APAT, 2008) and (Issa et al, 2010), (Smith et al,2006).

Nevertheless, LCA cannot be considered a common practice at the present time due to; perceived extra cost, time and skilled expertise lack of guiding principles that takes into consideration the unique character of every building, deficiencies in the databases’ completeness, and the inherent subjectivity of LCA. Another major problem for applying LCA is adopting partial concepts of the whole theme, which is causing confusion in the building industry and market[4], in addition to the lack of financial incentives to perform LCA in many contexts (Berardi, 2011).

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[1] It is an internationally standardized (ISO 14025) and LCA based method to communicate the environmental performance of a product or service

[2] Standard for the Design of High-Performance Green Buildings except Low-Rise Residential Buildings was released in January 2010
It recommends the use of LCA performed in accordance with ISO standard 14044 for ‘Section 9

[3] The International Green Construction Code

[4]For example; adopting ‘recycling’ and ‘reuse’ approaches without fully assessing their environmental impact leads to biased results. This argument shall be tested in the last chapter.

2.3.6.4. Strategies of using LCA in the building sector

LCA methods implemented in the building construction industry are mainly "Process-based LCA" where both inputs (materials and energy resources) and outputs (emissions and wastes to the environment) are calculated for each step required to produce a building product or process used in this particular project as shown in figure (8) (AIA, 2010).[1] Types of process-based LCA methods are: Cradle-to-grave[2], Cradle-to-gate [3], Cradle-to-cradle [4], and Gate-to-Gate [5].

Some criteria should be put into consideration when planning to conduct LCA study as discussed by (AIA, 2010); availability of information about building materials and assemblies, availability of building energy analysis results, time constraint, user skills and accuracy of required output (www.bdcnetwork.com), and it is necessary to check that the chosen tool considers the difference in fuel mix[6] for electricity generation when buildings in two different regions are compared (AIA, 2010), as well as proper benchmarking. Moreover, reducing the results to a single score requires questionable assumptions and generalizations, so it is frowned upon by many LCA experts (www.bdcnetwork.com).

LCA can be used to identify critical life cycle stages or burdens for which additional environmental assessment tools (such as risk assessment) may be applied to fully understand the potential impacts and risk (AIA, 2010), (www.bdcnetwork.com) ,(Howard,2005), (The New Zealand Green Building Council, 2006). It can range on various levels; Materials- Product, and whole building levels. Each larger level builds from the level below, as shown in figure (8) (Han, RB0511).

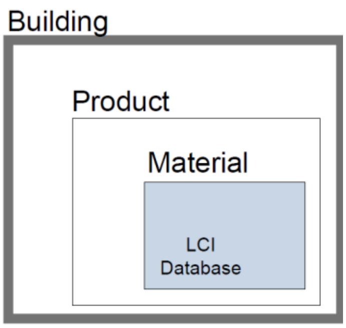

Figure 8: Levels of using LCA in the building process (AIA, 2010)

- ☐ **Material Level;** at its core, process-based LCA is defined at the material level and submitted for inclusion in various LCI databases.
- ☐ **Product/assembly Level;** product-level LCA data is growing in the market. LCA is calculated as a collection of materials which are assembled into a final (or intermediate) product, calculating each inputs and outputs. To complete a product LCA, a thorough knowledge of the source and quantities of materials and the manufacturing processes of the finished product are required

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[1] Another LCA variant which is outside the scope of this research, is the Economic Input-Output Life Cycle Assessment (EIO-LCA) method, which describes the financial inputs and outputs within a prescribed geographical area, region, country or continent- When combined with environmental data for these sectors, an estimate of the environmental impact per unit value of a sector can be made [8] (AIA,2010).
[2] It is the full Life Cycle Assessment from manufacture- use and disposal.
[3] It is an assessment of a partial product life cycle assessment, only for manufacturing. They are sometimes the basis for Environmental Product Declarations (EPDs) used for buildings
[4] It is a specific kind of cradle-to-grave assessment where the end-of-life disposal step for the product is a recycling process.
[5] It is a partial LCA that examines only one value-added process in the entire production chain, for example, evaluating the environmental impact due to the construction stage of a building.
[6] Fuel mix for electricity generation; Different regions of the world have different fuel mix. Fuel mix can be described as a distribution of the share of each renewable and non-renewable source of energy generation as a ratio of the overall electricity generation for a region.

☐ **Building Level;** Building LCA, or whole-building LCA is a product LCA where the product is the building itself.

a. The Building level LCA includes the following stages (AIA, 2010):

☐ Materials Manufacturing:, includes resource extraction or recycling, transportation of materials to the manufacturing locations, manufacture of finished or intermediate materials, building product fabrication, and packaging and distribution of building products.

☐ Construction: All activities relating to building project construction, including transportation of materials and products to the project site, use of power tools and equipment during construction of the building, on-site fabrication, and energy used for site work.

☐ Operation/ Use and Maintenance: including energy consumption for heating and electricity, water usage, environmental waste generation, repair and replacement of building assemblies and systems, as well as transport equipment used for repair and replacement.

☐ End of Life: Includes energy consumed and waste produced due to decommissioning and demolition of the building, to landfills, and transport of waste materials. Recycling and reuse related to demolition waste also can be included, depending on the availability of data.

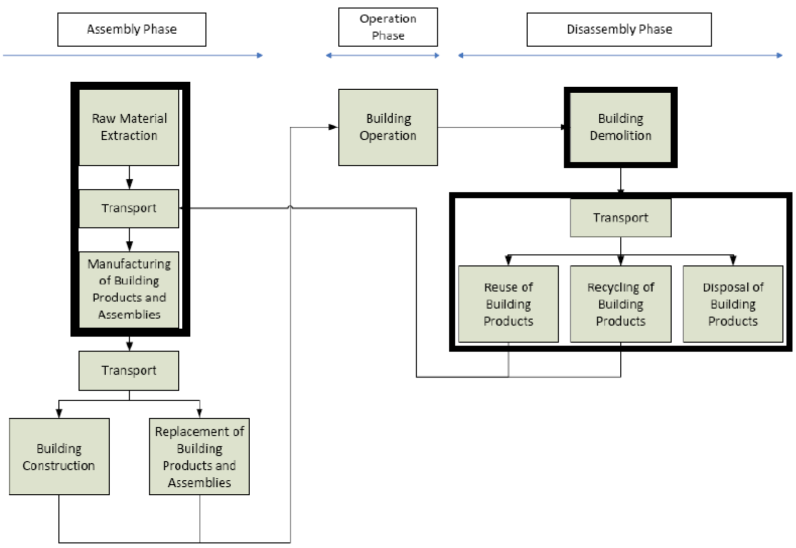

Figure 9: Life cyle of a building (Optis, 2005)

The figure above shows a breakdown for a building life cycle stages, and each step is composed of a number of activities having several life cycle stages (Howard,2005) . Hence, each activity comprising material and energy use can be represented as a sequence of (input flows) resources and output flows (emissions) (Lavagna, 2008 p.20).

b. Material/ Product/ Assembly level LCA

The Role of Life Cycle Assessment for this level is to prescribe and streamline environmental product certification programs which represent a key component in the design for environmental approach. Three types of product environmental label exist and are defined in ISO 14020 (2000). These are[1];

- ☐ The eco-certification environmental labels (type I)
- ☐ The self-declared environmental claims (type II)
- ☐ The environmental declarations (type III).

Type II is the most prevalent type of environmental labels in the market place but with the least connection to LCA studies, while on the other hand (type III) is the most related and trusted type to LCA studies.

2.3.6.5. LEED and LCA

Analysing LEED system (previous versions till V3.0) from a LCA perspective reveals serious drawbacks. Primarily, that LEED system does not refer explicitly to LCA (i.e. there is no single criterion that explicitly covers the whole life-cycle of the building or requires the use of LCA approach), although collectively, the LEED rating criteria covers practically the entire life-cycle of buildings but not from a life cycle approach. Notable exceptions are (1) manufacturing of building materials and equipment and (2) recycling/reuse processes. Transportation of building materials is indirectly accounted for as well (under MR-5 Regional materials). More importantly, each of these criteria covers a specific life-cycle phase, and because points are given independently for each criterion, it lacks insights over potential synergies and trade-offs scenarios between life-cycle stages. Additionally, Strategies recommended by the LEED system- are collectively sustainable but are not justified using life cycle approach (www.bdcnetwork.com)

Nevertheless, LCA can complement LEED system through quantifying the environmental impact arising from energy and materials use. Accordingly, LEED system has taken serious steps to integrate LCA as a mean to quantify environmental impact resulting from materials' selection. This is evident in the current version and the expectations for the future version as well.

a. LEED V3.0

I. Using LCA for structural adjustments

The inclusion of LCA is considered an important step for the technical development of LEED V3.0; individual credit weighting is based on; 1) the U.S. Environmental Protection Agency's TRACI[2] environmental impact categories, and 2) the weightings developed by the National Institute of Standards and Technology (NIST) comparing

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[1] Source: (Berardi, 2011), (www.bdcnetwork.com)

[2] TRACI: Tool for the Reduction and Assessment of Chemical and Other Environmental Impacts .
The TRACI software allows the storage of inventory data, classification of stressors into 10 impact categories, and characterization for the listed impact categories (www.bdcnetwork.com).

impact categories with one another and assigning a relative weight to each (LEED NC reference guide, 2009).

Materials and Resources credit category remains with the same general structure. Yet, Up to seven LEED material resource points (7%) were identified as applicable on the basis of the following credits; from one side; creating synergy to reduce embodied energy through; Construction waste management, Building reuse, Material Reuse, and Recycled content, and from the other side creating potentials to reduce the source of impact, through; Regionally sourced materials, and Rapidly Renewable Material (www.symbioticengineering.com). This acts as the first step to prepare for the formal use of LCA in the next LEED version.

Also, the Alternate Compliance Path for LEED EB (titled Life Cycle Assessment of Building Assemblies by the USGBC) has included the materials level, with an optional path for materials and resources credits based on the durability and embodied energy of existing materials, as determined through LCA criteria (www.bdcnetwork.com), using Athena LCA software tool (including Athena Eco-Calculator and Athena Impact Estimator) or other complaint tool.

II. Using LCA for materials level

Under LEED Materials and Resources credits, no change has occurred from previous version to develop the approach of choosing sustainable building products. The system offers little guidance towards decision making process and choosing from various alternatives, but does not take into consideration their functional unit[1] or the effect of contextual variations. Thus, practitioners probably rely on type II environmental product declaration because they are more prevalent in the marketplace, in spite of the fact that these types of labels have the least direct linkage to LCA.

b. LEED V4.0 (Future version)

I. LEED V4.0 for the building level

LEED requires conducting LCA under Option 4: *Whole-building life-cycle assessment* (3 possible points), in order to comply with MRc1: *Building life-cycle impact reduction* for the structure and enclosure. It is based on a comparative method to a reference building[2], and should demonstrate a minimum of 10% reduction in at least three of the six impact measures (one of which must be global warming potential), and not exceeding 5% for other categories [3] (www.usgbc.org.), and the reference and design buildings must be of comparable size, function, orientation, operating energy

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[1] It is the unit of comparison that assures that the products being compared provide an equivalent level of function or service.

[2] It is expected that when the new version is formally activated, more information shall be available regarding how to estimate the impact reduction of the reference building.

[3]The impact categories are: Global warming potential (greenhouse gases), Depletion of the stratospheric ozone layer, Acidification of land and water sources, Eutrophication, Formation of tropospheric ozone, and Depletion of non-renewable energy resources.

performance (as defined in EA Pre: Minimum Energy Performance), their expected service life, as well as LCA software tools and data used.

II. LEED V4.0 for the Material level

The new LEED V4.0 shall require the use of type III EPD- with the most direct linkage to ISO LCA, for the new development of the following MR credits;

- ☐ MRc2 Building product disclosure and optimization - environmental product declarations
- ☐ MRc3 Building product disclosure and optimization - sourcing of raw materials
- ☐ MRc4 Building product disclosure and optimization - material ingredients

These credits encourage the use of products/materials for which life cycle information is available, to reward project teams for selecting products from manufacturers who have verified environmental LCA.

Hence, it can be concluded that LEED V3.0 sets the base for integrating LCA in the LEED system through three steps; adjusting credit weighting, innovation points and compliance path for LEED EB- as an optional step to promote the application of LCA among practitioners. Nevertheless, a drawback exists for accounting for LCA based material selection. While, the new LEED version V4.0 has taken further steps to exceed the requirements through; requiring third type environmental certification building material/products, as well as promoting the application of LCA among practitioners. Yet, according to the research, LEED does not yet provide guidance on how to properly integrate LCA along the whole building process to support and guide decision making process.

2.4. Sustainable Project Management

Sustainable project management is better defined as a process that aims at achieving the three dimensional goals of sustainability, Benefits obtained from management processes are less tangible and do not in themselves provide direct environmental, economic or social benefits, but they help manage direct impacts, and may prove to be vital to the successful achievement of more sustainable objectives in a project (Yates, 2001).

Key factors for any sustainable building process should include; (a) *Organization and optimization*, through; providing the tools and techniques that enable the project team to organize and prioritize their work to meet constraints including; time, cost, quality, as well as other factors specific to each project situation, (b) Measurement and Benchmarking; to provide means of measuring and benchmarking performance goals, as well as (c) *Verification, control and feedback*; it is mainly needed to control monitor and manage the implementation process considering cost, risk, quality, time, change, and procurement, through measuring on-going project activities, project variables (cost, effort, scope, etc.) against the project management plan and the project performance baseline ,and finally, Identify corrective actions to address issues and risks properly[1].

The inputs to this process are the identification and development of a client's objectives (e.g. utility, function, quality, time, cost), project resources (e.g. staff, materials, labor, and finance), and their relationships (planning, organizing, controlling, and co-ordination of project activities), in order to draw potential alternative strategies, and evaluate and compare their impact on the project design, schedule, and overall budget. This is why it is necessary to consider the applicability of particular strategy to the project scope, type of building, climate, and location, as well as the degree of expertise required, along with considering both tangible and intangible benefits- taking into considerations whole life cycle savings from each strategy (Lovea et al, 2002), (Yellamraju, 2011 p. 82-83).

Sustainable project management has some commonalities with traditional methods of project management, and thus traditional methods and tools may be used to help plan, organize management activities, e.g. estimation and planning, scheduling, cost control and budget management, resource allocation, communication, decision-making, quality management and documentation or administration systems (Lacroix,2010), for example; Gantt chart, Program Evaluation and Review Technique (PERT), work breakdown structure (WBS) and resource allocation. More specific tools and software programs may also be used, e.g. the PRINCE2 process[2],PRiSM [3], or some borrowed methods, e.g. Lean project management[4] (Emmitt, 2007, p.13)- provided that project team members are aware of the difference between the two of them, and that sustainable project management is not only about sustainable building practices, but extends to cover the whole process (Process oriented thinking) in an iterative manner (Emmitt, 2007), as shall be discussed later in chapter five.

[1] The author's elaboration from (Wu et al,2010), and (Green Building Finance Consortium, 2010)
[2] It is specified with its key inputs and outputs divided into manageable stages and with specific goals and activities to be carried out to allow for automatic control of any deviations from the plan
[3] Projects integrating Sustainable Methods methodology is a process-based, structured project management methodology that introduces areas of sustainability based on ISO standard
[4]Lean project management uses principles from lean manufacturing to focus on delivering value with less waste and reduced time through the efficient planning and designing at the start of the project (Emmitt, 2007, p.13)

2.5. Summary

This chapter introduces the basic concepts upon which the research is built. It starts with setting a clear definition for 'Green buildings' stating that it is a comparatively relative concept usually based on a comparison to a base building- it includes both tangible and intangible benefits, and thus any comparison has to consider both of them. Both problems and potentials of Green Buildings are mainly related to the market which requires new activities for measuring, benchmarking, verifying, certifying and incentivizing green building performance, to create its value and provide a solid base for comparability. These requirements were challenging to achieve, hence Green Building Rating and Certification systems evolved- which is simple and more related to the stakeholders' interest and market requirements, and covers both qualitative and quantitative aspect, yet they face some criticism which the research investigates through differentiating between its 'Rating' and its 'Certification' mechanisms individually.

The research starts analysing the effect of both rating and certification mechanisms separately to investigate their potentials and drawbacks, pointing out that the first mechanism generally takes the form of a design checklist, and/or credit rating calculator to be applied along the building process to guide decision making process, and assess building performance- thus, it is more related to decision making and measurement and benchmarking metrics. While on the other hand, the certification mechanism takes the form of voluntary or mandatory schemes, and is more concerned about creating the value that shall reflect on the market, also it can be used as a tool to channel building sector, to achieve the national target regarding energy efficiency and CO_2 emission reduction. The first mechanism is criticised mainly for its structure including measurement criteria, weighting and benchmarking, particularly for the environmental assessment methods, while the second mechanism is criticised for permitting 'Point chasing' and 'Green washing' to affect the decision making process. It is also important to note that the Rating mechanism has direct impact on the Certification mechanism, and this explains the reason behind the current market confusion, due to the multiplicity of measurement and benchmarking tools which does not give clear indication about the true value of green buildings. It is also important to understand the relation between the two mechanisms and the role played by each, to be able to develop further discussion about the LEED system which is the research focus and one of the greatly adopted GBRS.

Efforts from the scientific society and the building industry attempt to integrate LCA (which is based on a scientific solid base) into LEED system for quantifying environmental performance of quantitative sustainable criteria- but considering that it is more complex, time extensive and expensive process, besides that it faces some challenges related to the lack of guidelines, data, and expertise to perform this type of assessment along the building process- hence, it is not considered an easy process.

Moreover, LEED system like the rest of GBRS faces two main criticism (although each system faces these criticism in a different way); the first is related to the system's structure (credit selection, weighting, single score…etc.), and the other criticism- which is the research interest- is related to means of applying the system along the project management process. This problem arises due to the reason that little guidance is provided for integrating the LEED system along the building process, which results in the risk of ‘point chasing’ and ‘Green washing’, and eventually leads to less environmental value obtained- especially that integrating LCA into LEED system is still a new development which also lacks proper guidance whether on the scale of the whole building or on the scale of individual material/product selection. This is besides other concerns regarding the adaptability and applicability of the LEED system to different building types and contexts, and how this affects the sustainable project management process.

Finally, a brief introduction has been provided about sustainable management process; highlighting the main communalities and differences between it and the traditional process for; principles, tools and methods, and shall be continued in chapter five discussing sustainable project management process under LEED system, but for now it should be pointed out that the key factors for any sustainable building management process should include; (a) Organization and optimization, (b) Measurement and Benchmarking, as well as (c) Verification, control and feedback- because this shall help draw the research framework in the coming chapters.

The next chapter shall compare between some of the famous GBRS systems, to be able to analyse and evaluate the LEED system status among other systems, and provide some recommendations for the application of LEED system along the building process.

C H THREE

3

ANALYSING & EVALUATING LEED SYSTEM

This chapter aims at analysing the LEED system through a theoretical and practical review. First; through a theoretical review of existing literature comparing LEED to other GBRS, then with particular focus on the LEED system investigating its applicability and adaptability to different building types and contexts.The aim of the first part, is to analyse various approaches for sustainable assessment and best practices encouraged by such systems; capturing a quick hint about the major pros and cons of the LEED system along with suggestions for development. Secondly; through a practical review analysis, citing the results of a survey conducted in mid 2012 among LEED practitioners in the italian context, and a LEED projects' market analysis, to investigate the system's critical aspects concluded from the theoretical review and compare it to international studies. Results of this chapter shall provide insights on the application of the LEED system for the next chapters.

3.1. COMPARING THE RATING & CERTIFICATION MECHANIMS OF GBRS

A timeline development for various GBRS[1] is represented in figure (10), in order to understand their chronological development and relate it to their logic of assessment. Both BREEAM[2] and LEED rating systems are considered among the first and most widely diffused building rating systems on the global scale. New systems are continually proposed and the most diffused ones receive a yearly update. Some studies (Essig et al, 2011) and (OECD/IEA, 2010) divide GBRS into two generations; first generation includes BREEAM and LEED systems, while the second generation includes DGNB[3], Green Star, CASBEE[4], GreenGlobes, HQE[5], MINERGIE, iiSBE[6], and Green Star…etc. The difference in generations is that the second generation is directed towards evaluating the building based on its whole life cycle.

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[1] Sustainable building rating systems evolve frequently to adjust to new scientific and research findings to raise building performance, and consequently raising the bar for sustainable real-estate market demand, therefore the current state of rating systems was identified to draw research limitations. It is recognized that there are planned updates to various rating systems, however for this section only the active attributes were considered.
[2] Building Research Establishment's Environmental Assessment Method
[3] Deutsche Gesellschaft für Nachhaltiges Bauen
[4] Comprehensive Assessment System for Building Environmental Efficiency
[5] Haute Qualité Environnementale
[6] International Initiative for a sustainable built environment.

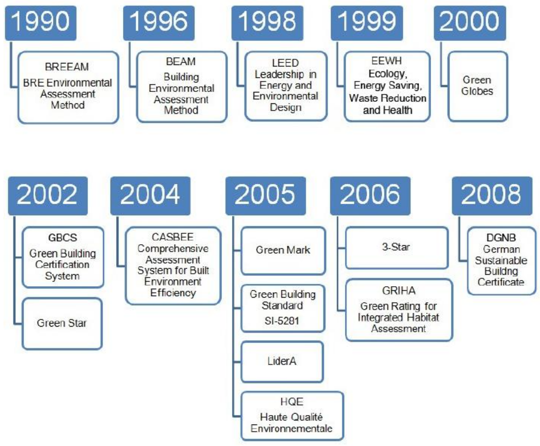

Figure 10: Rating system timeline, source (IFMA,2010)

Some studies provide a comparative analysis between two or more of the most well-known *Green Building* rating systems, in order to facilitate direct comparison between them (IFMA,2010), (Sleeuw, 2011), (Wu et al,2010), (Reed et al, 2011), (Nguyena et al,2011), (Fowler et al,2006), (Berardi, 2011), (ENERBUILD, 2010), and (The New Zealand Green Building Council, 2006). According to these studies, LEED rating system was found to be among the top scored rating systems. The aim of this section is to understand communalities and differences between the assessment systems; analysing their structure and how this affects their application in order to suggest developments for the LEED system application.

This section cites the results of the following studies, with particular concern on those points highlighted in the previous chapter as criticism for the LEED system, which are; system's structure and its application- with particular attention to their environmental evaluation methods for energy and materials credits, along with adaptability of the system to other contexts, and its applicability to different building types;

- ☐ The study carried out by (Reed et al, 2011), comparing BREEAM, LEED, Green Star and CASBEE
- ☐ The study carried out by (Saunders, 2008), comparing BREEAM, LEED, Green Star and CASBEE methods
- ☐ The study carried out by (Berardi, 2011), comparing BREEAM, LEED, CASBEE, SBTool, SBC-ITACA and Green Globes
- ☐ Another study by (Sleeuw, 2011), presented a comparison between BREEAM 2011 and LEED 2009.
- ☐ Another important report issued by (ENERBUILD, 2010), comparing eight of the current environmental labels for buildings actually used in the Alpine region; including LEED Italia, Protocollo ITACA, HQE and DGNB.
- ☐ An important study by (Wu et al,2010), comparing LEED, Green Globes and BCA Green Mark[1] to address the significance of project management through each system.

[1] Building & Construction Authority (BCA)

3.1.1. STRUCTURE OF THE RATING MECHANISM

There are different mechanisms for rating systems and this affects the complexity of the system as shown in figure (11). The first and widely used rating mechanism is to typically sum the weighted scores of individual factors to arrive at an overall rating for a building, e.g., BREEAM[1], LEED, and Green Star although they still differ in many internal structural details, for example Green Globes[2] takes the form of a questionnaire, GBTool displays the ratings for each factor in a set of histograms, but does not attempt an overall building rating, HQE attempts individual rating exceeding the minimum threshold predefined for each sustainability category, then an overall rating for the building itself. A special characteristic for HQE is that it includes both organizational and operational aspect for assessing- not only the sustainable practices, but the process as a whole. Also, DGNB, evaluates the overall sustainable building performance (economic, ecologic and socio cultural, and functional Quality), and life cycle of a building rather than individual measures[3].

On the other hand, tools such as CASBEE take a different approach, reporting the ratio of the environmental quality and performance to the environmental loadings of the building as a rating of its environmental efficiency. Also, an alternative way of expressing the results of environmental assessment was introduced by Promis-E system in Finland, where environmental efficiency is expressed as a function of property value, property cost and environmental impact[4].

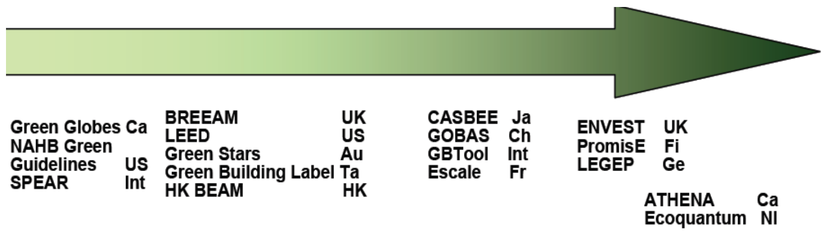

Figure 11: Sophistication and Complexity of green building rating systems

Thus, it can be concluded that it is difficult to compare what appears to be their corresponding rating classification as shown in table (2) (Bre, 2008) (Howard,2005). These variations have created obstacles and confusion around *Green Buildings* for the construction market, end users, building owners and building operators (McManus, 2010), while a common approach to environmental building assessment would facilitate

[1] For BREEAM system; evaluations is expressed as a percentage of successful over total available points: 25% for pass classification, 40% for good, 55% for very good, 70% for excellent, 85% for outstanding. While Green Star has three distinct classification levels.4 Star, with a score of 45 to 59 signifying best practice, 5 Star, with a score of 60 to 74 signifying Australian excellence and 6 Star, with a score of 75 to 100 signifying world leadership

[2] Green Globes is a web-based tool of approximately 150 questions ranging from 'yes or no' answers. It generates numerical assessment scores corresponding to a checklist with a total of 1,000 points listed in seven assessment categories

[3] Source: GreenSource%20Magazine.htm, 05/2010, By B.J. Novitski

[4]Efficiency = Property Value (Financial) / (Property Cost + Environmental Impact). All values are brought to dimensionless indices before being placed into the equation. It aims at integrating the building level assessment into corporate property portfolios (because the financial implications are inherently built into the efficiency measure.(Howard,2005)

the comprehension, dissemination and application of certification systems by the private and public stakeholders (ENERBUILD, 2010).

	BREEAM	LEED	Green Star	CASBEE
Management	15	8	10	It is not possible to calculate the value of each issue category, for CASBEE, as the value is dependant on the final score
Energy	25	25	20	
Transport			10	
Health and Wellbeing	15	13	10	
Water	5	5	12	
Materials	10	19	10	
Landuse and Ecology	15	5	8	
Pollution	15	11	5	
Sustainable Sites	-	16	-	

BREEAM	LEED	Green Star	CASBEE
EXCELLENT			
VERY GOOD	PLATINUM	SIX STARS	
		FIVE STARS	S
GOOD	GOLD	FOUR STARS	A
	SILVER	THREE STARS	B+
PASS		TWO STARS	B-
	CERTIFIED	ONE STAR	C

Table 2: Comparing the rating and certification levels of four GBRS[1]

Additionally, the rating mechanism differs according to the tools used. Some systems use new tools and methods for evaluation, e.g. CASBEE uses the graph method, GBTool uses the spread sheet, Green Globes uses the web-based questionnaire, LEED uses online letter templates and so on. This aspect is considered a cornerstone for their development, streamlining the rating and certification process and providing a more user friendly assessment tool. An important consideration for using online portals was driven from the Green Globes system, considering the necessity to establish direct interface with other online tools[2].

Also, some systems require earlier involvement for onsite inspections during construction e.g. BREEAM, or even at the beginning of the project and for post occupancy evaluation, example; the French certification (BDM)[3].

3.1.2. ASSESSING ENERGY EFFICIENCY

Giving more focus on assessing energy and resource efficiency reveals that it is considered among the most challenging sustainable criteria to measure and benchmark. This explains why some GBRS differ among each other in this concern. Primarily, because of the scope of energy/material category, standard reference and software tool required for compliance, measurement criteria and measurement unit[4].

For example, BREEAM, LEED and Green Star require conducting a computational simulation model for measuring energy credits. Assessment for BREEAM and LEED is based on comparison between a reference building and the original design, while for Green Star only one model is required to simulate the original design. Also, their measurement metrics differ; LEED system measures energy savings by cost- mainly based on ASHRAE 90.1 standard, while BREEAM depends on measuring CO_2 based

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[1] BRE, 2008 found in (Reed et al, 2011).

[2] The Green Globes online tool allows for direct interface with other online tools, such as the Natural Resources Canada screening tool and the US Environmental Protection Agency's ENERGY STAR Portfolio Manager, which can be used for benchmarking.

[3] Bâtiments Durables Méditerranéens certification- another French certification system.

[4] Inbuilt (2010) compared BREEAM Offices 2008 with LEED 2009 NC and found that; 34% of the points available in BREEAM were not available in LEED, and 16 of the points available in LEED were not available in BREEAM (Sleeuw, 2011).

index, taken from the Energy Performance Certificate (EPC)[1]. The asset rating is then calculated as the ratio of the CO_2 emissions from the actual building to the Standard Emission Rate which is determined by applying a fixed improvement factor to the CO_2 emissions from the reference building. Moreover, LEED compares building performance against a baseline not setting absolute target as in BREEAM, e.g. for energy and water credits. This makes LEED less prescriptive than BREEAM. For the Green Star, the score is determined for each category based on the percentage of points achieved versus the points available for that category- not all the credits are available for every project, which makes the scoring system flexible for each project. While on the other hand, Green Star measures greenhouse gas emission referring to the NABERS (National Australian Built Environment Rating System)[2].

The study conducted by (Lombard et. al, 2008) compares the energy scales of LEED-NC to BREEAM, CALENER and CEN systems- showing that they differ in the level of definition or number of classes, as well as the savings percentages corresponding to each of them as shown in figure (12)

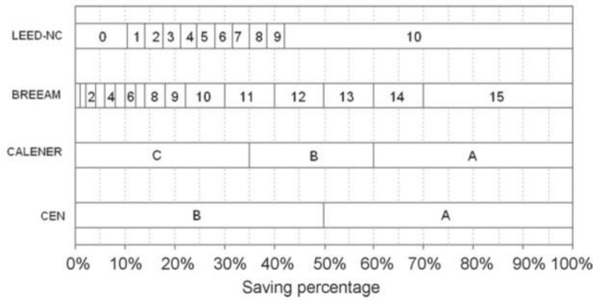

Figure 12: Comparison of energy scales (CEN and CALENER labels and BREEAM and LEED-NC credit points) of different certifications schemes in terms of saving percentage (Lombard et. al, 2008).

Moreover, Energy category in Green Globes requires reporting additional aspects, like; energy consumption, energy demand minimization, “right sized” energy-efficient systems, renewable sources of energy, and energy-efficient transportation. Green Globes uses the EPA Target Finder (recently introduced in LEED V3.0), as an energy benchmark -and prescriptive paths for smaller office buildings, and addresses few other points that are not fully addressed in LEED, e.g.; microclimatic design considerations, space optimization and the use of energy efficient technologies[3], in addition to the possibility of earning significant numbers of points for lower levels of modeled performance.

HQE system focuses more directly on the simulation or measurements of primary non-renewable energy and control of emissions, and rewards efficient building

[1]The EPC is generated based on the U.K. National Calculation Methodology (NCM). It provides an energy rating for the building ranging from A to G where A is very efficient and G is the least efficient.
[2] Green Star recognises simulation packages that must either have passed the BESTEST validation test, or be certified in accordance with ANSI/ASHRAE Standard 140- 2001 or European Union draft standard EN13791 July 2000. In BREEAM, there are two classes of approved software for energy performance assessment. The first is the approved software that interfaces with the Simplified Building Energy Model (SBEM) engine and the other is the approved Dynamic Simulation Modelling (DSM) tools.
[3]source: http://sustainabilityproblems.wikispaces.com/GuillotMatrix2_LEED

automation system and metering, as well as an additional credit for high performance in energy efficiency.

Also, the environmental assessment of the DGNB system requires assessment of risks to the regional Environment, microclimate, non-renewable primary energy demands and total primary energy demands and proportion of renewable primary energy.

3.1.3. ASSESSING MATERIALS AND RESOURCES EFFICIENCY USING LCA

Environmental evaluation of GBRS generally assigns weighting per each criterion that indicates their relative environmental impact. This weighting maybe or maybe not based on LCA. Additionally, the use of energy intensive products and corresponding global warming impacts are addressed indirectly by encouraging alternatives and recycling processes in almost all GBRS.

This section investigates LCA for some of the most famous and widely diffused GBRS, in order to evaluate different approaches to incorporating LCA into their assessment structure- this can be summarized as follows;

☐ ***BREEAM*:** uses LCA based credits for materials based on comparative elemental LCA profiles found in the Green Book Live and the Green Guide to Specification[1]. The Green Guide works only at the assembly level, where they are pre-ranked based on detailed LCA, thus users need only to select those that are highly ranked. The system incorporates benchmarking and scoring as it relates to operating energy and water use. In that case, the certification label may be able to provide data in both quantified form as well as comparative form[2].

☐ ***GBTool*;** LCA was used as the basis for materials, and embodied energy criteria in earlier versions; in the GBTool 2005 version, materials credits were based on attributes because many users did not have access to LCA data.

☐ ***Green Globes:*** Green Globes-Resource category includes Building Materials and Solid Waste (materials with low environmental impact, minimized consumption and depletion of material resources, re-use of existing structures; building durability, adaptability and disassembly; and reduction, re-use and recycling of waste). The system has a distinct rating criterion referring to LCA and requires the use of LCA tools for both the LCA material and the building levels. It recommends using Athena at the Schematic Design Stage to help the user select building assemblies with the lowest reported impact, and BEES[3] at the Construction Documentation Stage to compare the environmental impact of specific products and materials. Yet, it should be noted that it does not comprehensively address the functional quality of material selection, and many of the criteria are independently rated by cut-off values lacking an assessment of the trade-offs

[1] Information on the Green Book Live available at: http://www.greenbooklive.com/. Information on the Green Guide to Specification available at: http://www.bre.co.uk/greenguide/podpage.jsp?id=2126

[2] The author's elaboration from (Sleeuw, 2011) and (Howard,2005).

[3] Building for Environmental and Economic Sustainability

between them. This indicates that inspite of attempting to achieve an integrated building process, this issue needs further development.

☐ ***CASBEE;*** The system has a mechanism for including life cycle analysis in the process as an optional assessment, but the life cycle analysis does not impact the primary Building Environmental Efficiency assessment.

☐ ***Green Star;*** it offers a credit specifically for reducing greenhouse gas emissions

☐ ***PromisE – Finland***; it integrates the building measure of efficiency from bottom up assembly/product level LCA through systems level LCA to the building environmental assessment.

3.1.4. MANAGEMENT PROCESS UNDER GBRS

System's structure reflects on the management process. For example, comparing LEED and Green Globes, it is found that, while LEED has an online portal for filling in credit checklist and letter templates, while Green Globes takes the form of self-assessment questionnaire which requires less documentation and requires less cost. Projects are assigned Globe ratings based on the percentage of applicable points they achieve thus it is considered more suitable for projects with relatively smaller size and budget. Also the allocation of points for strategies and/or outcomes is different. Green Globes awards a number of points for implementing certain strategies, as well as for the outcomes themselves through applying 'Partial credit' to reduce the risk of point-chasing, whereas, LEED primarily allocates points for achieving a certain performance level, this signifies higher credibility in results especially for lower certification levels. Different strategies of point allocations are thus translated into trade-offs between flexibility and prescription between the two systems.

While, DGNB is structured to cover the three dimensions of sustainability, thus, it requires assessment of economic aspects as well; Building-related Life Cycle Costs and Value Stability. On the other hand, HQE approach is a twofold process; encompassing both *Organizational aspects* (defines the tool of the system), which is more similar to a project management tool, and *Operational aspects* (defines targets of work). It is noted that the client is actively involved from early stages for hierarchically defining 14 targets including standards target performance levels as shown in figure (13), to create a building environmental quality profile

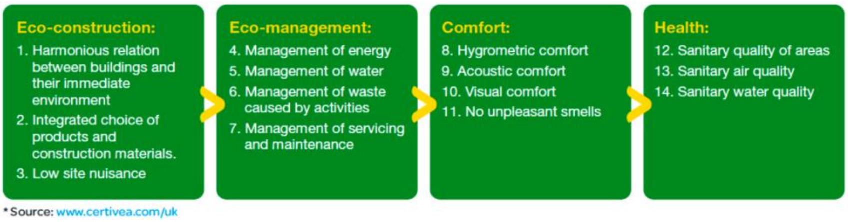

Figure 13: HQE 14 environmental issues, Source: www.certivea.com/uk found in (McManus, 2010).

Some GBRS dedicate special requirement for sustainable management activities, either in the form of category/ credit, and they may cover individual practices e.g. BREEAM[1], LEED[2], or the whole process, e.g. HQE, Green Globes[3], and CASBEE. The study conducted by (Wu et al, 2010), pointed out the difference between allocating points to management practices (the case for LEED and BCA), which is less efficient if not complemented by a more wider framework defining the whole management process (the case of Green Globes).

Another major difference between GBRS is the time and extent of integration of the rating system along the building process. For example, the LEED system has two submission options; design phase review (optional), and construction phase review (mandatory). While Green Globes, CASBEE, DGNB and HQE may be applied along different building stages- which is more helpful to practitioners and provide direct feedback, for example; in Green Globes, there are eight different times along the building process that the Green Globes tool can be used: Project initiation, Site analysis, Programming, Concept design, Design development, Construction documents, Contracting and construction and Commissioning. This makes it more flexible and easier in use to influence the design and planning processes of the project through immediate feedback. On the other hand, CASBEE has been developed as 4 integrated tools through the buildings' life cycle targeted for different involved parties, e.g.; Pre-Design Tool; targeted at the owner and planner, Design Tool; acting as a self-diagnosis software tool targeted at the designers, architects and engineers, third party environmental labeling tool- although this is not fully implemented by a labelling body, and finally, a Sustainable Operation and Renovation Tool, targeted at building owners and caretakers for the operation and maintenance of buildings.

Another aspect to point out is the role of the auditor/ assessor in various GBRS; for HQE, the auditor is assigned by the certification body (Certivéa). For, DGNB The certification process requires the presence of a certified auditor for the entire submission process. For CASBEE- The assessment process is assessed by trained individuals that have passed the CASBEE exam, while, for BREEAM certification, the assessor is chosen by the client, and his involvement is a necessity to determine the BREEAM rating based on quantifiable sustainable design achievements, thus the role is closer to an assessor but it also provides higher level of quality control. While for LEED, the involvement of a LEED AP is still optional, and his role is to guide project team members to follow a

[1] The following sustainable activities are required; commissioning, monitoring, waste recycling, pollution minimization, materials minimization.

[2] The current version includes implicit management practices, e.g. construction waste management, commissioning and indoor air quality, while, LEED V4.0 has included a separate credit to reward integrated building process but more information shall be obtained abut this credit after the formal activation of the new version.

[3] The following sustainable activities are required; integrated design, environmental purchasing, commissioning, emergency response plan

sustainable building process, thus his/her role is closer to a sustainable project manager, moreover, involving a LEED AP qualifies the project for an extra credit (ID C2).

3.1.5. CERTIFICATION MECHANISM FOR DIFFERENT GBRS

Certification mechanisms for different GBRS have a common goal but different procedures, which have created a variety of strengths and weakness, and can be indicated as follows;

Steps for attaining BREEAM certification starts with having a pre-assessment of the building completed by a BREEAM pre-assessment estimator, then, determining the correct rating system, and deciding the building's sustainable goals, including certification level, improved processes, the addition of alternative energy sources and more. Then, a copy of the assessment report is forwarded to BRE for quality assurance and a design stage certification is issued. Once construction is finished, a post-construction review is completed and the final certification is issued during the Post Construction Stage before handover and commissioning of the building.

For Green Globes; the certification scheme can be used internally as a self-assessments, or they can be verified by third-party certifiers. The system offers online consultants, software assessments and a rating and certification system[1]. The preliminary assessment occurs after conceptual design and the final assessment occurs after the construction documentation stage. To receive a certification, a third-party verifier must revise the building and supporting documentation. A percentage score is provided for each of the categories as well as an overall score for the building, which dictates how many globes the building is eligible for, and a report is provided summarizing the certification score and suggestions for improvement.

The certification process for DGNB includes building registration, issuance of a pre-certificate based on specifications signifying the intent to earn a certain rating level, documentation of the construction process and issuance of the final certificate[2]. A software-generated evaluation diagram summarizes the results, and the certification output is either in the form of a percentage or a grade[3].

Regarding the HQE system; for a building to receive minimum certification, it must receive a "very good" rating for at least three issues as shown in figure (14); "good" for at least four and "basic" for no more than seven. For the "good" and "very good" rankings, the "principle of equivalence" is allowed- that is, the applicant can suggest an alternative assessment approach to that described in the HQE, which opens up for some flexibility in the design approach chosen by project team members to achieve sustainable targets.

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[1] http://sustainabilityproblems.wikispaces.com/GuillotMatrix2_LEED
2 Source: GreenSource%20Magazine.htm, 05/2010, By B.J. Novitski.
[3] Percentage; minimum of; 50 % bronze, 65 % for silver, and 89 % for gold, or as a grade; 95% corresponds to grade 1.0, 80 % corresponds to 1.5, and 65 % corresponds to 2.0

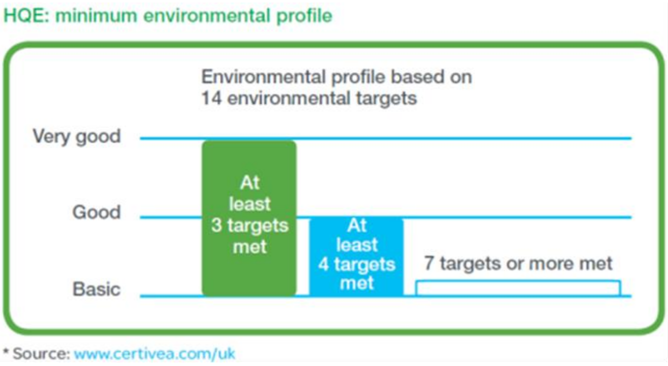

Figure 14: HQE certification levels of performance, Source: www.certivea.com/uk (McManus, 2010).

Thus, it can be concluded that the certification mechanism differs from one GBRS to another because it reflects their various approaches and relation with the market, which also reflects on the form and means of communicating the certification result. This requires different approach for managing projects certified under each system.

3.1.6. Contextual effect and Harmonization of GBRS

Sustainability is a global demand, but when it comes to application, then it must be interpreted into national and local terms. This creates the challenge for all rating systems, to agree on the same goals, principles, and measurement metrics but each according to national or even regional/local conditions- quoting from (Sleeuw, 2011);

' None of the schemes travel well if used in countries other than those which the system was initially designed to work in, and require tailoring to take account of the local context.'

Thus, when adapting GBRS to e foreign context, it needs to take account of the national priorities, regional variation, and environmental conditions, as well as national/local building codes and standards.

Additionally, it is important to note that systems of the same region tend to focus on more or less the same areas of concern due to mutual international commitments and agreements, for example the European area has set a stronger base for sustainability and this is pronounced in the requirements of; HQE in France, DGNB in Germany, and BREEAM in the United Kingdom…etc. On the other hand, more concern on how the system can be user friendly and better integrated as a design and construction tool in the building process is an important concern for sustainability in the North American region, e.g. LEED and Green Globes. In the first case, the system is seen more as an assessment tool, while in the latter case; it is seen as a guide for sustainable project management (as a checklist in LEED or questionnaire in Green Globes). It is worth mentioning that till the time of writing; GBTool is the only system designed with the goal to be adapted on the international scale. It is the only tool that more than one country share in settings its terms, nevertheless, it demands technical expertise to do the certification, while Green Globes is an example for system adaptation to other contexts and how it can differ substantially and evolve into new forms [1]. Such contextual considerations have to be mitigated when applying the system in foreign contexts. Among these contextual considerations, we can mention the following observations;

- ☐ ***LEED:*** it is geared towards climates which use mechanical ventilation and air conditioning
- ☐ ***CASBEE;*** gives land use a 2 to 3 times greater fraction of the total score than systems in Western countries[2]. Some of the indicators are measured according to benchmarks set by national laws, guidelines and best building practices.
- ☐ ***GBTool*****,** each country has a third party team that establishes benchmarks for each criterion. The criteria include a mix of quantitative and qualitative measures
- ☐ ***Australia's Green Star system,*** which is built on BREEAM and LEED, but modified for hot climates, has more weighting dedicated for efficient use of water

Mutual agreements are set in the form of Memorandum Of Understanding (MOU) between some of the above mentioned GBRS to eventually help establish common rating criteria - giving two examples as follows;

BREEAM and HQE established a MOU (June 2009) based on investigating market status. Buildings can be rated according to more than one rating system, obtain certificates, which have various advantages of each over the other (market, design guidelines, performance, economic, regional or local integration)...etc.

Another MOU was established in 2009 as well between BREEAM, LEED and Green Star, aiming to facilitate benchmarking of buildings across different countries and aligning measurement and reporting tools, as well as jointly developing common metrics to measure CO_2 emissions and encourage the adoption of sustainable building practices.

3.1.7. EVALUATION & RECOMMENDATIONS FROM OTHER GBRS

It can be concluded that the majority if not all rating systems are established on the same fundamental principles which are reflected in their credit categories, credit distribution and weighting. Nevertheless, environmental certification levels are not comparable, because they can be based on entirely different combinations of sustainable features and outcomes. Hence, it was useful to analyse and compare their rating and certification mechanisms individually, along with investigating their contextual adaptations and harmonization efforts, and how this affects their application on the management process, in order to reach some recommendations for applying the LEED system.

These recommendations can be highlighted in the following points for further discussion in the next chapters;

First; providing some general comments for the following concerns;

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[1] It was adapted from a combination of both BREEAM and Green Leaf systems
[2] source:http://sustainabilityproblems.wikispaces.com/GuillotMatrix2_LEED

- ☐ Following an integral multidisciplinary approach- to apply the LEED system taking into consideration its main targets, mechanisms of operation, which define its scopes and limits of operation as defined in chapter two. These implicit relations should be explored between LEED system's rating and certification mechanism and how this affects the decision making process.
- ☐ Exploring and developing means of applying the LEED system in a relatively simple practical, transparent and flexible mean, and through a widely acceptable structure and measurement metrics, but again with considerations for flexibility and adaptability when applied to different building types and contexts.
- ☐ Special attention should be paid to EA and MR credit categories.

Second; providing recommendations from other GBRS for the following concerns;

- ☐ Achieving a balance between the three pillars of sustainability; environmental, economic and social, and at the same time dealing with the whole building life cycle- this includes the property value, and other financial aspects, along with the environmental assessment to obtain a balanced sustainable process, e.g. DGNB
- ☐ Creating a balance between completeness in coverage and simplicity of use in a user friendly way, e.g. Green Globes.
- ☐ Applying the rating along all project phases, e.g. Green Globes, CASBEE- using the proper means according to the nature of the sustainable criteria to be measured.
- ☐ Applying a sustainable management process, covering both organizational and operational aspects to include guidance not only for management practices but to cover the whole process, and setting the minimum level for building performance for each sustainable category, as well as considering the various roles played by each involved party e.g. HQE, and better develop the role of the LEED AP- which is already prepared for more contribution.
- ☐ Developing the measurement metrics, so as not to rely on monetary values, but on environmental impact- particularly for EA and MR categories e.g. BREEAM, Green Globes and Green Star.

Third; there is some effort required by the USGBC as well , in order to continue maintaining wider diffusion in the global marketplace through opening up new regional chapters, developing more Memorandum of Understanding (MOU) with other *Green Building* rating systems, as well as establishing links with other sustainable labelling and certification programs to achieve more contextual adaptability of the system in foreign contexts (provided that they are based on the same sustainable principles and standards), and not only for materials/products, but also for services (e.g. commissioning) and/or features as part of the broader LEED whole building rating system to cope with the continuously developing scientific findings and market expectations. Hence achieve a balance between standardization and contextual adaptations for LEED application[1].

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[1] For example MR C7 requires using FSC certified wood products, but there exist other means of sustainable forest management certification systems in other contexts

3.2. COMPARING THE APPLICABILITY OF THE LEED SYSTEM TO OTHER GBRS

This section compares the applicability of the LEED system compared to other GBRS. It draws special focus on the applicability of LEED system categories, and finally sheds more light on individual EA and MR credits- and the effect of the building type and scale on their adoption rate. This argument has been discussed by many studies. Some shared the same results, while others did not. The research shall cite the results of some of these studies.

First; the comparison on the level of whole categories was discussed by (Berardi, 2011). It compared the weights assigned by six sustainable rating systems, grouping the respective criteria into seven categories. Figure (15) indicates that generally for most GBRS, scoring credits under Water Efficiency amd Materials and Resources (MR) categories represent some challenge for practitioners, while on the contrary Energy and Atmosphere (EA) has the greatest potential. It also indicates that LEED system has more potential for Sustainable Sites, Materials and Resources, and Indoor Environmental Quality, compared to other GBRS.

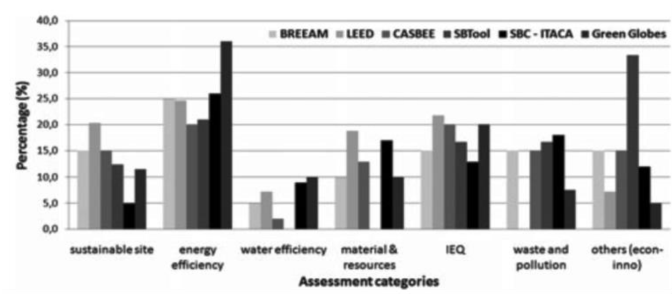

Figure 15: Comparing adoption rates by category for six GBRS (Berardi, 2011)

Nevertheless, when the study compared different LEED certification levels as shown in figure (16) . The results showed that both Energy and Atmosphere as well as Materials and Resources categories indicated least adoption rates.

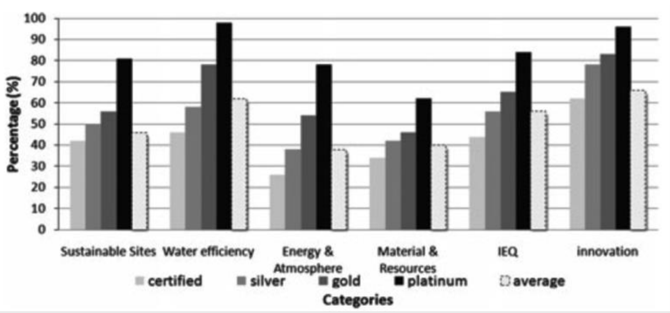

Figure 16: Showing the rate of adoption by whole category of each LEED certification level (Berardi, 2011)

The study conducted by (Azhar, et.al, 2010) investigating the adoption rates of LEED in a foreign context confirmed the results from the previous study, and indicated that although EA category has the highest weight credits but it is considered among the least adopted categories, this is due to the high cost of energy saving measures and the low preparedness of construction actors, as well as lack of incentives in some contexts.

The study conducted by (Lavy & L. Ferna´ndez-Solis, 2009), estimated the average adoption rates for various LEED credit categories as shown in table (3), and concluded that both EA and MR categories have the least adoption rates inspite of the fact that their total weight is almost half of the overall weighting of the LEED credits. The study also concluded that the average adoption rate for all LEED categories is not high, which indicates a drawback in applying LEED system and obtaining credits.

Category	**Average adoption rate (%)**
Sustainable Sites	54.9
Water Efficiency	58.2
Energy and Atmosphere	46.2
Materials and Resources	42.7
Indoor environmental quality	70.7
Weighted average	55.4

Table 3: Showing the rate of adoption of LEED categories, (Lavy et al,2009)

Secondly, comparison on the scale of individual credits focusing on EA and MR, as areas of concern - citing the studies conducted by (Lavy et al,2009), (Langdon, 2007), (Calkins, 2004), (Berardi, 2011), (Fowler et al,2006); reveal that adoption of new green practices varies according mainly to economic and contextual factors as shown in figure (17); showing that for MR category, the mostly adopted strategies with apparent economic advantage are the use of local materials, and the use of recycled/ salvaged materials, while those mostly adopted strategies with implicit economic advantage are the use of certified wood, and the use of materials with low life cycle impact.

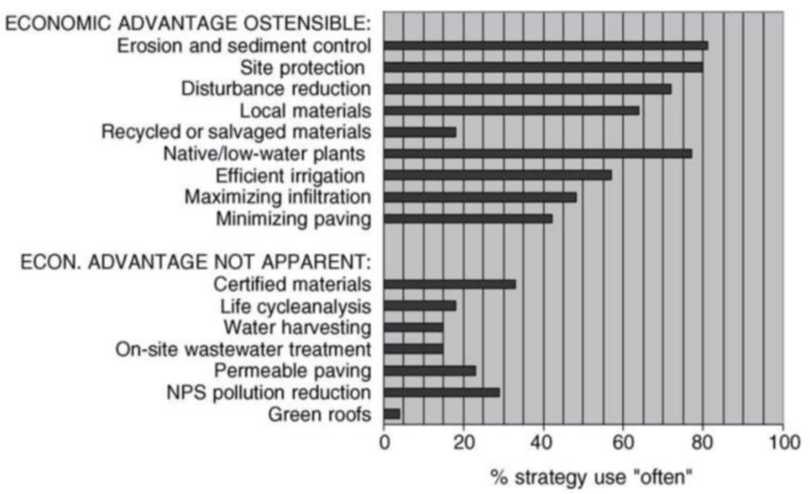

Figure 17: Comparing the adoption rate of some LEED strategies, (Calkins, 2004)

This can be clear in the comparatively more adoption of some LEED credits than others as shown in the table below. For example; the average adoption rate for EA category is higher for EA C1: Optimize Energy Performance, and least for EA C2: On-Site Renewable Energy (Lavy et al,2009).

On the other hand for MR category NC V3.0, it has notable wider range variations, and it is higher for MR C2: Construction Waste Management, MR C4: Recycling content materials, and MR C5: Regional material, and least for MR C1: Building Reuse (Lavy et al,2009). The study done by (Langdon, 2007) added that for Materials and Resources credits: more projects are pursuing the second construction waste recycling credit, fewer projects are pursuing the second recycled content and local content credits, due to the raising of compliance thresholds in these points.

These results were correlated with difference in building type, scale, program and context in the study conducted by (Yellamraju, 2011); where it compared the application of LEED NC 2009 for three building types: a) office and institutional, b) Multifamily (High rise- over 7 stories), and c) Multifamily (Midrise – 4-7 stories) , and the result revealed that it was generally easier to obtain credits for case (a), and more difficult for case (b), and even harder for case (c) as shown in tables (4) and (5); focusing on EA and MR categories.

Energy and atmosphere

LEED EA Credits	**Average adoption rate (%)**	**Points**	**Office & Institutional (University, Public)**			**Multifamily (Highrise - over 7 stories)**			**Multifamily (Midrise - 4-7 stories)**		
			E	**M**	**D**	**E**	**M**	**D**	**E**	**M**	**D**
EA p1: Fundamental Commissioning of the Building Energy Systems	-	Y	Y			Y			Y		
EA p2: Minimum Energy Performance	-	Y	Y			Y			Y		
EA c1: Optimize Energy Performance	93.1	1 to 19	15	4		10	9		10	9	
EA c2: On-Site Renewable Energy	22.5	1-7		7			7			7	
EA c3: Enhanced Commissioning	63.7	2	2			2			2		
EA c5: Measurement and Verification	51.0	3	3				3			3	
EA c6: Green Power	47.1	2	2			2			2		

Table 4[1] : LED NC V3.0 EA category[2]

EA category revealed more influence by building type especially for EA C1: Optimize Energy Performance, and EA C5: M&V Process, as it was easier for Office & Institutional buildings. While, the rest of EA credits were either medium state achievable by all building types, e.g. EA C2: Onsite Renewable Energy, or easily achievable, like the

[1] The author's elaboration based on (Yellamraju, 2011 p.195), and (Lavy et al, 2009).
E: Easily obtained credits, M: Medium difficulty obtained credits, D: Difficult obtained credits.
[2] Only energy credits were cited, thus EA pr 3, and EA C4 discussing refrigerant management were not included in this study

two EA prerequisites; EA Pre 1: Fundamental commissioning of Building Energy Systems, and EA Pre2: Minimum Energy Performance, as well as EA C3: Enhanced Commissioning, and EA C6: Green Power.

Materials and Resources

LEED MR Credits	**Average adoption rate (%)**	**Points**	**Office & Institutional (University, Public)**			**Multifamily (Highrise - over 7 stories)**			**Multifamily (Midrise - 4-7 stories)**		
			E	**M**	**D**	**E**	**M**	**D**	**E**	**M**	**D**
MR p1: Storage and Collection of Recyclables	-	P	Y			Y			Y		
MR c1.1: Building Reuse-Maintain Existing Walls, Floors and Roof.	7.8-4.9	1-3		3			3			3	
MR c1.2: Building Reuse-Maintain Existing Interior Non structural Elements	7.8	1		1			1			1	
MR c2: Construction Waste Management	85.3-63.7	1-2	2			2			2		
MR c3: Materials Reuse	23.5- 8.8	1-2		2			2			2	
MR c4: Recycled Content	84.3- 60.8	1-2	2			2			2		
MR c5: Regional Materials	85.3- 52.9	1-2	2			2			2		
MR c6: Rapidly Renewable Materials	25.4	1		1			1			1	
MR c7: Certified Wood	44.1	1	1				1				1

Table 5: LED NC V3.0 MR category [1]

On the other hand, MR category showed more consistency in adoption rate with less effect from difference in building type except for MR C7: Certified Wood, which increases the difficulty of achieving this credit from office and institutional buildings, to high-rise multifamily building, to midrise multifamily building. Yet, the rest of MR credits are not affected by building type. They are either easily achievable, like MR Pre 1: Storage and collection of recyclables, MR C2: Construction Waste Management Plan, MR C4: Recycled Content material, and MR C5: Regional material- or medium state achievable, for example; MR C1: Building Reuse, MR C3: Material Reuse, and MR C6: Rapidly Renewable materials.

Hence, it can be concluded that the adoption rates of some EA and MR credits vary significantly as a result of their feasibility and cost, and according to the context of application, building type, scale and complexity, as well as the degree of expertise of design team.

[1] The author's elaboration based on (Yellamraju, 2011 p.195), and (Lavy et al, 2009).
E: Easily obtained credits, M: Medium difficulty obtained credits, D: Difficult obtained credits.

3.3. COMPARING THE ADAPTABILITY OF LEED SYSTEM TO THE ITALIAN CONTEXT

This section presents the research analysis to the LEED's system adaptation process in the Italian context (both its rating and certification mechanism); it starts with comparing two main adaptations of GBRS; SBTool and LEED Italia, then it provides a market analysis for LEED projects, and finally it presents a survey among practitioners, to investigate the application of the LEED system in the Italian context. Findings shall indicate how LEED system's requirements are adopted in practice- highlighting the effect of the context, which shall eventually help build up a comprehensive understanding about the challenges faced by practitioners when applying the LEED system, and this shall help build up the suggested research framework for applying the LEED system in the coming chapters.

3.3.1. ANALYSING GBRS ADAPTATION TO THE ITALIAN CONTEXT

Italy has introduced several *Green Building* rating and certification systems; the most significant are; protocollo Itaca and LEED rating system[1]. Both LEED and ITACA belong to the same family of assessment (Total Quality; multicriteria assessment as explained before in chapter two), and they represent contextual adaptations to international GBRS in the Italian context.

3.3.2. ADAPTATIONS OF SBTOOL; ITACA

Protocollo ITACA is based on the international assessment methodology SBMethod of iiSBE and it has been contextualized at local level by several regions: Piemonte, Liguria, Valle d'Aosta, Veneto, Friuli Venezia Giulia, Lazio, Marche, Toscana, Umbria, Puglia and Basilicata (ENERBUILD, 2010). At regional level, Protocollo ITACA is a voluntary self- assessment system, mostly used to promote sustainable building policies; in particular for social housing programs in Piemonte region, where economic incentives are given on the base of the environmental performance achieved. Beside the regional versions, in 2011 a national version of Protocollo ITACA has been delivered and a national certification process has also been implemented, hence, creating a point of reference for the market stakeholders (ENERBUILD, 2010). All the criteria included in the assessment systems are totally linked to the national technical standards of UNI[2].

[1] Itaca protocol is the contextual adaptation of the GBtool offering a comprehensive set of sustainability but in a self- assessment form which did not satisfy the market demand for distinguishing high performance green buildings and third party certification and this finally led to the introduction of the LEED system later in May 2010. It is hence noted that ITACA provides ranking while LEED system provides rating for sustainable building performance.

[2] It is applied in two incentive programs for social housing (10.000 apartments by 2012) and for private single houses (Housing plan). On the base of the score reached it's possible to receive a financial contribution up to 10.000 euro per apartment or a construction volume bonus.

A direct comparison between LEED Italia and Protocollo Itaca is included in appendix (A), which shows that both systems have different aims, base structure, assessment method, weighting criteria, among other variations. This makes it impossible to compare their rating results. Nevertheless, LEED has wider scopes and limits of operation for the building process- particularly related to its market role. This mainly gives it a competitive advantage over Protocollo itaca, although it appears that the later has stronger base for environmental assessment.

3.3.3. ADAPTATION OF LEED; LEED ITALIA 2009

Italy has its own *Green Building* organization, known as the *Green Building* Council Italia (GBCI). It sponsors its own version of LEED, known as LEED-Italia which was launched in 2009. This rating system is very similar to the USGBC version of LEED NC 2009 adapted to the Italian climates, construction practices, and regulations, including Italian-specific units and outline alternative compliance paths appropriate to the region; climate, building characteristics and construction standards. However, there are currently only one LEED certification types under the GBC Italia- which is LEED Italia for New Construction (LEED Italia NC), and it refers to both the American and Italian norms and directives .As for the other types of rating systems, they are still under development (till the time of writing of the research).

Tracing the adaptation process of LEED system[1] to the Italian context highlights the following points, e.g.

- ☐ Variations in some credits' threshold e.g. MR C 5; Regional Priority
- ☐ Variations in references, e.g. referring to UNI (the European standard) instead of ASHRAE (American standard) for WE, EA and some of EQ credits.
- ☐ The Italian sustainable real estate market had to introduce new types of sustainable building product certification systems, e.g. FSC certified wood, as well as new types of sustainable services, e.g. Commissioning.

The adaptation process had to create a balance between two aspects; a) preserving standardization of the LEED system; which maintains its value in the global marketplace, and b) reflecting sustainable building practices specific to the Italian context. Nevertheless, Materials and energy credit categories are considered areas of concern when applying LEED system in the Italian context because energy is an integral part of the national policy complying with international agreements, while materials credits are more related to regional market variations.

[1] It is worth noting that the adapted version of LEED Canada has directly addressed durability through "Materials and Resources Credit 8 – Durable Building" , which requires building designers to develop a Building Durability Plan to ensure that the predicted service life of the building and its components exceeds the design service life (Green Building Finance Consortium, 2010).

Some areas have implemented or are considering incentives for LEED-certified buildings; e.g. the Autonomous Province of Trento dedicates economic incentives for sustainable buildings and since 2008, it has imposed the adoption of LEED rating system for assessing sustainability of buildings for the construction of new province owned buildings. Additionally, it has assigned incentives to New Construction or Major Renovation certified with LEED rating system (according to the law n. 825/2007 of the Province) and Energy consumption lower than 60 kWh/m^2 a year (energy class B) (ENERBUILD, 2010)[1]

3.3.4. ANALYSING LEED CERTIFICATION PERFORMANCE IN THE ITALIAN CONTEXT

LEED system is positioned to reward the top 25% of best practices at 4 different levels corresponding with LEED certification levels (Howard,2005). It is promoted as a market tool to attract investments in green market and provide differentiation for green buildings, standardization for sustainable building practices and branding for LEED certified projects in the global marketplace. This section aims at investigating LEED certification mechanism in the Italian context regarding the following aspects; Geography- Certification level- Project Type and Type of ownership. [2]

Total number of LEED projects in Italy is growing fast. Till the time of writing and according to USGBC published project directory (http://new.usgbc.org/projects , accessed 22 March, 2013), total sum of LEED certified projects have reached 34 projects (with a sum total of 5,716,266.5 gross square foot and 3,951,513.7 square foot of total property area). They are most widely concentrated in main cities as Milan (6) and Rome (3), as well as other cities. As for registered projects, the total number has reached 150 projects with a total area of 30,494,553.15 gross square foot (16,657,752.57 square foot of total property area again), and similarly, they are mainly concentrated in the main cities; Milan (38), Trento (13) and Rome (11). LEED certification is also spreading in other smaller cities but in a comparatively slower rate.

The most widely diffused type of rating systems is LEED for New construction and major renovation as shown in figure (18), followed by LEED for Core and Shell, then LEED Italia 2009, while other types of LEED rating systems are spreading in a slower rate. The type of rating system is probably decided by the owner, moreover it is an important decision that affects the whole building process; starting with drawing the system's application framework- determining its scopes and limits of operation, setting a performance level, exploring incentives, and it is related to market acceptance.

[1] http://www.delibere.provincia.tn.it/scripts/GSearch.asp

[2] It is important to note that consideration was only paid to project visibility declared and identified on the USGBC homepage www.USGBC.com.
Similar studies was performed for LEED projects found in (Yudelson, 2006), and on BREEAM and Greenstar to investigate the effect of the building type and certification level in foreign contexts, found in (Reed et al, 2011). Another study conducted by (Cidell, et al, 2008) investigated the regional variations of applying the LEED rating system among American states. All these studies shared the result that a regional variation does exist when applying GBRS to other contexts, and this maybe manifested in the adoption of some building type(s), or certification level(s) than others.

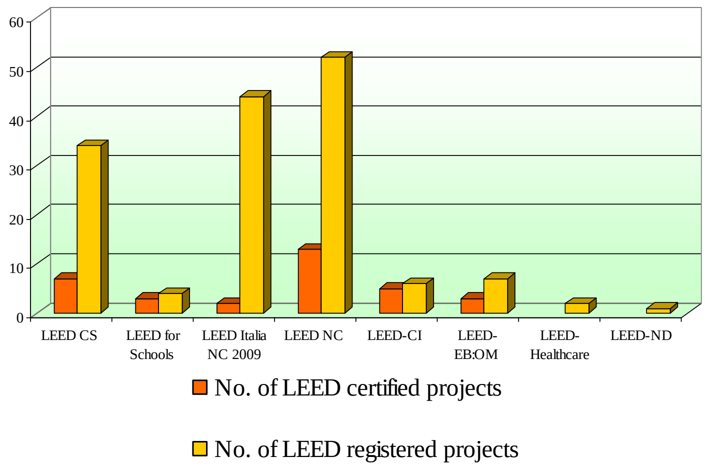

Figure 18: Types of rating system

'LEED Gold' certification level- ranging from (60-79 points) is the most widely obtained level of LEED certification as shown in figure (19), due to the stringent sustainable international as well as national commitments and obligations, which creates a high sustainable threshold for the Italian building industry. Hence, performance levels are usually determined high to be differentiated in the marketplace.

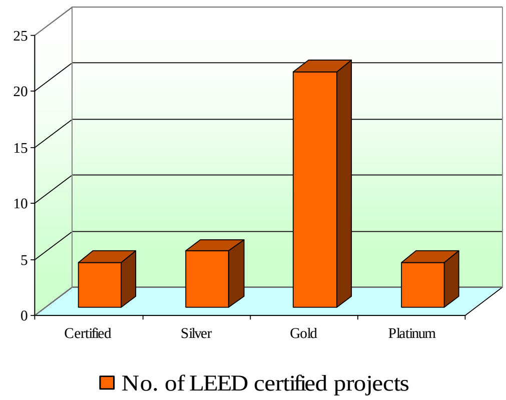

Figure 19: Certification level obtained by LEED projects

LEED system mostly attracts stakeholders of private investments and for profit organizations for their brand name as shown in figure (20). Nevertheless, it is considered a requirement for other regions and for particular types of projects as previously mentioned (e.g. in the autonomous region of Trento, where it is supported by both legislations and incentives mechanism).

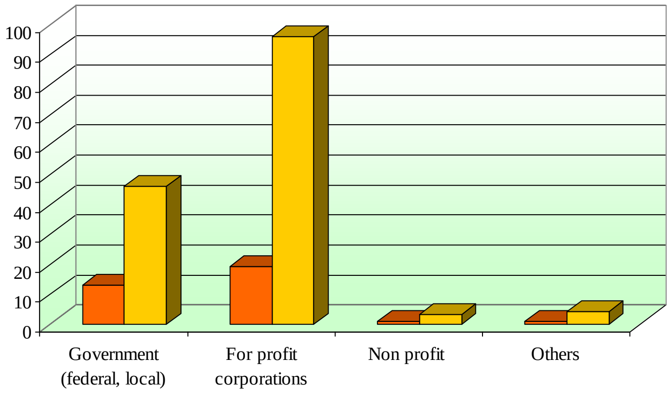

Figure 20: Type of ownership for LEED projects

Commercial office buildings are the most widely diffused project type acquiring the LEED certification, followed by private institutions, then governmental buildings for public use as shown in figure (21).[1] While, registered projects mainly belong to private corporations, then by governmental buildings, then commercial office buildings- which shows a different trend that shall affect the application of the system.

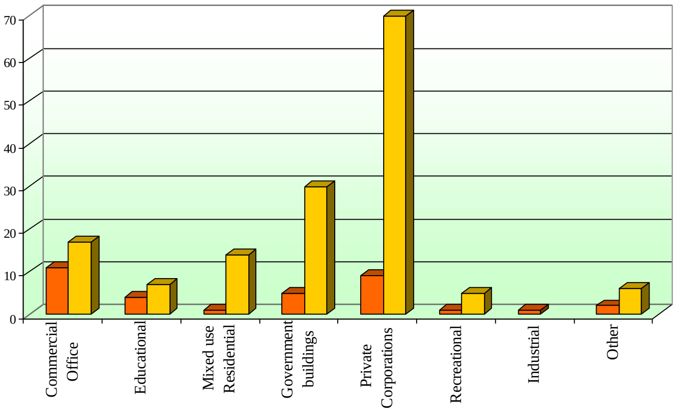

Figure 21: LEED projects' types

The results of LEED market analysis in the Italian context confirmed with the international studies, which has shown that the LEED system adopts a focalization and vertical market approach. This is particularly evident when starting in a foreign context. Hence, practitioners should understand this approach and understand the difference between it and other systems [2] and how it affects its application.

[1] It should be noted that LEED registrations by project type are a bit harder to discern, because USGBC data groups many projects into a "multiple use" category.

[2] For example; Green Globes which rewards obtaining 'Partial Credit' to encourage practitioners on taking serious steps to adopt sustainable building approach, even if the total credit requirement, they can still be rewarded. But for LEED, probably practitioners shall not invest time and money in sustainable features if

3.3.5. Research Survey

Practitioners’ evaluation of applying the LEED system in the Italian context

This survey aims at investigating the LEED rating system among practitioners in the Italian context in order to reach more objective indications regarding the potentials and drawbacks of using the LEED rating system in the building industry generally and indicate specific problems for applying LEED system in the Italian context. The practical review was obtained from a web-based questionnaire and ten in person interviews. The detailed questionnaire and interviews are included in Appendix B.

a. Reason for choosing the LEED system

Analysing the results obtained in figure (22) showed that LEED rating system is chosen mainly for its reputation in the global marketplace. It is perceived to increase sustainable building performance by more than 50% through introducing sustainable management practices, as well as measurement and verification procedures for sustainable building performance;

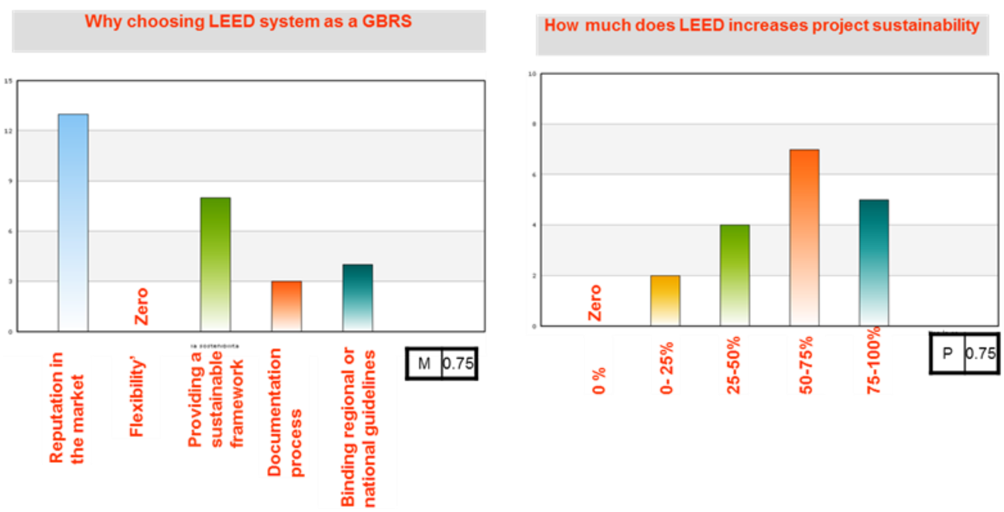

Figure 22: Reasons for choosing LEED system

b. Applying LEED system

Applying LEED credits is perceived to be of medium difficulty (individual practices). Nevertheless, managing projects under LEED certification is perceived more difficult (the whole process) as shown in figure (23). During interviews; practitioners highlighted the existence of some challenges and drawbacks for using the LEED system; first concerning project management practices, complains around the system’s structure which does not provide definitive limits of operation nor does it provide a ‘*Know how’ to* integrate LEED requirements in the ordinary building process or perform an integrated building process to explore synergies and trade-offs, this represents a challenge especially for first time users of the LEED system.

eventually they will not be rewarded for it (because either it is not requested by LEED credits or they will not be able to satisfy the credit threshold), and accordingly, may not properly reflect the building’s greenness. .

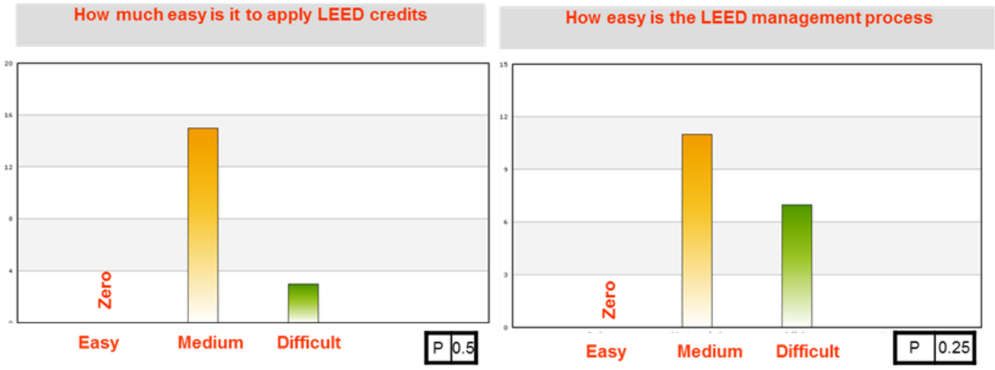

Figure 23: LEED management process versus practices

Both calculation and simulation methods were perceived difficult and/or expensive to perform as shown in figure (24). Another concern was raised during the interviews; stating that using new tools to support a sustainable decision making process is still not a mature practice because computer simulation models are used for certification reasons instead of experimenting design options.

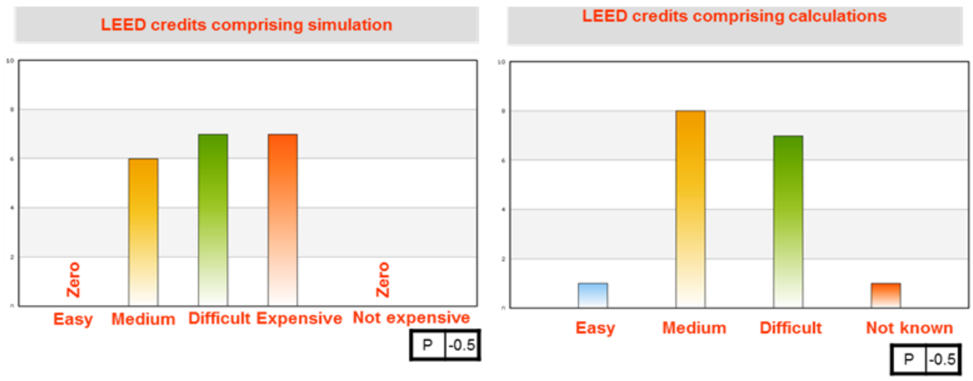

Figure 24: LEED simulation and Calculation credits' requirements

Results of the interviews complemented the survey results shown in figure (25), and they both indicated that applying LEED system enhanced green education and communication among team members, particularly within the boundary of the applied version and its requirements[1], but LEED online is rather considered an upload tool rather than acting as a user guidance, not promoting direct interface for step by step guidance along project phases. This may not help avoiding a lot of timely, costly change orders, or on the other hand, it might cause inability to gain credits or make best use out of the system- this problem is assumed to be diminishing the more LEED experience gained, and hopefully with more advancements in the LEED online tool.

[1] LEED system issued new developed guidelines for streamlining the management process of multiple buildings, LEED 2009- but the majority of the practitioners in the survey sample were not aware about it. This may give further indication related to the extent of knowledge and education practitioners acquire about LEED development process.

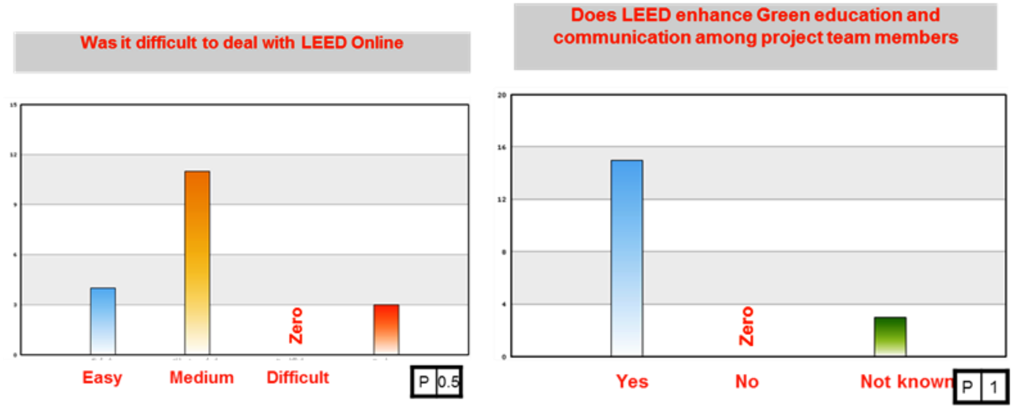

Figure 25: LEED communication channels, and enhancing green education

Figure (26) shows that LEED certification is perceived to have higher sustainable requirements than national/regional norms and/or standards, but for the purpose of managing projects, both types of references were used to comply with the requirements of local building codes as well as with LEED system's requirements.

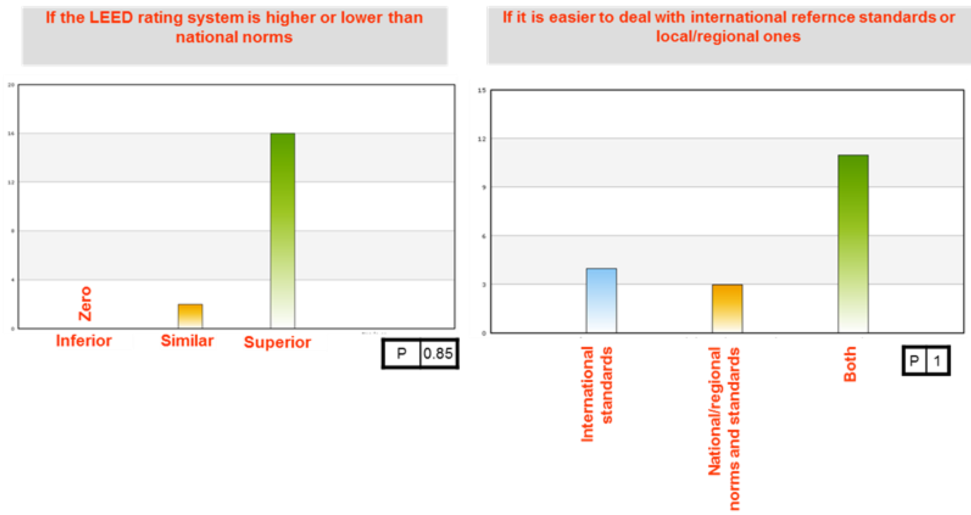

Figure 26: LEED and national norms, LEED and reference standards

Figure (27) and (28) show that extra cost for applying LEED system was estimated between 5-20%, and mostly is considered soft cost; directed for commissioning process, energy simulation, as well as documentation and certification purposes. EA was perceived to result in the greatest future payback, within around 5-10 years.

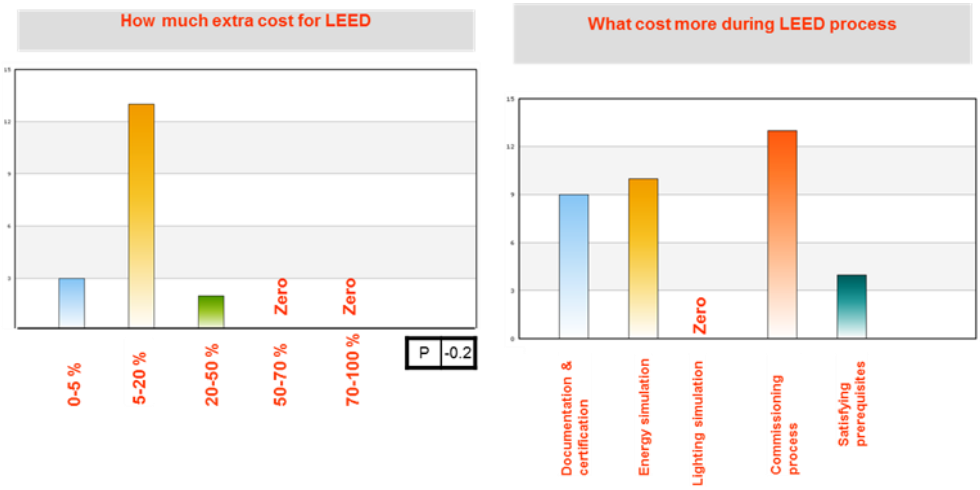

Figure 27: Extra cost premium for LEED certification

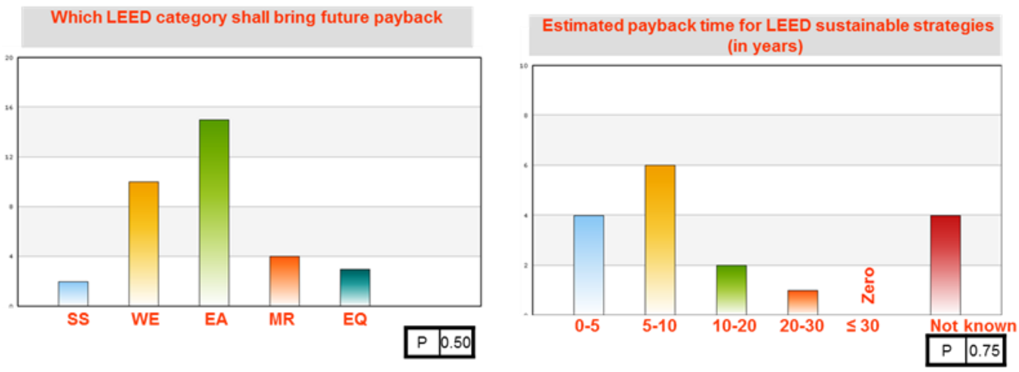

Figure 28: Future Payback for LEED categories

c. Applicability & Adaptability of LEED to different building types & contexts

Testing energy and materials credits shown in figure (29) reveals that; it is on the contrary with international studies, EA category was found to constitute the more achievable point category; while on the other hand, MR category remains among the most challenging ones. While testing adaptability on the scale of individual credits was complemented through the interviews; indicating that some credits exceed national building regulations and current best practices. Some credits were easier to apply in the Italian context due to already existing strong sustainable base for national building regulations. Other credits required regional variation, or were relatively difficult to obtain due to perceived capital cost, e.g. onsite renewable energy sources- although there exist some national incentives to reward onsite renewable energy especially from photovoltaic cells but it is not enough to satisfy the required threshold for project energy demand as required by LEED system. Additionally, Commissioning services and simulation requirements require extra cost, schedule and expertise which vary according to building type, scale and complexity- but by time, probably they shall be considered common building practices to raise the quality of sustainable building performance.

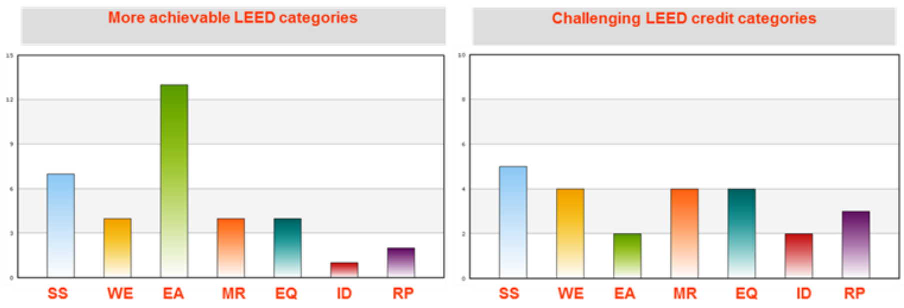

Figure 29: Perceived easily and difficult LEED credits

d. LEED Certification and market performance

Figure (30) and (31) show that; the national market requires more potential to comply with LEED system's requirements. Then focusing on sustainable energy and materials market showed that some EA credits are substantially easy to achieve owing to the high energy efficient baseline required by national/regional building codes, yet methods of compliance differ, and this requires additional effort by design team. Interviews pointed out that it is still not a common practice to perform the required simulation and calculation for Measurement and Benchmarking criteria, in addition to some difficulty to obtain some sustainable building materials, products and services according to LEED requirements- they are either difficult to obtain, document and/or expensive - but by time the market is gaining more acceptance and this problem is diminishing.

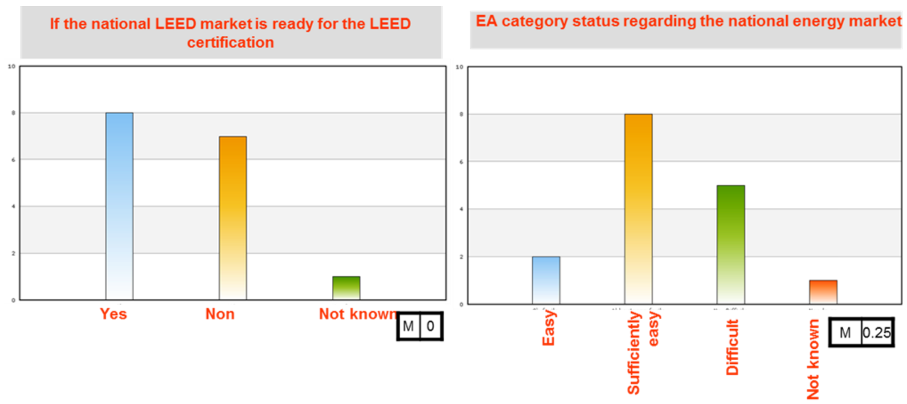

Figure 30: LEED and Green market

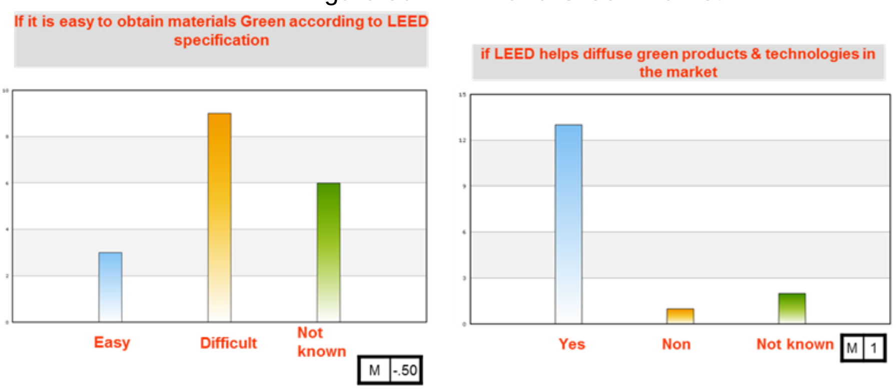

Figure 31: LEED and Green requirements

Figure (32) shows that the more challenging barriers for the diffusion of LEED system in the Italian market were perceived to be; low financial/ structural incentives, lack of stakeholders' interest, as well as the complexity of the certification process requiring more time, and money premium- which represents a challenge especially for smaller size and budget projects. This indicates that more efforts should be directed to adapt LEED system's certification mechanism.

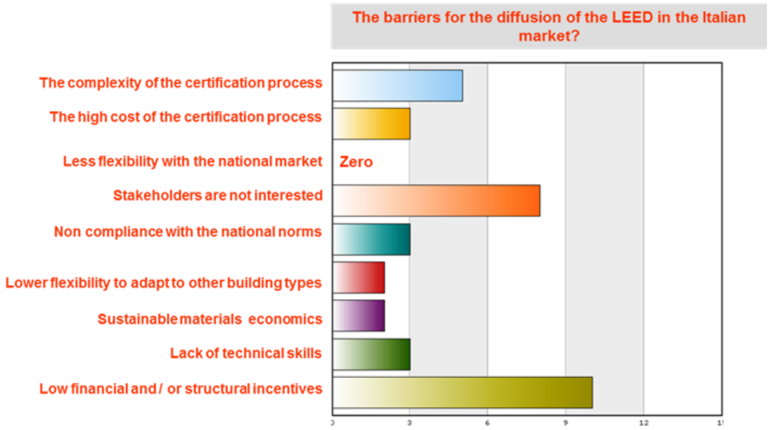

Figure 32: Barriers for the diffusion of LEED system

e. Potentials and drawbacks of applying LEED system

The following points were highlighted as potentials for applying LEED system;

- ☐ Reviewing and improvement of building process
- ☐ Diffusion of information on sustainable & innovative practices.
- ☐ Management control of the project to its construction
- ☐ International visibility and better market position.
- ☐ Durability and savings for energy and materials
- ☐ Promoting an Integrated Design approach (but further development is required)

While on the other hand, some drawbacks were pointed out as follows;

☐ If LEED system is misapplied or applied through a single market perspective without attention to the actual quality of the process taking a short term rather than a long term perspective- driven by point chasing and seeking easily achieved credits, it is likely to cause more unsteadiness in the construction industry.

☐ Another concern was raised regarding the inflexibility for applying the LEED system equally to all project sizes, types and contexts. According to practitioners, it was more reasonable to apply it on large scale/ complex projects with huge investment size.

☐ A concern related to the contextual adaptation of the LEED system in the Italian context revolved around the lack of a detailed assessment of regional priorities specific to various sectors of the construction process, paying more attention towards the multidisciplinary nature of the building process and adaptability methods to various types and scales of buildings.

- Another contextual related issue has pointed out the need to establish direct interface with other national sustainable programs, certification systems and incentive mechanism, along with studying specifics related to the Italian construction market in order to be able to establish radical contextual adaptations- especially that the European context has advanced initiatives for sustainability.

3.4. ANALYSIS & EVALUATION RESULTS

This chapter analyses and evaluates the LEED rating system through a comparative methodology to other GBRS to be able to extract its points of precedence and drawbacks, and provide some recommendations for applying the system.

The analysis discussed variations among GBRS regarding the following points; a) rating mechanism (including their different structure, tools and methods used, and focusing on their criteria for environmental assessment particularly for energy and materials efficiency), b) certification mechanism, and additional critical points related to their c) applicability to different building types, and d) adaptability to different contexts.

The results of the analysis indicated that LEED compared to other GBRS address the same sustainable targets and share the goal of measuring and certifying a building's "Greenness", yet they have different approach, structure, scope, assessment method, measurement metrics, and performance standards in addition to other contextual peculiarities for each of them. It is also important to discuss how the design community adapts rating mechanisms; how this reflects on its structure, and eventually how these variations have significant effects on applying the system along the sustainable project management process.

More specifically, the research highlights other considerations for applying the LEED system. This requires following an integral multidisciplinary approach- to apply the LEED system taking into consideration its main targets, exploring and developing means of applying the LEED system in a relatively simple practical, transparent and flexible mean (through a widely acceptable structure and measurement system) creating a balance between completeness in coverage and simplicity of use; achieving a balance between the three pillars of sustainability; environmental, economic and social, and at the same time dealing with the whole building life cycle (hence, develop the use of LCA to support its environmental assessment), considering flexibility and adaptability to different building types and contexts, and paying particular attention to EA and MR credit categories, in addition to the need to ensure that certification schemes are adaptable enough to evolve with expected and unanticipated developments in the future.

Additionally, the research included some recommendations from other GBRS. These recommendations urge on developing a management framework for applying the LEED system along all project phases , developing and integrating better tools and methods, and covering both organizational and operational aspects to include guidance not only for management practices but to cover the whole process, setting the minimum level for building performance for each sustainable category, as well as considering the various roles played by each party involved, and better develop the role of the LEED AP- which is already prepared for more contribution. Another recommendations to include property value, and financial aspects, along with the environmental assessment to obtain a balanced sustainable process, and to develop the decision making process, so as not to rely on monetary values, but on environmental impact- particularly for EA and MR category, whose adoption rates vary significantly as a result of their feasibility and cost, and according to the context of application, building type, scale and complexity, as well as the degree of expertise of design team.

The last point discussing LEED system's contextual adaptation required further investigation- applied to a defined context; hence, LEED Italia was compared to Protocollo Itaca- as both of them represent contextual adaptations to international GBRS- and the results showed that their obtained results are extremely difficult to compare, but an important point was raised concerning the power of market acceptance and demand in adopting and applying the rating system, i.e. Protocollo Itaca may possess a stronger adaptation potentials to the Italian context, but its certification scheme does not satisfy the market demand for differentiation and branding, this is why the LEED system was introduced to attract more investment to the sustainable real estate market.

Additionally, the research used questionnaires and interviews to complete the full image for analysing and evaluating the LEED system in the Italian context. Hence, practitioners in the Italian context pointed out some areas of precedence of the LEED system related to its certification and market position, while there are some doubts and confusion about how to integrate the system to obtain a sustainable management process, besides other drawbacks related to the availability of some of LEED system's requirements in the national marketplace.

This analysis and evaluation steps set the base for the following research contribution: to draw a framework for applying LEED system in the sustainable management process.

C H F O U R

4 A SYSTEMIC FRAMEWORK TO LEED SYSTEM ENERGY & MATERIALS CREDITS

This chapter represents the core theme of the research contribution for suggesting a systemic framework based on better defining and developing the system's structure, main mechanisms and scopes of operation- highlighting its potentials and drawbacks, while proposing developments for its points of concern, and finally, drawing a general framework for applying LEED system, and applying it on both energy and material credits being areas of concern as shown in previous chapters.

4.1. INTRODUCTION: SYSTEMIC APPROACH TO GREEN BUILDINGS

System is a mental construct that influences the way designers think; generally, it is a combination of organized interrelated elements comprising a unified whole with interaction. This approach is necessary to deal with complex systems considering their internal and external network of interrelationships (Vallero et al,2008), (Butera, 2008).

Green buildings' approach should use the 'Systemic approach'[1], considering; site, energy, materials, IAQ, acoustics, natural resources and their interrelation together, to consider the building structure and systems holistically, hence explores its complexity and any particular dynamics of each project- discussing the building as a system not as assembled parts (Keeler et al, 2009), (Kibert, 2005) - borrowing Lovins statement[2] 'Optimizing [3] components in isolation tends to pessimize the whole system and hence the bottom line ...'.

This approach may prove efficient when interactions are non-linear and strong. It provides guidelines specific to each project conditions, and validates performance comparing the building to itself under basic conditions- creating open channels of feedback to highlight synergies and tradeoffs design alternatives.

[1] More about 'Systemic approach' can be found in http://pespmc1.vub.ac.be/ANALSYST.html

[2] Amory Lovins, Natural Capitalism (1999): Optimizing components in isolation tends to pessimize the whole system—and hence the bottom line. You can actually make a system less efficient while making each of its parts more efficient, simply by not properly linking up those components. If they're not designed to work with one another, they'll tend to work against one another."

[3] Optimization is a process of design refinement that results from questioning each component and process to achieve the most with the least expenditure of resources. It works best when applied on the building and site scale, rather than simply on components

4.2. BREAKING DOWN- BUILDING UP LEED SYSTEM

MECHANIMS, SCOPES AND LIMITS OF OPERATION

In order to effectively apply the LEED system, there is a prior step to draw a plan to identify the main goals of the system, its scopes and limits of operation and explore their implicit interrelations- so as to draw up a comprehensive framework which considers its potentials and drawbacks, and explores proper means of using it, to ensure the sustainable performance goals are being met when desired ratings are achieved.

Hence, the first step for developing the research framework is to break down LEED system's operation into; 'Rating' and 'Certification' mechanism, and accordingly break down each mechanism into integrated scopes based on the system's targets defined in chapter two; Guidelines, Measurement, Verification and Market as shown in figure (33). Then the research investigates each scope to highlight its potentials and/or drawbacks putting in mid the recommendations from the previous chapter about how to improve the adaptability, applicability and standardizations of the rating system, in order to build the suggested research framework based on this suggested structural analysis.

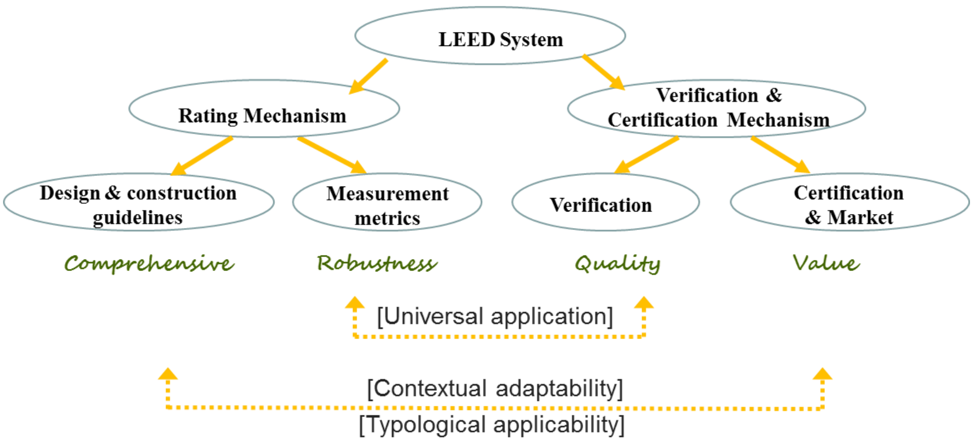

Figure 33: Breaking down LEED system

The figure shows how the LEED system maybe analysed according to the suggested mechanims and scopes of operation pointing out the value contribution for each scope in the building process, and highlighting how areas of concern related to the adptability and applicability of LEED system can be mitigated. Moreover figure (34) shows how each scope comes to satisfy the increasing sustainable market demand; it starts by providing guidelines for green buildings' requirements, then the sustainable real estate market develops to require a mechanism to measure & benchmark sustainable building performance, then moving to higher requirements for quality assurance and quality control, and then to a proven business case for sustainable building performance.

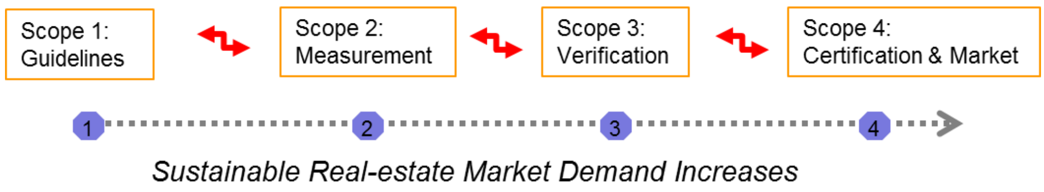

Figure 34: Market demand evolution

4.2.1. RATING MECHANISM

LEED system was originally designed to *rate* sustainable building performance, but by time practitioners have transformed the use of the LEED rating system to a guideline and decision making support tool, while in fact this role is not clearly defined along the sustainable building process because the checklist and scorecard approaches do not provide design guidance and do not provide feedback on how well a given design decision is actually working. It presents guidance for some sustainable building practices, but none address the the whole process. Thus, practitioners have to plan for complementing this drawback for both organizational and operational aspects, as well as providing standardized measurement metrics for comparing sustainable building performance.

Hence, the research develops this mechanism to include two interrelated scopes as shown in figure (35); where the LEED system provides guidelines and decision making support tool(s) for both organizational and operational aspects- which is directly related with scope (2) for measuring and evaluating design options and their corresponding building performance. This is an iterative process to evaluate all possible design options in order to guide for a sustainable decision making process.

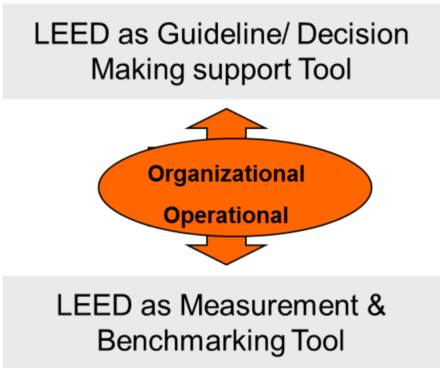

Figure 35 Scopes of LEED Rating Mechanism

4.2.1.1. SCOPE 1: GUIDLINES AND DECISION MAKING SUPPORT TOOL

Optimizing Organizational efficiency

Organizational aspect is missing in the current LEED version. Hence, the research recommends starting with defining the design approach, as well as the recommended tools and methods for decision making process, according to the nature of sustainable criteria, and applied along different project phases.

It is recommended to use an Integrated design approach noting that it is not a checklist for integrating environmental issues into design through a prescriptive source of guidance[1], but it is rather an organizational model or process adapted to the unique circumstances of each project (Green Buildings BC, GVRD and NRCan). This approach, with its focus on the whole building, can lead to better assessment of the overall environmental impact of a building. It also permits explicit assessment among potentially competing goals, and it allows planners to develop integrated strategies achieving a balance among elements and across stages considering the interdependence effect between them (Fischer,2010).

Early integrated design approach is the key to achieve the perceived sustainable performance targets for LEED projects- based on applying whole system thinking exploring synergies and high levels of total quality management in which both quantitative and qualitative considerations are valued (Vallero et al,2008 p.19, 28, 29), along with integrating interdisciplinary coordination and collaboration of design team efforts, front loading important decisions in an iterative manner for refining design options based on feedback from various decision making tools (Yudelson, 2006 p. 20,21,41), (Emmit,2007) (Vallero et al,2008), (Yellamraju, 2011 p.29, 30) and (Boecker et al,2009). This shall eventually downsize or even eliminate operational cost and critical first cost, as well as minimizing change orders (Boecker, et.al, 2009 p.25, and 67,68) (Fischer,2010), (Emmitt, 2007, p. 26).

LEED system suggests techniques for integrating design team efforts and improving communication and coordination, through conducting 'Design Charrettes', but it is not rewarded into points, and not required for LEED submission. Nevertheless, the whole process including the design approach and the decision making process is rather left for the skill and experience of design team members, and according to the results of the survey presented in chapter 3- not all practitioners were able to develop their traditional design approach especially when there is no incentive to do so. This does not provide solid base of applying the LEED system as a tool for sustainable building process and eventually leads to change orders, or achieving less performance levels.

Hence, the research recommends that it is highly important that team members plan (plan in the sense of allocating time and resources) a sustainable management process, besides working on developing specification, documentation, procurement, and

[1] The new LEED V4.0: IPc1 shall introduce a new credit to discuss: Integrative process with one possible point, and more information shall be available about this credit after the formal activation of LEED V4.0

delivery methods to satisfy the requirements of green building design and construction. Also, it might be useful to apply some borrowed methods, e.g. Lean project management (mentioned in chapter two) to highlight sustainable project targets at early design stages.

Optimizing Operational efficiency

Applying LEED system as guidelines for optimizing operational efficiency requires considering that LEED system's approach aims at achieving 'eco-efficiency', which is more concerned with quantities of energy and materials saved, rather than achieving the 'ecosystem model' which concerns the type of materials and energy, and how they are used [1]. Thus aiming at developing beyond LEED system requirements should set higher targets for sustainable ecosystem goals. This requires using LEED system as a tool; pursuing performance targets based on the intent of each credit and understanding that each credits represents one or more environmental issues that are deeply interrelated (dealing with the whole), and how they differ from regional to global sustainable issues. Additionally, special concern has to be paid related to the adaptability of the system to different contexts and its applicability to different building types and how this affects performance targets.

Operational efficiency should investigate more synergistic relations between credits, for example; synergies between site, materials and resources efficiency, indoor environmental quality and energy efficiency. This aspect is directly related to the second scope discussing measurement and benchmarking, creating a mutual relationship, and requiring feedback depending on the stage of development. The intensity of this relation may vary along building stages as shall be highlighted in chapter five, for example early stages require less detailed input and should provide fast feedback, to be able to choose among a variety of design solutions.

Strategies may include; minimizing material and energy consumption, selecting low impact processes and resources; selecting more eco-compatible materials, processes and energy sources, optimizing product life span, extending material life span through recycling, incineration and composting, and facilitating disassembly (Vezzoli et al,2010) (Vezzoli et al,2010 p.55, 61-64)

To sum up the 'breaking down- building up' process for scope (1); it can be represented in the following diagram. The figure shows the gaps and limitations in the existing LEED version to cover the first defined scope, and the research proposal for development.

[1] Explanation about Eco-efficiency, and Eco-system models, found in (Kane, 2010 p. 20)

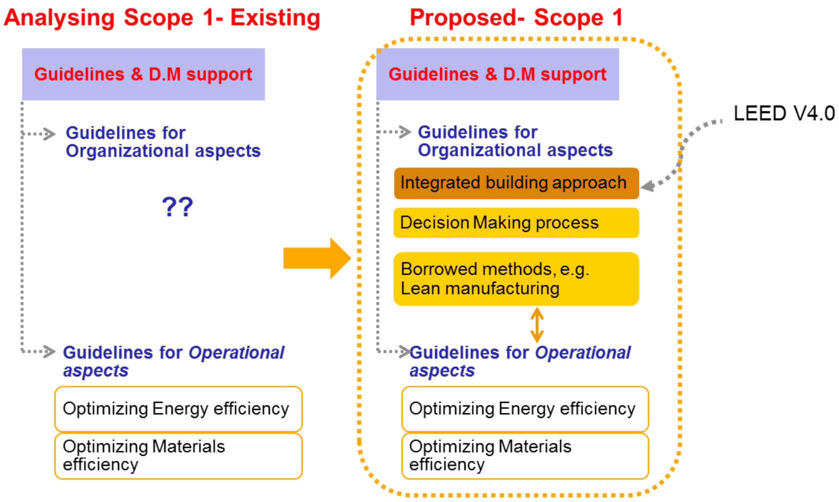

Figure 36: Breaking down- Building up process for scope (1)

Applying Scope 1 for Optimizing Energy efficiency:

Energy consumption in buildings is the result of a complex set of interrelationships among external factors (form, massing, orientation, landscape, micro and macroclimate, national energy mix), and internal factors (building program, occupancy, density, use pattern and internal loads of equipment) as well as the use of onsite renewable energy sources [1]- Understanding and manipulating these interrelationships is the key to reduce energy use while also improving building users' comfort.

The key to understanding building performance as a whole is to carefully and systematically reduce the overall building loads and then to optimize the integration of various building systems (Mendler et al, The Guidebook to Sustainable design, 2nd edition p.24, 118), (Keeler et al, 2009). The first step should start with optimizing architectural, orientation, form and massing and so on. Second step is to optimize the building envelope, considering also the external landscape mitigation effects to reduce heating and cooling loads. Third step, is to attempt to reduce interior cooling loads, and the optimization of mechanical system design including both HVAC and lighting systems, and finally to consider engaging in a contract for Green power supply.

The research translates previous studies into 5 step plan as shown in figure (37). It is noted that the first three steps shall help achieve EA pre 2: Minimum Energy Performance (a prerequisite to determine the minimum level of energy performance), and EA C1; Optimize Energy Performance (which has the highest weight credit among all LEED credits). Then to categorize energy strategies in terms of whether they affect peak energy loads, energy use, energy cost and/or demand cost. Then, develop diversity factors to reflect actual usage patterns to model energy efficient design options. Then step 4 shall help comply with EA C2: Onsite Renewable energy systems, and finally step

[1] This section does not discuss Pre 3: Fundamental Refrigerant Management, neither C 4 Enhanced Refrigerant Management

5, shall help comply with EA C6: Green Power. It should be noted that this plan should be explored in an early integrated manner; it is also important to note that for some contexts (e.g. Europe, citing the Italian context as previously discussed in chapter three) many of these steps are already part of national/ regional building regulations, while for others they are not. This is why it is important to mention them as part of a general framework to optimize energy efficiency for LEED EA credit category. Yet, other credits are considered new requirement for both cases, for example; EA C6: Green Power (also LEED EA V4.0 shall introduce Demand Response plan, and Carbon offsets[1]).

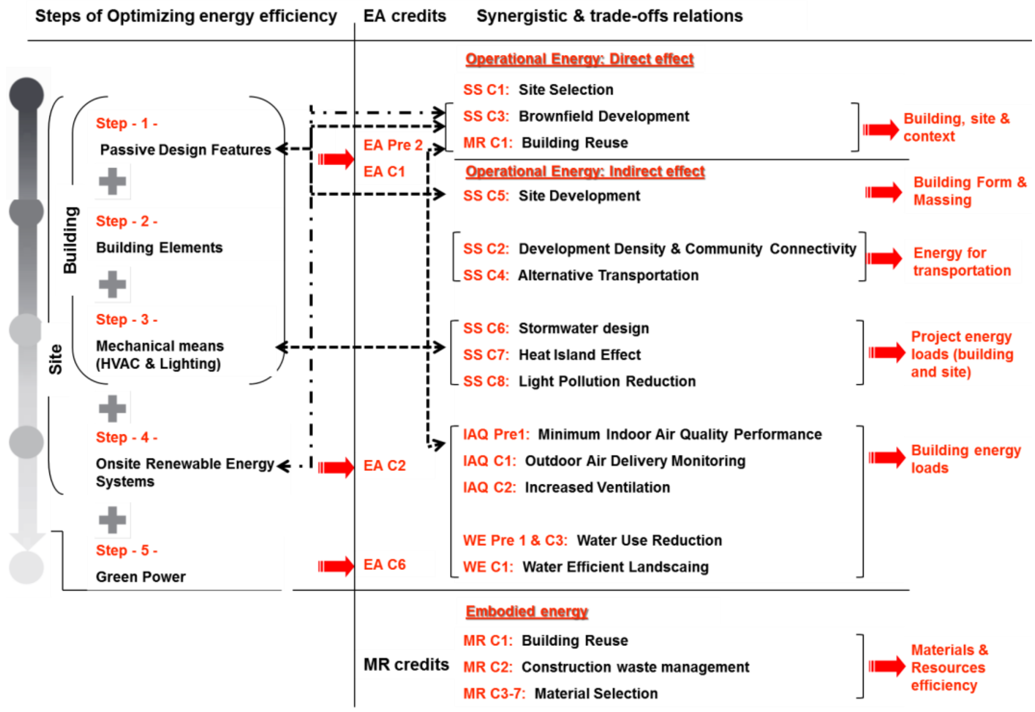

Figure 37: Planning for optimizing energy efficiency

Two main points should be noted when analysing LEED EA category; first; that there are very few direct EA guideline credits in the current LEED version, and second; that the LEED system does not identify synergistic relation between EA and other LEED credits, that may directly or indirectly affect the building's energy use as shown in figure (37), for example; direct effect on EA credits may result from MR C1: Building Reuse; having direct effect on the building performance, as well as many of the Sustainable Sites credit category, starting with site selection process, and this includes SS C1: Site Selection, and SS C 3: Brownfield development, which determines the building context and which may create synergistic or trade-offs relation depending on the project condition and this requires careful consideration at the first design stages. Also, indirect effect on EA credits may result from SS C5: Site development which may affect the form and

[1] This concept is applying the idea of buying 'carbon credits' in carbon trading schemes to balance the amount of carbon dioxide produced (in this case by the project) through investing in voluntary projects, i.e. low carbon projects such as renewable energy, obtaining credits from certified sources , or purchasing allowances from 'cap and trade' schemes and 'retiring' them (Kane, 2010 p. 104-106) . Deciding on which type of scheme to adopt depends on the project case and the Owner Project Requirement.

massing of the building. These credits may probably affect the first step in the figure; developing passive design features. Additional relations may result from the indirect effect of energy use for transportation for SS C2: Development Density and Community Connectivity, as well as SS C4: Alternative Transportation. Also, SS C8: Light Pollution reduction, SS C6: Storm Water design, and SS C7: Heat Island effect- as well as IAQ Pre 1: Minimum Indoor Air Quality Performance, IAQ C1: Outdoor Air Delivery Monitoring, IAQ C2: Increased Ventilation, which may affect the third step by reducing building energy loads. Also, some of the Water Efficiency credits may also be considered with synergistic relations to EA credits if they result in reducing some of the energy loads required for water pumps, automatic irrigation system or similar equipment.

Applying Scope 1 for Optimizing Materials & Resources efficiency

Materials and Resources category discusses resource efficiency through several means and along design and construction process- as can be summarized;

First, MR Pre1: Storage and collection of recyclables, is a design guideline. It aims at reducing operational waste disposed in landfills, through providing an easily-accessible dedicated area (or areas) for the collection and storage of materials including at a minimum: paper, corrugated cardboard, glass, plastics and metals, for recycling for the entire building. Yet the system does not mandate a minimum area; it is left for team members estimations and project condition. It is noteworthy that the design concerns for choosing the internal recycling area shall also be complemented by choosing the external one required for MR C2: Construction waste management plan, in the sense that recycling area should have direct access from main road, so design considerations shall be considered regarding the type and size of means of transportation, other visual concerns, and relation with other entrances when choosing the exact location. The challenge for choosing the recycling location depends on project condition- probably more difficult for existing building and easier for new construction - as shall be highlighted in chapter six.

Second, LEED MR Category promotes the adoption of sustainable design approach in early phases, this includes adopting scenarios for building reuse (MR C1; for external structure as well as for internal one[1]). It is notable that the credit does not consider the value of maintained area, it treats the whole area equally- only maintaining the difference between external and internal building reuse as shall be discussed in chapter six. This credit is highly dependent on building type and condition, and this requires a careful evaluation for new construction design approach versus existing building reuse scenarios- evaluating them compared to new functional requirements. Hence, it represents a radical design decision that shall greatly affect other credits

[1] Calculations should exclude window assemblies and non-structural roofing material. Hazardous materials that are remediated as a part of the project must be excluded from the calculation of the percentage maintained. If the project includes an addition that is more than 2 times the square footage of the existing building, this credit is not applicable.

(particularly energy credits: EA Pre 2: Minimum Energy Performance and EA C1: Optimize energy Performance). In addition, in case of historic buildings, it shall be related to cultural heritage concerns, and thus an additional social and cultural dimension shall be added[1].

Third; LEED system rewards performing a construction waste management plan (MR C2) in order to minimize landfill and incinerator disposal for materials that leave the building- focusing on reducing the amount of waste that buildings generate during both their construction and operation cycles (Yellamraju, 2011 p.10). The system provides guidelines for designating a specific area(s) on the construction site for segregated or comingled collection of recyclable materials, and identifies materials to be diverted from disposal, which includes; cardboard, metal, brick, mineral fiber panel, concrete, plastic, clean wood, glass, gypsum wallboard, carpet and insulation, and requires tracking recycling efforts throughout the construction process[2]. This requires guidelines for prioritising salvaged materials according to recycling potentials, and this shall require some form of verification methods to support the decision making process with environmental considerations- so this aspect is directly related to the third scope (verification methods), as well as the fourth scope (market) because it requires prior investigation to the recycling potentials in the existing market, e.g. some incentives of financial form.

Also, one of the most widely used tools for eco-efficiency is the waste hierarchy[3]- this sets out waste management options in order of preference as shown in figure (38). This plan is a simple rule of thumb and is not based on any rigorous scientific or economic analysis, thus it requires to be supported by verification methods from the verification scope. According to the waste hierarchy; reuse is preferable to recycling due to the use of energy for transporting recycled materials onsite, but the main obstacle is matching the amount of material(s) generated with the reuse opportunity.

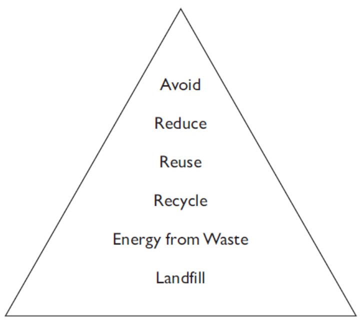

Figure 38: The Waste hierarchy[4]

Fourth; LEED system offers a set of prescriptive requirements for choosing a sustainable material/ product, considering reused, renewable, recycled[5] (methods), regional, rapidly renewable, as well as FSC certified wood products- but this requires

1 LEED V4.0 has differentiated between historic buildings' reuse, and non-historic ones- hence has created value difference for applying this credit in the real-estate marketplace.
2 Note that diversion may include donation of materials to charitable organizations and salvage of materials on-site.
3 More about this argument is found in (Kane, 2010 p. 82)
4 Source: (Kane, 2010 p.82)
5 Recycled content is defined in accordance with the International Organization of Standards document, ISO 14021-Environmental labels and declarations-Self-declared environmental claims (Type II environmental labeling). LEED prioritizes pre-consumer recycled content than post-consumer one roughly giving the latest double priority because it constitutes greater embodied energy

using verification methods. Also, the system does not indicate synergistic relations between EA and MR credits as shall be discussed at the end of this chapter. This additionally requires careful means of specifications and documentation, as well as extra time for research and communication to cover green materials according to LEED requirements. This results in higher soft cost of extra charges per hour of design team, and less availability of these materials leads to their relatively higher cost. Hence, this aspect is directly related to the third scope (verification) to quantify actual environmental impact from these materials. Also, it is related to the fourth scope (market) to investigate the availability and price of these materials before taking final decisions to avoid timely and expensive change orders.

Yet, it is notable that the LEED system does not account for Durability/Flexibility/Adaptability e.g. Design for Disassembly (DFD), and Design for Disassembly and deconstruction (DFDD)[1], which are considered important components of a sustainable building and building products/ materials to extend their lifecycle, reduce energy consumption and carbon output significantly, as well as reduce waste in landfills (Green Building Finance Consortium, 2010). Building durability is significantly influenced by its flexibility and adaptability to changing tenant and investor demands, and this reflects on the market scope.

There may exist some synergistic or trade-offs relations between most if not all MR credits; MR C4, 5, 6 and 7 to determine the features of sustainable materials selected; recycled, regional, rapidly and certified wood. Other relations exist between MR C4-7 and IAQ 4: Low emitting materials, and may exist also for MR C5: Regional materials and SS C1: Site Selection, as well as with SS C2: Development Density and Community Connectivity. Also some probable relations may exist for MR C1: Building Reuse, or MR C3: Material Reuse with SS C3: Brownfield development , as well as between MR C1, and EA Pre1 and EA C3 for optimizing building energy performance.

Notes on applying Scope (1) for EA and MR credits

Summarizing LEED's guideline for sustainable building performance for both Materials and Resources and Energy and Atmosphere credit categories indicates the following;

It is notable that LEED's role as guidelines and decision making support tool differs for EA and MR credits. Materials credits in LEED system (V 3.0) are mainly comprised of prescriptive requirements; while on the other hand, energy credits are mainly comprised of performance requirements. This means that more flexibility is provided for energy efficient performance depending on the project situation– allowing for more innovation in design tailored according to the project situation, while on the other hand, materials credits represent a tight set of requirements in which project team members are obliged to comply with whatever extra cost this may require. Hence more time should be invested

[1] More about DFD and DFDD found in (Kibert, 2005 p.282)

to investigate innovative energy efficient design solutions for energy credits, while for materials credits, more time in invested searching and documenting green materials.

Also, when determining the project's goal; the logic for EA credits is based on defining a single target for optimizing energy efficiency in early design stages, and providing a flexible framework to guide for energy efficiency according to project case, and guided by computer analysis software programs. While for MR credits, the logic of materials and resources efficiency can be possibly achieved through a number of means that can be achieved in various stages; starting with adopting a sustainable building reuse approach in early design phases, then complying with a number of prescriptive requirements for material selection during design development (also called design detail) phase, and finally, conducting sustainable waste management during construction and operation stages.

It should also be noted that some challenges may arise when attempting to balance a range of environmental, economic and performance attributes of building type, program and budget requirements, with material selection criteria; for example; using reused materials may or may not affect building functionality and durability, and using regional materials may not be the best green alternative for the project. Additionally, it should be noted that LEED system has been greatly criticized for its criteria of material selection (scope 1), and measurement criteria for resources efficiency (scope 2), and this lays more weight on using verification methods (scope 3) to support measurement, and guide decision making process - in addition to insights from market potentials and drawbacks (scope 4).

4.2.1.2. Scope 2: Managing, Measuring and Benchmarking tool

Tools for Managing sustainable building performance;

This aspect is not considered under LEED system, nevertheless, it occupies a huge importance from the application perspective. Using tools to help manage sustainable project guidelines highlighted in scope 1, requires using project management tools and software programs mentioned in chapter two, but considering the additional environmental considerations required, for example; Gantt chart, Program Evaluation and Review Technique (PERT), work breakdown structure (WBS) and resource allocation. More specific tools and software programs may also be used, e.g. the PRINCE2 process and the PRiSM method. There are not guidelines on how to make this successful integration, and still this area should be subject to further research work, but it is important for now to identify it when discussing the application of the LEED system.

So for the research purpose, only the other two points of concern (Measurement & Benchmarking) shall be used to identify this scope.

Tools for Measuring and Benchmarking sustainable building performance;

This aspect reflects actual LEED energy and materials credits' measurement metrics. Practitioners should first identify the following; goals, scope and boundaries of measurement, what is to be measured and the nature of the assessment criteria (quantitative or qualitative), assessment method (performance or prescriptive), scale of measurement, benchmarking, weighting, tool or methods of measurement, assumptions, as well as estimating expected risks and degree of reliability of results.

For the purpose of this section; two types of assessment methods shall be identified for LEED system- based on the nature of sustainable criteria (Qualitative versus Quantitative assessment) and the criteria of judgement (Performance versus Prescriptive assessment);

Qualitative versus Quantitative assessment

- ☐ ***Qualitative assessment;*** depends on subjective assessment for non-quantifiable criteria, and there is a rising attention to the contribution of this type of assessment to Green building business case.
- ☐ ***Quantitative assessment;*** it relies on obtaining measured performance, and the degree of uncertainty related to this type of measurement is comparably smaller than the next type. The study done by (JÖnsson, 2000), suggested four ways to present quantitative data: (a) absolute values, (b) relative values, (c) relative to a threshold value, and (d) belonging to an interval- as shown in figure (39).

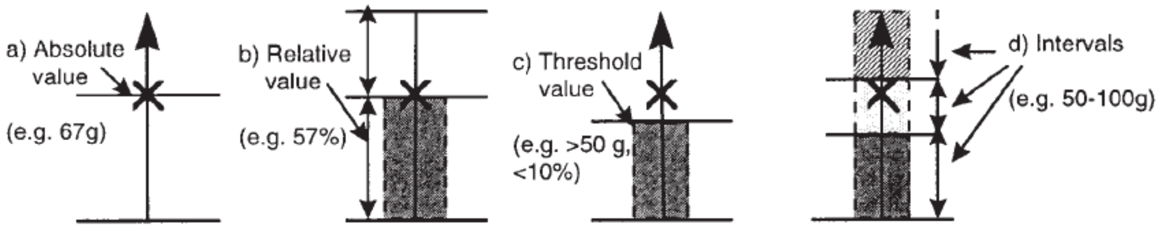

Figure 39: Ways of presenting quantitative data

It can be roughly assumed that most LEED SS and IAQ credit categories may well be considered qualitative criteria. While, for the research focus, most energy and materials credits may well be considered quantitative criteria- applying mostly type (b): Relative value for MR credits, and type (b) Relative value, and type (d): Interval for EA credits to present quantitative data. Thus, quantitative measurement metrics can be used to measure their environmental impact, and they can provide a robust mean for comparing environmental building performance against other buildings.

Performance versus Prescriptive assessment

LEED system may roughly be seen as having mainly two types of assessment methods based on the measurement criteria. They can mainly be categorized into;

- ☐ ***Prescriptive assessment;*** this type of assessment depends on the achievement of certain types of sustainable building practices requiring the implementation of a specific technology and their performance value is considered fixed and implicit (Berardi, 2011),(Eijadi et al, 2002) . This does not provide a flexible sustainable approach, in addition to the criticism related to the suitability of such requirements to the nature of the project.

- ☐ ***Performance assessment;*** this type of assessment depends on exceeding a pre-set sustainability threshold or benchmark regardless of the method used to fulfil the requirements. The points awarded for the credit does not mandate a specific strategy to obtain the credit (Eijadi et al, 2002), (Berardi, 2011). This provides some flexibility for project team members to adopt a wide range of sustainable building practices according to project's conditions. It is worth noting that the general direction of developing LEED system like other GBRS (presented in the previous chapter) is seen to rely more on providing performance assessment method to provide more flexible framework that may match with different projects' conditions.

The system tries with more developed versions to perform credit restructuring and/or reweighting in order to develop its measurement criteria according to the previously discussed categorization, but the logic for measuring some credits- especially for EA and MR categories is still based on; 'mixing environmental and economic savings', hence it reports energy and materials efficiency in the form of monetary values (cost savings for EA credits, and cost of purchased materials for many MR credits)[1], and this does not provide a solid mean for comparing their environmental impact among certified LEED projects or with other certified green buildings. This requires developing additional verification methods to account for the building's environmental performance, guide decision making process, and allow for more comparability of obtained results according to standard common metrics. Finally, practitioners should report environmental building performance transparently and detailed- so that outputs could clearly indicate actual environmental impact of LEED certified buildings in the global marketplace.

To sum up, the 'breaking down- building up' process for scope (2) can be represented in the following diagram. The figure shows the gaps and limitations in the existing LEED version to cover the second defined scope, and the research proposal for development.

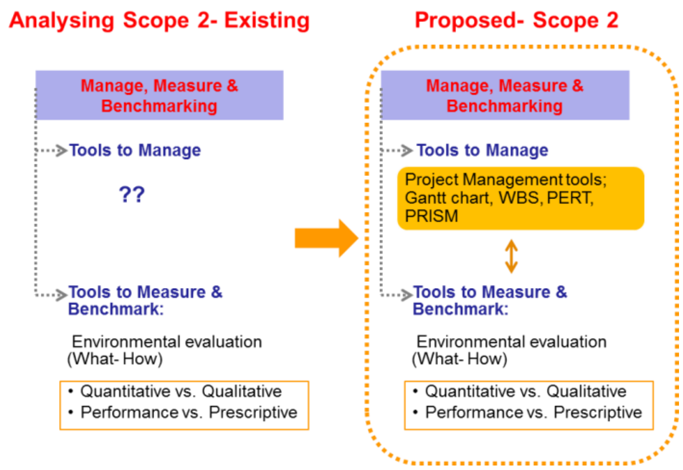

Figure 40: Breaking down- Building up process for scope (2)

[1] For EA, LEED V3.0 has introduced more advanced means to account for environmental impact, but it is still translated at the end to cost savings.

Applying Scope (2) for measuring and benchmarking Energy efficiency

Measuring and benchmarking energy efficiency maybe well considered quantitative sustainable criteria. There are some critical aspects to be considered when attempting to measure energy efficiency[1]- the first is that till the time of writing, it is not possible to measure energy efficiency, hence substitutes are used in energy efficiency analysis, including energy intensity or energy performance indicators, while LEED system substitutes by measuring energy cost savings as an indicator for energy efficiency- this is an important assumption that should be considered by team members, and this requires gathering more information about the magnitude for energy use (site energy, source energy, CO2 emissions and energy cost) and accounting for energy end use (lighting, hot water, HVAC, cooking, refrigeration, etc.).

Another important differentiation has to be made between 'Site' and 'Source' energy. It should be noted that both types are not directly comparable because one represents a raw fuel while the other represents a converted fuel (Green Building Finance Consortium, 2010)- noting that 'Source energy' is a more holistic measure based on the total energy resources expended (Mendler et al, The Guidebook to Sustainable design, 2nd edition p. 54). Prior LEED versions accounted for 'Site energy' source but LEED V3.0 has started to differentiate between the two types of energy, and require both types of information for measuring and benchmarking energy efficiency.

There are mainly two types of measuring operational energy performance, according to CEN, they are Metered consumption and Calculated (or asset) rating[2]. For New Construction buildings, this scope may well use the calculated rating to estimate the predicted energy savings required to comply with LEED credits - based on data derived from building drawings and/or specifications- hence, it calculates building energy use in relation to the characteristics and systems of the building itself. Yet, for existing buildings, both calculated and measured ratings are applicable, but the later is preferred to reduce energy performance discrepancies and limit consumer risks[3].

There are two prescriptive approaches[4], and one performance approach[1], to assess building energy performance for EA C1: Optimize Energy Performance,

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[1] Energy efficiency should be calculated based on a ratio of energy input to service output, and this is very difficult due to the fact that assessing the quality and quantity of a given service is a complex task. Hence, some authors [28] propose multiple indices to consider simultaneously energy use, though energy use per unit of area and year is almost the standard EPI for buildings (Lombard et al, 2008)

[2] Calculated rating are subdivided into standard (also called asset) and tailored rating. The asset rating use the calculation procedure within standard usage patterns and climatic conditions- not to depend on occupant behaviour, actual weather and indoor condition, and are designed to rate the building and not the occupant. Asset ratings can be shaped to buildings during the design process (as designed), new buildings (as built) or to existing buildings. For the latter, when calculated under actual conditions (different to standard usage patterns) the rating becomes a tailored rating. More about this topic can be found in (OECD/IEA, 2010) and (Lombard et al, 2008).

[3] In accordance with CEN recommendations, a building energy certification scheme for existing buildings should be implemented by the use of operational ratings with reference values (benchmarks) taken from the building stock in order to establish the classification system. In like manner, for new buildings, an asset rating should be used in comparison with the references values set by the regulation, the building stock and the zero energy building (Lombard et al, 2008),[22].

[4] This requires complying with either (Option 2: prescriptive measures of Advanced Energy Design Guide for Small Office Buildings 2004, Advanced Energy Design Guide for Small Retail Buildings 2006, or Advanced

depending on the scale and type of the building. Energy analysis for LEED certification is typically estimated by load calculation and annual energy analysis software, such as DOE-2[2] and Energy Plus which shall be referred to in the next chapter. These methods are appropriate to analyze the building thermal loads and size the cooling or heating equipment (Han, RB0511). Then, LEED performs the calculation based on building energy cost analyses- which is relatively easier to measure and are high enough to have a significant impact on most businesses. It should be noted that in modelling energy cost savings, engineers typically utilize the current rate schedule from the utility companies that serve or will serve the subject property. Higher than anticipated energy prices result in higher savings, and lower than anticipated energy prices result in lower savings, for the same level of investment, all other things being equal. Total energy expenses will depend on the mix of energy use at the subject property and the price of each source (Green Building Finance Consortium, 2010). This is how it is greatly affected by scope 4 (Market), but it needs to be supported by feedback from scope 3 (verification).

Applying Scope (2) for measuring and benchmarking Materials and Resources efficiency

Analysing the measurement criteria for LEED MR credits show that Materials and Resources efficiency is measured based on compliance with LEED system's (V3.0) prescriptive requirements and estimated materials savings and not on actual measurement for environmental impact, for example; calculation method for accounting for sustainable materials is based on area for MR C1: Building reuse, weight or volume for MR C2: Construction waste management, and material cost for MR C3-C7. It is thus necessary to include an additional step to account for their embodied energy to be able to evaluate their environmental impact[3].

Notes on applying Scope (2) for EA and MR credits

LEED's role as Measurement and Benchmarking tool differs for EA and MR credits. It can be concluded that LEED's Measurement logic for energy credits is mainly based on how integrally the project performs, it depends on a comparative method to a base model, While the measurement logic for materials and resources credits in LEED V3.0 depends on compliance with a set of prescriptive requirements defined by the LEED system- but this measurement method is not able to account for the environmental impact arising from neither energy systems nor material selection, nor account for the synergies between them. Although LEED V4.0 initiates the integration of LCA in the Materials and Resources credits' category, nevertheless, it might create biased result because it

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Energy Design Guide for Small Warehouses and Self Storage Buildings 2008; or (Option 3: prescriptive measures in Advanced Buildings Core Performance Guide).

[1] Using either Building Performance Rating Method in ASHRAE 90.1–2007, Appendix G and addenda, or California Title 24–2005, Part 6.

[2] U.S. Department Of Energy

[3] LEED version 4.0 has included an option (option 4: whole building life cycle assessment) as previously explained in chapter two.

attempts to create cutoff values accounting for materials and energy individually, and not considering an integrated approach as within ISO standard. The optimum way is to combine energy and materials measurement criteria under unified whole building LCA, and although this may still be difficult to achieve but the measurement science relating to *Green Building* is an active area of research.

Also, for energy simulation modelling, practitioners need knowledge and expertise on how to assess the accuracy and reliability of forecasts- differentiating between the two types of measurement (metered and calculated rating) considering risks and uncertainties related to each tool, in order to reduce the error factor to the minimum. Consensus may not exist on specific measurement goals or metrics, and reliable and consistent data may be difficult to obtain, thus, it is important to combine the results obtained from measurement criteria with some means of verification criteria, as shall be discussed in the next section.

4.2.2. Verification & Certification Mechanism

This mechanism is either not clearly defined, or not properly integrated in the building process, although it may have great effect on the decision making process- this requires better defining and developing its scopes to serve its promising role for verifying and certifying green buildings' performance- hence, raising the quality of the building process and measured performance, and determines the value of LEED certification in the global marketplace. It can be divided into two scopes as shown in figure (41).

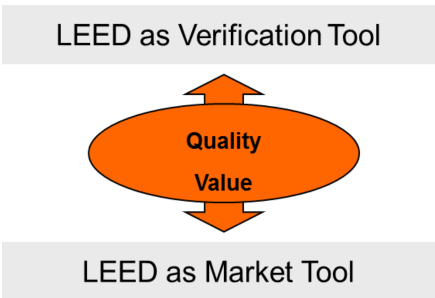

Figure 41 Scope of LEED Verification and certification mechanism

4.2.2.1. Scope 3: Verification tool

This scope discusses the 'quality' of the certification scheme, which is raising more concern in the sustainable building industry, and it varies among GBRS according to the comprehensiveness of guidelines and robustness of their measurement metrics. It is important to note that verification strategies should extend along the whole building life cycle and not only during design and construction, and sustainable criteria differ in the methods and tools required for monitoring and controlling building performance. The research shall focus only on verification methods for buildings' environmental performance, which may vary according to a number of factors, for example;

unanticipated patterns of behaviour by tenants and occupants; the ways and extent to which users and building operators understand and engage with environmental technologies; design and equipment changes; and poor installation practices (Green Buildings BC, GVRD and NRCan). Methods can either assess the avoided impact from energy and/or materials use, or through normalized savings as follows[1]

Hence, owing to the fact that LEED system has a substantial criticism for their measurement metrics, so this creates an urgent need to better develop robust means for verifying LEED projects' environmental performance, and this requires using new sustainable practices, tools and methods to act as a quality assurance and quality control mechanism- hence, providing for monitoring and control procedures, to reflect back and adjust their measurement metrics, support the decision making process and raise LEED certified projects' value in the market.

Finally, it should be noted that this scope is much related to scope 4: Market because Verification methods provide a credible way to document and claim benefits like improved air quality, increased productivity, and reliable system operations, all of which increase the building's value and market appeal.

The research shall focus on verification methods used to support quantitative measurement metrics for energy and materials credits. It is also important to understand the types of energy use in buildings and their relative share in the overall building energy consumption. This helps formulating scenarios for measuring and verifying building's energy performance. There are mainly two types of energy use in building industry; "Operational energy "and "Embodied energy". Studies show that for new construction buildings, energy use for operation phase accounts for 80-94% of total building energy consumption[2], while material extraction, transportation and production accounts for almost 6-20%- and less than 1% is accounted for end of life treatment (Howard,2005) . These estimations may differ according to project type, and time (APAT, 2008)[3]- and this calls to the necessity of establishing a comprehensive plan employing proper tools and methods suitable for each type.

Some of the verification issues concern operational energy use- for example building commissioning and M&V process (already in the current LEED version) and the research recommends using POE to account for occupant's evaluation for operational

[1] Avoided Impact is the reduction in energy/materials and resources due to reuse/recycle scenarios, relative to what would have occurred if the facility had been equipped and operated as it was in the baseline model, and this maybe applicable to both energy and materials credits.
Normalized savings calculations adjust baseline and the post-installation models to a fixed set of conditions other than those of the reporting period. The conditions may be those of the baseline period, some other arbitrary period, or a typical, average, or "normal" set of conditions. This is probably relevant for energy credits because operational energy performance changes by time.

[2] Source, (Suzuki and Oka, 1998)

[3] For example, they may differ for renovation buildings because embodied energy in this type of projects is greater in the construction phase rather than the operational phase, and they might change with time due to the rising tendency to renovate old buildings, thus embodied energy in the construction phase will have greater share than in operational one (APAT, 2008).

performance as well, in addition to employing LCA to quantify building's environmental impact (LEED V4.0). And now discussing the recommended verification methods;

Building Commissioning process:

Commissioning process (Cx) is quickly becoming one of the most important topics in the building management arena, as well as making a strong business case owing to the awareness about the energy, cost and operational benefits. It can be considered a response to the emerging emphasis on long term performance and life cycle costs. It can be valuable for most building types and situations, but it is particularly valuable for some cases, e.g. large / complex buildings, having very large loads on the mechanical equipment, or highly variant occupancy levels, or those buildings in extreme climates (Matthiessen et al,2004), (Green Building Finance Consortium, 2010), (Mendler et al, The Guidebook to Sustainable design, 2nd edition p.44, 45), (Commissioning existing building, 3.0), (Yellamraju, 2011 p.197).

It requires early commitment, and should be evaluated to the proper use of the process according to project, type, situation, as well as any particular concerns- providing a solid base for the system boundary drawn, and elements and sub-elements included, as well as defining the expected targets from the process.

Commissioning has emerged as a key step in the LEED certification process. It continues to evolve, from its original role of testing and balancing HVAC systems to a more complete check of all building systems throughout the entire project, promoting the development of new functional criteria (Boecker et al,2009) and [34], (Yellamraju, 2011 p.197). For LEED NC purpose, there are two levels of Cx activities, the first is the 'Fundamental' (basic) commissioning , which is a prerequisite, and the other level is the 'Enhanced' commissioning which is a whole building commissioning process adding 2 extra points, and it requires more commitment and follow up, which might result in more cost and time expenditure. It is also important to note that it is the responsibility of the owner/design team to designate a third party commissioning (Cx) agent.

The difference between the two levels can be summarized in the following points;

☐ Fundamental building Cx aims at controlling the basic management, operation, and maintenance of the facility regarding; energy and renewable energy resource usage, HVAC&R systems, lighting and day lighting controls, alternative energy systems, water systems, and power management systems, through avoiding common and pervasive design flaws, construction mistakes, and faulty equipment (Energy and sustainability, 2010).

☐ Enhanced Cx[1] aims at integrating commissioning into the total life cycle of a building, covering all of building systems, with commissioning activities occurring throughout the

[1] LEED NC reference guide version 2.2. p.155. Enhanced Commissioning differ from Fundamental Commissioning in the following additional tasks; conducting a design review prior to mid construction documents, reviewing the contractors submittals applicable to systems being commissioned, developing a

design, construction and operation of the facility (Energy and sustainability, 2010). The owner can add other aspects to this scope through OPR, for example; monitoring and controlling waste diversion and recycling activities.

It is notable that the scope of applying Cx process in the LEED system (likewise in most building practices) is limited to focus on some basic design elements (i.e. HVAC systems) or singular objective/goal (i.e. saving energy) due to the increased cost, time and expertise, but this narrowing of scope is not likely to obtain true integration[1], nor to optimally explore other means of employing commissioning process. Hence, more discussion about the use, cost and types of commissioning is required, as shown in the following table citing a comparison between different commissioning approaches.

system manual for the commissioned systems, verifying training requirements, and reviewing building operation till 10 months after substantial completion

[1] The author's elaboration citing (BCA, 2008)

Commissioning Approach	Primary Objectives & benefits	Relative Costs	Best Applications
New building or new equipment commissioning	Focus on new equipment installation and operation. Raising the quality assurance, and better documentation and training, are useful to future Recommissioning activities.	Costs vary by size of building and complexity of systems: $0.50 to $3.00 per square foot (Welker 2003).	It should start at the beginning of the project-planning phase.
Recommissioning (RCx)	It works on two parallel scopes; actual equipment specifications, and current mission/tenant operating requirements. This requires a prior step for inventory analysis of the current situation.	Cost ranges from $0.05 to $0.40 per square foot. Hence, it is relatively cheaper than Cx process, but this depends on specific building features and the scope of the RCx effort.	Best applications are for buildings/systems that have not been adequately maintained or that have not been adapted to accommodate changing space or tenant needs.
Continuous Commissioning™	Integrates comprehensive commissioning approach into on-going facility O&M program to identify and addresses problems as they occur.	Highest cost option for existing buildings and systems.	It is the preferred approach when resources (staffing and equipment) are available.
Value Recommissioning (VCx)	Focus on the most frequently available commissioning opportunities with highest payback as part of daily O&M. It Can be completed by in-house staff, with minimal up-front cost.	Lowest cost option for existing buildings and systems.	It is used to demonstrate benefits of larger, existing building commissioning program.

Table 6: Summary of Commissioning approaches (Commissioning existing building, 3.0)

After this explanation for various types of commissioning, the research recommends expanding the scopes defined by LEED system according to project specific case and requirements, for example more focus on 'Value Commissioning' is recommended for smaller sized and budget buildings, hence working on the critical points, while continuous commissioning should consider integrated building performance. It mainly depends on the budget, building scale and complexity, but with more attention to risk. A Re-commissioning process is recommended to take place on a periodic basis (3 to 5 years is a frequently cited time frame), or if building performance degrades, or if the building occupancy or usage changes significantly.

Commissioning process has construction and soft cost implications[1]. Yet, it can provide significant benefits, both in the short (Fundamental commissioning) and long term (Enhanced commissioning). In the short term, it can help the project team develop an efficient design process, performing the necessary verification and documentation activities to reduce change orders and call-backs, warranty claims, reducing liability risks and increasing certainty. While, on the long term, it may result in improvements in system performance and reduced operating cost (around 5-10 % of O&M related energy efficiency with payback period of around 2 years), preparing quality assurance plans, as well as providing building operators with adequate instruction and information on the use and maintenance of building systems (WBDG,2004 p.86), (Green Buildings BC, GVRD and NRCan), (Energy and sustainability, 2010), and (Green Building Finance Consortium, 2010). Hence, both short and long term savings should be put into consideration when performing a cost benefit estimation to determine whether or not to perform commissioning process- and to what level.

Expected risk factors may be related to cost and quality of the commissioning process, which depends on the availability of competent/experienced commissioning agent(s), or proper time of involvement, also the lack of generally accepted industry guidelines and standards, which leads to widely varying proposals in terms of scope and costs (Green Building Finance Consortium, 2010). This puts more effort on design/ construction team to prepare proper contracts stating the goals, targets, scope, responsibilities of commissioning process, practices and agent.

[1] Soft cost; results from the fees paid for the commissioning agent and other design fees, while construction fees results from the additional work required by the contractor to support the Cx process, followed by performing the corrective actions recommended. This includes performance tests, verification and validation checks, and archiving operations and maintenance manuals, schedules, data sheets, warranties (WBDG, 2004 p.86), (Langdon, 2007). A study conducted by (Green Building Finance Consortium, 2010), about commissioning cost found that Median commissioning costs: $0.30 and $1.16 per square foot for existing buildings and new construction, respectively. Median whole-building energy savings: 16% (existing) and 13% (new). Median payback times: 1.1 (existing) and 4.2 years (new). Median benefit-cost ratios: 4.5 years (existing) and 1.1 years (new). Cash-on-cash returns: 91% (existing) and 23% (new).

Measurement and Verification Plans

Measurement and verification (M&V) is an important process to raise the accuracy and reliability for monitoring energy and resource consumption after construction or major retrofit[1]. It acts as a feedback mechanism to provide capability to track the performance of equipment, a mechanical system, or an entire building. Ideally, this tracking allows for adjustments that reduce resource use and operating costs, it can also be employed as a more direct mean of reducing energy use, proving efficiency and managing risk, as well as providing means for quantifying and recognizing the emission reductions that results from green building, and explore opportunities for greater efficiency even when systems are operating as intended[2]. This helps bridge the gap from construction to operation and maintenance.

M&V practices was driven by a growing market demand for post-construction validation of the performance of new buildings; linking M&V verification with certification aspects through Energy Service Companies (ESCOs) that operate on performance-based contracts[3], yet they are not receiving great market attractions, and is hardly ever part of a bid package. This motivation for M&V is likely to become more relevant as more regions adopt cap-and-trade systems for greenhouse gas emissions[4].

Requirements is to develop and implement a M&V plan for a period of no less than one year of post construction occupancy (i.e. one year of stable and optimized operation) which can be summarized as shown in figure (42)

- ☐ Developing and prioritizing a list of objectives and constraints for the project, that will affect the M&V plan for individual energy conservation measures (ECMs) as well as for the whole project.
- ☐ Evaluating various M&V Options.
- ☐ Evaluate the savings risk associated with the selected M&V Option(s).
- ☐ Estimate the cost-benefit of using the selected M&V Option(s).
- ☐ Identify and start documenting the type of required data- whether for the whole building baseline model or for subsystem energy use data. The next step is where both modelled (kW) is compared to metered (kW).
- ☐ Describing the efficiency measures taken, identifying the baseline for each measure, describing the analysis approach (identify features to field verify, describe measure metering, determine measure level sampling). Then, modifying the model using M&V,

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[1] LEED-EBOM offers up to four points for M&V. Up to three are awarded for metering a range of specific items. The fourth point calls on owners to quantify emissions reductions resulting from their buildings' energy savings, report them through a third-party certification program, and retire at least 10% of them through that program. It also requires owners to "ask the suppliers of goods and services for the building to do the same by implementing actions of tracking, reporting, and retiring emissions reductions and asking their suppliers to do the same."

[2] http://www.buildinggreen.com/auth/article.cfm/2006/6/7/Measurement-and-Verification-Monitoring-Building-Systems-for-Optimal-Performance/

[3] M&V emerged as a mechanism to determine whether the predicted savings had been achieved and, in turn, to reduce the building owner's financial risk of investing in efficiency improvements

[4] http://www.buildinggreen.com/auth/article.cfm/2006/6/7/Measurement-and-Verification-Monitoring-Building-Systems-for-Optimal-Performance/

which verifies whether or not the expected equipment are installed (or whether they are still operating), verifies it operates with scheduled hours and occupancy, Set points and control schemes.

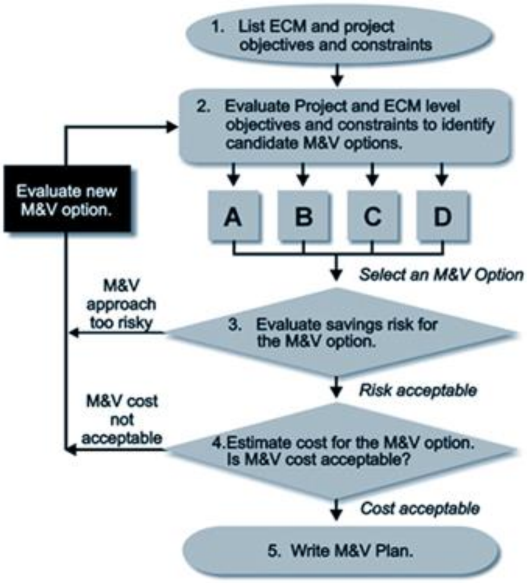

Figure 42: M&V plan[1]

The results of a M&V process should indicate whether the installed energy efficient systems (features) are realizing the predicted claimed savings, and analyse opportunities for more savings, thus provides confidence in the investment values, and estimate probable risk. Finally, it should also discuss Building life cycle costing, thus reveal the reasons for the level of savings impacts over the life of the building[2]. This type of analysis is useful for energy audits/ benchmarking/ assessment to evaluate energy efficiency programs and impact evaluation, Performance contracting/ energy service companies, demand resource certification, Retro commissioning/ troubleshooting to act as a feedback mechanism to designers, and/or to owners[3].

Some typical objectives and constraints for M&V are listed below[4]

Typical Objectives	**Typical Constraints**
Track energy savings through utility metering	Historical utility data not available
Verify energy performance continuously or periodically	Lack of building level utility meters
Track post-retrofit consumption and adjust baseline for changes in weather, occupancy, mission, etc.	ECMs scope affects a small portion of overall utility baseline
Maximize infrastructure improvements by utilizing least-cost M&V option	No energy management control system available for data acquisition

[1] Source: http://www1.eere.energy.gov/femp/news/news_detail.html?news_id=7359
[2] Source: http://www.slideshare.net/Aarongrt/energy-modeling-for-leed-using-equest
[3] Source: http://www.slideshare.net/Aarongrt/energy-modeling-for-leed-using-equest
[4] Source: http://www1.eere.energy.gov/femp/news/news_detail.html?news_id=7359

Ensure equipment performance for life of contract	
Quantify savings from ECM	High degree of interaction between ECMs

Table 7: Typical objectives and constraints for M&V

It should be considered early in the design process, considering that introducing M&V can alter the design of the mechanical system or the building automation system. Common risks for applying M&V plan is a lack of follow up after the project is completed, installing or designing the necessary systems too late in the design process, and when the staff lacks knowledge about how to interpret the M&V data or fine tune the building if data indicates underperformance (Green Building Finance Consortium, 2010)

After having this general review about M&V Process, the next section shall discuss LEED system's requirements for M&V plan.

Many energy-consuming building features that earn LEED credits require on-going maintenance to maintain validity and credibility of LEED certification. This aspect is considered under EA C 5 Measurement and Verification, but LEED credit expands upon IPMVP that M&V objectives as it should not necessarily be confined to energy systems where ECMs or energy conservation strategies have been implemented. Under the compulsory Minimum Program Requirements in LEED 2009, all certified projects must commit to sharing with USGBC/GBCI all available actual energy and water usage data for the whole project for a period of at least five years from occupancy (LEED NC reference guide, 2009).

This credit requires significant capital cost which may not encourage design team to adopt it. Cost estimations includes soft cost resulting from the cost for writing and implementing the M&V plan, and hard cost which comprises metering and sub metering equipment. The feasibility and cost of this credit depends on some factors, including building type (Yellamraju, 2011 p.195), size and complexity, and above all whether Building Automation System (BAS) and/or Building Management Systems (BMS) is integrated in the project's base requirements because- although the level and quality required for monitoring exceeds conventional BAS/BMS (WBDG,2004) ,(Langdon, 2007), (Matthiessen et al,2004). It is also worth noting that the fourth scope (market) has much influence on its development - for example, due to perceived extra cost and time, M&V was not included under the new LEED V4.0- instead only a requirement of installing metering system which is only one requirement of the M&V plan[1].

[1] It is still early to judge the credit, and more information shall be available after the formal activation of LEED V4.0.

Post occupancy Evaluation

Post occupancy evaluation (POE) or in other terms 'Building Performance Evaluation' is currently not part of LEED NC, but the research recommends introducing them early during the design and construction processes to highlight important issues for post occupancy evaluation. A typical Post Occupancy Evaluation has three phases: Preparation (2-3 weeks), Interview (1 week), and Analysis & Reporting (3-6 weeks). It results in a report on existing performance and identifying changes from the original design brief, in addition to adding recommendations for corrective actions and lessons learnt considering the building as a whole sum.

Benefits of POE are to evaluate both hard and soft metrics, including; energy and water efficiency, emissions reduction, waste minimization, and other sustainability objectives, as well as evaluating occupant satisfaction, in addition to some criteria such as cost, performance, durability, and flexibility. Hence, it may provide a way of verifying the success of some green strategies, in terms of actual efficiency, operating costs, and productivity impacts, and it may even be used to adjust management practices, and provide a valuable feedback. POE can be linked with the green leases practices, and the Procure and Operate packages as discussed in chapter two to provide direct feedback to improve the link between environmental building operation and management practices regarding; the environmental standards of building materials, as well as the effectiveness of the building operations and management programs

It is obvious that verification methods proposed by the LEED system are more concerned with operational energy savings, while on the other hand, resources and materials savings are dealt in isolation without considering the linkage between them. LCA provides a mean to complete the whole picture through accounting for embodied energy as well- as shown in figure (43). Hence, this requires further discussion about LCA .

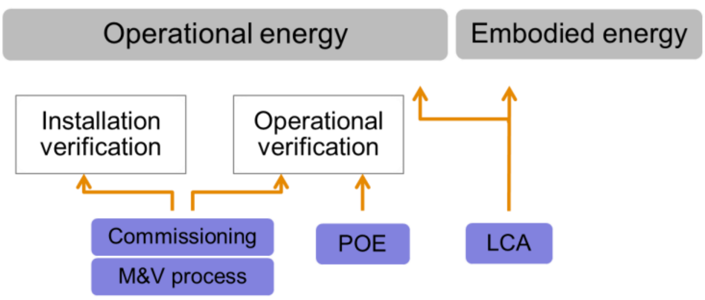

Figure 43: The types of energy use in buildings and their corresponding verification methods

Life Cycle Assessment

The current LEED version does not constitute LCA[1]. Nevertheless, as previously mentioned, the new LEED version shall integrate LCA as a method to verify environmental impact from materials and resources, which can support sustainable decision making process for material selection, develop resource strategies, such as optimal waste management, and improve sustainable material selection and procurement activities (Publications Office of the European Union, 2010) as shown in figure (44), nevertheless, it is still a beginning and needs to be further developed to establish links with existing environmental and performance databases in order to present comprehensive environmental assessment. It is worth mentioning that using LCA is only provided to obtain MR credits inclusively, while in fact its calculation method may constitute accounting for operational energy use as well- to avoid cut off measurement method.

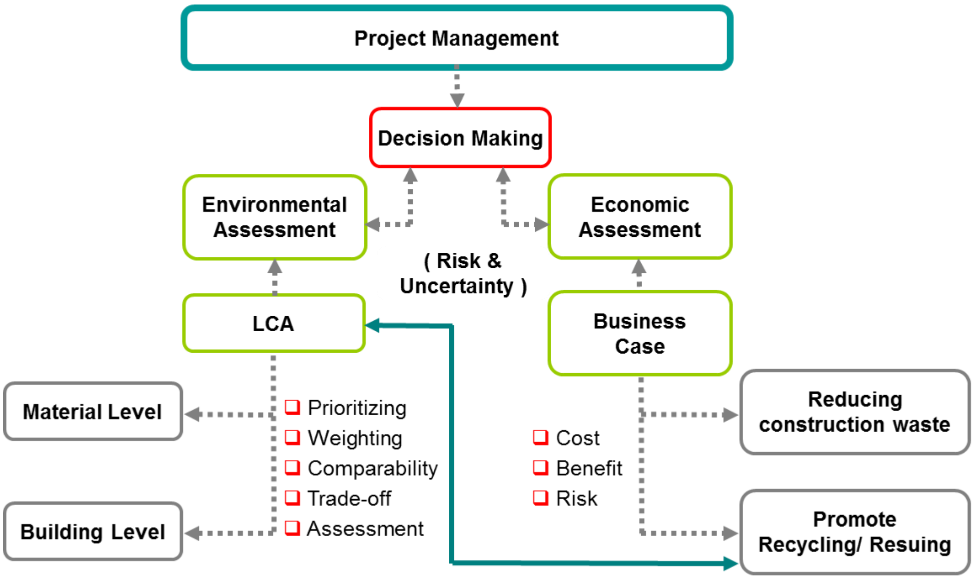

Figure 44: The environmental and economic advantage accounted from using LCA in the building process

To sum up, the 'breaking down- building up' process for scope (3) can be represented in the following diagram. The figure shows the gaps and limitations in the existing LEED version to cover the third defined scope, and the research proposal for development.

[1] Detailed review about LCA was included in chapter two, so will not be repeated here.

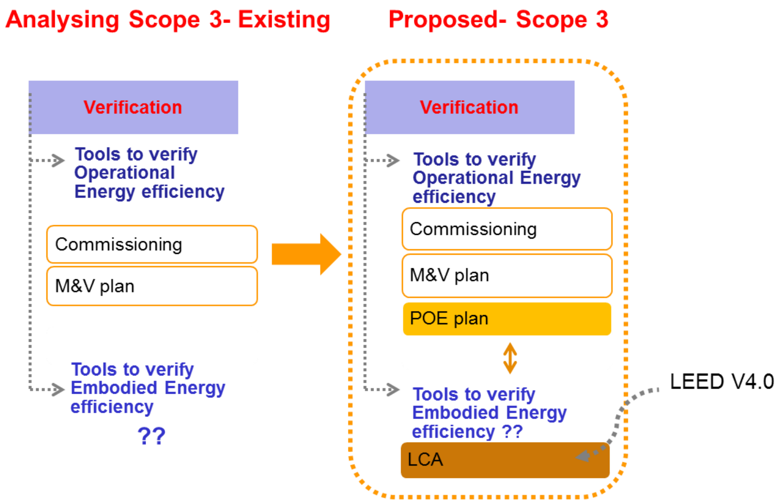

Figure 45: Breaking down- Building up process for scope (3)

Notes on applying Scope (3) for EA and MR credits

After individually discussing each verification method, it is noted that the space for communalities and differences is widely open, depending on the use and scope of each method- but what assures working within budget and reaching higher performance levels is to integrate these methods together- as shown in figure (46). This is an example of the challenge between performing individual practices, and integrated process as a whole. This requires setting a base for verification plan, including defining the method used, defining the work boundary, verification benchmark, tools and methods as well as any assumptions or normalization procedures.

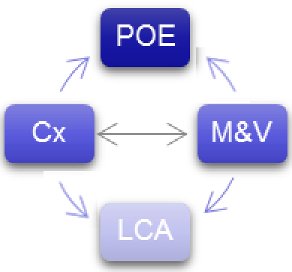

Figure 46: Integration between different verification methods

It is noted that the relation between operational and embodied energy is still missing in LEED, so the research recommends that it is performed as part of the third scope (verification), where the output from an energy model 'calculated consumption' can be considered the "operational energy" and is one component of the input needed to complete a LCA for a building (AIA, 2010). Also, 'Metered consumption'[1] may also be used to document how efficiency upgrades affect the building's energy consumption through commissioning or Measurement and Verification plans [2](BCA, 2008).

[1] It relies primarily on consumption data acquired from utilities, e.g. energy or water consumption (OECD/IEA, 2010)

[2] Real time metering help occupants learn how do prices of electricity vary along the day, to be able to manage peak energy use hours (Vezzoli et al, 2010 p.65)., and User Interface Dashboards are "real time" systems that

Additionally, M&V should optimally begin during commissioning to validate whether the commissioning was done correctly or not. The Cx process requirement to conduct trend analysis or functionally-test equipment operations after installation corresponds to the operational verification requirement for the M&V process. Often the data collected during the Cx process may be used in the post-installation M&V analysis (QuEST, 2012). M&V also shares some territory with post-occupancy evaluation, because it may involve the future building operators who shall execute the plan[1], and consider the qualitative aspects of a building's performance. POE also differs from M&V in that it represents an isolated snapshot of a building's performance, whereas M&V involves regular, long-term analysis[2] and both types of analysis are required. Also, POE can help confirm life-cycle performance projections; this can be very useful regarding new green technologies to reduce risk and uncertainty. Also, some synergistic relations may exist between EA C5: Measurement and Verification with IAQ C7: Thermal comfort verification, and conducting a POE.

And now presenting some comparisons to attempt to explore communalities and differences between some of the previously discussed verification methods, citing some very few and recent studies as follows;

Comparing Fundamental building systems commissioning against Measurement and Verification is shown in the following table[3] :

EA Pre 1: Fundamental Cx Process	EA C 5: M&V Process
It is a prerequisite for the LEED certification, thus it is mandatory to do.	It is not a prerequisite, thus it is not mandatory
It aims at verifying and ensuring that fundamental building elements and systems are designed, installed and calibrated to operate as intended, in the form of 'Quality Control'- described as 'work-as-designed' approach.	M&V plans are planned and executed in conjunction with energy simulations, thus, it encompasses much of what fundamental building systems commissioning purports to do for energy efficiency. It enables on-going tuning and refinements of a building to its conditions of use- described as 'work-as-used' approach,
The estimated value is a net improvement in operating efficiency of 5-10% (USGBC 2001)	It offers better assurance of energy efficiency over time

measure and display building performance metrics to enable stakeholders to improve operational efficiency, and facilitates the process of monitoring ongoing performance against the previous day, month or year's metrics.

1 http://www.buildinggreen.com/auth/article.cfm/2006/6/7/Measurement-and-Verification-Monitoring-Building-Systems-for-Optimal-Performance/

2 http://www.buildinggreen.com/auth/article.cfm/2006/6/7/Measurement-and-Verification-Monitoring-Building-Systems-for-Optimal-Performance/

3 Source: (Howard,2005)

Costs are typically estimated at 0.75-1.5% of total construction cost, with smaller building having the higher cost estimate.	It might be half as expensive as fundamental commissioning for the same level of energy efficiency and with more long term value.

The table shows that comparing EA Pre1: Fundamental commissioning to EA C5: Measurement and Verification, shows some commonalities between the two strategies and shows the relative advantage of M&V over fundamental Cx in terms of long term energy and cost savings[1].

Table 8: Comparing Existing building commissioning with M&V process[2]

EBCx Process	M&V Process
Planning Phase Establish building requirements Review available information Visit site / interview operators Develop EBCx plan Document operation conditions **Investigation Phase** Identify current building needs Perform facility performance analysis – Diagnostic monitoring – System testing Create list of findings Estimate energy savings Estimate costs Recommend improvements	**Baseline Period** Define scope of M&V activity Identify affected systems Select Approach – System – Whole building Collect data – Energy measurements – Independent variables – Frequency & duration Document the baseline – Equipment inventory – Operations – Energy baseline and adjustments – Assess uncertainty Finalize and document the M&V Plan
Implementation Phase Prioritize recommendations Install / implement recommendations Functionally test recommendations Document improved performance	**Implementation Phase** Verify proper performance
Turnover Phase • Update building documentation • Develop final report • Update systems manual • Plan ongoing commissioning • Provide training	**Post-Installation Period** • Collect post-installation data • Calculate savings for reporting period • Estimate annual savings • Develop savings report(s)
Persistence Phase • Monitor and track energy use • Monitor and track non-energy metrics	**Persistence Phase** • Verify continued equipment performance • Monitor energy use

[1] According to (QuEST, 2012), that it is a drawback in LEED system to mandate Fundamental commissioning, with relatively larger investments than M&V process. This shall eventually drive investments away from adopting additional energy efficiency strategies like M&V process.

[2] Source: (QuEST, 2012)

• Trend key system parameters • Document changes • Implement persistence strategies	• Calculate savings • Provide periodic savings reports

As shown in the table, there exist an overlap between EBCx and M&V processes, which relies in: Shared Data (whole building and system energy data, as well as system operational data), Engineering Savings Estimates, which help with the selection of the measurement boundary, and they provide a reference point to test the sufficiency of the energy model. IPMVP-adherent M&V processes require two kinds of verification: energy savings verification and operational verification.

It is notable that using LEED as a verification tool for both energy and materials credits is an emerging requirement to green building practices. Verification scope may well be considered complementary to reflect the actual image of building/ project long term sustainable performance. Tools and methods may appear different but the logic is almost the same because they provide a flexible framework to be applied according to project condition, and they could be employed in a consecutive, complementary, or an encompassing manner. Accordingly, they require defining the work, time and budget boundary, inputs and outputs, unit of measurement, tools and methods used as well as degree of expertise required, and it is always better to include them in early design phases to perform the necessary changes.

There are two important aspects for this scope; the first, it that practitioners understand that the identified credits are used for Verification purposes, and understand the importance of this scope on other scopes. Second, that practitioners define proper means of using and integrating different tools and methods whether already recommended by the LEED system or exceeding its requirements- maintaining quality, cost and time as planned.

4.2.2.2. SCOPE 4: CERTIFICATION AND MARKET TOOL

This scope aims at evaluating the value (which accordingly shall set the price of LEED certified projects in the real estate market place) based on interrelations with other scopes- particularly the verification scope, which carries extra value for financing and marketing, and allows it to be used in the market as a classification and evaluation tool. This shall eventually provide more consistency and reliability of documented results in order to be communicated clearly to support performance claims.

Comparing LEED system to other GBRS shows that LEED is one of the mostly adopted and adapted GBRS. This indicates the good contribution of this scope; yet, this strong aspect has to be introduced early in the building process, in order to explore its interrelations with other scopes- particularly how it affects decision making process. This may include; certification aspects of LEED system and its reflection on the market.

Certification Scheme Performance

LEED Certification is a highly case-specific process, dependent upon the type of building, the individual circumstances of each building, and the building's ownership, along with expected value, revenue, risk and uncertainty. It plays an important role in the financial assessment of sustainable properties in the global/national marketplace, because they provide a basis for investment potentials, complying with some national policies, and generally they simplify the complex mix of decisions about buildings to facilitate the decision making process[1].

The research identifies two perspectives to cover this discussion; first discussing practitioners, and second discussing the USGBC's contributions to develop the application of LEED system's certification scope.

First; discussing practitioners' contributions shall include; choosing the proper type of rating system, exploring benefits and risks from LEED certification, as well as its applicability to different building types. These aspects shall be sequentially discussed as follows;

LEED certification must be sought in one of nine rating systems; each is designed for a specific type, sectors and project scopes. It provides an internationally recognized third-party certification system for the whole building performance which is considered one of the main powerful tools for the LEED system (Azhar, et.al, 2010), (McManus, 2010), (Eijadi et al, 2002). This gives an indication about the building performance in a unified score (level), categories, and/or more specified in credits[2]. Types of LEED rating systems convey different messages in the real estate market. Thus, it is important to properly choose the rating system matching more with project situation, performance requirements and management framework, and eventually, this shall reflect back on the identified LEED system's scopes of operation.

LEED certificates are considered valuable among many stakeholders/tenants in the building sector to provide a mechanism by which prospective buyers and tenants can compare sustainable building performance through the certification level provided, yet more transparency is needed to convey the true image of building performance, in order to address; incomplete information and the split incentive problem discussed in chapter two. This is why the research recommends making the results transparent to promote

[1] More discussion about sustainable certification scheme in general is found in (OECD/IEA, 2010), (Howard,2005)

[2] Some owners do not consent publishing any data about their LEED certified projects, some others consent publishing very few data including the project name, location and certification level obtained. Other owners provide more data regarding the credits earned, and the points obtained, yet it is not mandatory.

better communication and comparability; clearly stating the guidelines followed, strategies performed, assessment methods and compliance paths, verification methods applied, as well as linkage with other sustainable certification entity. This shall guarantee proper consideration of revenue and risk in the decision making process, reduce the possibility of using LEED certification for Green-washing, balance standardization of LEED certification with its contextual adaptation, and eventually shall reflect positively on the LEED certification market performance.

Another significant issue is related to the applicability of the LEED system to different building types. This problem may arise for certifying new building versus existing buildings- considering their building performance and service life cycle, as shall be discussed in chapter (6). Another issue of concern is multi-dwelling buildings, because energy performance implies two aspects: the building as a whole and each individual apartment/ unit. Thus, the certification scheme should include information on both the entire building and on individual apartments/units.

Market Scheme Performance

Practitioners need to continuously update their knowledge about the existing and expecting potentials in the international/national green market, to be able to understand the size and factors influencing *Green Building* demand and explore their influences on the decision making process along the whole building process. It is generally noted that as more and more projects are certified, the market becomes more incentivized, and the bid community is more willing to adopt sustainable innovations.

Additionally, employing market strategies is an important consideration for LEED projects. This includes conveying signalling messages, branding, standardization and differentiation in order to gain a competitive market advantage, grant value, control the price of the LEED certification, and includes taking a risk factor especially when adopting new innovative solutions[1].This necessitates employing verification methods to ensure quality control, financial control and performance monitoring.

Additionally, both certification and market performance share a mutual interest in estimating 'Building value'[2] offering greater public credibility in distinguishing "green" buildings within a competitive market[3], hence, it is useful for investor demand, which in turn has a great share in the decision to pursue LEED certification. Citing the certification

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[1] More discussion about marketing strategies is found in (Stein et al, 2004) , (Howard,2005), (Paumgartten, 2003).

[2] Value and risk management; (value management techniques) aim to articulate value for the project as perceived by key project participants. (risk management techniques) ; identify risk and uncertainty and mitigate their adverse impact on the project. They are both considered complementary activities (Green Building Finance Consortium, 2010)

[3] The study conducted by (Lacroix, 2010), and another by (Veritas, 2009), about estimating green value stating that there are seven factors to consider in terms of green building economics: Direct capital costs, Direct operating costs, Lifecycle costing, Productivity benefits, Property values, External economic savings, besides other intangible benefits (Lacroix, 2010). According to (Yates, 2001), (Green Building Finance Consortium, 2010); Operational resource use costs account for approximately 5 times constructional costs over the typical 60 year life of a building. A Business Case for Green Buildings (CaGBC, 2005)

and market analysis presented in chapter three, it can be concluded that factors influencing market demand[1] for LEED certification may be; context, ownership type[2], type of rating system, type of sector, building type and scale, as well as type of development. It is more appealing for commercial buildings and primarily offices, large and complex buildings. Yet additional concern needs to be given for the existing building certification, as well as multi-dwelling buildings, due to the reason that they require more transparency in assessment, and paying more attention to various needs of involved parties.

Similarly, the financial benefits associated with LEED are uncertain[3]- it depends on the project case specific, but it must be robust to establish the business case of LEED certified buildings and explore their tangible and non-tangible benefits. This aspect is directly related to its role as a certification tool, with additional consideration to ownership and occupancy type and nature, leasing type and existing incentives' mechanisms[4]. It is generally noted that by time, it is becoming easier to identify 'LEED-related' and 'green building-related' costs, making it easier to budget for such costs. It shall even become cheaper to realize LEED system's requirements as more practitioners learn how to achieve these goals within conventional building budgets.

Another important aspect although it is generally not presented; is the assessment of risk. Sustainable property risk can also be significantly mitigated through an assessment of process and feature performance. (Green Building Finance Consortium, 2010); either by decreasing the probability of risk occurring (process)- through assuring an integrated design process and applying verification methods, or decreasing its impact- if that risk does occur, e.g. using specialized contracts e.g. ESCOs, green leases and green procurement, surety market ,service provider, due diligence,.and other mechanisms (Kane, 2010 p.80). Hence, risk should be assessed at early design process; for each individual feature, and for the whole building performance (Green Building Finance Consortium, 2010), (Yates, 2001), (Azhar et al, 2010).

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[1] More information about green/ LEED market performance can be found in (Howard,2005), (OECD/IEA, 2010), (The New Zealand Green Building Council, 2006), (Yudelson, 2006 p.5,6,34), (Persram, et al, 2007), (BCA, 2008), (Matthiessen et al, 2004), (Northbridge Environmental Management Consultants, 2003), (Yudelson, 2006).

[2] Each building owner pursues different measures of value, that is reflected in the OPR, to guarantee common understanding with design team for important issues; range of acceptable risk and uncertainty, as well as "payback" time for sustainable building features

[3] (Kats, 2003) analysed the incremental capital costs of 33 LEED certified projects, estimated the average green cost premium as a percentage of total construction cost to be 0.66 % for certified level, 2.11% for silver, 1.82% for gold and 6.50% for platinum, with an average of 1.84 % (Yudelson, 2006 p. 39, 40). Other reports have identified no significant difference in construction costs between green buildings and non-green buildings (Matthiessen and Morris, 2007).. According to (Northbridge Environmental Management Consultants, 2003), obtaining LEED certification adds from four to eleven percent to a project's construction costs, with more than half of these costs are for "greening:" investments in alternative systems, practices, and materials that earn points under the LEED system and go beyond standard practices. , while Davis Langdon (2007) and Miller (2010) posit that the marginal increase in construction and development costs are essentially zero for well-planned LEED certified projects, , Jackson (2009) finds nearly three quarters of developers believe green development adds more than 5 percent to construction costs, with more than 40 percent believing cost premiums exceed 10 percent (Harrison, et al, 2011). While some studies have found construction cost premiums to reach 6.5% for the highest level of LEED certification (Kats, 2003)

[4] More discussion about green building market and the business case of green building is found in (Yudelson, 2006 p. 2), (Understanding LEED Version 3, 2009)

*The first category of risk concerns '*Development risk' – which is driven by property cost uncertainty, property performance uncertainty and legal and contractual risks. Pioneering design and construction, the availability of experienced contractors and subcontractors, pioneering products and systems, building code and regulation complexities and limitations, and other issues drive property cost uncertainty. Property performance uncertainty arises due to energy cost volatility, unreliable energy modeling, and underperformance of products, materials, systems or contractors. (Matthiessen et al,2004), (Green Building Finance Consortium, 2010).

New projects are subject to very different risks related to the construction process, construction completion, cost control, risks related to regulation and code compliance problems , which varies significantly by context, and achieving the market acceptance (Green Building Finance Consortium, 2010), (Matthiessen et al,2004). While on the other hand, existing property involves more detailed assessment of the existing asset performance (Green Building Finance Consortium, 2010).

The second category of risk; is related to people, product and process. Design team members have less and/or expensive expertise. Risk is also perceived when using innovative green technologies and systems which might carry higher cost, or neglecting some green innovations that do not fall under LEED requirements-e.g. heat pump, or the monopoly for some certain materials and/or products, e.g. FSC certified wood. Additionally, some innovative systems might be incompatible e.g. Building Automation System. On the other hand, Process risk is when project managing LEED projects is dominated by the LEED Brain, adopting short term approach to sustainable design with a narrow marketplace appeal (Yates, 2001) - not regarding long term operational savings, and/or increased change orders (Green Building Finance Consortium, 2010).

To sum up, the 'breaking down- building up' process for scope (4) can be represented in the following diagram. The figure shows the gaps and limitations in the existing LEED version to cover the fourth defined scope, and the research proposal for development.

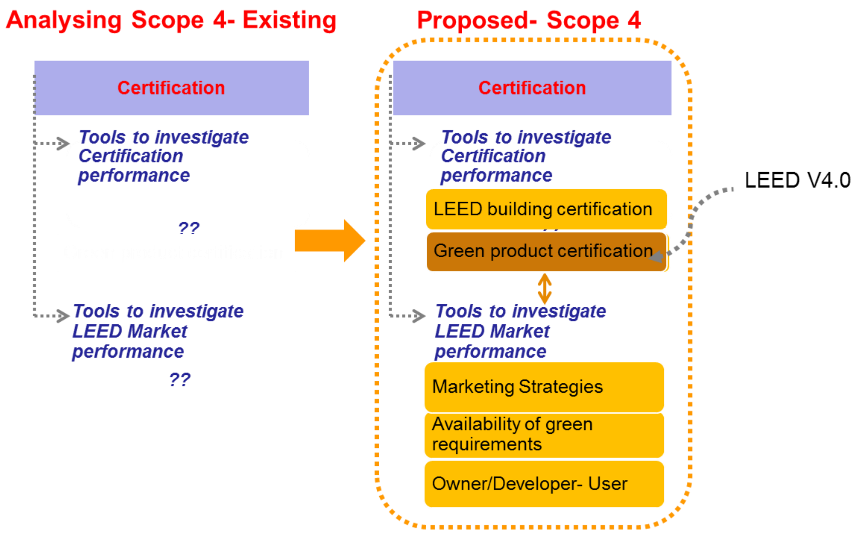

Figure 47: Breaking down- Building up process for scope (4)

Applying scope 4 for certifying energy and resource efficiency

Energy/carbon reduction is a critical driver of sustainable property value. Energy prices impact the underwriting of sustainable properties in several important ways – in estimating energy cost savings, in projecting cash flows and determining value, and in assessing risk. Property owners and managers are interested mostly in reduced energy consumption, because energy efficiency gains are relatively easy to identify and address, and the measures required tend to pay for themselves very quickly[1] - noting that the risk associated with rising and/or volatile energy prices will be mitigated by reductions in energy consumption at the subject property (Green Building Finance Consortium, 2010), (Kane, 2010 p.87), but, the perception of reduced (increased) risk can cause cap rates and discount rates to be lower (higher) (Green Building Finance Consortium, 2010). For example; Onsite renewable energy, and Green power agreements are considered expensive credit, and this requires careful economic analysis for their benefits (payback) compared to their capital cost, also underperformance of expected energy savings would have a negative impact on net operating income (NOI), reducing expected building value and the owner/ investor's rate of return (ROI) (Green Building Finance Consortium, 2010). Hence, the liability risk relative to performance claims and marketing need to be carefully evaluated (Green Building Finance Consortium, 2010).

As for MR category, it should be noted that the durability, flexibility and adaptability of building and building products to meet the changing needs of regulators, space users,

[1] Goering (2009) estimates energy savings from typical *Green Building* projects in the range of 20-35 percent. Similarly, Choi (2009) suggests LEED certified operations reduce building operating costs by nearly 10 percent, with energy costs accounting for roughly 30 percent of total building operating costs and LEED certified operations lowering these expenses roughly 30 percent. Watson (2009) also reports LEED certified buildings use approximately 25 percent less energy than comparable buildings (McManus, 2010), The cost savings alone from a 30% reduction in energy costs can result in 2+% increases in value (Kane, 2010), while some critics have also argued that LEED buildings may not, in fact, generate reductions in energy use (Cater, 2010).

and investors may prove cost efficient as well [1]. - some important market considerations for MR credits can be summarized as follows;

- ☐ MR Pre1: Storage and collection of recyclables, requires prior investigation to local construction haulers and recyclers.
- ☐ MR C1: Building Reuse, raises the value of existing building stock, this shall result in market transformation.
- ☐ MR C2: Calculations are based on weight/ volume, this type of calculations matches with the nature of the recycling business, which considers quantities of materials.
- ☐ MR C3-7: It depends on the availability and price of these materials in the local context- provided they are well documented. These credits promote the demand for reused, recycled, regional, rapidly renewable and certified materials, and raise their value in the sustainable marketplace.

Notes on applying Scope (4) for EA and MR credits

The market scope has been discussed in several studies but there is no guidance on how to properly account for this scope during applying the LEED system for project management process. The discussion reveals that it has significant implicit effect on the whole building process and more significantly on obtaining several LEED credits. These relations were highlighted as part of the suggested research framework for applying the LEED system pointing out the mutual interrelations between the market scope and the verification scope, as well as with other scopes in the rating mechanism which represent implicit interrelationships that practitioners investigate.

For example; Applying the first scope for optimizing energy efficiency is directly related to the fourth scope; discussing the certification and market role played by LEED system, and investment interest. Hence related decisions regarding building energy efficient performance are taken in early phases, and usually the owner (representative) is directly interfering to require certain certification level, which is translated correspondently into a certain range of energy cost savings - and the owner may require to include this requirement formally in the contract. This might even occur before sufficiently studying the project situation, which may endanger design or construction office to financial risk[2].

The previously discussed points of concern related to each scope are summarized in the following table.

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[1] The true cost of waste to a business has been estimated to be between 5 and 20 times its disposal cost This is because the true cost includes the cost of raw materials, auxiliary materials, labour, energy opportunity, cost of not selling wasted product, as well as the cost of disposal (Kane, 2010 p. 81)
[2] This point was highlighted in some interviews that were discussed in chapter three.

	Rating mechanism		Verification and certification mechanism	
	Scope 1: Guideline and decision making support tool	**Scope 2: Measurement and benchmarking tool**	**Scope 3: Verification tool**	**Scope 4: Certification and market tool**
Limitations	Operational guidelines are not clearly defined- hence practitioners use the measurement scope for guidance.	Measurement metrics mix environmental and economic performance, hence this does not reflect the true image of the building environmental impact and does not provide a solid mean for transparency and comparability	Some verification methods are included in the LEED system e.g. Cx and M&V processes, others should be proposed, along with providing an integrated framework exploring synergies between different methods.	LEED system's Certification role is not clearly defined, although it implicitly affects the decision making process starting from the decision to apply LEED and choosing the proper LEED rating type.
Gaps	Organization guidelines are very poor and not rewarded	Criticism about the reliability of the measurement metrics, especially for energy and materials credits.	Underestimating the value of this scope and its effect on other scopes is lacking.	LEED system's market role is not defined, although it implicitly affects the decision making process regarding market potentials and drawbacks- and this is closely related to the adaptability of the system to other contexts.
Economic considerations	Since this scope is almost not rewarded in LEED scorecard, then less time and money is dedicated for it- while in fact the building performance and weighting gained actually depend on decisions made under this scope	This scope is perceived to require more time, money and additional expertise (especially for EA simulation)- nevertheless, its adoption rate is high (reaching 90%) especially for those credits with greater score weighting.	This scope is perceived to require more time, money and more expertise (Cx, M&V)- meanwhile it has less weighting, this is why it is around 50-60% adopted (except fundamental Cx which is a prerequisite). This is why it needs to be carefully applied according to its specific goals, and within planned time and budgetary resources.	This scope requires more consideration for the owners - occupant relation, market potentials and risk assessment, in order to make the business case for LEED certified buildings.
Applicability	Applicability of other building types requires more development for this scope	It exists in the different weights & benchmarks assigned for some credits differentiating between new construction and major renovation projects (LEED V3.0), and in LEED V4.0 another variation considered core and shell projects.	Some verification methods should investigate specific performance requirements of building types - but report findings in a standardized form (e.g. Commissioning).	It exists primarily in choosing the appropriate LEED rating type, in addition to assessing risk factors associated with each type of building.
Adaptability	Adaptability to other contexts is subject to continuous development according to regional variations.	It is considered in LEED V3.0 through the Regional priority credits, and in regional versions having some different measurement benchmarks or reference standards, and more specifically for using regional climatic data for energy simulation analysis.	Some verification methods should investigate the requirements of specific contexts- but report findings according to standardized framework (e.g. using national LCI database for LCA)	It requires more development under this scope to integrate local, regional sustainable building certification systems, and to explore national markets' potentials and drawbacks.

Table 9: Summarizing the critical aspects for each scope discussed

4.3. BUILDING UP THE RESEARCH FRAMEWORK

This section sums up the whole picture and draws up the proposed research framework as shown in the following diagram.

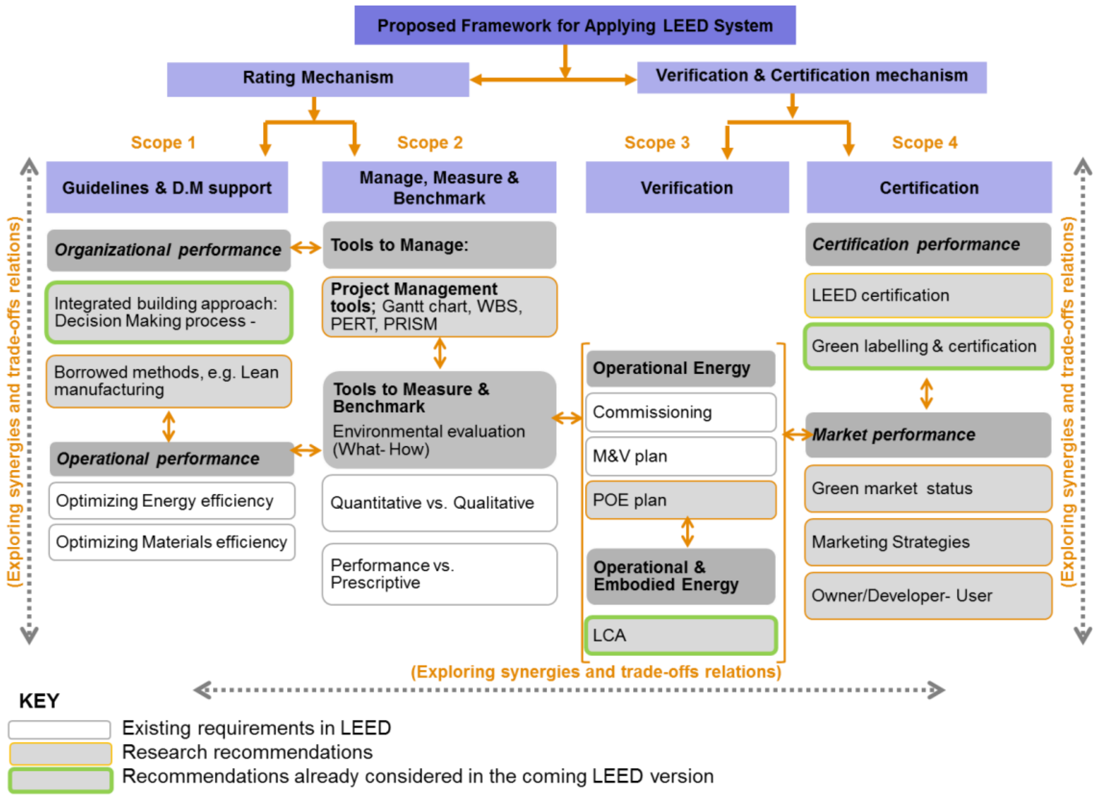


Figure 48: Defining and developing the scopes and limits of operation of the LEED system

Hence, the research presents the suggested framework for applying the LEED system based on integrated, whole system thinking to consider interrelations between mechanisms and scopes, and a profound understanding to the contribution of each credit's intent; yet, better expanded and developed to best employ it in the building system- pointing out potentials and challenges. Some of these requirements are already in the current LEED version, e.g. Commissioning and M&V, others are research recommendations, e.g. POE

Scopes may directly lead to gaining credits- while others exceed LEED system requirements in order to improve the sustainable management process. Yet, the key to achieving higher levels of process integration is to explore synergies and trade-offs between different scopes and sub scopes- this is challenging for team members but opens wider horizons of sustainability.

4.4. COMPARING ENERGY AND MATERIALS CREDITS

Applying the previously explained mechanism and scopes on both energy and materials credits reveals much interesting results. Although both categories are considered quantitative sustainable criteria, yet comparing LEED's sustainable policy for both of them reveals interesting variation as shown in tables (10) and (11).

The tables were constructed so that each credit is identified in the form of (1) or (0) indicating its contribution to one or more of the previously defined scopes. This analysis is performed in order to draw attention to the multiple roles played by some credits, and how they may be properly realized and used by practitioners. At the end, this may give an idea about the direction of development of the LEED system (through comparing the total weight assumed for each scope to the total LEED category), and accordingly the way the system maybe applied for project management process in terms of the number of credits, and possible credits' weighting.

Finally, this section includes a collective table summarizing what has been previously discussed, where both EA and MR categories are analysed according to the previously explained scopes- highlighting recommended synergies and trade-offs relationships between the two credit categories.

Table 10: Comparative analysis for EA category in LEED V3.0 and LEED V4.0 (1)

Framework Analysis

	Energy and Atmosphere V3.0	35 Points	Guidelines	Measurement	Verification	Market
Pr 1	Fundamental Commissioning of Building Energy Systems	Required			1	
Pr 2	Minimum Energy Performance	Required		1		1
C1	Optimize Energy Performance	1 to 19		1		1
C2	On-Site Renewable Energy	1 to 7	1	1		1
C3	Enhanced Commissioning	2			1	
C 5	Measurement and Verification	3			1	
C 6	Green Power	2	1			1
			2	3	3	4

	Energy and Atmosphere V4.0	33 Points	Guidelines	Measurement	Verification	Market
Pr 1	Fundamental Commissioning and Verification	Required			1	
Pr 2	Minimum Energy Performance	Required		1		1
Pr 3	Building-Level Energy Metering	Required			1	
C1	Enhanced Commissioning	6			1	
C2	Optimize Energy Performance	18		1		1
C3	Advanced Energy Metering	1			1	
C4	Demand Response	2	1			1
C5	Renewable Energy Production	3	1	1		1
C7	Green Power and Carbon Offsets	2	1			1
			3	3	4	5

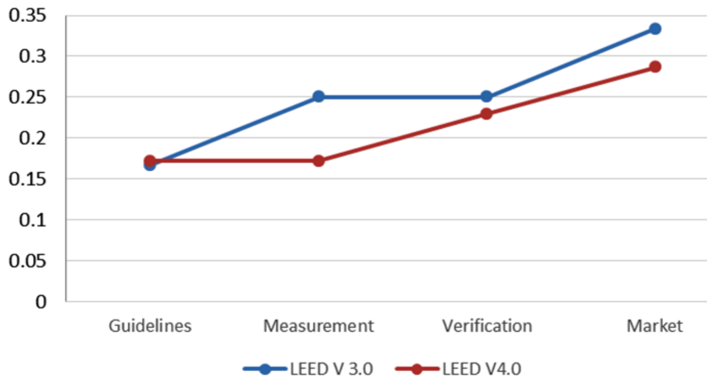
The table shows that for LEED V3.0, the majority of LEED EA credits do not provide direct guidelines for project team members, while few energy credits do- related to the use of onsite renewable energy and using green power. It is the same for LEED V4.0, with adding demand response control programs as well. Other credits provide a mean of measuring and benchmarking energy efficiency - yet LEED V4.0 recognizes different cases of building development; new construction/ major renovation/ core and shell projects- as well as dedicating additional points for special project types, i.e. health care and schools. As for the verification scope; both LEED V3.0 and LEED V4.0 require conducting a commissioning process (as a prerequisite and credit), also for LEED V3.0 a more comprehensive credit requires conducting a Measurement and Verification plan –while for LEED V4.0- this requirement is transferred into a simpler requirement of installing energy metering (which is considered one component of a M&V plan- but this level of complexity is compensated by mandating this requirement as a prerequisite and an additional level as a single credit. Finally, for the market scope; an addition in LEED V4.0 is recognized for accounting for carbon offsets and demand response control plans.

Table 11: Comparative analysis for MR category in LEED V3.0 and LEED V4.0 (2) Framework Analysis

Materials and Resources V3.0		Points 14	Guidelines	Measurement	Verification	Market
Pr 1	Storage and Collection of Recyclables	Required	1			
C1.1	Building Reuse—Maintain Existing Walls, Floors, and Roof	1 to 3	1	1		1
C1.2	Building Reuse—Maintain 50% of Interior Non-Structural Elements	1	1	1		1
C2	Construction Waste Management	1 to 2	1	1		1
C3	Materials Reuse	1 to 2	1	1		1
C4	Recycled Content	1 to 2	1	1		1
C5	Regional Materials	1 to 2	1	1		1
C6	Rapidly Renewable Materials	1	1	1		1
C7	Certified Wood	1	1	1		1
			9	8	0	8

Materials and Resources V4.0		Points 13	Guidelines	Measurement	Verification	Market
Pr 1	Storage and Collection of Recyclables	Required	1			
Pr 2	Construction and Demolition Waste Management Planning	Required	1	1		1
C1	Building Life-Cycle Impact Reduction	5			1	1
C2	Building Product Disclosure and Optimization - Environmental Product Declarations	2				1
C3	Building Product Disclosure and Optimization - Sourcing of Raw Materials	2				1
C4	Building Product Disclosure and Optimization - Material Ingredients	2				1
C5	Construction and Demolition Waste Management	2	1	1		1
			3	2	1	6

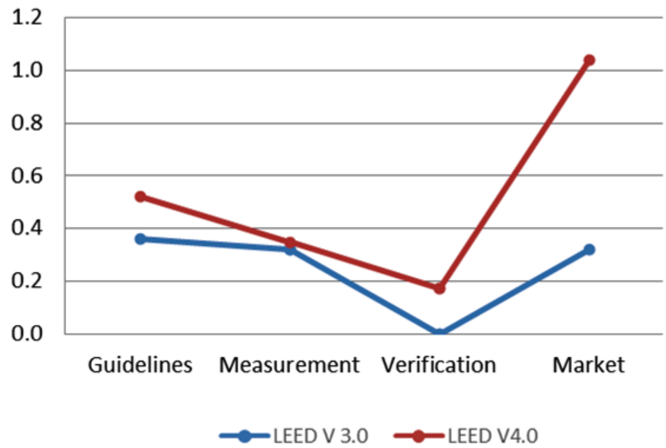
LEED V3.0 and the expected development of LEED V4.0 adopt different approaches for achieving sustainable building material and resource criteria. The table shows that LEED V3.0 provides more direct prescriptive guidelines; whether a) in the form of a single mandated design guidelines, which requires dedicating a special area in the project for storage and collection of recyclables, or b) recommended sustainable building practices for example building reuse and construction waste management plan- or c) in the form of recommended sustainable building materials; for example; reused, recycled, regional, rapidly renewable and certified wood products. LEED measurement criteria for MR credits directly support these guidelines, because it depends on how project team members were able to satisfy these guidelines. This method does not provide flexible framework for team members to act, and does not properly explore potentials and synergies between different sustainable criteria; also there is a significant lack of verification methods that indicates the environmental impact from complying with this credit category. This is why in LEED V4.0 the development is anticipated to put less weight on direct prescriptive guidelines in favour of better means of verifying environmental performance. It is also clear that for both versions, credits' requirements are more linked with building material market potentials, but according to different credit requirements; whether for availability and price for LEED V3.0, or for disclosure for LEED V4.0. Also LEED V4.0 introduces a mandated requirement or conducting a construction waste management plan, and performing a whole building LCA.



EA	Guidelines	Measurement	Verification	Market
LEED V 3.0	0.17	0.25	0.25	0.33
LEED V4.0	0.17	0.17	0.23	0.29

Figure 49: Analysing the relative weighting of each scope for the development of EA credits from LEED V3.0 to V4.0

Drawing the curve of the LEED system for energy credits shown in figure (49), gives us an idea on the direction of development of EA category in LEED V4.0 according to the four scopes previously defined. It indicates that less percentage weighting (with respect to the overall possible points for the EA category) shall be dedicated for measurement and market scope, but it shall remain almost the same for guidelines and verification scopes. This shows that for EA category; slightly more weighting is assigned for the certification rather than the rating mechanism and this may somehow be challenging to compare buildings of equal EA category weighting because it includes contextual effects arising from the market scope influence , yet more tendency is noted to balance credits' weighting among all four scopes- which according to the research may be the optimum approach for the development of the EA category.



MR	Guidelines	Measurement	Verification	Market
V 3.0	0.4	0.3	0.0	0.3
V4.0	0.5	0.3	0.2	1.0

Figure 50: Analysing the relative weighting of each scope for the development of MR credits from LEED V3.0 to V4.0

On the other hand, drawing the curve of the LEED system for materials' credits shown in figure (50) gives us an idea on the direction of development of MR category according to the four scopes previously defined. It indicates that for MR category in the current LEED version; the rating mechanism has relatively more weighting than the verification and certification mechanism- pointing out that in the current LEED version; the research was not able to identify any verification tools. Yet, the future development of LEED V4.0 putts more weighting percentage (with respect to the overall possible points for the MR category) for all scopes particularly the market scope because it is has made significant changes for introducing environmentally certified materials and products. Yet, this indicates that it shall significantly depend on the availability and disclosure of building materials' environmental data. Also, it is notable that the verification scope is starting to be more pronounced, which is considered a good development start but needs to be further developed. The graph does not show balanced weighting between the four scopes, but this issue may be resolved with future LEED versions.

Some issues needs to be highlighted from the previous analysis. First, noting that the graphs indicate how the market scope is expressed in many credits although it is not explicitly highlighted in LEED credit scorecard, accordingly it is important to explore its potentials and risks to assure that the process is performed efficiently. Secondly, it is important to note that the direction of development does not identify the interrelation between energy and materials efficiency. The LEED system treats them as two separate items with few exceptions of the materials that are required as inputs for energy simulation and may also serve for the LEED MR category, for example; some building insulation materials. It is also expected that LEED V4.0 shall recognize building renovation- which constitutes the decision of building reuse- for the base model, but it does not yet identify any guidance on how to achieve synergies and trade-offs between MR and EA categories.

	Scope 1: Guideline and decision making support tool	Scope 2: Measuring & benchmarking tool	Scope 3: Verification tool	Scope 4: Market tool
Analysing current LEED version of Energy credits	**(Mainly) Performance guidelines** Optimize building energy use through energy efficiency (EA Pre2, and EA C1), and using renewable energy sources, whether onsite (EA C2: Onsite renewable energy sources), or offsite (through Green power purchase agreements).	**Quantitatively** Computer simulation software programs Comparison against a baseline model using the performance rating method— Appendix G of ASHRAE 90.1-2007 standard (for LEED V3.0, and ASHRAE 90.1-2010 for LEED V4.0) Calculation based on building energy cost savings analyses	**Operational energy** Commissioning M&V POE (operational performance)	**Certification** Energy savings affect certification level. Green Power certification programs **Market** Availability and price of energy efficiency systems. Making the Business case: Energy/carbon savings, and incentives.
Analysing current LEED version of Materials & Resources credits	**Prescriptive guidelines** MR Pr1: area for recycling MR C 1: Building reuse approach for existing and interior structure MR C 2: Construction & Demolition waste management plan. Materials selection: MR C3- MR C7: reuse, recycled content, regional materials, rapidly renewable materials and certified wood products.	**Quantitatively** Calculation MR C1: percentage by area MR C2: percentage by weight or volume Materials selection: MR C3- MR C7: based on cost of total material cost excluding labour and equipment.	**Embodied energy** LCA	**Certification** In LEED V4.0, dependence on 2nd and 3rd party certified building materials and products, e.g. FSC certified wood products **Market** Building Reuse Construction waste management Availability and price of materials
Risk	Risk of misinterpretation LEED guidelines and following a point chasing mentality.	Risk of not obtaining correct measurement and giving fault information about sustainable building performance which shall strongly affect LEED's market performance.	Certain degree of risk assigned with applying each verification method.	Risk of dominance of certification prestige, and market performance, or risk of market failure.
Recommender Synergies & trade-offs between EA & MR	Synergistic guidelines exist between: EA pre 2, and C1- MR C1 for building energy use, and MR C3-7 where the effect of some materials can affect operational energy, e.g. insulation materials.	Synergies require to be further developed for measuring EA and MR credits- accounting for: *Operational building energy use:* MR C1: Building reuse, and *Operational energy from transportation and recycling:* MR C2: CWM plan and MR P1: Storage & Collection of Recyclables. Embodied energy: MR C2: CWM, and MR C3-7: Reused, Recycled, Regional, Rapidly Renewable and Certified Wood materials- but they may also affect operational energy.	Using outputs from energy simulation (operational energy) as input for LCA to account for both operational and embodied energy- hence justify measurement metrics for both EA and MR credits.	It reduced uncertainty and risk, hence savings in one category may justify investments in the other- but both have to take into account long term savings, and hence, it may justify operational as well as first capital cost to attract more investments in green building construction.

Table 12: Summarizing the application of the suggested four scopes of applying LEED system on EA and MR credits

4.5. SUMMARY

This chapter presents an integrated framework for applying LEED system based on the analysis presented in the previous chapter. The research recommends drawing a framework for applying LEED system based on differentiating between its rating and its verification and certification mechanism, and acting on four defined scopes- noting that each scope should establish mutual interrelations with others to reflect true synergy and trade-offs relationships.

Its *'Rating Mechanism'* provides a mean for guiding, measuring and eventually rating sustainable building performance. It depends on the system's targets, structure, as well as its assessment process. It includes two interrelated scope;

First scope defines LEED system's role as a *Guideline and Decision Making Support tool* where the LEED system provides guidelines for both organizational and operational aspects. This scope is lacking in LEED system, so the research suggests some recommendations for improvements- but it is still open for more future research.

Second scope defines LEED system's role as a *Measurement and Benchmarking tool* where the LEED system provides measurement and benchmarking metrics to measure/ evaluate design options and their resulting building performance. It should operate in an iterative manner to support the first scope. This scope is considered the main pillar for measuring and comparing sustainable building performance, this is why it should rely on standard metrics. It employs different tools and methods; comprising calculations and simulations- to be able to consider the different nature of measurement metrics; actual or predicted, quantitative or qualitative- prescriptive or performance. This scope is continuously developing with more developed LEED versions, and the research just pointed out some critical aspects while applying this scope for both EA and MR credits.

On the other hand, its *'Verification and certification mechanism'* provides a mean for quality assurance and quality control for measured performance, and creates the value of LEED certified projects in the global marketplace. It includes other two interrelated scope;

Third scope defines LEED system's role as a *Verification tool* to verify sustainable building performance in order to support the previous scope covering both operational and embodied energy. It requires additional level of practices performed in an iterative manner to support the decision making process, but it is considered an important cornerstone to insure more transparency and comparability in the global market place. This aspect derives the quality that explores the value and this shall eventually reflect on the market performance (scope 4). Verification methods require providing monitoring, auditing and feedback procedures. They follow universal application belonging to standardized framework, yet tools, software and data inputs are tailored according to project goals, scope, scale, complexity, and budget. They provide reliable results in the form of quantified numeric measurements to facilitate absolute and relative performance evaluation. LEED NC V3.0 already includes some verification methods; for operational energy, e.g. commissioning and M&V process. Moreover, the research recommends including POE to strengthen the link between design and operation and assure a mean to develop feedback channels from practitioners' experience, and includes LCA (in future plan for LEED V4.0 to quantify building/ building product environmental impact). All verification methods should be integrated together, and whenever possible, they should be considered in early project phases, and along different project phases. They could be employed in a consecutive, or complementary, or an encompassing manner to support important decisions making processes.

Fourth scope defines LEED system's role as a *Market tool*- where it investigates the value and explores the bond between certification and market performance. The system possesses abundant power in the global marketplace, and this requires investigating how it influences important decisions along the whole building process-starting from the decision to select a LEED rating system to match with the building type and nature, ownership and occupancy, leasing type and existing incentives' mechanisms. It should cover both tangible and intangible benefits of sustainable criteria to make the business case for LEED certified buildings; discussing the cost premium of applying the LEED process, and the payback time for sustainable strategies recommended by LEED system, in order to promote investment opportunities and mitigate uncertainty and risk, to enable a better decision making process through assessing market response to sustainable criteria and building performance. This scope discusses its certification mechanism which investigates the value of the project, while its market performance investigates the markets' potentials, readiness and acceptance for LEED certification, which shall reflect on the project's feasibility and cost, along with means to control the revenue and risk expectation of the project.

This includes decisions to adopt energy and resources strategies, reduce carbon footprint, procure certified sustainable materials/products, and to establish links with other sustainable labelling and certification programs. Employing market strategies is an important consideration for LEED projects as well, this includes conveying signalling messages, branding, standardization and differentiation in order to gain a competitive market advantage, grant value and control the price of the LEED certification. These strategies vary according to the building type, ownership, as well as occupancy/users it addresses.

It can be concluded that both second and third scopes are more likely to be considered standard application and are subject for improvements according to the latest research findings, while, the first and fourth scopes are more subject to spatial/ regional variations, hence it could indicate means of improving the adaptability of the LEED system to foreign contexts. Hence, working on these two perspectives can solve some of the criticism against LEED system.

Risk assessment and risk management can be applied to each scope; for the first scope, there is risk of misinterpretation LEED guidelines and following a point chasing mentality, for the second, there exist risk of not obtaining correct measurement and giving fault or incomplete information about sustainable building performance which shall strongly affect LEED's market performance, for the third scope, there exist certain degree of risk assigned with applying each verification method, for the last scope, risk of dominance of certification prestige, and market performance, or risk of market and investment performance failure.

CH FIVE

5 MANAGING LEED PROJECTS: ENERGY & MATERIALS CREDITS

This chapter starts with reviewing the latest research findings about decision making process for five main critical points during the sustainable building process, and investigates the contribution of the suggested research framework for each of them, the second part aims at guiding practitioners on how to best use the LEED system, through applying the proposed research framework explained in the previous chapter along all stages of the building process- focusing with discussion on Energy and Materials credits.

5.1. INTRODUCTION: PROJECT MANAGEMENT UNDER LEED CERTIFICATION

LEED NC is mainly targeted for developers, owners and design team members (Howard,2005), yet it does not award credits towards sustainable management process[1] although they are very important to the overall 'sustainable impact' of the building, but they tend to be more difficult to integrate into a rating tool. Also, there is little guidance on how to apply the system along the building process, which leads that important decisions are not taken at its exact time, for example; many LEED MR credits are submitted in the 'construction submittal' phase- while actually the decision to use, specify and procure green materials according to LEED requirements should be taken in design phases. This has been an area of concern and focus for some studies to discuss methods and recommendations to integrate LEED system in sustainable building process.

Few studies have attempted to fill in this gap, providing insights on integrating LEED *'credits' requirements'* into the ordinary building process, yet this provides narrow means of outdo LEED requirements, because the general framework is lacking. While on the other hand, the research adopted a different approach. It started first (in the previous chapter) by defining the system's scopes and limits of operation- exploring how they can act together in an integrated manner, and providing recommendations- as a form of 'Know How'- on how to best use the system as a mean, not at as end in itself, so as to open up chances for surpassing LEED requirements. The next step is to apply this

[1] Sustainable management procedures found in (The New Zealand Green Building Council, 2006). The Sustainable Performance Institute (SPI) certification program is designed to improve design and construction organizations' ability to manage and deliver sustainable projects by monitoring and certifying their consistent use of processes that consistently result in sustainable building design and construction (Green Building Finance Consortium, 2010).

framework along different phases of the building process to illustrate how these scopes and sub-scopes may integrate together to form a systemic approach to LEED application.

Quoting from (Mendler et al, The Guidebook to Sustainable design, 2nd edition p. 28);
'LEED should be viewed as a floor not a ceiling'

This section attempts to discuss these drawbacks through developing a systemic project management framework for applying LEED system for energy and materials credits discussed in the previous chapter, and incorporated into the traditional building process from a whole life cycle perspective. This discusses the decision making process under LEED system, and the effect of each of the four scopes (discussed in chapter four), when scheduled according to the required time, resources and expertise, and keeping in mind that the best way to use this approach is to follow an iterative overlapping manner as shown in the following figure.

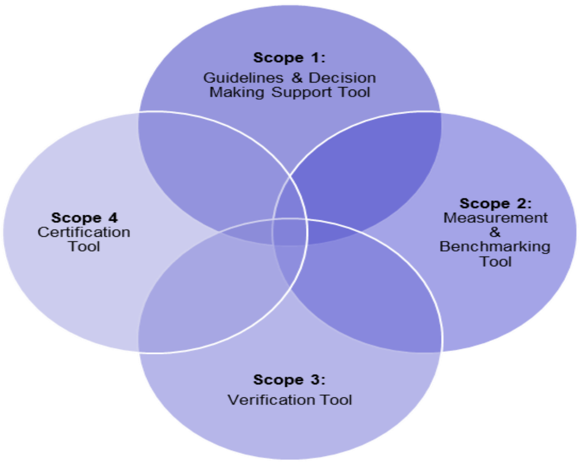


Figure 51: The suggested scopes of operation of the LEED system

5.2. Decisoin Making Process

The shift to adopt sustainable building processes and practices into typical design and construction processes requires a redefinition of the existing roles of project participants. Moreover, a better developed decision making process should be based on early involvement and full awareness of project's goals and methods to achieve it, considering a long environmental aspect along all phases of the building process. It is a challenge that is continuously developing and requires additional effort from team members to make best use of available potentials and compensate for gaps and limitations- considering the true sense of sustainability through a better developed project management framework- considering; time, quality and budget.

Additionally, new types of skills and expertise among team member is required to satisfy the developing requirements of sustainable building process ; designing, measuring and benchmarking as well as verifying sustainable building performance to enable considering the value, revenue and risk in order to achieve higher level of process and system integration with more coordination and collaboration of interdisciplinary framework - or else, it may be outsourced to specialized parties, yet this shall result in higher cost, besides the cost of the software itself. This shall be added to the soft cost of sustainable design, which varies according to some factors, for example; project type, scale and complexity, and it should be noted that the availability of skills and services in the local context plays a significant role for determining their prices as well- this concern shall be highlighted again in chapter six.

5.2.1. Roles and responsibilities

Greater commitment and added responsibility are required from the design and construction team (Riley et al. 2003, Mogge 2004, Samaras 2004) in an integrated approach that differs from the traditional hierarchical one as shown in figure (52) . For example, the role of the LEED AP may be better described as a sustainable project manager, moreover, he/she can also act as an 'on board' environmental consultant. The architect may need to write *green* specifications, the mechanical engineer may need to create an energy model for the building (Yellamraju, 2011 p.20), while, the constructor can provide input on aspects such as material selection, system performance, decreasing construction waste, and improving indoor air quality, as well as, streamlining construction methods, value engineering methods, and constructability reviews in order to achieve green project goals (Syal et al,2007). Employed professionals maybe called to give a qualified insight participation regarding critical technical issues early in the design phase, for example, commissioning authorities, lighting professional, energy and renewable energy expert, (Yellamraju, 2011 p.20). Also, concerns about the service provider[1] quality and capacity will vary significantly by property type, market, and the specific type of service. This shall probably influence cost and time schedules, but may also result in cost savings through exploring innovative design solutions and improved performance (Green Buildings BC, GVRD and NRCan). Additionally, it is interesting to note that small sized and budget projects, tend to require in their job description a LEED AP with MEP specialization, who is capable of performing energy simulation for LEED EA credits compliance.

[1] It refers to green services required by LEED system, e.g. commissioning, recycling, green transportation, green power…etc.

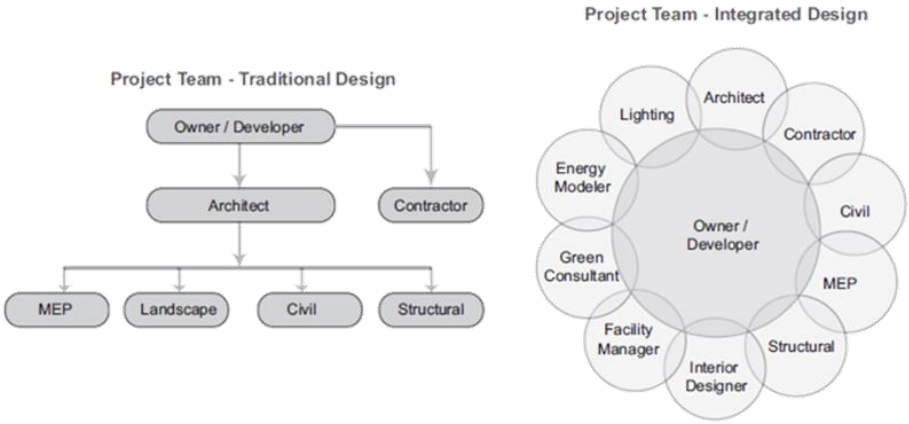


Figure 52: Project team relationship in both traditional and integrated design process[1]

LEED reference guide defines credits' responsibilities and decision making for each of the owner, design team and contractor[2]. Additionally, the level of involvement in the LEED process varies among team members- some team members may 'Lead', while others 'Support' the implementation of some credits as shown in the following tables (Yellamraju, 2011 p.20). Also, their roles might even fluctuate during different stages of the process. This requires more sustainable education and better integrated building process throughout all varies disciplines[3] (Lacroix,2010).

EA Credits	**Owner**	**Building manager**	**Architect**	**MEP Engineer**	**Civil**	**Landscape**	**Interior**	**General Contractor**	**CxA**	**LEED Consultant**
EA p1: Fundamental Commissioning of the Building Energy Systems	*			S				S	L	
EA p2: Minimum Energy Performance				L						S
EA c1: Optimize Energy Performance				L						S
EA C2: Onsite Renewable energy			S	L						S
EA c3: Enhanced Commissioning	*			S				S	L	S
EA c5: Measurement and Verification				L				S		S
EA C6: Green Power	S	S		S						L

Table 13: EA credit responsibility personnel [4]

[1] Source: (Yellamraju, 2011 p.40)
[2] LEED reference guide V2.2; p. 152 (for EA category), and p.240 (for MR category).
[3] It is different for BREEAM and HQE, because the assessor (who is chosen by the client in the case of BREEAM) – and assigned by the certification body (Certivéa) in case of HQE, is an external party and his role is restricted to assessment to determine their proper project rating.
[4] Source: Green Potential LLC (www.green-potential.com) found in (Yellamraju, 2011 p.85)

MR Credits	Owner	Building manager	Architect	MEP Engineer	Civil	Landscape	Interior	General Contractor	CxA	LEED Consultant
MR p1: Storage and Collection of Recyclables		S	L							S
MR c1.1: Building Reuse-Maintain Existing Walls, Floors and Roof.			L					S		S
MR c1.2: Building Reuse-Maintain Existing Interior Non-structural Elements			L					S		S
MR c2: Construction Waste Management								L		S
MR c3: Materials Reuse			S					L		S
MR c4: Recycled Content			S					L		S
MR c5: Regional Materials			S					L		S
MR c6: Rapidly Renewable Materials			S					L		S
MR c7: Certified Wood			S					L		S

Table 14: MR credit responsibility personnel[1]

Notes:

1- * Defines additional responsibility as indicated in LEED reference guide

2- Those spaces highlighted in green are the researcher's addition (opinion) to previous studies.

The tables show that for EA category; more responsibility is laid on the MEP engineer with the support of diverse disciplines, for example; the owner, the general contractor, the commissioning agent and the LEED consultant. This may indicate that the job description for the MEP engineer should be developed carefully to be able to support LEED system requirements for EA credits; including energy simulation which is mostly adopted to comply with EA Pre 2, EA C1, and EA C5.

On the other hand, for MR category; shared responsibility requires early open channels of communication between the architect who performs the material specification process, and the contractor who procures, installs and documents the specified green materials according to architects' selection, and with the support of the LEED consultant.

Yet, it is worth noting that the connection between EA and MR credit responsibility should be more defined through assigning special responsibility among team members for checking the effect of material credits on energy credits. This may be significantly pronounced for MR C1: Building reuse, because the decision to reuse building structure-whether externally and/or internally directly reflects on the building energy performance, and this requires additional consideration in early design stages. Another indirect effect may arise when accounting for the whole life cycle impact from some of the chosen green materials according to LEED requirements for MR C3-C7, and this requires a building life cycle analyst to support the decision making process.

[1] Source: Green Potential LLC (www.green-potential.com) found in (Yellamraju, 2011 p.85)

5.2.2. Tools and models

Different types of decisions require different types of tools, models, methods of analysis and types of data [1]. The more LEED system develops and adds more requirements, the more it is required to improve methods to support the decision making process. The current version of LEED system requires using energy computer simulation modelling as a compliance path for energy analysis as explained in the previous chapter, while the next version requires conducting a whole building LCA. Hence, it is important to understand the scopes of operation and benefits of these tools/models and how they may support the decision making process, streamline the LEED documentation process, increase credibility and improve construction schedule, as well as minimize change orders to eventually save both time and money.

5.2.2.1. Energy simulation models

Decisions related to energy, lighting and ventilation efficiency can be supported by computer simulation models, which provide efficient means to compare between design choices, and evaluate energy efficient design alternatives to support the decision making process based on performance criteria, as well as their economic impact considering not only their capital cost but their long term savings as well[2] (Mendler et al, The Guidebook to Sustainable design, 2nd edition p.98-122).

Tools' capabilities must suit their use, and this is a factor of cost, time and expertise; some are useful for early design decisions, which perform calculations based on preliminary estimations and less detailed data input, while others are more suitable for later stages, when more detailed data are obtained, and the estimations can be more accurate and reliable. They may also differ according to the building's size, type and complexity, and the main target of the simulation (energy analysis, HVAC sizing, or both), and if the project includes special design element (e.g. skylight), or advanced energy efficient strategies e.g. free cooling and heat recovery, thermal storage, or cogeneration[3] - this aspect shall be better discussed in chapter five. This is in addition to other important factors like if the software performs environmental assessment only or combined environmental and economic assessment, considering that some simulation tools provide

[1] "Green Building: Assessing the Risks", published by Marsh in 2009 (http://global.marsh.com/news/articles/greenbuildingsurvey/index.php) (Green Building Finance Consortium, 2010)
Other tools are recommended for other LEED categories, but are not included under this research.
[2] Operational cost savings for each option includes energy savings, as well as reduced demand charges 'Peak Shaving' strategies for design options that may have little impact on energy consumption overall but have a larger impact on demand charges (Mendler et al, 2 edition)
[3] To reward both the production of heat and electricity (OECD/IEA, 2009)

certification, while others do not (Mendler et al, The Guidebook to Sustainable design, 2nd edition p.80[1]).

LEED system encourages the use of 'Energy simulation' models in order to deal with the complexity of the calculations and the multiple variables involved describing energy usage of buildings. Yet, it should be noted that software simulation packages vary in their level of complexity and degree of expertise required to perform the analysis- some has a more user friendly interface while others are based on more sophisticated means. This determines its role and time of use, either in early phases- as a decision making support tool, for example to determine the optimal; cost beneficial R-value[2] of the roof, walls and slab insulation, as well as the appropriate quantity and type of insulation, or rather in later phases as a Measurement and verification tool. For LEED EA credits' compliance[3]- the fourth and the sixth model maybe used as shown in figure (53) while for the other uses project team members should refer to external studies.

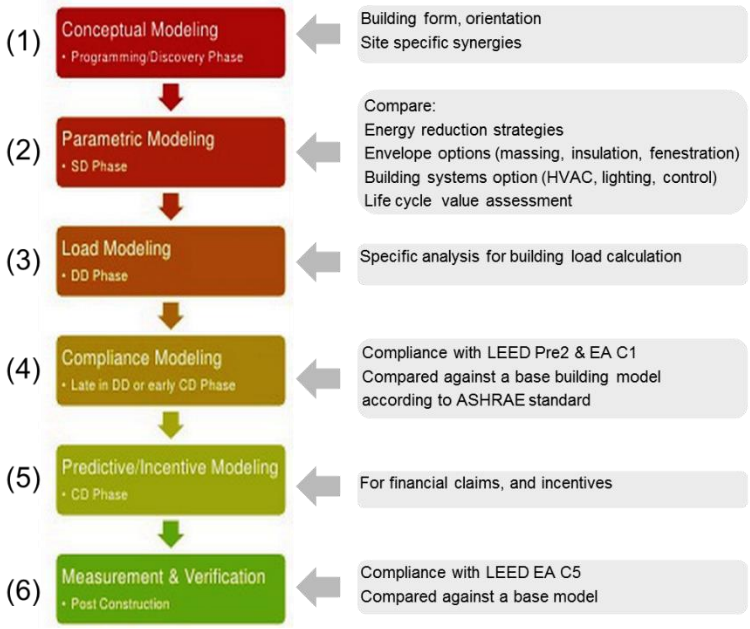


Figure 53: Energy modelling process [4]

Hence, the fourth type of energy models (according to the figure) is used to comply with EA pre2, and EA C1. Measurement and benchmarking for EA credits requires determining the following information:

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[1] ASEAM is a simplified energy analysis for existing buildings, and there is another type of energy simulation for both water and energy called Watergy- it is a spread sheet model that screens sites for potential water conservation opportunities and illustrates the energy savings that result from water conservation activities. Another special software for renewable energy is called FRESA. http://www.wbdg.org/design/energyanalysis.php.

[2]The R-value is a measure of thermal resistance used in the building and construction industry. Under uniform conditions it is the ratio of the temperature difference across an insulator and the heat flux (heat transfer per unit area per unit time)

[3] More about energy simulation can be found in (Green Buildings BC, GVRD and NRCan), and (Yellamraju, 2011 p.108-110).

[4] The author's elaboration from the following source: http://www.slideshare.net/rbarnwell/cmcfsusersrm-barnwellmy-documentsrmb-docsintegrative-design-working-with-your-mep-final

a. General Information: Simulation Program, Principal Heating Source, Energy Code Used, New Construction Percentage, Quantity of Stories, Weather File, Climate Zone and Existing Renovation Percentage

b. Space use summary (calculating conditioned and unconditioned spaces)

Then the method requires creating two types of building models; the first is the proposed building model and the second is the baseline building model, which needs to be set up with orientations of 0, 90,180 and 270 degrees respectively in order to normalise the self-shading effect-

c. Comparison of Proposed Design Versus Baseline Design Energy Model Inputs, and this includes; walls, floors, roof, slabs special design features, fenestration features, lighting power densities & controls, receptacle equipment & loads, HVAC system information, Domestic hot water system type, as well as General schedule information

d. Energy Type Summary; energy type, Utility Rate Description, Units of Energy, and Units of demand

e. On-Site Renewable Energy ; Renewable Source, Backup Energy Type, Annual Energy, Generated, Rated Capacity, as well as Renewable Energy Cost (dollar)

f. For determining the Baseline Performance using the Performance Rating Method these information should be gathered; End Use, process energy, Baseline Design Energy Type, Units of Annual Energy & Peak Demand (Energy use in Kwh, and Demand in kW), Baseline model performance rotated (0º ,90º ,180º and 270º rotation: defining the Baseline Design Energy Type, Units of Annual Energy & Peak Demand Baseline- to calculate the total Baseline energy use.

Thus, the average is calculated for energy (kWh), peak (Kw), and cost (monetary value/year). In order to compare baseline model versus proposed design, these conditions must be maintained: climate data, purchases energy rates, schedules of operation[1] (except for energy efficiency features), as well as the schedule of operation, occupancy, orientation, building envelope, lighting system, HVAC system, Service Hot Water Systems as well as Energy rates[2]. The energy rating is calculated based on the annual energy cost of running the proposed building against the average annual cost of running the baseline building by using actual rates for purchased energy or State average energy prices (LEED NC reference guide, 2009) and (Roderick et al, 2009).

The input data required for simulation is shown in table (15):

Inputs	Required data
Building site data	Weather data, orientation, adjacent structure shadows…etc
Utility rates	Electric/gas, peak/off-peak

[1] Schedules should be capable of modelling adaptations with fluctuations of occupancy regarding lighting power, miscellaneous equipment power, thermostat set points, as well as HVAC system operation.

[2] Source: http://www.slideshare.net/Aarongrt/energy-modeling-for-leed-using-equest

Building operation	Occupancy, thermostat set points, day lighting photo sensors
Building envelope (heat transfer surfaces)	Wall/ internal partitions (U Factor) Windows (U factor, SHGC, T_{vis}, Shading coefficient) Roof (U factor, reflectance) Floor (U factor)
HVAC (equipment and performance).	Ventilation type (mechanical) Heating & cooling (type, schedule, energy source)
Service Water Heating	Type, operation schedule
Other Equipment	Equipment power density/ receptacle loads
Activity Schedule	Schedule- hours, days (holidays)
Lighting	Control (auto), lighting energy (LPD) Operation schedule, luminaire type, radiant fraction Task/ display light (gain, operation schedule)
Economic parameter	Life cycle costing, interest rates

Table 15: Required inputs for some simulation tools[1]

The sixth type of energy models (according to the figure) is the one used to comply with EA C5: Measurement & Verification. It is considered one of the components of the M&V plan according to the IPMVP- which analyses the efficiency of the measures taken, verifies whether or not the expected equipment are installed (or whether they are still operating), verifies that it operates with scheduled hours and occupancy, set points and control schemes. The results should indicate whether the installed energy efficient systems (features) are realizing the predicted claimed savings, and analyse opportunities for more savings.

The key risk of energy models and their forecasts is that the actual building fails to live up to the performance indicated in the model. This forecasting error is interpreted as the percentage error between actual energy consumption and forecasted energy use based on building's actual design characteristics and use profile, eventually, this leads to increasing uncertainty and risk in forecasting savings (Green Building Finance Consortium, 2010). Many factors are cited to explain the variability in forecasts including the following points (Green Building Finance Consortium, 2010), (Lombard el al,2008), (Mendler et al, The Guidebook to Sustainable design, 2nd edition p.32, 33):

- ☐ The quality of the data inputs, and intrinsic error ranging from 10% to 20%
- ☐ Variations in weather conditions, occupancy pattern and users' type, or actual building schedule of operation, accounting for thermal mass, and or actual energy intensity or energy prices.
- ☐ Or maybe because Fundamental commissioning was not performed

[1] Source: http://www.slideshare.net/Aarongrt/energy-modeling-for-leed-using-equest

☐ Also, if exists a disconnection between the MEP engineer and the sustainable engineering consultant. This maybe especially true when HVAC delivery system was through design-build contractors.

There are other risks related to the type of development as shown in table (16). Yet, it is worth noting that many of the risks to obtain reliable and accurate forecasts above can be effectively mitigated with three important steps: using an experienced energy modeller, competent commissioning, and performing proper measurement and verification process (Green Building Finance Consortium, 2010 p.170).

Risk related to modelling energy performance for NC buildings	**Risk related to modelling existing building energy performance**
The design parameters, unusual design features or employing new Smart building elements which may fall outside the range that the model can adequately handle, or because sufficient time was not allowed for the building to “settle down” after being put in service and before measuring energy consumption[1].	Prior deferred maintenance in relation to upgrades leads to increased energy use.

Table 16: Risk related to new construction or existing building energy simulation analysis

5.2.2.2. LCA software

A LCA tool is an environmental modeling software that develops and presents life cycle inventory (LCI) and perhaps life cycle impact assessment (LCIA) results through a rigorous analytical process that adheres closely to relevant ISO standards and other accepted LCA guidelines. The most basic LCA tool takes inputs in the form of material take-offs (in area or volume) and converts it into mass. Then it attaches this mass value to the LCI data available from LCI database and other sources. This step results in quantities of inputs and outputs of a product system, which may include the use of resources and releases to air, water, and land associated with the system[2].

The simplest software tools are spreadsheets, in which material quantities can be entered. More complex tools act more like cost-estimating software, so that automated tabulation of material quantities from assemblies can be completed on a square-foot basis. Choosing an appropriate tool to help conduct LCA is an important step, and different approaches demand different requirements in terms of data collection and quality assurance, resulting in varying levels of robustness (Publications Office of the European Union, 2010), (AIA, 2010).

[1] It takes about one year for a newly constructed building to settle down or stabilize in terms of its energy consumption

[2] Arena, A.P. and C. de Rosa, Life cycle assessment of energy and environmental implications of the implementation of conservation technologies in school buildings in Mendoza--Argentina. Building and Environment, 2003. 38(2): p. 359-368, and Trusty, W.B., J.K. Meil, and G.A. Norris, ATHENA: A LCA Decision Support Tool for the Building Community, ATHENA Sustainable Materials Institute: Canada found in (AIA,2010).

Currently, available whole building LCA tools may apply to new projects, to existing buildings, and to major renovations or retrofits covering a wide range of building types. The amount of LCA expertise and time required to employ the different types of tools vary widely. The appropriate tool depends on the project's specific environmental objectives and budget (www.bdcnetwork.com). Hence, LCA is suggested to be incorporated case sensitive- depending on the project's situation, where a narrative is developed explaining how LCA may support important decisions according to project type, scope and complexity. This opens up the opportunity to include as many LCA as it dictates in order to support the decision making process for sustainable building performance, and consequently, this results in more sustainable building performance verification, which shall eventually add more value to LEED certification.

In order to select a LCA tool, it is important to take the following points into considerations (www.bdcnetwork.com), (AIA, 2010); the configuration of the tool (LCI, LCIA), the type of tool (Material/ assembly/ whole-building LCA tool), life-cycle stages accounted for in the tool, Inputs & Outputs[1], interoperability[2] of the tool, cost and degree of expertise required, as well as subjectivity and normalization of results.

LCI database contains material and energy use data as well as emissions data for commonly used products and processes. These databases contain elementary flows (inputs and outputs) for each unit process for a product system and are specific to countries and regions within countries. The LCI data are region-specific because the energy fuel mix and methods of production often differ from region to region. LCA databases may contain industry averages or product-specific data. Industry averages make more sense in whole-building LCA tools, as these tools are designed to be used to make decisions about assemblies at the schematic design stage. A specific supplier is not usually identified in early-stage design. Thus, the process of benchmarking may provide a basis for comparing building performance against either past performance, industry average, best in class or best in practice[3].

Several combinations of LCA studies can be formulated through defining four main variables; Life-cycle stages to be included in analysis- Building systems to be studied- Type of expected results from either Life Cycle Inventory (LCI) Analysis or Life Cycle Impact Assessment (LCIA) and Project phase at which LCA analysis is carried out. The seven most common scenarios of LCA application and their corresponding LCA tools have been briefly explained in table (17).

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[1] This includes accounting for methods, type, number, complexity and degree of detail and accuracy of input data regarding material and energy- method of viewing the outcome/results

[2] If it accepts databases from other sources, and if the outcomes of the tool compatible with other analysis and documentation tools

[3] According to (AIA,2010): Past performance—A comparison of current versus past performance
Industry average—Based on an established performance metric, such as the recognized average performance of a peer group
Best in class—Benchmarking against the best in the industry and not the average
Best practices—A qualitative comparison against certain, established practices considered to be the best in the industry.

Scenarios	Life Cycle Stages	Building Systems	LCIA Result	Blg. Process Step	LCA Tool
Scenario 1: Optimize a Building Design Evaluate alternatives to support D.M. process.	All	Whole building	All	Preliminary	Simplified LCA Tool Minimal Information LCIA results - e.g. Envest
Scenario 2: Evaluating the Impact of One Assembly to help in D.M. process	All	One building assembly	All	Design development	Assembly LCA tool -impact categories, ATHENA® EcoCalculator ATHENA® Impact Estimator.
Scenario 3: Evaluating a Specific Impact for the Whole Building	All	Whole building	E,g GWP	Preliminary/ design development	Simplified or detailed LCA tool, e.g.EQUER
Scenario 4: Calculating the Environmental Payback of a Green Technology	All	Assembly	All	Design development/ detail design	Very limited A detailed LCA tool: +/- e.g. GaBi, Boustead & SimaPro
Scenario 5: Evaluate a Building Design	All	Whole building	All	Detailed design	
Scenario 6: Evaluating the Impact of Using a Product	O&M	Product	All	Post construction	Detailed LCA Tool Quality and precision Impact distribution
Scenario 7: Evaluating a Building's Environmental Footprint after Construction - for Future Studies	All	Whole building	All	Post construction	

Table 17: Scenarios of using LCA for building environmental assessment[1]

Notes:

Each of these tools/models provide a valuable piece of information that support a decision making process. Energy simulation accounts for operational energy, while the picture is completed by using LCA to account for both operational and embodied energy use through the building's lifecycle, and they should not be considered in isolation but as a suite of mutually supportive processes to explore optimum synergistic and trade-offs relations between them- and this draws the attention to the need to introduce new user friendly tools which can perform both simulation and calculation requirements to calculate the expected energy savings by the end of the building service life and recommendations for synergies or trade-offs scenarios. It can be formulated as follows;

Embodied energy (calculated from LCA)+ [Operational energy (calculated by energy simulation models[2]) multiplied by the expected building service life (in years) = Total Energy use by the end of the building service life.

Keeping an eye on the market may be useful to track new advancements in the field of green building technology, as well as new services, skills and expertise that probably are not included in the traditional job description for project team members. This is why they are usually outsourced to energy consultant, energy modelling firms, design engineering, measurement and verification specialist, as well as LCA expert, and hence this reflects on the project's budget.

5.2.3. Project Delivery Methods for Green Projects

By comparing different types of project delivery method, the research concludes that better developed types of contracts matching *Green Building's* requirements should

[1] The author's elaboration from (AIA,2010), (Smith et al, 2006).
[2] It is worth noting that Target finder for LEED V3.0 does not only provide the targeted energy use for the building/ project, but its CO2 emission as well. This may be considered a start of combining operational and embodied energy calculation.

provide early and direct means of communication between various involved parties. It should define roles and responsibilities, and it should account for long term revenues and risks. Also, sound integration of design and construction processes will result in less wastage of time and resources.

Two recommended types of contracts are discussed in (Green Building Finance Consortium, 2010), which are[1];

- ☐ **Design-Build:** it focuses on combining the design and construction schedules. This can result in a more collaborative environment that can reduce change orders, enable a more value-oriented decision process, and improve communications. By integrating design and construction in the same entity, input by contractors may start from project initiation or during the feasibility phase, to provide a better communication between key parties and sharing responsibility for successful completion of the project. These benefits can be offset by a short-cut design process and reduced competition for the construction contract, or if design-build contracts do not have major incentives for building performance- this happens when their fees are tied to the cost of the systems they install.
- ☐ **Integrated Project Delivery:** it is a new method where the owner, architect, and contractor enter into a multi-party contract up-front with incentives and penalties. This type of process links the three key service providers up front, forcing a more integrated approach to designing and delivering the project.

It should be noted that there is no standard format for such types of contracts, but using the research framework may better define the scopes of work- pointing out their interrelations, and hence assign roles and responsibilities to involved parties- and this opens up the discussion to the coming closely argument about documentation activities.

5.2.4. Documentation and specification activities

Documentation activities for LEED purpose is used to clearly document sustainable design goals and strategies in the contract specification. It is recommended to develop a new specification section to address sustainable requirements such as construction waste recycling, environmental certification of materials, sequence of finishes installation (for IAQ), and so on (Mendler et al,2nd edition p.147-154). In addition credit responsibility should be documented stating exactly (responsibilities and methods) to perform each task, in addition to clearly stating specific wants/needs of parties, and ensure the availability of software information; about how to use, design, detail, specify and construct a new technology/ innovation; and evaluation information; about how an innovation is expected to perform (Calkins,2004). Effective briefing, specification, target setting and benchmarking are important at the design stage to minimize risks of unforeseen problems, also documentation activities can offer some evidence of building performance as well ,e.g. energy and resource savings (Vezzoli et al,2010), (Green Buildings BC,

[1] More discussion on this subject is found in (Green Building Finance Consortium, 2010)

GVRD and NRCan), also different sustainable property decisions require additional sub-analysis, new types of data, and a re-emphasis on different parts of the underwriting and valuation process (Green Building Finance Consortium, 2010).

Yet, it should be noted that key failures or underperformance due to service provider capacity and quality problems include project delays, Insufficient or inadequate commissioning, and higher cost. One of the ways to address potential service provider quality problems is to carefully design contracts, carefully review warranties, and move towards performance-based compensation, greater specification of goals and outcomes, as well as the specific process and approach (Green Building Finance Consortium, 2010).

Yet, it is notable that it involves recording how the requirements of individual credits have been met in preparation for submission but not for the whole process. This highlights the importance of process and feature underwriting. Hence, the research recommends using the same framework explained in the previous chapter as follows;

a. Recommended documentation and specification activities for scope (1) for EA and MR categories:

It is important to set requirements for organizational and operational issues through regular meeting sessions to present work in progress, typically before the end/start of each building stage, and urgent sessions, in particular situations and depending on the project's case. The plan should first identify and prioritise issues for discussion, responsible personnel, or persons in charge and would be directly influenced by the decision outcome from each session; whether directly or indirectly- also, to primarily identify if any special expertise is required. The recommendations concluded at the end of each session should be documented; stating who proposed it, how and when to perform it, in addition to other financial concerns, like additional capital cost and/or expected savings[1]. These sessions should be presented to the owner (if he is not already taking part in such sessions) to be updated and take the final decisions For example; integrated design and construction charettes (previously explained in chapter two) may take the following form shown in table (18).

	Date	Issues to discuss	Specialization/ personnel		Recommendations			Preliminary feasibility analysis		signature
(Building stage)			Direct relation	Indirect relation	Who	What	When	Capital cost	Savings	
Session 1										
Session 2										

Table 18: Planning and documenting integrated project sessions 'Charettes'.

[1] Cost estimations maybe simply stated in the form of percentage of the overall project budget- or maybe even highlights if the recommended design solution/alternative shall bring additional cost, or long term savings. Then better developed and detailed can be executed after the final approval is given from the owner or his representative(s).

For EA category[1];

- ☐ Energy performance requirements for; a) equipment (Kw requirements, and the power factor or efficiency rating), b) lighting (lamp type, wattage and color, ballast, and fixture), c) control systems, d) insulation (type, thickness and R-value per inch), and e) glazing (R-value, shading coefficient and visible light transmittance), to limit any change orders during procurement.
- ☐ Include energy efficiency ratings for all equipment in the specification.
- ☐ Include specification of HVAC system design criteria, ventilation criteria and the building program requirements in the commissioning specification.

For MR category[2];

- ☐ Enforce requirements related to use of environmentally preferable materials
- ☐ Document detailed environmental performance criteria for materials specified
- ☐ Document all environmental requirements in the specification, and require submittals from manufacturers to certify their compliance with the requirements.
- ☐ Specify minimum recycled content requirements and maximum allowable VOC content for all applicable materials and products.
- ☐ Require that contractor keep a materials log of all materials used in the facility construction
- ☐ Require manufacturers to make recommendations in writing for preferred maintenance methods that have a minimal impact on building air quality[3].
- ☐ Develop construction waste recycling section for specification, include a salvage and reuse plan for demolition of existing construction
- ☐ Specify reuse of onsite materials to the greatest extent possible
- ☐ Require that the contractor submit a construction waste management plan prior to the outset of demolition and/or construction.
- ☐ Evaluate requirements for appropriate handling of hazardous waste.

b. Recommended documentation and specification activities for scope (2) for EA and MR categories:

For EA category; Clearly identify; measurement metrics, standard reference (version, errata and addenda), method[4], and what compliance path, in addition to recommending software tools to satisfy LEED requirements

For MR category; indicate credit threshold for each sustainable material/product, and other related issues to their calculation method, i.e. MR C4; identify post and pre-

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[1] Guidelines for green energy efficient specification (Kane, 2010).
[2] Guidelines for Materials and resources efficiency (Mendler et al, 2 edition p.125-133)
[3] Maintenance can introduce high levels of VOCs on a regular basis into the building despite the designer's efforts to reduce emissions in materials and ventilate the initial resources.
[4] Quantitative/qualitative, performance/prescriptive, source/site energy, metered/calculated method- as explained in chapter four.

consumer recycled content to comply with LEED requirements, as well as other environmental data about material performance.

c. Recommended documentation and specification activities for scope (3) for EA and MR categories:s

Specify and document methods to verify operational energy performance (e.g. Commissioning and M&V process- as well as POE), and embodied energy performance (e.g. LCA)- identifying their common data base requirements, and means of integrating them together, as well as highlighting potential synergies and trade-offs.

d. Recommended documentation and specification activities for scope (4) for EA and MR categories:

Specify and document the types of certification required for energy efficient products and systems, as well as 3rd party certified materials and products. Also, more research suggested that a clear contract specification is important to limit risk, as well as clearly defining performance or certification expectations, and it is important to explicitly allocate the risks of new technology and to consider performance testing of systems and technologies (Green Building Finance Consortium, 2010).

Finally, it is important to note that documentation-related costs can be significantly reduced if documentation activities started in the early phases of a project (Green Buildings BC, GVRD and NRCan), (Stein et al, 2004)- also, they are expected to go down in the future through the development and use of more efficient software tools.

5.2.5. Material Selection and procurement

Material selection must take into consideration flexibility/adaptability and durability for material-use implications of alternatives. In other words, comparisons should be made in the context of building systems, rather than on a simple product-to-product basis (www.bdcnetwork.com), with additional consideration to 'End of life' as criteria for judgment.

The material selection problem has been treated extensively in the literature through many approaches, such as multi-objective optimization[1], ranking methods[2], index-based methods[3], and other quantitative methods like cost–benefit analysis[4]. However, current literature in the building domain lacks a standard method that may help

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[1] Found in (Lacouture et. al, 2008) : Sirisalee P, Ashby MF, Parks GT, Clarkson PJ. Multi-criteria material selection in engineering design. Advanced Engineering Materials 2004;6(1–2):84–92, and Ashby MF. Multi-objective optimization in material design and selection. ActaMaterialia 2000;48(1):359–69.

[2] Found in (Lacouture et. al, 2008): Jee DH, Kang KJ. A method for optimal material selection aided with decision making theory. Materials & Design 2000;21(3):199–206, and Chan JWK, Tong TKL. Multi-criteria material selections and end-of-life product strategy: grey relational analysis approach. Materials & Design 2007;28(5):1539–46.

[3] Found in (Lacouture et. al, 2008): Holloway L. Materials selection for optimal environmental impact in mechanical design. Materials & Design 1998;19(4):133–43, and Giudice F, La-Rosa G, Risitano A. Materials selection in the life-cycle design process: a method to integrate mechanical and environmental performances in optimal choice. Materials & Design 2005;26(1):9–20.

[4] Found in (Lacouture et. al, 2008): Farag M. Quantitative methods of materials selection. In: Kutz M, editor. Handbook of materials selection. New York: Wiley; 2002.

the decision-maker select the more-appropriate materials while at the same time looking at the accomplishment of environmental goals and meeting design and budgetary requirements (Keeler et al, 2009), (Lacouture et al, 2008). It is still a developing area of research and results are expected to change the practical methods of decision making for material selection process, hence, it depends on practitioners' experience and local building materials market availability.

The study conducted by (JÖnsson, 2000)[1], stated that material selection maybe carried out under any of these three types of situations; a) determinant type of product, but not the brand, or b) if the type and brand are not determinant, or c) if only the brand is determinant, but not the product type. The research can apply these situations on the suggested framework as follows; Type (a) may better belong to the scope 1 (guidelines), where the type of product maybe recommended without prescribing the type of certification, for example; using MR C3, 4, 5, 6 where reused, recycled, regional and rapidly renewable materials are prescribed. Type (b) requires some forms of measurement and verification scopes to support the decision making process. It requires taking into consideration a variety of aspects (e.g. environmental and economic) depending on the project situation, e.g. choosing flooring type between linoleum, vinyl flooring and solid wood flooring, while, Type (c) is well fit in the certification scope, where environmental certification requirements are determined in advance, e.g. using FSC wood, or in LEED V4.0 disclosure and optimization for MR C 2, 3 and 4.

Risks result primarily from uncertainty due to the use of new and untested materials or from traditional products being used in new and untested ways. Additional risk results from "green washed" materials that fail to meet sustainable standards or expectations. Another risk is that the documentation relating to the green features of a product may be incomplete (Green Building Finance Consortium, 2010).

Hence, the research recommends considering the market scope (certification and market performance) to obtain documentation and certification according to LEED requirements, order quantities and specifications to closely match project's requirements (Kane, 2010 p.94,98), (Green Buildings BC, GVRD and NRCan). Moreover, it is important to allow for more credits' synergies (maybe applying the 'Lean design philosophy as referred to in chapter two). It is also important to note the synergistic and trade-offs relations between energy and materials efficiency when choosing materials, for example; insulation materials, and/or some floor materials may affect the building's internal cooling and/or heating loads. Hence, the research recommends running a final energy simulation models after construction and before occupancy (and this exceeds LEED requirements),

[1] The study discussed 6 approaches to the environmental assessment of building products; LCA study, an eco-label, two eco-guides, a product declaration and an environmental concept (The Natural Step). It found that different approaches answer different questions and that stakeholders may need to use different tools for external communication, external decision-making support, and internal development.

with the full input of the chosen materials to double check if the designed operational energy efficiency of the proposed model is affected.

5.3. APPLYING THE RESEARCH FRAMEWORK TO MANAGE EA & MR CREDITS

Following LEED GBRS to achieve a sustainable building process does not only mean adopting the intentions and requirements of credits pursued because the sum of optimized design steps does not always guarantee reaching an integrated design approach, but it can be accomplished if performed under defined framework for the scopes and limits of operation of the LEED system along the whole building process to support a systemic approach, and it should basically be primarily planned by team members according to project conditions.

This section explains how to apply the suggested research framework- including the previously defined scopes of operation of the LEED system on different phases of the project management process as well as individual practices for LEED energy and materials credits- assuming that the four scopes operate integrally and in parallel along each phase of the building process and with equal weighting importance.

It is important to note that this management framework presents an attempt to provide a general idea- a 'Know How'- about how to integrate the four proposed scopes for each building phase, yet it should be noted that some of the activities that shall be mentioned in one phase may take place in the precedent or the following stage, or they may extend to cover more than one phase depending on the scope and extent of work.

5.3.1. Pre-schematic stage

Scope 1

LEED system urges the importance of this stage due to the reason that many important decisions are considered in the early design stages according to the 'Front Loading' principle. It is not rewarded into points in the current LEED version[1] but it definitely improves the whole building process and the decision making process; where typically, the building is considered along with all its interrelations and connections, both externally with its context as well as internally with its systems and subsystems in an integrated manner- accounting for synergies and conflicts. This goes in parallel with the owner's contribution to define the purpose, program, and functional requirements of the building as well as energy efficiency goals[2]. Moreover to exceed LEED requirements, the owner may also include any goals related to construction and operational costs, as well as any future expansion plans as well as setting goals for Design for disassembly (DFD) and/or Design for disassembly and deconstruction (DFDD), which can be developed by

[1] In LEED V4.0 is shall be rewarded with one possible point.
[2] These include the targeted energy efficiency goals with respect to the local energy code, ASHRAE, or LEED standards.

team members to design guidelines and shall eventually reflect on end of life management building stage[1].

Typically, data should be gathered for contextual conditions (site area[2], location, development condition[3], surrounding, climate…etc.). Practitioners then use LEED credits' checklist to determine the scope of work, where a LEED pre-assessment can help determine the credits which could be achievable and their cost benefit estimate.[4] The optimum choice is to discover synergies that result in both capital cost and operational cost savings.

Moreover the research recommends setting base for both the organizational and operational aspects; the first requires selecting the most appropriate project management models to manage time, budget and quality objectives and constrains- this may include the use of traditional tools and methods but developed to consider LEED requirements and additional sustainable criteria, also it requires defining the framework for decision making process, and using any borrowed method to guide sustainable building process (for example; Lean Philosophy to set targets for minimizing waste, which was previously explained in chapter two), and identifying special aspects in the project that requires special attention where depending solely on LEED checklist is not enough to support an in-sighted decision making process. Additionally, the project delivery method is preferably defined to match with the nature of sustainable projects.

While, optimizing Operational aspects of the building process includes setting targets for both energy and resource efficiency early in this stage by setting the environmental goals of the project, and integrating passive and mechanical design features to develop energy and resource efficiency design solutions. Among the most important design elements are; lighting and HVAC systems, envelope design including external structure, roofs and window fenestration- with special emphasis on the synergistic/tradeoffs relation between energy and materials credits.

Scope 2

Applying this scope in this early design phase is not defined in LEED system, nevertheless, the research recommends conducting Energy and Material budget estimating inputs and outputs during the building process, which shall serve to compare against benchmarks and project's goals during later phases. Additionally, the research recommends that design team categorize LEED credits setting prescriptive, and others setting performance targets, as well as qualitative versus quantitative sustainable targets

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[1] More about this argument can be found in (Yellamraju, 2011 p. 69, 70)

[2] LEED site area is defined as the area within the LEED project boundary of the site., Open Space Area (required by local zoning ordinance)- Open Space Area (proposed or provided)- LEED Open Space Area

[3] Site Predevelopment condition includes Greenfield or previously developed, prime farmland, habitat for endangered species. Proximity to wetlands/water bodies, Previously public parkland, Brownfield or contaminated, Flood plain zone

[4] An important issue to be fixed before the project budget is fixed, is whether decision making will be based on life cycle costing (LCC) or first economics. In some cases LCC is used within a fixed budget that has a contingency amount set aside to pay for LCC effective upgrades, yet another approach is to secure special finance for LCC effective upgrades through energy service contracts (ESCOs)

and their corresponding measurement criteria to be able to act on their different corresponding approaches as explained in the previous chapter.

The research also recommends identifying what is to be measured along the building process and using what method and/or tool. It is worth noting that during these early design phases, software tools that require basic or minimum input data maybe used to give indications about the development course of the design process and not as an assessment method because in either cases it is not accounted nor rewarded for LEED submission- but it is useful to guide the decision making process. For example, developing conceptual modelling; for new construction projects, it may be able to guide design team members to choose the best orientation, form and massing as well as external structure, while for renovation projects, it may guide team members to choose among different renovation plans.

Scope 3

Some verification methods start during this scope as recommended by LEED reference, for example, Commissioning process starts with designating an individual as a (commissioning authority) (CxA) to lead, review and oversee the commissioning activities and acts as the advocate of the owner. His/ her mission is to develop commissioning requirements, review OPR (Owner project requirements), BOD (Basis of design) and design requirements, and set a commissioning plan which defines the general scope of the project, type and nature of the commissioning process, the scope of services which shall be recorded in the A/E contract[1], as well as expectations for energy and daylight analysis and energy audits (for the case of existing buildings)[2].

Yet, choosing the type and scope of commissioning activities is not provided in the LEED reference; hence this aspect can be complemented by other studies to complete the proposed management framework as shown in table (19);

Type of building	Type of commissioning process
New or major renovation project	**Commissioning**- ideal for new construction or major renovation and best implemented through all phases of construction project.
Old and expensive to operate and experience a lot of equipment failures	**Retro-commissioning**- ideal for older facilities that have never been through a commissioning process
Relatively new and was commissioned during construction, but energy use has been increasing	**Re-commissioning**- ideal to tune up buildings that have already been commissioned, and bring them back to their original design intent and operational

[1] Architect- Engineer contract

[2] Energy audits evaluate the energy usage within an existing building and the potentials for improvements (Mendler et al, 2 edition p.43)

	efficiency
Large and complex projects having a metering system and a preventive maintenance program, but still has high energy use and tenant complaint	**Continuous commissioning**- ideal for facilities with building automation system (BAS), advanced metering systems, and well run O&M organizations.

Table 19: Comparison for choosing the commissioning approach suitable to the project scope (Commissioning existing building, 3.0).

Additionally, the research recommends planning for scenarios of use of LCA for accounting for environmental impact especially for certain stages or activities which require further decision making support tools, this includes; LCA study goal(s), system boundary, environmental impact categories and stages of building process, scope of LCA (Material, Product and/or Building level), as well as defining the functional unit of the assessment.

Scope 4

It is important to note that this scope is not clearly defined in the LEED system, so the research highlights the following aspects;

The focus for this scope in this early design stage is to analyse the business case of project potentials, along with employing marketing strategies; (conveying signalling messages, differentiation, competitive advantage and branding). This shall be possible through investigating the value of the certification process, along market acceptance and expectations, which represent an important factor for determining the type of LEED rating system to follow and determining the owner's desired level of LEED certification as well as any additional goals, such as meeting any federal, state, or local Green Building standards.

Hence, guidelines from scope 1 are translated into environmental and sustainability goals to contribute to raising the certification's value, which is considered by far the hardest step to accomplish because it depends on quantitative and qualitative indicators for both direct and indirect measures which are not always easy to measure/evaluate[1].

The next important step that the research recommends is to conduct a stakeholder analysis, including the relation between the owner/ developer and the occupant/ user. In addition to exploring opportunities for establishing a mean of financing mechanism, for example ESCOs, and/or searching opportunities and types of incentives (Utility incentive programs, manufacturer discounts, governments programs…etc.) to mitigate risk factor coming from investing in green technologies/ systems.

5.3.2. Schematic stage

Scope 1

[1] Savings from energy reductions can be estimated using engineering calculations or savings estimators. Savings related to purchasing and waste diversion can also be calculated. However, benefits, such as increased property value and/ or greater longevity of tenants are still difficult to evaluate (IFMA,2010).

Typically, the schematic design phase of the project involves refinement of the vision from the previous phase considering time, cost and resources. During this phase, it is important to develop design optimization; exploring, testing and evaluating a broad range of solutions, as well as innovative ideas and technologies, through design ‘Charrettes’ of multidisciplinary team members and expertise involvement, exploring synergies and trade-off scenarios. Sustainable design requires the design team to consider a large number of issues in the decision making process. The intent is to establish an agreed-upon scope of work and the first preliminary design solution; including information about the building program, footprint, form, orientation, massing, building elements, building structure and envelope, HVAC and lighting systems.

Energy efficiency targets should extend to consider integrating renewable energy sources, whether from onsite sources, or through purchasing Green Power, and additionally under LEED V4.0; consider participating into a Demand control program. While resource efficiency; considers dedicating a specific location for storage and collection of recyclables- for MR Pre1, in addition to, evaluating building reuse scenarios for MR C1, and conducting a construction and demolition waste management plan for MR C2[1], and requires searching and identifying green materials, products, systems and services, along with their potential implementation strategies. It is also recommended to identify and document scenarios for Design for disassembly and deconstruction (DFDD) to be followed at the end of building life stage. These early decisions may significantly affect the design process, and finally, it is important to integrate green requirements into the schematic design drawings.

Scope 2

The research defines the requirements for this scope for using tools to manage guidelines, measurement, verification and certification requirements according to the required time, budget and quality constrains. While tools for Measurement and benchmarking are employed to understand the environmental impact associated with design options and to identify preferred approaches for materials selection and integration of energy efficient technologies. This includes performing credit calculations and simulation to support the decision making process, using more general data when detailed ones are not ready yet.

Also the research recommends that at this stage, it is important to decide whether simulation activities shall be performed on board, or shall be outsourced to specialized agencies. If they shall be performed by team members, then it is recommended to start gaining more knowledge about the latest standard references required for LEED credit compliance, e.g. ASHRAE, to be able to determine benchmarks for minimum

[1] For existing buildings- MR C2 may starts in this early phase to account for both demolition and construction activities, while for new construction buildings, it may start right before construction begins to account for construction activities.

performance levels. If they shall be outsourced, then this has to be included in the project's time and budget estimation.

At this stage more detailed tools can be used to guide the decision making process, for example; developing the parametric model for energy efficiency to compare energy reduction strategies, envelope options (massing, insulation and fenestration), building system options (HVAC, lighting, control systems). Throughout the analysis, three types of energy performance measures should be evaluated; energy conservation, energy cost reduction, and peak demand reduction, and it is important to consider the primary source energy when evaluating energy use on site. It is also recommended to develop pie chart energy analysis in order to identify and prioritize building energy requirements, by cost and by end use for the most important energy elements and systems[1].

On the other hand, some materials credits' calculations should be integrated in early design phases for existing buildings to support important decisions in scope (1), for example LEED MR C1 is performed based on total percentage of maintained area relative to the total building structural area, but summing existing building structure (flooring and deck), and envelope (exterior skin and framing) for compliance with MR C1.1, while interior non-structural elements (interior walls, doors, floor covering, and celling systems), yet it is recommended to break the total area of maintained elements, and identify its base components or assemblies to make it easier to provide feedback from scope (3) verification scope using LCA based on actual accounting for their environmental impact. While, LEED MR C2 calculates the total percentage of diverted/ salvaged construction and demolition waste based on weight or volume (but consistently throughout the calculation). Also for this credit, it is recommended that a breakdown of the included materials to be able to provide feedback from the verification scope (LCA).

Scope 3

Verifying energy efficiency for this stage requires setting a commissioning plan which includes three main aspects:

- ☐ Commissioning program overview: setting goals and objectives, general project information and systems to be commissioned.
- ☐ Commissioning team: identifying team members, roles and responsibilities, Communication protocol, coordination, meetings and management procedures.
- ☐ Description of commissioning process activities: documenting OPR, BOD, and design requirements. Also, building occupant and O&M personnel requirements should be determined to give an idea about how the facility will be operated and specify whether any training is necessary for the occupants to operate the building's systems.

[1] Using this analysis, life cycle costing can be developed for energy saving design alternative or package of alternatives, based on first cost, maintenance cost, operational cost and replacement cost (Mendler et al, 2 edition p.98-102).

Verifying materials and resources efficiency for existing buildings may start in this stage and it requires performing a LCA, which can be used to define specific impacts and accordingly guide decision making process related to building reuse scenarios, and construction waste management plan.

Scope 4

The certification scope for this stage should act on two important aspects; LEED certification (LEED system provides enough guidelines for this aspect) and, Green certification of required building systems, services, materials and product (which is mentioned in each LEED credit requirement for the construction submittal, but the research recommends that they should be determined in early phases to reduce change orders). This can be better explained as follows;

Certification prospect should include registering the project on the USGBC, and LEED system requires deciding on the option for submission and review; 'split' or 'combined', and gaining access and communication through the USGBC. LEED system offers some streamlining methods for documentation process, e.g. LEED Guide for multiple buildings project. Hence, it is recommended to update practitioners' knowledge about the latest LEED system's developments corresponding with the LEED version used though the USGBC website, also, it is important to check eligibility to LEED certification, thus, satisfying all LEED Minimum Program Requirements (MPR), prerequisites, compliance paths, in addition to preparing a preliminary LEED credit checklist to ensure that the minimum number of points satisfying the required level of certification can be obtained- and eventually the results of this scope shall reflect back on scope (1).

It is also recommended to identify data and requirements for obtaining sustainable materials, e.g. supply chain, second or third party certification- (percentage of post-consumer, pre-consumer, regional materials, as well as rapidly renewable materials), manufacturer location, vendor, as well as documentation requirements, in addition to determining equipment and system expectations- these define the owner's desired level of quality, automation, and maintenance requirements for equipment and systems used in the building. If desired, the owner may include information on efficiency targets or preferred manufacturers of building systems.

5.3.3. Design development stage

Scope 1

Typically, the design development phase is the process of refining the schematic design idea and optimized for best performance from a whole building design perspective. Hence, the research recommends that during this stage, design team should work out all the details, calculations and analysis including the selection of materials and the engineering systems. It is also recommended to gain feedback from the contractor regarding LEED construction credits, as well as the availability and cost of green materials, and their effect on the design process, and the contribution of other specialized experts. In addition to developing building management policies for example; construction waste management plans clarifying diversion plans, which will be later implemented in the construction phase. It is also important in this stage to explore opportunities for (Innovation in Design) credits- exceeding the minimum levels of sustainable requirements set by LEED reference guide either through exemplary performance for LEED credits or adding new criteria (to be evaluated by the USGBC). Additionally, it is important to explore opportunities for (Regional Priority) credits corresponding with the local context.

Scope 2

This stage is considered a development for the previous stages. More detailed information is available in this stage, so predicted energy consumption measurement is more accurate which provides more accurate decisions regarding the design of the HVAC system, lighting system, as well as any other energy efficiency systems.

It is worth noting that at this stage more detailed tools can be used to guide the decision making process. In this stage, it is recommended to develop two types of energy models; at earlier time; developing the energy load modelling, with specific analysis for building load calculation (which is not considered among LEED system's requirements). While, later at the end of this stage; compliance modelling should be developed to comply with LEED Pre2, and EA C1- comparing it against a base model according to ASHRAE standard; to earn points and obtain LEED credits, and to support the owner's investments, hence reduce risk and uncertainty..

As for materials credits:

MR C3-7 credit calculation is performed according to LEED requirements as shown in the following table, first estimating the total construction material value (excluding labor and equipment), or taking a default value equals to 45% of total construction materials' value.

Preliminary budget estimates for LEED MR credits			**MR C3**	**MR C4**			**MR C5**	**MR C6**	**MR C7**
CSI Master Format 2004 divisions (LEED credits MR C3 to MR C7)	Total construction estimate from preliminary budget	Material cost (default value= 45% of estimated cost)	Materials reuse	Recycled content			Regional materials	Rapidly renewable materials	Certified wood
				Post consumer	Pre-consumer	Value			

Table 20: Example of a MR credit calculation; Green potential LLC (www.green-potential.com) (Yellamraju, 2011 p.135)

Scope 3

In this stage, energy efficiency is verified using both commissioning and Measurement and Verification processes. Commissioning process includes at least one design review process (EA C3: Enhanced Commissioning) and obtaining review summary including OPR, BOD and design requirements and matching them with design documents to focus on clarity, completeness and adequacy of process. Meanwhile, it should be noted that M&V design and implementation is recommended not to be part of the project's team member, and it starts with identifying the M&V option and developing appropriate M&V strategies suited to the unique requirements of individual project.

On the other hand, resource efficiency is verified using LCA, which can be used to evaluate and verify a specific impact for the whole building (to gain incentives or to comply with some building codes, e.g. carbon reduction) or to calculate the environmental payback of a Green technology (LEED V4.0 MR C1: Building life cycle impact reduction) - this requires the use of a detailed LCA software program.

Scope 4

Now that the design is mature and project's energy requirements are almost definitive, thus certification prospect may include establishing Green Power purchase agreements, Demand control programs & carbon offset (LEED V4.0)- Material selection for certified building elements and technologies to link with other sources of second and third party certification systems (e.g. Energy Star), considering that it is highly dependent on the dynamics of the current sustainable market, both locally and globally. This requires continuous update for latest market movements. According to LEED requirements, the materials that are anticipated to meet requirements of MR C3 through C7 should be identified based on information available from manufacturer and suppliers. A more detailed cost estimate may also be prepared at this phase as shown in table (21);

Green/Energy Efficiency features (in addition to base building design)	**Green Premium**	**1 year payback scenario**	**10 year payback scenario**	**20 year payback scenario**
Energy efficiency				
Resources efficiency				
Sub total (operational only)				
Total productivity savings				
Total marketing benefit				
Total CO_2emission savings				
Total benefits (operational + intangible)				

Total energy				

Summary of results	
Total Green Premium	
Total Green Premium/sf	
Total NPV[1]/sf	

Table 21: Sample cost-benefit analysis Credit: Green Potential LLC (www.green-potential.com) (Yellamraju, 2011 p.124)

5.3.4. Construction drawings stage

Scope 1

Typically, during construction drawings stage, drawings are detailed , and working drawings are prepared with complete specifications of the project, which present the design with a level of detail for all spaces, systems, and materials, and their operational schedules, along with their implementation strategies and any other special requirements so that it can be ready to be delivered to contractors, for example; detailing of building envelope to control thermal, air and moisture, also, selecting and specifying the type of control systems (e.g. CO_2 monitoring control systems), occupancy sensor and specifying their coverage patterns and mounting configurations.

Moreover, the research recommends that specifications are developed based on requirements identified from the four scopes; guidelines, measurement, verification, and certification requirements. The project delivery contract should be prepared based on identifying the roles and responsibilities, tools and models to be used, documentation requirements, in addition to any special requirements- putting into consideration risk factor and means of mitigation.

Scope 3

Commissioning process includes incorporating Cx agent's requirements into construction drawings, and conducting a Cx review of 50% construction drawings. In addition, setting a M&V plan as discussed in the previous chapter, and specifying and detailing meters and sub-meters according to IPMVP requirements, and the output of these models maybe used to trace building performance for the verification scope under M&V plans or POE for feedback analysis.

Scope 4

Certification prospect is increased in LEED V4.0 regarding Materials and Resources category; requiring building product disclosure through Environmental product Declaration (MR C2) / Sourcing of raw materials (MR C3) and/or material ingredients (MR C4). Bidding and procurement processes are influenced by the dynamics of the current

[1] Net Present Value

sustainable market, both locally and globally. This requires continuous update for the latest market movements, to determine the availability and price of sustainable building materials/products, as well as systems and services.

Robust documentation activities along the design phase(s) shall eventually streamline the certification process. Documents are provided for the USGBC for the Design Review (optional in LEED V3.0), and comments are discussed which may require reconsiderations through an iterative building process. USGBC credit ruling is ‘anticipated’ or ‘denied’, and consequently it can either be ‘accepted’ or ‘appealed’ by team administrator (within 25 business days).

5.3.5. Construction stage

Scope 1

Typically, the construction phase begins when the contractor starts building the project according to the construction documents, conducting site visits, construction administration, material procurement, subcontractor management, and budget control. The contractor (sub-contractor) has to ensure that the specified sustainable materials/products/systems are installed, and quantify the total percentage of materials installed, and finally provide full documentation to their quantities, specification (satisfying LEED requirements), operation schedules, maintenance requirements, and any other special concern.

LEED system prescribes some guidelines for construction practices to be conducted, which may not be familiar to practitioners, e.g. Construction waste management plan[1], including recycling activities which may be documented using the following table[2].

Demolition waste	**Diverted waste**	**Land filled**	**Commingled waste diverted offsite**	**Offsite % diverted**	**Hauler or location**
Material	(Cu.yd./tons)	(Cu.yd./tons)	(Cu.yd./tons)	%	(Name/location)
Subtotal demolition waste					
Construction waste	**Diverted waste**	**Land filled**	**Commingled waste diverted offsite**	**Off site % diverted**	**Hauler or location**
Material	(Cu.yd./tons)	(Cu.yd./tons)	(Cu.yd./tons)	%	(Name/location)
Subtotal construction waste					
Total combined waste					

[1] Also through Indoor air Quality management plan, but it is outside the scope of the research.
[2] The form must be accompanied by weight tickets and receipts. Diverted waste includes waste that was recycled, salvaged and/or donated

Total waste diverted (%)					

Table 22: Sample waste reduction report Credit [1]

Nevertheless, LEED system provides little guidance regarding sustainable construction process which should cover planning and scheduling. Thus, it might be an area of concern especially that LEED system does not require site visits or other means of process control for the project- it relies on documentation purposes, and is left to project team members skill and expertise. Hence, the research urges that it should extend above traditional construction practices concern, which focuses on time management and cost reduction, in addition to delivery and storage requirements, but also to take the environmental aspect into consideration, in order to minimize site disturbance, minimize waste, and reduce energy consumption, and this extends to cover labor training[2], equipment and materials. Thus, it is recommended that they be organized in (just-in-time) JIT approach [3], adopting the rim delivery system[4], and participate in sustainable manufacturers programs[5].

Scope 2

More accurate results can be obtained from energy and materials measurement metrics. For example; at this stage, predictive/ incentive energy modelling can be used for financial claims. Additionally, all MR construction submission calculations can be finalized for submission at the end of this phase.

Scope 3

Energy efficiency is maintained through a set of prescriptive requirements to specify and install metering and sub metering, occupancy sensors, CO_2 monitors and automatic lighting control systems for different tenants, uses and floors considering the presence of peak energy demand infrastructure as part of building automation system. Examples of installation verification include: Photographs of new equipment, and of new control set-points, Screen captures from EMCS, as well as invoices from service contractors (QuEST, 2012). M&V process continues to gather required data according to the measurement scope of work for installation and operational verification.

Documentation for Commissioning and M&V credits maybe finalized at the end of this phase. Commissioning agent reviews contractor's submittals (EA C3 Enhanced

[1] Source: www.green-potential.com, and (Yellamraju, 2011 p.139)

[2] It is worth mentioning that the importance of labor is only addressed in the Green Globes by providing training, action plan, and raising awareness of the employees (Wu et al,2010)

[3] Such that all the deliveries of the materials, construction, and installation activities are taken into consideration so that no unnecessary movements happen on site. The right parts needed are delivered to site at the time they are needed and only in the amount needed. However, it requires a stable relation between the suppliers and the contractors so that no last minute changes would be made (Wu et al,2010)

[4] It discusses combining possible deliveries together for both materials and equipments in order to save energy and cost (Wu et al,2010).

[5] They are also called 'take back programs' e.g. some carpet and ceiling manufacturers who take back scrap materials after installation is complete for recycling (Mendler et al, 2 edition p.147-154).

Commissioning) to match with OPR, BOD and design requirements. This covers both installation and operational verification. Next, the commissioning agent(s) develops a summary report after substantial completion including confirmation from commissioning authority for each individual system, summary of processes (tests) and results-observations, conclusions and outstanding items. Finally, commissioning requirements should be incorporated into construction drawings. As for LCA, it is used in this stage to verify reduced environmental impact resulting from building reuse scenarios, material selection, new energy efficient systems, and prioritize diversion plan.

Scope 4

This stage constitutes 'Construction submittal' after substantial project completion, where documents are sent to the USGBC for Construction Review- comments- response with accept or appeal- granting the certification level (in case of obtaining the LEED certification). It is important to note that LEED V3.0 Minimum Program Requirement (MPR 6) requires signing a contract with the USGBC to gain access to actual energy and water consumption for 5 years period.

On the other hand, purchasing offsite renewable for compliance with EA C6: Green power can be achieved, after having submitted EA design credits in the previous stages, as well as enrolling in demand control programs and carbon offsets

5.3.6. Operation and maintenance stage

This stage greatly reflects the impact of previous stages. Decisions during the design process need to be made with long-term operational benefits in mind. Hence, it is important at the end of the previous stage to incorporate activities to ensure the transition from the design and construction team to the building owners, occupants, and operating staff occurs smoothly. Then, it shall depend on prior stages' contribution in addition to occupants' behaviour[1] to reduce operational energy consumption.

Scope 1

Operational stage is where energy efficiency measures resulting from efficient features/systems (EA Pr2, and EA C1), besides onsite (EA C2) and offsite (EA C6) renewable energy systems come to real test. Additionally, other credits' requirements continue in this stage, for example; Green Power purchase agreements, and Demand Control systems operation which may require real-time metering, and carbon offsets.

Scope 3

The research urges that under this scope; it is important to verify that the actual building performance corresponds with the predicted one through continuous

[1] Building and Construction Authority _2008_ proposed the provision of a building users' guide that includes details of the environmental friendly facilities and features within the building and their uses in achieving the intended environmental performance during building operations (Wu et al,2010)

commissioning and M&V process. These methods are based on visualization of *operational* data (as opposed to *energy* data) collected during one or more site visits after the measures have been installed. Studies[1] state that measures with low expected savings, and measures whose savings estimates have considerable certainty, may need only *installation verification* conducted in the construction phase. While, measures with large savings and measures with less certain savings (whose savings can vary greatly dependent upon application) typically require *operational verification*.

M&V modelling is required to comply with EA C5, to compare it against a baseline model according to the design intentions.

M&V plan and POE should work to ensure proper functioning of MEP, lighting and renewable energy technologies- educate occupants of energy conservation measures, evaluate day lighting strategies & lighting controls to ensure that they work as designed; light shelves, monitors, skylights, and other day lighting apertures. M&V should review status of electricity provider to ensure that the Green-e certification remains intact and suggest alternative providers in case of inefficiency. Additionally, M&V and POE plan should extend to materials' efficiency as well; to review performance of green materials; salvaged or refurbished, recycled content materials, rapidly renewable materials, as well as regional materials, in addition to, scheduling periodic review of recycling programs to determine if recycling goals are being met, and to identify additional recycling opportunities. As well as tracking quantity of waste material generated annually, in respect to the quantity and type of materials diverted from the waste stream. Also, they may act as a feedback mechanism for energy efficiency performance, and track 'churn rate' to assess how well goals for flexibility and adaptability are being met.

This aspect shall have a reflection on the market scope through calculating the tipping fees avoided and revenue gained from recycling annually. Also shall reflect back on the guideline and decision making scope, through auditing waste stream to determine quantity of hazardous waste materials that are being disposed of, and explore opportunities to modify materials procurement and materials-use to reduce the quantity of hazardous waste generated.

Scope 4

LEED V4.0: demand control management systems, enables opportunities for using 'Feed-In Tariffs' which guarantees a price for small generators connecting renewable energy to the grid. This aspect should be linked with certification and market performance to estimate the amount of benefits obtained by building owner versus its cost.

Also, Verification scope contributes positively towards reducing risk and uncertainty- which creates very strong bond with the market scope creating a strong business case along with other building operational savings and productivity benefit. This enforces the LEED certification brand name in the real estate market, and creates

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[1] Source: (Mendler et al, 2 edition)

investment attraction to LEED certified buildings[1].In addition to estimating the value of the other information derived from feedback analysis for new sustainable building materials, systems or building elements- and/or evaluating sustainable management scenarios. This knowledge although it is case specific but it is valuable for the improvement of sustainable building practices.

5.3.7. End of Life stage

Scope 1

End of life management is discussed by the LEED system through construction and demolition waste management plan (MR C2) in LEED V3.0, which developed into dual level in LEED V4.0- (MR P2) and (MR C5) indicating the necessity to plan early for reducing waste obtained from construction and demolition processes. It is worth noting that guidelines for design and disassembly (DFD) and/or design for deconstruction and disassembly (DFDD) are missing in LEED system guidelines, which makes it difficult to consider issues related to end of life management process if not considered early enough during the design process as indicated in the pre-schematic and schematic stages.

Scope 3

LCA studies can provide valuable feedback analysis to guide knowledge about different materials and their embodied energy and accordingly their environmental impact at the final stage. They can provide reliable results for partial life cycle concepts, for example recycling and reuse to judge their actual environmental benefit and hence provides a mean to support decision making process.

Scope 4

End of life management potentials depend greatly on the local/national market potentials- availability of recycling/ reuse programs, haulers, contractors' knowledge and experience in recycling activities, bidding terms and conditions, as well as searching for local financial incentives accompanied by recycling/ reuse activities. It is useful to link this target to the business case of green buildings adding to its certification prospect and raising its value and revenue.

These stages can be represented in the following diagrams:

[1] Additionally, it is very beneficial to consider seeking LEED for Existing Building Operation and Maintenance (EBOM), which represents an addiiotnal level to certify sustainable building performance through operation and maintenance stages to guarantee continuous monitoring and adjusting to improve performance, developing a better connection between the intended design and actual operation.

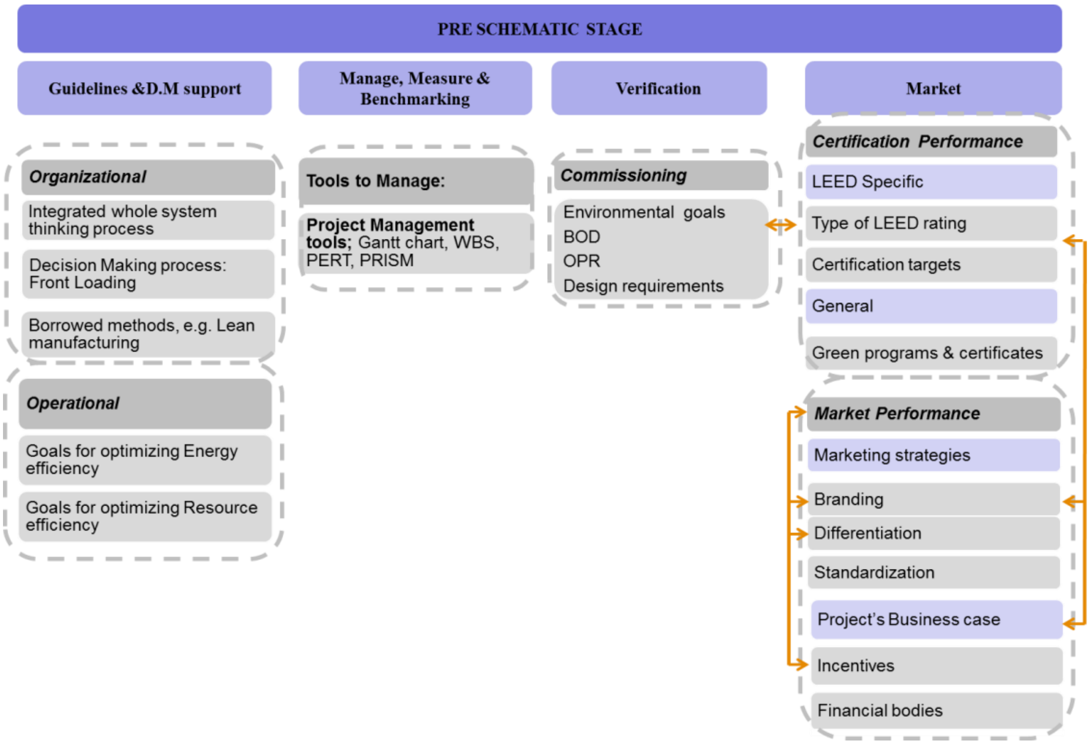


Figure 54: Structure of using LEED system in the pre-schematic phase

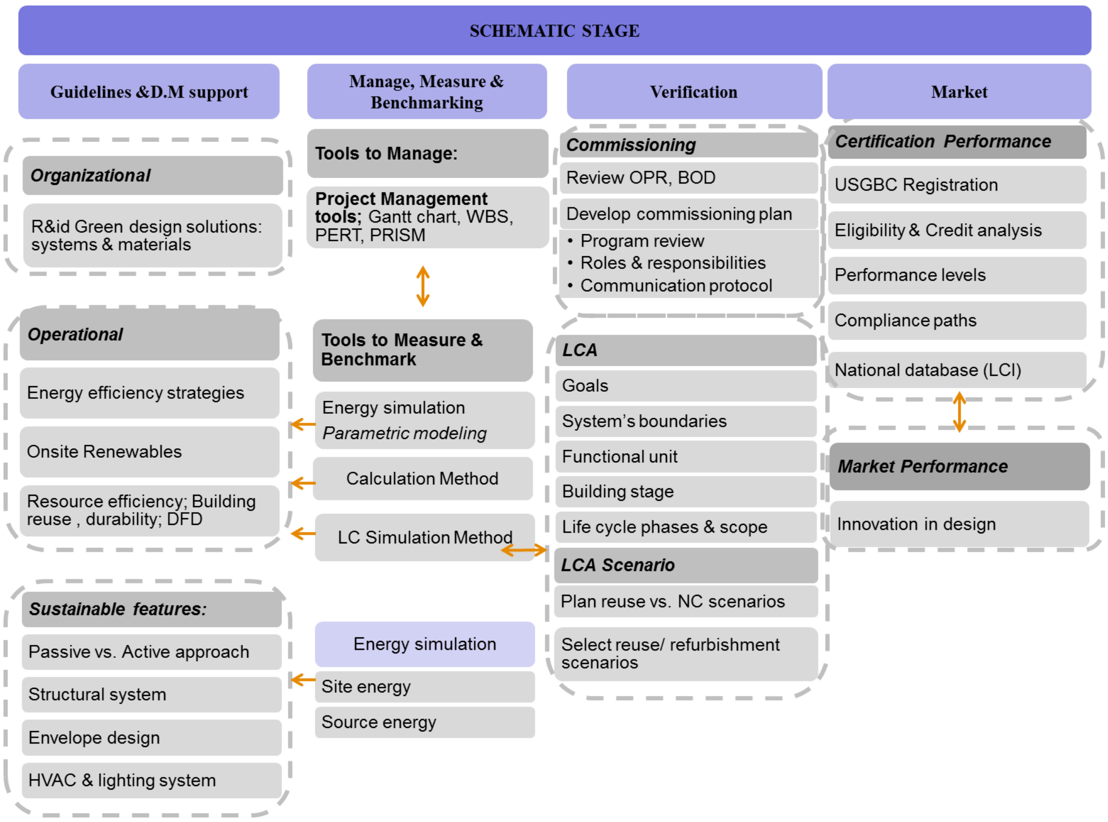


Figure 55: Structure of using LEED system in the schematic phase

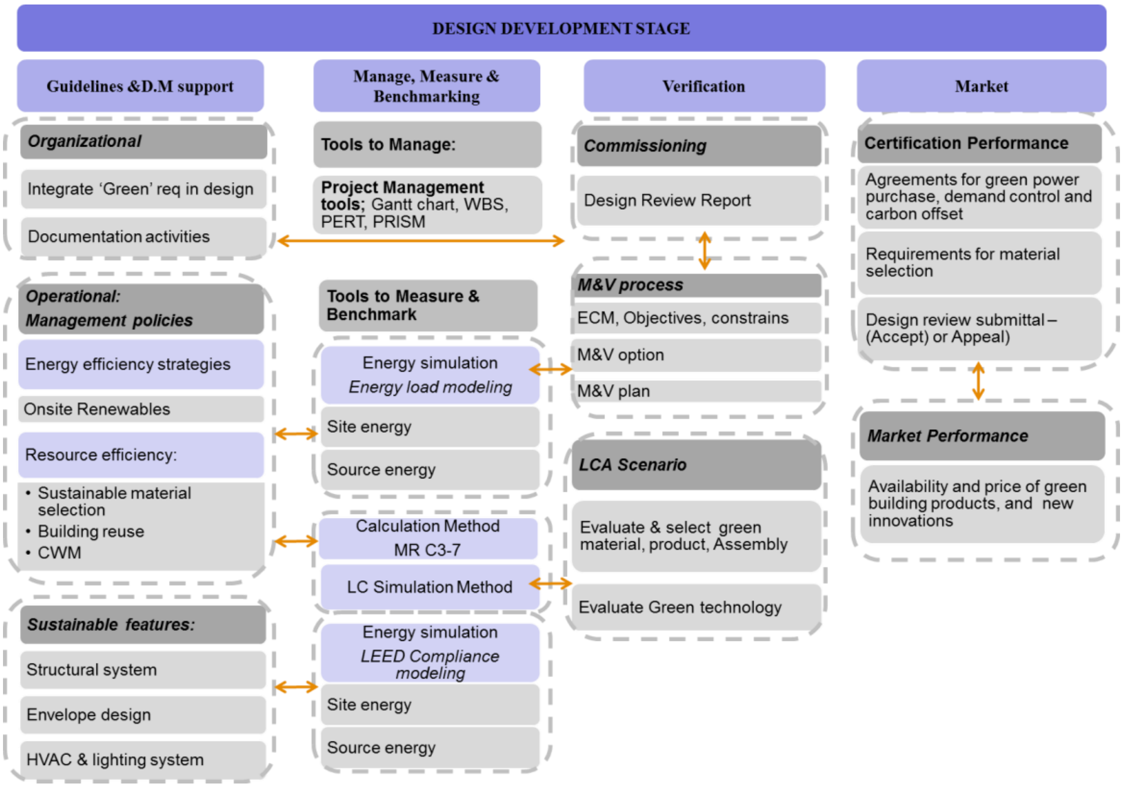


Figure 56: Structure of using LEED system in the design development phase

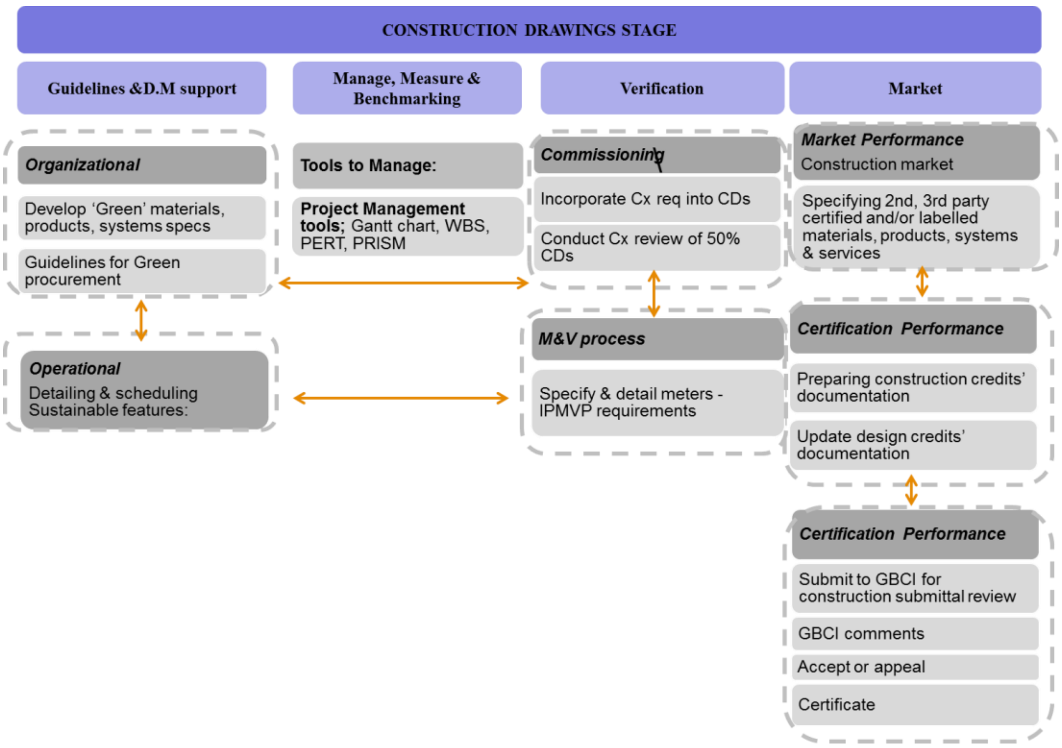


Figure 57: Structure of using LEED system in the construction drawing phase

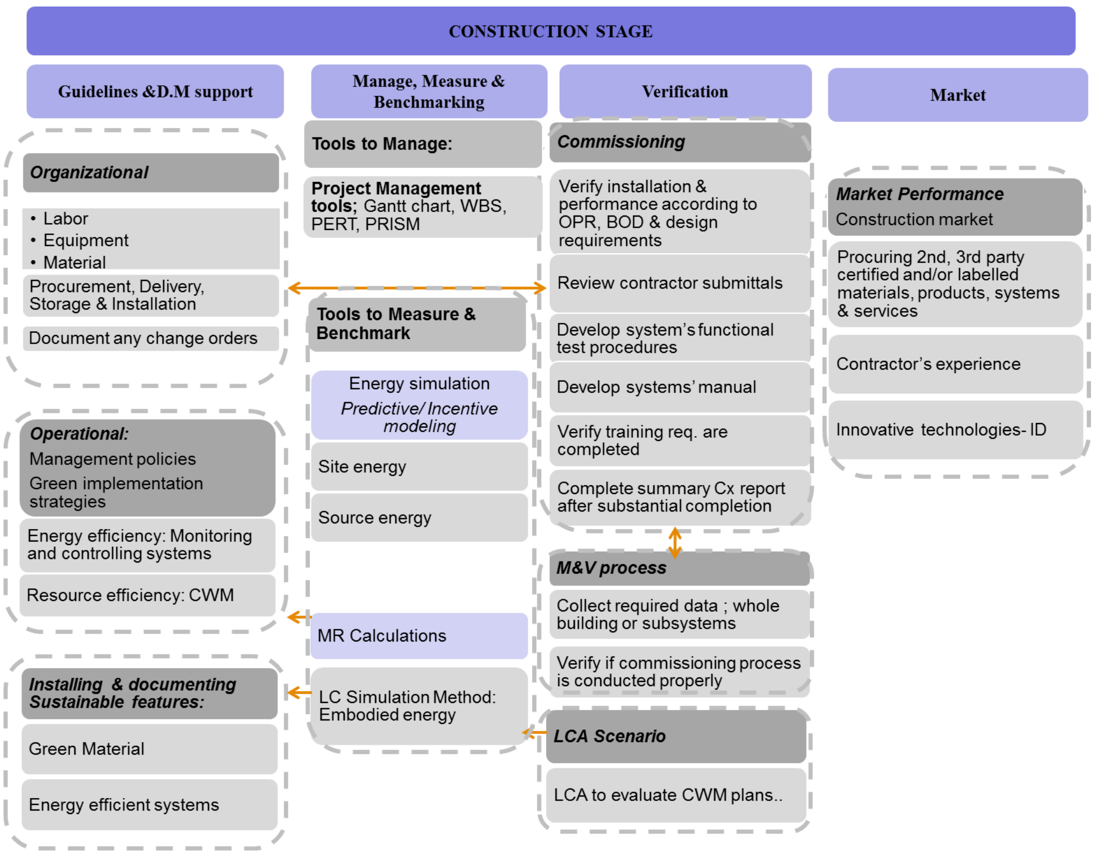


Figure 58: Structure of using LEED system in the construction phase

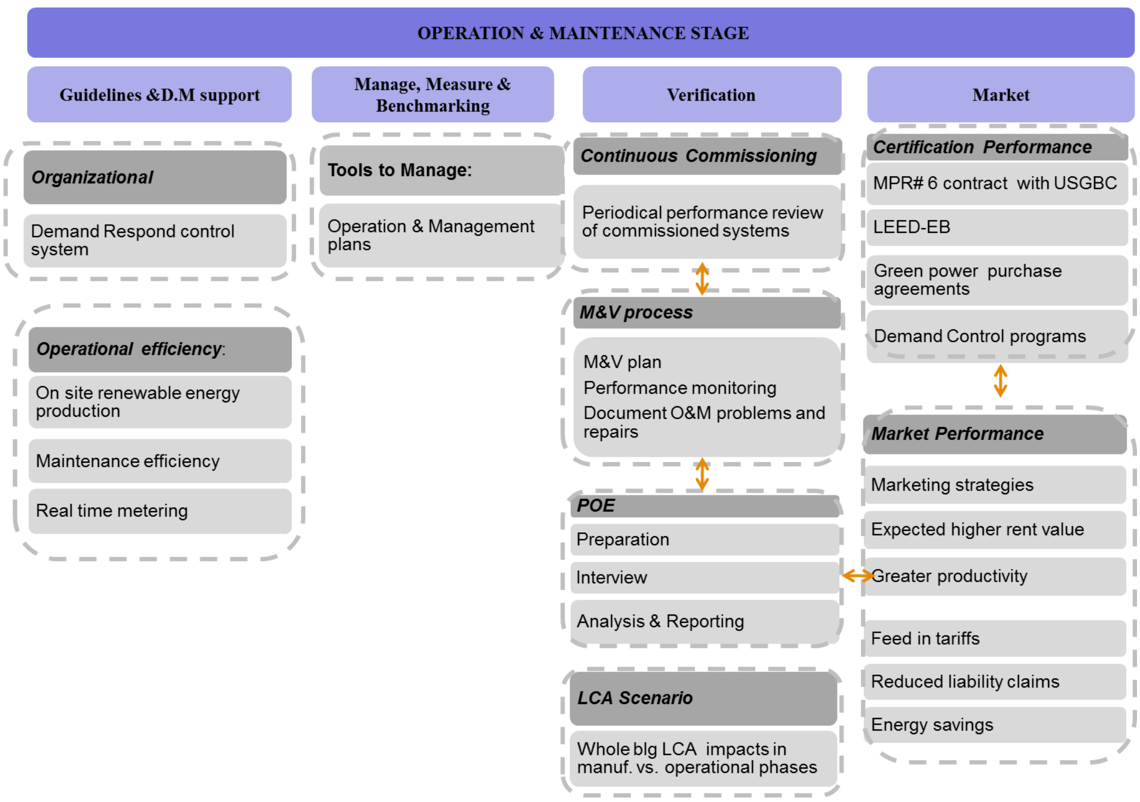


Figure 59: Structure of using LEED system in the operation and maintenance phase

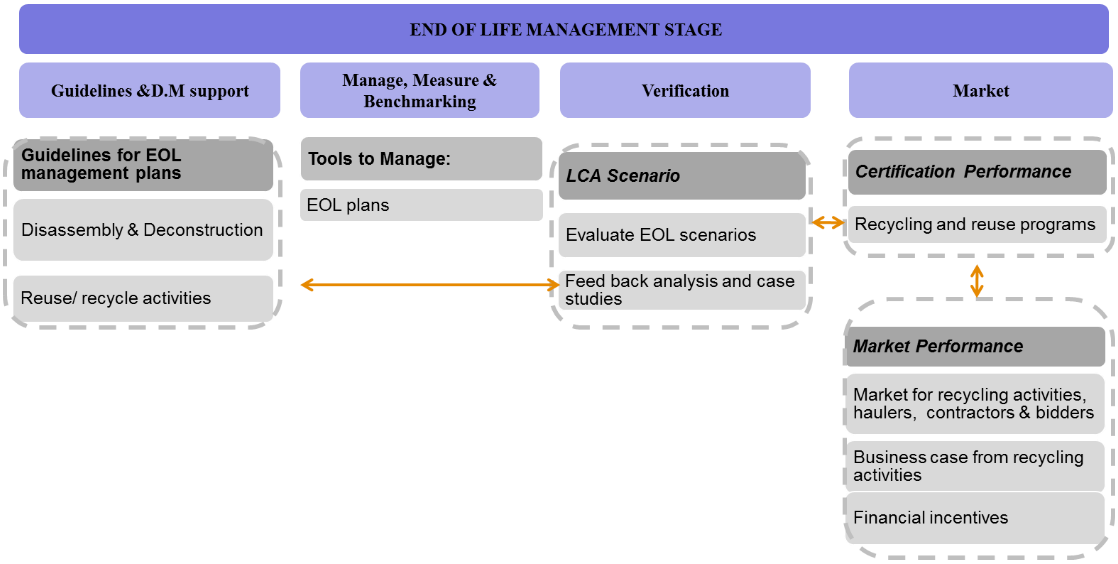


Figure 60: structure of using LEED system in the end of life phase

5.4. SUMMARY

Managing LEED process requires adding another dimension to the traditional building process- considering an integrated process with high level of quality management and coordination levels. It has significant impact on project costs, schedules, durations, and even administrative and contractual aspects. The traditional and the LEED building processes need to be integrated in a unified manner to make it easier and clearer for practitioners to use the LEED system as a guideline for sustainable building practices.

Applying the suggested framework should be based on a long term vision of building life cycle, along all stages of the building process including; front loading and iterative process wherever possible. This puts more weight on the early design decisions as explained along the chapter. The framework presented in this discussion explains how to integrate the LEED process in the traditional design process, based on identifying and developing the various scopes of application of the LEED system into the building process- taking energy and materials credits as the pilot focus of study.

It starts with investigating LEED guidelines for sustainable project management. This requires new methods for decision making process; additional roles and responsibilities assigned to project team members, new tools and models, as well as choosing appropriate project delivery methods, and managing specification and documentation activities to support the optimum material selection process.

Then, the research presents a step by step analysis for how to apply the framework along different stages of the building process. The summary of each discussion is presented briefly as follows;

The ‘Decision making process’ for sustainable project management using the LEED system should be based (and exceeds) the first scope (guidelines), while also considering the second scope (measurement and benchmarking criteria) for sustainable criteria, and the third scope (verification scope) which is an emerging requirement in the sustainable real estate market, thus, it is recommended to be employed for best use in order to raise the quality of the building process. It also depends on the fourth scope of LEED application, and investigates the market acceptance and readiness - creating the ‘value’ and setting the price of LEED certified projects in the global real estate market.

Additionally, these scopes should provide a clear guidance on how to choose design team members based on new tasks and responsibilities identified by the four scopes of applying LEED system- First scope requiring expertise to document and specify sustainable features, Measurement scope using simulation methods requires simulation expertise, Verification scope requires expertise to perform commissioning, M&V process and LCA methods, while Market scope requires expertise to integrate certification and market aspects, employ market strategies, as well as the ability to derive value, revenue and minimize risk and uncertainty perceived from green innovations.

Also, the Project Delivery method adopted must be able to cover all four scopes in order to make best use of the approach adopted. Documentation and specification must be clear from the beginning of the project- clearly mentioning guidelines that should be considered, sustainable criteria to be measured, method(s), scale and tool(s) of measurement, in addition to scope, benefits and limitations of verification methods adopted. This is in addition to clearly documenting the value of sustainable criteria used, their expected revenues and risk (uncertainty) perceived, along with any risk mitigation efforts. Material selection must be considered in the first scope as guidelines, supported by the fourth scope where the effect of the local sustainable market is clearly observed.

Applying the suggested framework for applying EA and MR credits along the building process shows that the first design stages has more stress on the fourth scope (market) because it includes important decisions related to the certification aspect, stakeholder's interest and investment potentials as well as market acceptance- this determines the type of rating system to follow, certification level and performance level required. Accordingly the first scope is defined to set sustainable design guidelines and compare them using the second scope (measurement and benchmarking methods). While, the role of the third scope (verification) starts from early stages to prepare for the scope, methods of the analysis, but contributes effectively in later design, construction and operation phases to verify sustainable building performance, and support the decision making process particularly for certain activities which takes place in specific building stages, hence identifying these activities and/or stages of concern might open up the road for more reliable performance results, and accordingly raising the building's value. This shall be better explained in the next chapter.

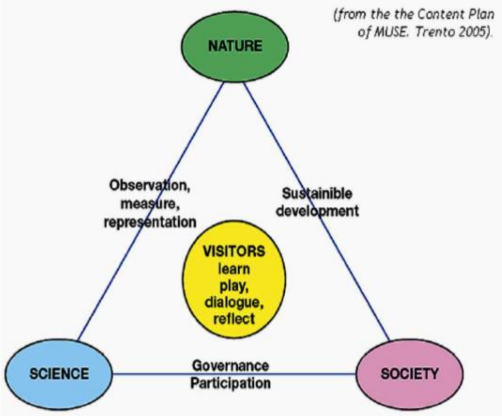
C H S I X

6 TESTING THE RESEARCH FRAMEWORK: ENERGY AND MATERIALS CREDITS

This chapter tests the proposed research framework discussed in chapter (4) and (5), for both energy and materials credits- on two case studies, in order to discuss the application of LEED system in the management process, as well as discussing points of concern regarding its adaptability to the Italian context, and its applicability to different building types and status of construction process (new construction versus existing building projects), as well as different LEED rating systems. The testing methodology explores how LEED system acts as guidelines for new construction and for existing buildings, and highlights variations for measuring and verifying energy and materials credits with particular focus on using LCA, and how this reflects on using LEED system for the other scopes. Finally, it investigates market forces affecting the decision making process for both cases. A final validation and adjustment step is done to improve the proposed research framework.

6.1. CASE STUDY 1: SCIENCE MUSEUM- TRENTO

The museum is the new science centre in Trento, designed by the famous architect Renzo Piano certified LEED Gold V2.2. This case study investigates the application of LEED GBRS to new construction buildings- a public museum[1].The museum building is considered an icon for its community, and a point of reference for studies, research and diffusion of the local history, with regards to its institutional, social, economic and cultural importance and preserve an educational role as well carrying a special emphasis on preserving the Alpine ecosystems, as indicated in the following diagram. Hence, it shall attract a huge number of visitors, and its visibility shall offer an opportunity to



[1] Owned by Castello SGR- a leading investment management company engaging in the design and execution of real estate investment strategies with a consolidated experience in national and international real estate and financial markets. It aims at creating value for investors through dynamic asset allocation. Its core business includes land development, asset renovation and dynamic and professional management of different asset classes and real estate portfolios, from leisure/hospitality to office and logistics.

Figure 61: Conceptual idea for the MUSE project

showcase environmentally responsible design and promote more innovative green design solutions.

6.1.1. LEED as a Guideline and Decision Making support Tool

The considerations taken place under this scope were not directly identified by LEED system, but surely they reflect on achieving points under LEED credits.

At the pre-schematic stage, organizational aspects were considered primarily at the beginning of the project, and this included defining the project goals, certification level, scope of work, roles and responsibilities for each team member, as well as defining the design approach.

First; taking decisions and gathering information about the project and its surrounding context. The site has been chosen; 11-hectare previously developed industrial area (Michelin tire factory) located adjacent to the Adige river. The projects is part of a complex of projects with other sustainable certification (residential complex certified casaclima[1], and a new project to be certified LEED Italia) as shown in figure (62) and (63). It consists of approximately 219400 m^2, on 5 floors above grade and 2 floors below grade. The ground floor area is freely open. It overlooks the park and connects to the palace of Albere. The first floor till the last floor houses the large temporary exhibitions, and the permanent exhibition of the Alps and glaciers, to finish at a large greenhouse with the African rainforest, and connects right, with the Adige river banks. The functional program of the project consists of; housing, leisure, commerce, office space, exhibition spaces, A small children’s area, a conference hall, laboratories, educational labs, a tropical greenhouse with large indoor tropical garden, a library and a café.

Figure 62: Museum context

Figure 63: Perspective diagram for the project

Applying LEED system was decided in early stages. The team also included around 2-3 LEED APs, who have directed the project in the right direction for LEED

[1] Casaclima provides an energy certification, and it is widely used in some Italian regions.

certification right from the start and almost with no change orders. The whole project was discussed early and integrally in the design process in order to reach energy and materials efficiency goals, exploring synergies and trade-offs solutions through design Charrettes, as well as front loading important decisions particularly related to energy efficiency. Yet, it should be noted that it was owing to the efforts of the project team members who applied these generalized guidelines efficiently within budget, i.e. estimated 2% increase in cost for applying and certifying LEED system

6.1.1.1. Guidelines for optimizing Energy efficiency

At the schematic phase, design approach started with site analysis as shown in figure (64), in order to optimize passive design solutions, thus design team gathered data concerning climatic data; solar radiation and sun path diagram, direct, diffuse and reflected daylight, including any effect from surrounding landscape/neighbouring areas - which all contribute to incident solar radiation, and/or insulation, wind rose showing direction of prevailing wind direction and velocity, local temperature means and extremes, rainfall, as well as relative humidity concerns.

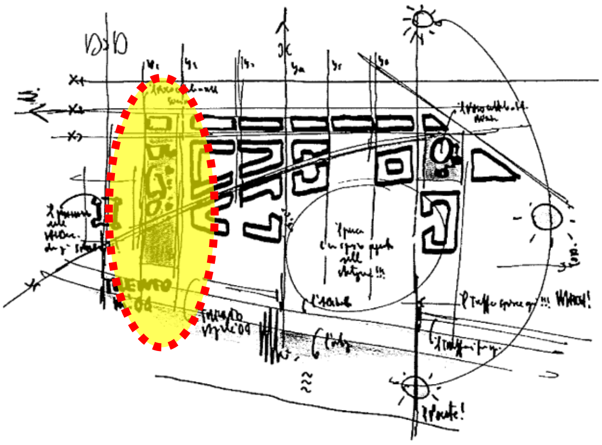


Figure 64: Pre-schematic studies showing the sun path diagram of the project

The preliminary decision making process was performed by the design office, who used schematic studies for site analysis, and modelling for massing and form decisions as shown in figures (65) and (66). Computer simulation were used during the detailed design stage, to guide for decisions mainly related to HVAC, lighting and control systems in order to comply with LEED credits' requirements. Energy Plus v2-2-0' was used for computer analysis which was found appropriate to the project type, size and complexity.

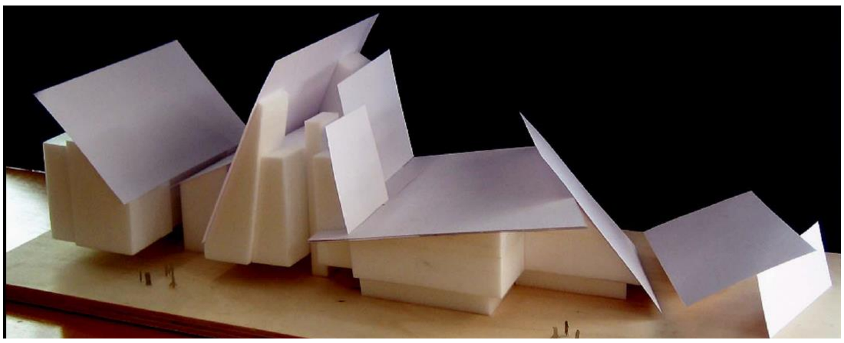


Figure 65: Schematic section showing massing and forms

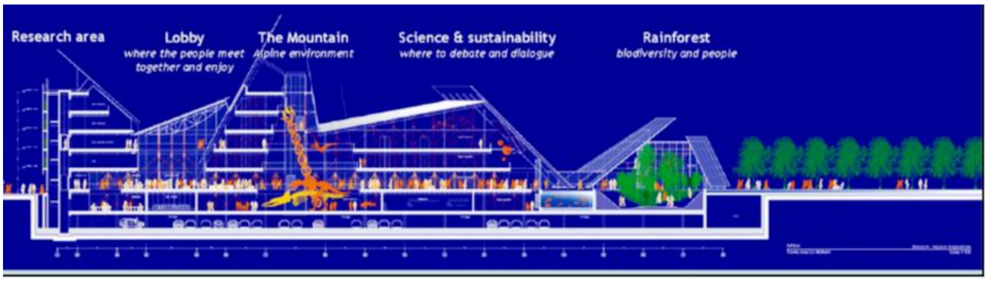


Figure 66: Section showing development of design details in the detailed design stage

This can be traced clearly through the design of both envelope and roof design- First: for *Envelope design:* they employed shading devices and fritted glass to limit heat gain and loss while providing natural light- employing dual glazed façade system. While, roof design played a significant role in developing an integrated sustainable solution that responds to the sun, rain and wind.

Next step was to discuss the functional program of the museum, and it is important to note that LEED system does not provide guidance, neither does it reward design considerations related to the requirements of each building type, as it considers it among the classical building design considerations left for each project team member to decide. Thus, design team focused on analyzing design requirements for each exhibit zone, function and considerations. This reflected directly particularly on lighting and HVAC system. Additionally, material selection has been decided early by the design office as part of the integrated design approach for the project and considering LEED requirements, for example; the use of bamboo in interior finishes- which also qualifies for MR C6; Rapidly renewable materials.

During design development, important decisions about lighting and ventilation systems were taken. They can be shortly explained as follows;

First; the lighting system: Project team developed a lighting concept based on a holistic approach that considers daylighting, heat gain and loss, lighting quality and reduced reliance on electric lighting. They worked on integrating day lighting strategies with the roof design, considering opportunities to penetrate the roof surface to allow natural light into inner spaces, and using roof overhangs to shade exterior walls from direct sun. In addition, the roof surface was used to generate energy with photovoltaic cells, and to capture and channel rain water for internal irrigational purpose.

The strategy was based on daylit zones, partially daylit zones and dark zones[1]. Additional level of concern was given towards direct and indirect beam day-lighting, in addition to separating lighting system into task and ambient applications wherever possible, with the indirect lighting for general ambient illumination. Also, the atrium was

[1] Most artifacts and exhibits are required to be displayed with indirect daylight, while dark zones were dedicated for exhibits that must have no daylight contribution.

used to create a stack effect that supports natural ventilation system, in addition to its part providing natural lighting.

Second; Energy efficiency strategies were integrated successfully in the museum environment because sophisticated building management systems and operations staff were typically already in place to meet the museum's tight environmental controls. Strategies included the following considerations and shown in figure (67):

- ☐ Mechanical system was designed according to multiple zones to enable systems serving different zones to adjust to variable occupancy or to scale back when unoccupied, with Variable flow pumping and air delivery.
- ☐ Air-to-air energy recovery was incorporated into all of the 12 air handling units; 7 of them had energy recovery wheels; the other 5 had plate-style air-to-air heat exchangers.
- ☐ Automatic Shading System was installed on the (East, South, and West) to limit solar heat gain. They were of two types: a) fabric roller-type shades on the vertical glass, and b) louver-blade type for horizontal building elements.
- ☐ Day lighting control to make use of natural light, Occupancy controlled ventilation and lighting systems, CO_2 sensors on various air handling units, and submetering systems.
- ☐ *Photo Voltaic (PV) System* consisting of four generators were installed on the rooftops and façades. Anticipated total annual energy production from the PV system of the Museum is 45,300 kWh/year. The energy produced is delivered to the local electrical utility.
- ☐ Additional consideration for fire protection and acoustics.

Some of these strategies directly contributed to achieving LEED EA Pr1, and EA C1; through including them in modelling the proposed building – while others, like the ground source heat pump system, occupancy sensors and CO_2 monitoring, were not included in modelling the proposed building, but had an indirect contribution to obtaining the credit through affecting other factors resulting in more energy efficient performance.

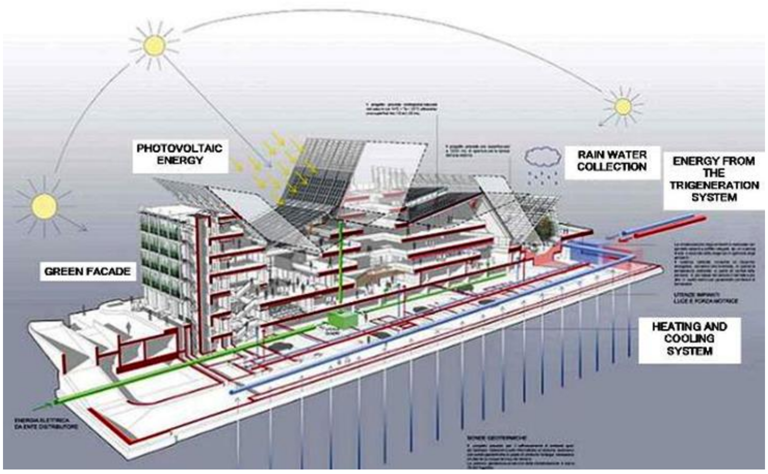


Figure 67: Schematic drawing explaining the project's sustainable design approach[1]

[1] Picture: *Green Building* Council Italia

Applying LEED system for the project was relatively easier than what the project team expected, and this was evident in earning higher certification level than what was planned[1]. This maybe explained due to the reason that the Italian context has already higher bar for sustainable requirements, and this is included in all building codes, especially for some regions- including Trento region- where sustainable requirements for building codes are even higher than in other regions. Nevertheless, complying with the regional building codes did not actually help satisfy the requirements of EA and MR credits, because both of them are calculated differently. Also, other considerations were required for complying with the building codes alone and were not included under LEED certification, e.g. simulation for fire protection and acoustics.

On the other hand, there were other challenges for obtaining LEED certification. The first one revolved around the difficulty to obtain the commissioning services in the Italian context when the project started some years ago, because commissioning agents were not easily available then, and this lead to increase in the additional price of the commissioning services, this was one of the main reasons that the project team decided to restrict the commissioning services only on EA Pr1 (Fundamental Commissioning), and not to extend it to EA C1 (Enhanced Commissioning), and this is also one of the reasons that the project did not attempt M&V credit. Yet, it is worth mentioning that this problem is diminishing by time due to more demand for commissioning services which is encouraging more companies to provide such sustainable building services- but it is still not so for M&V process.

The second problem occurred during LEED review due to the reason that the building is a part of a complex of buildings and depends on district thermal energy system as shown in appendix (C) – and the building being a museum building had a lot of process load, this was challenging for practitioners to satisfy credit requirement, but this has changed now under LEED V3.0- which has considered district thermal energy systems.

6.1.1.2. Guidelines for optimizing Materials and Resource efficiency

a. **Design for flexibility:** this aspect although not covered by the LEED system, but it is considered an important design consideration for museum buildings to cope with the changing space requirements of exhibitions, for example - high floor-to-floor, modular structural grid, raised floor, 'plug and play' MEP systems. In addition, adopting this design approach shall minimize future waste generation resulting from change is use type or pattern, requirements of exhibition spaces, as well as employing new technologies.

b. Material selection: the design office based its criteria for material selection on using durable, low maintenance materials that meet sustainable criteria and meet the

[1] A Silver LEED certification was expected, but finally the project obtained Gold level.

expected building relatively long life span (50-100 years) requirements, and at the same time comply with LEED MR requirements for using recycled, regional, rapidly renewable materials and certified wood products. e.g. Titanium zinc[1], Verdello stone, bamboo, and cork as shown in figure (68).

Figure 68: Cork sheets used in the project

c. *Waste management:*

This credit relies greatly on the project situation and the experience of the contractor to be able to divert construction waste from landfill, balancing between fees for landfill, and means of diversion.

According to LEED system guidelines, the project approach sets a plan for comprehensive in-building recycling, to allow for easy collection, sorting, baling and picking up of discarded items as shown in figure (69)- providing crate storage and repair areas for exhibit crates to be used by exhibitors. On the project site, in designated areas, the General Contractor (GC) organized covered containers and bins clearly marked with the name and code CER (Code European Waste) of the waste content. The (GC) of this project developed and implemented a Construction Waste Management Plan (CWMP) that identifies the waste materials to be diverted from disposal and whether the materials will be sorted on-site or commingled, then set contracts with qualified waste haulers (BIANCHI, RIGOTTI) to pick up the waste containers and to move them to recycling firms.

For each hauled container the General Contractor develops a 'Waste Identification Form' also called 'FIR' in Italian [2]- which is a document numbered and stamped, which accompanies the transport of waste carried out by qualified waste haulers and provides traceability of the waste stream in various stages of transport from the producer to the target site. It contains all the necessary data for identification of those involved in transport, vehicles and nature and amount of waste. The GC held orientation meetings

[1] Zinc is a malleable sheet metal that has been used on the exterior of European buildings for a long time ago- as a natural weathering metal, with a long service life (varies by application type), besides its ease of fabrication, clear storm-water runoff, maintenance free, economical first cost, high salvage value, & time-tested performance. It has a low embodied energy compared to other architectural metals. Capable of eliminating all waste (100% scrap recycling is possible), source: http://www.designandbuildwithmetal.com/FeaturedArticles/Articles/zinc_cladding_the_value_and_future_of_light_gauge_gray.aspx

[2] It is also called FIR (Formulario di Identificazione Rifiuto)

with construction team to explain Construction Waste Management Plan requirements and submittal documentation to Subcontractors. The plan recommended separating plastics, metals, paper, cardboard, glass, organics, batteries and lamps, showing of recycling materials paths and circulation on level -2.

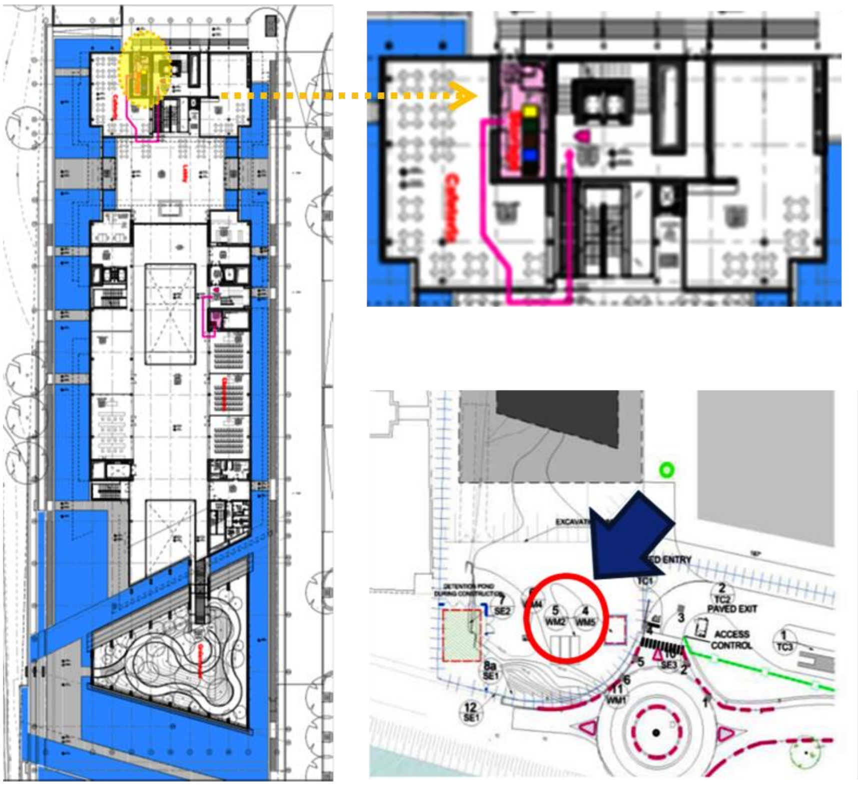


Figure 69: The figure shows spaces dedicated for recycling in the building (to comply with MR Pre1), and others for onsite waste management (MR C2)

6.1.2. LEED as a Measurement and Benchmarking Tool for sustainable building performance

The simulation has been done by systems' designers[1], internal to the project. The research presents the calculation method performed by design team to comply with LEED credits. The full calculations for EA and MR credits' compliance can be found in appendix C

6.1.2.1. Measurement and Benchmarking for Energy Credits

a. EA Pre 2: Minimum energy performance- EA C1: Optimize energy performance

Energy type	Proposed design			Baseline design			Percentage savings	
	Energy Use		Cost ($)	Energy Use		Cost	Energy Use (%)	Cost (%)
Electricity	1,308,394	kWh	231,586	1,492,231	kWh	263,783	12.3	12.2
Purchased Heating	150,097	kWh	16,210	327,113	kWh	35,331	54.1	54.1
Purchased	345,205	kWh	51,436	413,388	kWh	61,599	16.5	16.5

[1] Manens - Tifs

Cooling								
Subtotal (model output)	6,154	MBtu/ year	299,232	7,618	MBtu/ year	360,713	19.2	17

Table 23: Calculating Energy Cost and Consumption by Energy Type- Performance Rating Method for EA Pre 2 & EA C1

Estimated energy savings were calculated as follows in the following table, as a result the project was eligible with EA Pre1, and obtained 2 points under EA C1.

b. EA Credit 2: On-Site Renewable Energy

Option 1 - The model results from EA Credit 1 are used to project the annual building energy costs for the project.

	Energy generated		Renewable energy cost					
Onsite renewable energy	45,331	kWh	8,023	(subtracted from model results to reflect Proposes building performance)				
	Proposed design			Baseline design			Percentage savings	
	Energy use		cost	Energy use		Cost	Energy	Cost
Subtotal	6,892	MBtu/ year	243,382	6,843	MBtu/ year	316,319	-7	23.1
Total	52,224		251,406					

Table 24: Calculating Onsite renewable energy for EA C2

Percentage Renewable Energy (100 x Renewable Energy Cost / Building Annual Energy Cost) = 100* (8,023/243,382) = 3.19%, Which is eligible for one point under EA C2

c. EA C6: Green Power

Purchase Type	**Green Power / Green-eTradable Renewable Certificate Provider Name**	**Annual Green Power Purchased**	**Contract Term (yrs)**
Green-e certified power provider	TRENTA ENERGIA RINNOVABILE - RECS[1]	1000000	2

Table 25: Calculating Green power for EA C6

The project estimated electricity consumption is 1,308,394 kWh,

Thus, the percentage Green Power (over a 2-year contract period): 76.4%

This makes it eligible for 1 points under EA C6, and 1 exemplary point under ID.

Analysing EA credits' calculation

The project's scores under EA credits show that the project was not able to achieve more points under EA C1 because LEED V2.2 was not able to understand the project's particular case for accounting for energy consumption of a district central heating plant[2], and inspite that the project employed many energy

[1] Renewable Energy Certificates

[2] It is worth mentioning that the following LEED version considered this situation, and provided guidelines that would consider projects with district heating plants.

efficient strategies, but they were not eligible for compliance under LEED requirements, e.g. CO_2 *monitors and control.*

This indicates that complying with EA measurement requirements for LEED certification was challenging. Thus obtaining a total of 7/16 (including the ID points, and excluding atmosphere credits) i.e. its adoption rate can be estimated to be 43.75% for LEED EA category, which is as low as estimated by some international studies cited in chapter three.

6.1.2.2. Measurement and Benchmarking for Materials and Resources Credits

a. MR Credit 2.1 (50%) ,2.2 (75%): Construction Waste Management

Total Construction waste generated= 992.54 tons

Total Construction waste diverted= 934.25 tons

Therefore, Total percentage of construction waste diverted from landfill= 94.127%, which is eligible for 2 points under MR C2, and 1 point under ID.

Then, in order to calculate MR C4-7:

Based on the Default Materials Value (45% of total construction cost (excluding labor and equipment))- (hard costs for CSI Master Format 1995 Divisions 2-10 only)

Total construction cost= 42,536,226.98 dollars
Default materials cost (total construction cost x 0.45)= 19,141,302.141 dollars

b. MR Credit 4.1 (10%), 4.2 (20%): Recycled Content:

Total value ($) of post-consumer content= 3,274,333.78

Total value ($) of pre-consumer content= 1,952,020.2499

Total combined recycled content value ($): post-consumer + 1/2 pre-consumer= 4,250,343.9

Combined Recycled Content Value as a percentage of Total Materials Cost= 22.2 %, which is eligible for 2 points under MR C4.

c. MR C5 (10%- 20%): Regional Materials

Total value ($) of locally manufactured and extracted materials: 5,986,171.4

Local material value as a percentage of total materials cost: = 31.274%, which is eligible for 2 points under MR C5.

d. MR Credit 6 (2.5%) : Rapidly Renewable Materials

Total value ($) of rapidly renewable materials= 1,109,584.2

Rapidly renewable material value as a percentage of total materials cost= 5.797%, which is eligible for 1 point under MR C6, and 1 exemplary point in ID.

e. MR C7: Certified Wood products

Total Value of Wood Components: $780,599.00

Total Value of FSC Certified Wood Components: $408,732.00

FSC Certified Wood Value as a Percentage of Total new Wood-Based Cost: 52.361%, which is eligible for 1 point under MR C7.

Analysing MR credits' calculation

Analysing the project's scores under MR credits show that the project was not able to achieve MR C1 because it did not constitute any refurbishment activities (it was all new construction), neither did it attempt MR C3, because of the nature of the project owner's requirements, and the market availability[1]. The project scored higher percentage than MR C2 requirements owing to the contractor's competence, as well as common best practices for recycling activities. Although MR C4 is not considered an easy to achieve/document credit, but team members managed to adequately reach the threshold required, and requirements for MR C5 was exceeded due to availability of sustainable building products in the local market. MR C6 and MR C7 were exceeded as well; with the use of Bamboo, and FSC certified wood (respectively)- because considerations of sustainable material selection and procurement process was considered in early project phases. Yet, project team members note that it was to some extent challenging- not to specify but to document the required materials.

This indicates that scope 2 (measurement) is affected by the availability of sustainable materials, as well as the availability of data confirming their environmental features, i.e. by scope 4 (market). Consequently it leads scope 1 (guideline) and affects design decisions for determining the type and quantities of materials required. Potentials for ID were achieved for MR C2, and MR C6. Thus obtaining a total of 10/13 (including the ID points), i.e. its adoption rate can be estimated to be 77% for LEED MR category, which is a higher percentage compared to international studies presented in chapter three

6.1.3. LEED as a verification Tool

The project employed LEED system as a verification tool through EA Pre 1: fundamental commissioning process (and not EA C3: Enhanced Commissioning), while the project did not attempt EA C5: Measurement and Verification, nor was it required to conduct a POE process, and neither LCA in LEED NC V2.2. hence, the research shall analyse the results of verification methods employed, i.e. the commissioning process, and adds the use of LCA for decision making process.

[1] It should be noted that this does not give an absolute indication that the project did not employ used materials, but the score indicates only that the project was not eligible for this credit.

6.1.3.1. EA Pre 1: Fundamental Commissioning of the Building Energy Systems

The commissioning process was done by external parties[1] as required by LEED system. Systems Commissioned were: Air Handling Supply, Exhaust, and Energy Recovery, Primary Heating Water, Primary Chilled Water, Heating and Chilled Water Distribution, Radiant Ceiling Heating and Cooling, Hydronic Fan Coil Units, Ground-source Heat Pumps, Automatic Shading System, Day Lighting and Lighting Controls, Photo Voltaic (PV) System, Domestic Water Heating System, and controls associated with these systems.

Results of the commissioning process revealed that the Museum's commissioned systems were operating in a stable and appropriate manner in accordance with the project requirements. Functional testing has been conducted with good results. The HVAC and lighting systems have been tested to guarantee appropriate and stable operation. The Commissioning Report identified several outstanding issues, which were resolved and documented through the Follow-up testing, i.e. the winter testing revealed potential insufficient cooling in a few South exposure rooms, and provided direction to the project team on how to resolve this issue.

Deficiencies and associated corrections

The following list identifies some of the issues addressed and resolved:

- ☐ Radiant Ceiling Heating and Cooling valves could be open at the same time, Thus, they implemented controls changes to provide a 5 minute delay for valve opening after initial call for cooling or water flow.
- ☐ Some photocell strings were not operating.
- ☐ Controls Systems Graphics: corrections were made to the graphics
- ☐ Pump Support: a support was added to the pump motor

6.1.3.2. LCA study

Applying LEED as a Verification tool (scope 3) requires using more integrated methods to support the decision making process. Hence, The research recommends using LCA in the design development phase to explore the environmental impact of the specified assemblies, then to support the decision making for materials' selection to comply with MR C4,5 and 6- in order to be able to compare between materials/products considering their life cycle environmental impact, additionally, for MR C2 to prioritize materials for diversion which have the higher embodied energy and higher potential for recycling.

[1] FTC & H in the United States

a. As a first step, exploring the environmental impact of the specified assemblies

	EE	EC
03200 reinforcing steel	24,848,084.83	1,270,640.70
03300 cast in place concrete/ 03500 cementitious deck and underlayment	32,811,120.00	4,822,011.60
05100 structural metal framing	5,120,000.00	242,460.00
05300 metal deck	193,010.48	11,147.19
06100 rough carpentary	601,771.80	39,273.53
07200 thermal protection	1,080,056.00	51,302.66
08800 glazing	6,375.00	386.75
09600 flooring	624.42	84,921.09
09700 wall finishes	654,777.60	42,560.54

Table 26: The environmental impact of the specified materials/ products

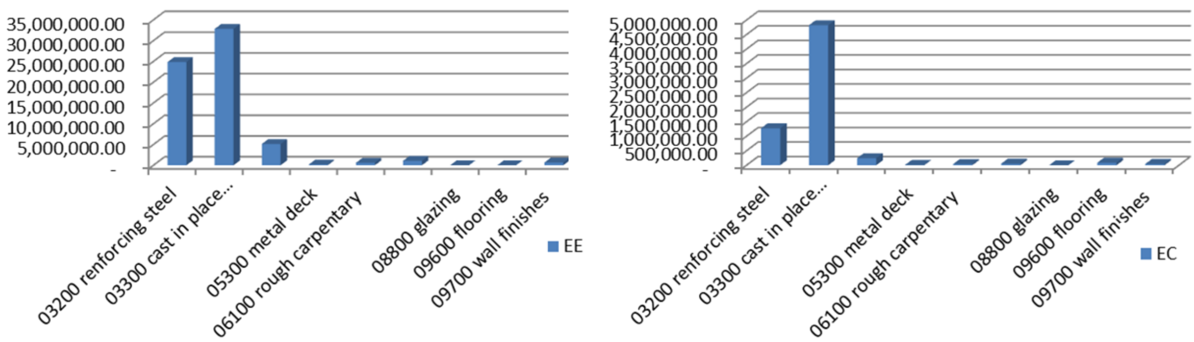


Figure 70: The environmental impact of the specified building assemblies

The graph shows that concrete material quantities have most significant environmental impact, followed by reinforcing steel, while the other material quantities have minor impact. This would have highlighted possible areas of intervention to reduce negative environmental impact – mainly from the use of concrete and reinforced steel during early design stages.

b. Using LCA for MR C4, 5, 6

The aim should be to correlate MR credits LCA with LEED calculations based on materials' cost, to choose among materials and products for credit compliance. Thus, cost, embodied energy (EE), and embodied carbon (EC) were normalized into percentage of the total materials contribution for each credit's compliance. This shall enable a better decision making process based on relating the percentage of materials' contribution to achieving the credit to its actual environmental effect.

LCA for MR C4: Recycled Content Materials

Studying the Italian context construction materials and products' market presents some interesting indications; post-consumer recycled content were mainly achieved through reinforced steel (90-98%) and Titanium zinc (60%), while pre-consumer recycled content were mainly achieved through cast in place concrete (43-48%), and other forms of steel products (40-60%). This indicates the environmental considerations paid for materials' selection[1].

In order to verify environmental decisions related to this credit, this type of analysis calculates the avoided impact from using recycled content for the specified weight of materials contributing to obtain the credit- instead of using virgin materials.

	Total avoided EE (MJ)	**Total avoided EC (kgCO2e)**
Reinforcing steel	56,150,798.52	6,385,777.09
Cast in place concrete/ Cementious deck & underlayment	12,960,549.02	2,028,544.78
Structural metal framing (Steel)	7,223,520.00	674,630.40
Metal deck (Titanium Zinc)	1,062,613.83	61,740.28
Glazing	101.30	9.26
Total	77,397,582.68	9,150,701.81

Table 27: Calculating the avoided Impact from using recycled content materials

Then, comparing their contribution again to LEED MR C4 requirements in percentage as shown in the following table;

MR C4 : Recycled Content Materials			
	% EE of avoided impact	% EC of avoid impact	% LEED (cost)
03200 Reinforcing steel	72.55	69.78	48.76
03300 Cast in place concrete/ 03500 Cementious deck & underlaym	16.75	22.17	10.82
05100 Structural metal framing (Steel	9.33	7.37	24.15
05300 Metal deck (Titanium Zinc)	1.37	0.67	15.03
08800 Glazing	0.00	0.00	1.25

Table 28: Comparing the percentage share contribution of avoided impact of recycled content materials with their contribution to LEED MR C4

[1] Choosing Steel which is a 100% recycled content, and its recycling process is relatively easy. Also, Aluminium Recycled content material use only 5-25% of the energy required to produce new material, which creates a good opportunity for promoting recycled content aluminium materials for many purposes. Glass can be post and/or pre consumer recycled, and it can be used for primary or secondary use (Lavagna, 2008 p. 195, 197).

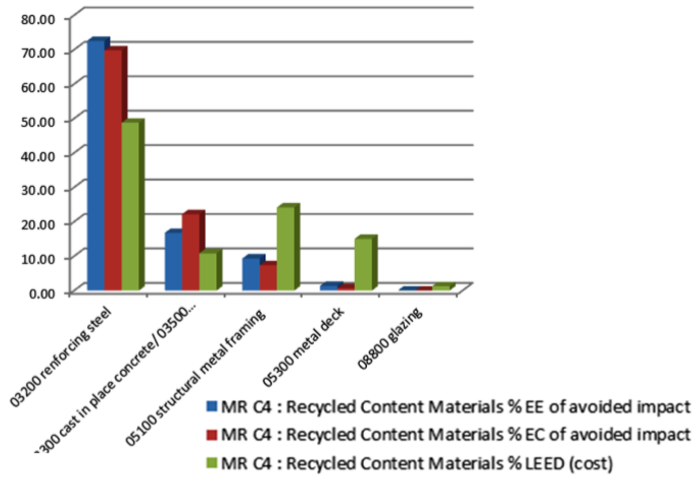


Figure 71: Comparing the percentage share contribution of avoided impact of recycled content materials with their contribution to LEED MR C4

Figure (71) shows that comparing the avoided impact from reinforced steel, and cast in place concrete are underestimated according to LEED calculation method, while LEED system overestimates the impact from structural metal framing and metal deck, compared to their real contribution in the overall avoided impact from using recycled content.

Hence, the optimum decision making would create a directly proportional correlation between environmental impacts and LEED credit contribution.

Using LCA for MR C5: Regional Materials

MR C5: Regional Materials	EE (%)	EC (%)	LEED (%cost)
03200 Reinforcing steel	26.85	26.92	31.64
03300 Cast in place concrete/ 03500 Cementitious deck and underlayment	30.56	26.47	34.90
05300 Metal deck (Titanium Zinc)	4.45	2.57	12.19
06100 Rough carpentry (legno lamellare)	10.87	12.56	3.71
08800 Glazing	0.02	0.03	4.97
09700 Wall finishes (Botticino stone)	27.24	31.45	12.59

Table 29: Comparing the percentage share contribution of EE and EC of regional materials with their contribution to LEED MR C5

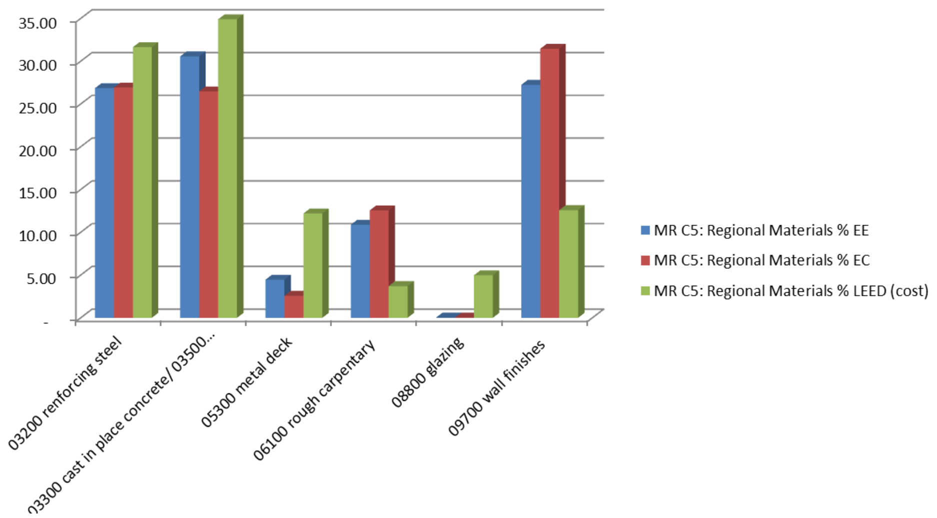


Figure 72: Comparing the percentage share contribution of EE and EC of regional materials with their contribution to LEED MR C5

It is noticeable that regional materials contributing for this credit were mainly resulting from cast in place concrete and reinforcing steel[1], yet, at the same time, they hold the greater environmental impact- which requires reconsideration for their environmental impact [2] to balance materials contributing the highest with LEED requirements with the lowest environmental impact resulting from transportation.

Hence, the optimum decision making would create an inversely proportional correlation between environmental impacts and LEED credit contribution.

Using LCA for MR C6: Rapidly Renewable Materials

Rapidly renewable materials were mainly resulting from using cork thermal insulation, and bamboo flooring[3], and the optimum decision making should create an inversely proportional correlation between environmental impacts and LEED credit contribution.

MR C6: Rapidly renewable Materials	EE	EC	LEED (cost)
07200 Thermal protection (Sughero corkpan)	99.96	95.35	71.60
09600 Flooring (Bamboo)	0.04	4.65	28.40

Table 30: Comparing the percentage share contribution of EE and EC of rapidly renewable materials with their contribution to LEED MR C6

[1] It should be noted that this credit should have taken into consideration the environmental impact for the materials not contributing to achieving the credit as well, but due to lack of data, it was not performed.
[2] End of life scenarios for laminated wood is not possible due to the gluing, while Hard wood can (Lavagna, 2008 p. 203). This is why this aspect has to be considered when choosing the proper construction method.
[3] Cork is considered a rapidly renewable material, every 8-10 years. Without gluing, it can be reused, recycled and composted (Lavagna, 2008 p. 213).
The problem with using bamboo is the high environmental impact caused by transportation http://www.usgbccolorado.com/news-events/documents/LCA.pdf

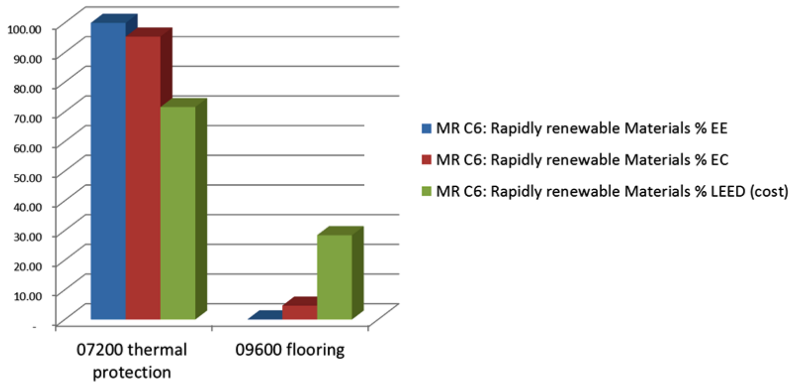


Figure 73: Comparing the percentage share contribution of EE and EC of rapidly renewable materials with their contribution to LEED MR C6

Figure (73) shows that more LEED credit contribution results from using cork for the thermal insulation, while on the other hand cork has relatively higher environmental impact than Bamboo (disregarding the effect from transportation)- so this decision has to be reconsidered again to find materials that can achieve both objectives; more contribution for LEED credits and less environmental impact.

c. Using LCA for MR C2: Construction waste management plan

At the construction phase, LCA may be used to guide decisions related to conducting a construction waste management plan with environmental consideration.

	LCA Calculations		**LEED Calculation**
	% Embodied energy of whole credit	**% Embodied carbon of whole credit**	**% Material weight (kg) of whole credit**
Concrete (CER 17 01 01)	1.32	1.40	34.59
Bricks	1.00	1.06	26.27
Tiles	0.40	0.43	10.51
Ceramics	0.20	0.21	5.25
Wood (CER 17 02 01)	27.53	33.50	11.95
Glass (CER 17 02 02)	0.71	1.10	0.44
Iron and Steel (CER 17 04 05)	26.81	41.93	5.44
Cardboard (CER 15 01 01)	13.79		2.41
Plastic packaging (CER 15 01 02)	25.52	17.73	1.38
Plasterboard (CER 17 08 02)	2.71	2.64	1.74

Table 31 Comparing the percentage share contribution of EE and EC of construction waste materials with their contribution to LEED MR C2

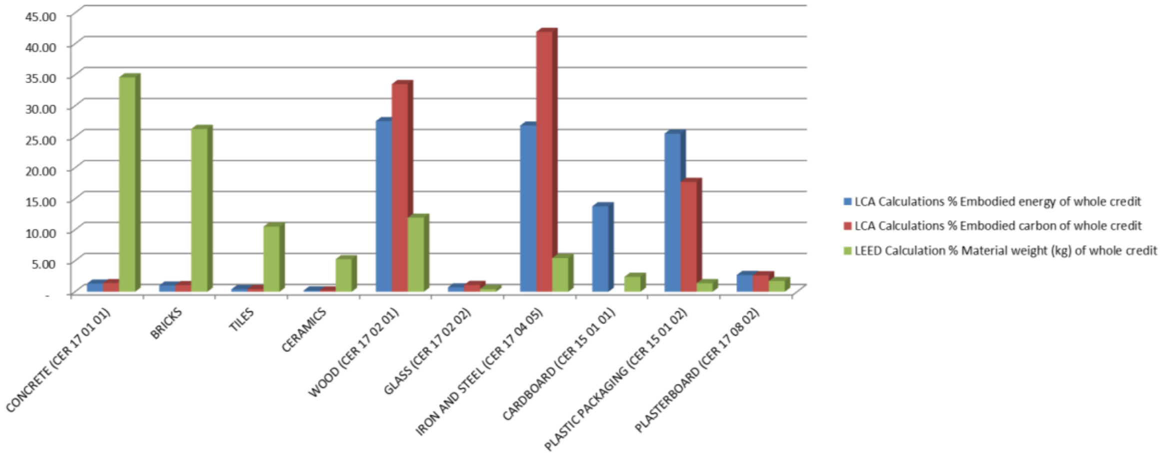


Figure 74: Comparing the percentage share contribution of EE and EC of construction waste materials with their contribution to LEED MR C2

This analysis may help prioritise materials for diversion plans according to the 'avoided impact principle'. The aim should be to relate the contribution of each salvaged material to obtain LEED MR C2 by cost, with its environmental impact. The optimum case is to obtain a directly proportional relationship; where the highest material weight contributing to LEED credit compliance, should have the highest LCA impact. Nevertheless, this might be difficult for the case of concrete, bricks, and tiles & ceramics, because their significant contribution for credit compliance (by weight, or volume), is not correlated with their reduced environmental impact for their secondary use as aggregates, and hence they contribute a considerable amount of the total credit weight inspite of their comparably lower embodied energy and embodied carbon. The opposite case is clear for wood, as well as iron and steel, because their contribution for credit compliance underestimates the larger amount of embodied energy and embodied carbon they possess.

This means that the CWM plan actually converts 76% into a lower grade component. On the other hand, recycling wood, as well as iron and steel represents 5% of the total waste weight, which may contribute in producing new recycled materials with good material quality to extend their original life cycle[1], and the same is applicable for paperboard and cardboard. This indicates that the plan mainly aims at diverting construction waste materials from landfill, but more concern should be paid to the diversion route and expected value of the materials diverted for recycling.

Correlating LCA and LEED credit analysis

On the material level; this analysis investigates the correlation between the environmental impact (embodied energy and embodied carbon) arising from the materials contributing to LEED MR category calculation. It shows that it is difficult to obtain a

[1] Recycling wood is most beneficial when it is possible to extract the original wood material from any gluing or additives, or else, they are recycled into lower grade wood products

relation between environmental effect and cost of materials to comply with LEED credit requirements, yet the optimum decision making process would seek to achieve a directly proportional relationship between the environmental impact calculated, and LEED credit contribution for MR C2 and MR C4, while an inversely proportional relationship with MR C5 and MR C6, also, attention should be paid especially when dealing with certain materials as indicated in the study.

On the LEED credit level; LEED MR C4 and MR C5 have equal weighting, and double that of MR C6. This analysis was used to correlate LEED credit weighting with LCA results, in order to be able to direct practitioners for credit compliance, synergies and trade-offs scenarios. It can be observed that comparing between MR C4,5,6; the highest price paid for MR C5- the lowest environmental impact achieved, but the total material price was not an indicator for environmental impact in the case of MR C4.

	LCA		**LEED**
	Sum EE for credit	**Sum EC for credit**	**Sum price of credit calculation**
MR C4	28,476,646.62	1,464,393.98	4,250,345.00
MR C5	785,745.02	41,707.74	5,986,174.00
MR C6	1,080,497.11	111,293.44	1,029,008.00

Table 32: Co-relating LEED and LCA analysis

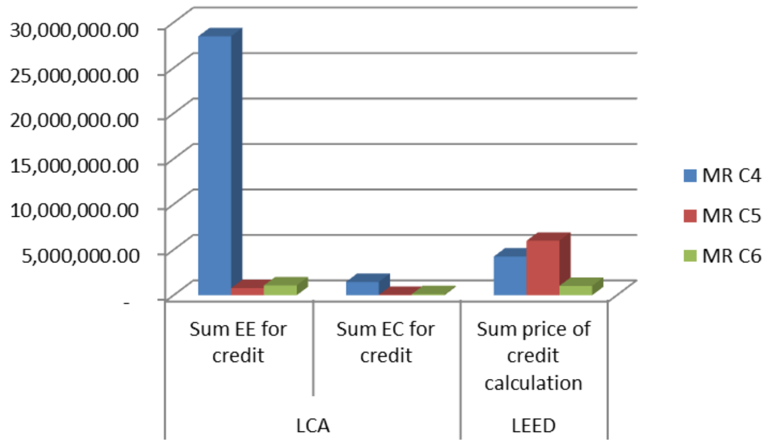


Figure 75: Co-relating LEED and LCA analysis

6.1.4. LEED as a Certification & Market Tool

6.1.4.1. Certification scheme performance

LEED certification is currently mandatory for new construction public buildings in the province of Trento- this maybe one of the primary reasons behind adopting LEED certification on the level of this regional real estate market- to act as a mean of environmental stewardship. Hence, the decision to pursue LEED NC certification was performed at the early pre-schematic phases, and this included setting a certification goal (Silver) and accordingly performance targets, identifying the scope of work, including LEED credits which were obtainable, call in the necessary expertise, define the tools and methods required, setting time and budget plans. It is worth noting that at project completion, it was eligible for a higher certification level (Gold) which allows for more market visibility to act as an environmental stewardship.

6.1.4.2. Market performance

Investigating the market performance for this project requires considering both the regional as well as the global real estate market. Through earning the LEED Gold certification, the project made use of the LEED brand name, as a mean for differentiation and branding, while at the same time provides standardization to the type of environmental assessment for green projects. This determines the value of the project in the global real estate market.

Green materials and products are relatively available in the Italian market owing to the European commitments for sustainable construction; rapidly renewable materials, local/regional materials, recycled content materials, and/or certified wood products, but it was challenging to document some credits, e.g. MR C4, MR C6 and MR C7. Also, green power was available in the Italian market, so this enabled the project to obtain 1 point under ID for achieving more points than EA C6.

It is also important to point out that it is a public building, thus investment opportunities did not aim mainly on maximizing direct economic benefit to the owner through resources and maintenance savings, but rather to maximize intangible public benefits through promoting environmental awareness and learning and acting as a prototype for environmental and social stewardships.

6.2. CASE STUDY 2: PALAZZO RICORDI BERCHET- MILAN

This case study investigates the benefit of applying LEED system to existing building stock, including; Sustainable Adaptive reuse/ refurbishment of existing building elements and materials, as well as methods of decision making process[1]. The project is an existing building, from the nineteenth-century located in the urban Core- historic district "Nucleo Antica Formazione“-Via Vittor Pisani, 22, next to the Duomo- as shown in the figure. The owner is a private for profit organization[2].

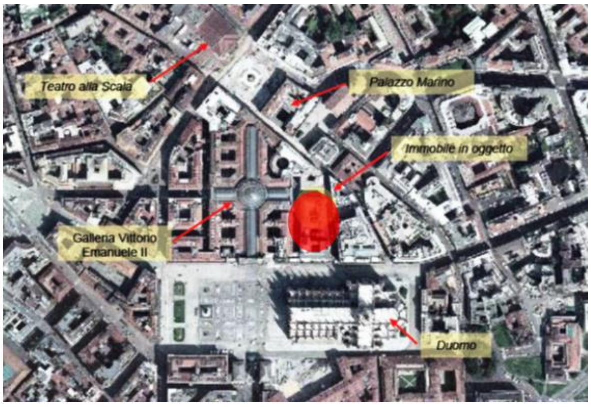


Figure 76: Urban context of the Palazzo project

6.2.1. LEED as Guidelines and Decision Making support Tool

The considerations taken place under this scope were not directly identified by LEED system, but surely they reflect on achieving points under LEED credits.

At the pre-schematic stage, many important decisions have been taken. This includes defining the goals of the project, certification level, investigating the existing building condition, setting the organizational framework; including the scope of work, roles and responsibilities, special expertise required, as well as defining new tools and methods to comply with LEED requirements.

The goal of the project has been defined as a major renovation to transform the property into a high standing trade/business asset from an architectural, plant engineering and technological standpoint. The project is Gold precertification under LEED CS V3.0 - the estimated target will be Silver/Gold, and the estimated date of substantial completion is noted as January 31, 2014.

Then, the existing building condition has been investigated; total site area within the LEED project boundary is 59,555 square feet, of 100% ratio of building area to site area. It has six stories above grade, and one story below grade (excluding parking). The project has a significant historical and cultural value as shown in the following figure, thus

[1] It is important to note that till the time of writing the project was still in the precertification[1] process. thus, the data used for the research purpose might have been subject to some changes.
[2] Antollo Manuali Holdings

the design office had to consider this aspect on designing for the new functional adjustments. It uses energy from electricity and onsite renewable (geothermal source; which is not accounted for LEED certification), uses water from a municipal potable water system, and sewage is conveyed to a municipal sewer system.

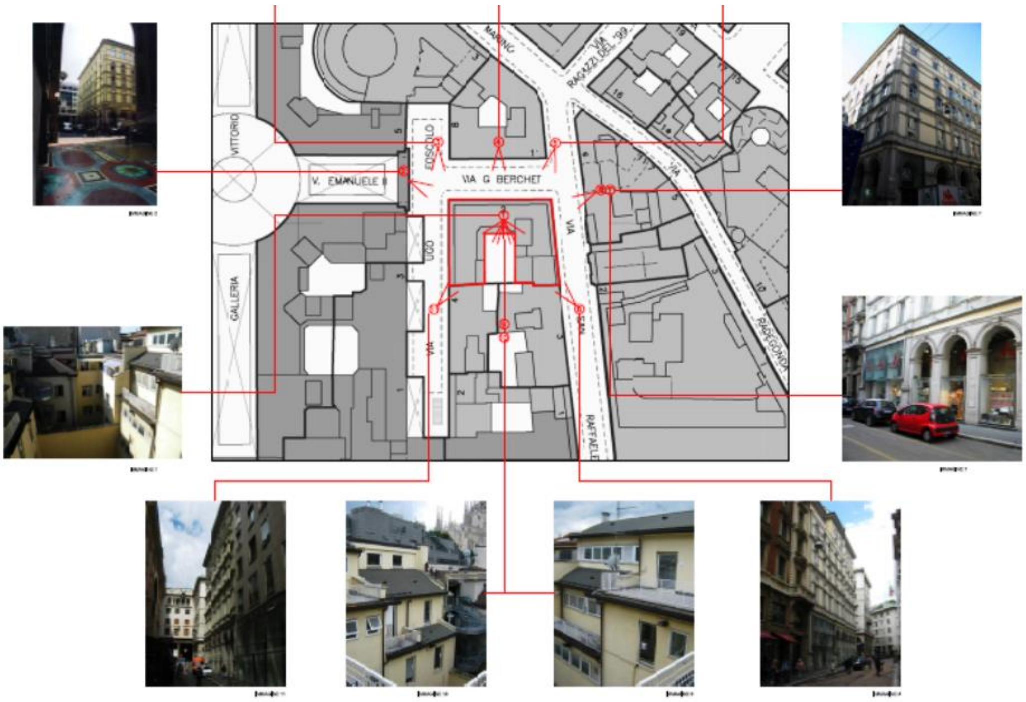


Figure 77: Neighbouring architectural buildings' styles, and elements[1].

The default average Full Time Equivalent (FTE) value is 189 plus 177 transient retail customers, which equates to 366 peak users, and the building is occupied 355 days per year. The project has no unconditioned area, and the speculative building is intended to be owner-managed after project completion. The LEED Project Information Form has been stating that the building developer has control over all building systems (including general buildout, HVAC, electrical and plumbing) except for the fit-out of the tenant spaces, which will be controlled by the future tenants.

Organizational aspects have been carried out to organize the work flow, identify roles and responsibilities, tasks, time frame and estimated budget. An example of the organizational framework can be shown in the following figure. The figure shows the direct relationship between the owner and the commissioning authority, work director, contractor and the role of LEED AP and Cx for guiding the tasks according to LEED requirements.

[1] Reference; Project team members

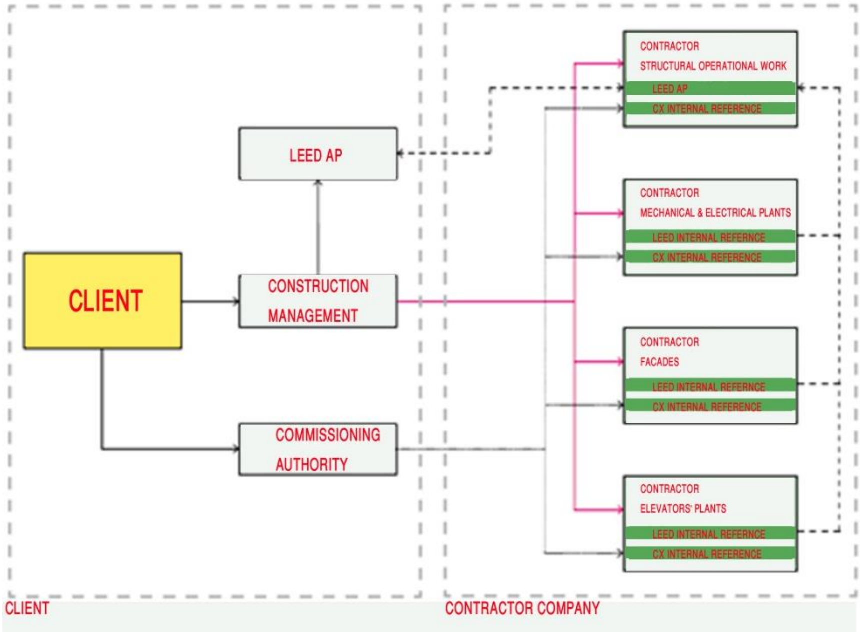


Figure 78: Planning an organizational framework for mixed responsibilities of LEED certification[1]

At the schematic and design development stages, design team had to carry a sequence of investigating practices to the existing building to evaluate its status and conditions, in order to be able to draw an eco-renovation plan; considering raising the building's environmental performance through reduce/ salvage and reuse building and building elements. The first steps for determining the scope of work and extent of renovation aims at; 1) identifying historic resources and evaluating potentials for reuse scenarios especially that there exist several types of slab construction as shown in figure (79), 2) evaluating the building's structural integrity, functional suitability to the new functional program, code compliance, historic and cultural significance and adaptability, 3) next steps identify total floor area for renovation, type of renovation intervention and system upgrades, base building improvements e.g. employing new mechanical system and installing building automation system. It is also important to note that the use pattern for this project requires considering long indoor stay period. Thus, sustainable building performance target was set to improve efficiency and reduce resource consumption, as well as putting into consideration 'Designing for flexibility and/or adaptability' to cope with the changes resulting from occupants use of space along its relatively long life cycle. Thus, it is important to identify anticipated length and density of occupancy and life cycle for interior fit-out, identify rate of churn and identify expected life span of current use, anticipated occupant densities, activities and use patterns, as well as potentials to accommodate different uses in the future, in addition to anticipated equipment or material usage.

[1] Reference; Project team members

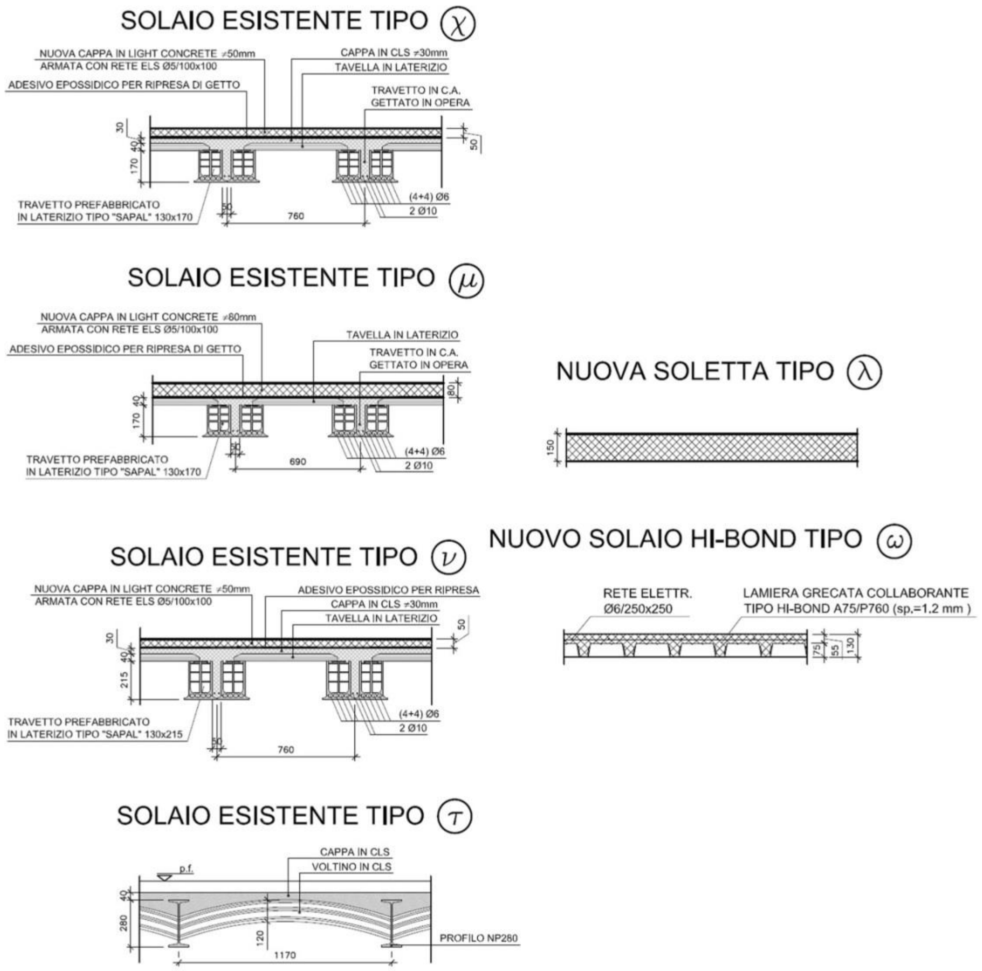


Figure 79: Existing and new floor slab construction

6.2.1.1. *Guidelines for optimizing Energy* efficiency

Applying LEED system on the project faces a set of challenges, primarily, because the ability to improve building performance is limited by basic building elements including systems, floor plate size and dimensions, orientation, amount and type of glazing as well as floor to floor height. Secondly, because the building is considered a historic building, and this limits intervention actions to comply with historic building regulations, so some credits were not eligible according to project situation, e.g. EA C2: Onsite renewable energy.

Hence, the first step is to perform an energy audit in order to evaluate the existing conditions prior to the start of the design[1]. The procedures for energy audit can be summarized as follows;

- ☐ Mapping the project; identifying energy source and end use.
- ☐ Identifying anomalies, and areas of poor performance.

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[1] Process of energy auditing was discussed in (Mendler et al, 2 edition p.125-133)

- ☐ Identifying more saving opportunities.
- ☐ Drawing up a priority list of energy efficiency measures.
- ☐ Developing action plans to improve energy efficiency.

As a result, the project’s design goal was set to optimize building envelopes, and systems (HVAC, lighting and control systems) to obtain maximum energy efficiency and comfort, including additional insulation for existing walls, roofs, and floors, high efficiency glazing, reduced interior lighting power density, air-side energy recovery, and high efficiency water cooled VRF systems. These measures along with the potential benefit of thermal lag associated with heavy wall mass construction provided good basis for obtaining credits under LEED EA category, inspite of the fact that the project was not rewarded for the use of solar hot water systems and geothermal energy sources[1].

6.2.1.2. Guidelines for optimizing Materials and Resource efficiency

The design team considered the following points:

- ☐ **Design for flexibility:** adopting this design approach as part of the basics for core and shell projects minimizes future waste generation resulting from expected changes by tenants.
- ☐ **Material selection:** selecting sustainable materials according to LEED MR category requirements, but at the same time, to cope with the nature of the core and shell projects- providing durability and low maintenance requirements.
- ☐ **Waste management:** The project approach sets a plan for building and material reuse, as well as comprehensive in-building recycling as shown in figure (80).

Figure 80: The basement floor plan, and the dedicated area for recycling

[1] It is compulsory in Italy to use solar hot water systems, nevertheless, neither these nor geothermal energy, are considered eligible for the LEED certification due to the fact that they produce hot water and not electricity. Hence, the project was not able to earn points under EA credits for their use of those two energy efficient systems.
More about these systems can be found in (Mendler et al, 2 edition p. 95).

First; in the design phase, while planning for accommodating the new functional requirements of the project, considerations for dedicating a special area for storage and collection of recyclables has been considered (to comply with MR Pre1), in order to promote recycling activities resulting from building operation: the recycling plan identified waste materials to be recycled, including; paper, corrugated cardboard, glass, plastics and metals, organic compounds, and any other solid waste in general. The dedicated waste room is located at underground level, easily-accessible by all building occupants - commercial and offices areas ones - and is overall ADA compliant[1]. The whole area provided for recycling collection is about 430,00 sf. Also, in order to ensure odour control and to avoid possible air contaminants leakage, mechanical ventilation will be provided. While regarding finishing, floor and wall cladding will be rough and easily-washable. Waste will be daily moved away from the building by a dedicated service guaranteed by the Municipality of the City of Milan. Finally, in order to encourage recycling, the Project Team in accordance with the Owner will provide inside the "Tenant Guidelines" a proper guide regarding how to collect and stock waste.

Second: discussing Construction waste management plan[2], in order to reduce the environmental impact resulting from both demolition and construction activities. The plan starts with estimating the ratio between maintained versus demolished areas or elements and estimate quantities of waste produced, then exploring opportunities and prioritize action to salvage materials for reuse or recycle[3] prior to demolition (Waste plan hierarchy discussed in chapter four may have been used)- and determine and estimate quantities for those which will be diverted for reuse or recycle, while at the same time considering a balance between the fees of sending them to landfill is evaluated to the fees of sending them to recycling haulers (and if there shall be any financial benefits provided), then, determining the demolition schedule and accordingly adjust activities and scope of demolition (Mechanical versus Manual demolition), also, requirements for site storage and transportation of materials to the salvage company is considered in addition to consideations to reduce economic and environmental impact from transporting waste materials.

[1] Americans with Disabilities Act (ADA)

[2] It may require more time to manually remove materials, while on the other hand, mechanically assisted demolition will require less time but may result in more waste.
More about Construction waste management plan can be found in (Mendler et al, 2 edition p.125-133), and (Kane, 2010 p.83)

[3] Recycling of concrete, masonary, wood (dimension wood not engineered wood), metals, cardboard, and paint at the job site are mostly cost effective (Kane, 2010 p.83)

6.2.2. LEED as a Measurement and Benchmarking Tool

The full calculations for EA and MR credits' compliance can be found in appendix D

6.2.2.1. Measurement and Benchmarking for Energy Credits

LEED V3.0 provides more developed means to measure energy credits by using the Target Finder to estimate targeted energy, which considers the mix of fuels (thus the result is affected by the estimated CO_2 emissions as well), and accounts for both site and source energy use intensity. Additionally, for core and shell projects, tenants' electricity use estimations maybe considered in the calculation (Advanced Energy Modelling for LEED Technical Manual, USGBC, 2011).

a. EA Pre 2 and EA C1: Energy Use Summary: Total Building Energy Use Performance

Energy type	Proposed design			Baseline design		
	Energy Use	**Energy Savings- Exceptional calculation measure**	**Energy Savings- Onsite Renewable energy (if applicable)**	**Process kWh**	**Energy use- Onsite Renewable energy (if applicable)**	**Total energy use**
Electricity	574,270.96 kWh	0	0	209,044	885,633.38	574,270.96
Natural Gas	0	0	0	0	0	0
Totals MMBtu	1,959.41 MBtu/year			713.26 MBtu/year	3,021.78	1,959.41
					Percentage savings	35.16 %

Table 33: Calculating Energy Cost and Consumption by Energy Type- Performance Rating Method for EA Pre 2 & EA C1

Estimated energy savings were calculated as shown in table (33), as a result the project was eligible with EA Pre1, and obtained 16 points under EA C1. It should be noted that the GBCI had some revision comments as stated in appendix (D), and they were mainly related to the input data about the proposed versus the baseline model performance- especially with the fact that some adjustments exist for energy modelling for existing building projects, yet, the most important of all is understanding that the baseline in this case is the original state of the existing building, so for example, the baseline performance does not need to be normalized through getting the average of its four basic orientations, but the original orientation is enough to represent the baseline model, and so on.

It is observed that project team members planned to gain 22 possible points in EA C1: Optimize energy performance, but due to the particular criteria of measuring and benchmarking existing building performance, some comments were provided by the GBC review committee, and accordingly the project anticipates less points than what has been planned (17 possible *points), and this points out the importance of paying due care on how the building type may affect the measurement and benchmarking method. Adoption rate cannot be estimated yet because the construction credits have not been prepared yet.*

6.2.2.2. Measurement and Benchmarking for Materials credits

The research focuses on MR C1 and MR C2 due to the reason that the project is a major renovation for an existing building.

a. MR C1; Building Reuse

LEED reference guide sets the following thresholds in table (34) for credit compliance. It is also worth noting that credit weighting for this credit differ from LEED NC (3 total points) than that of LEED CS (5 total points). This reflects additional consideration for core and shell projects for building reuse approach rather than new construction.

Building Reuse	Points
25 %	1
33 %	2
42 %	3
50 %	4
75 %	5

Table 34: LEED corresponding points to building reuse percentage

The project obtained the following results;

Structural external walls have maintained Percentage 100%

Structural decks have maintained Percentage as shown in figure (81).

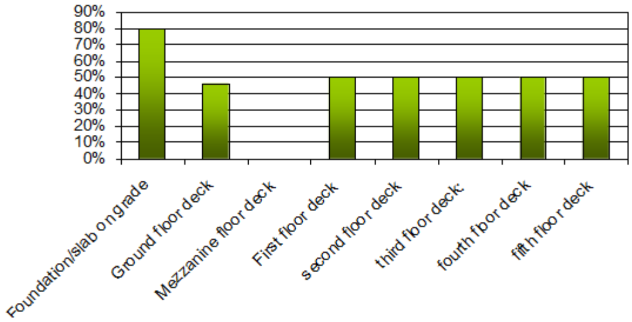

Figure 81: Maintained percentage of External structure

Structural internal walls have maintained percentage= 50% as shown in figure (82).

Thus, the whole maintained percentage of structural elements is 58%- which makes the project eligible for four points under LEED CS MR C1; Building Reuse.

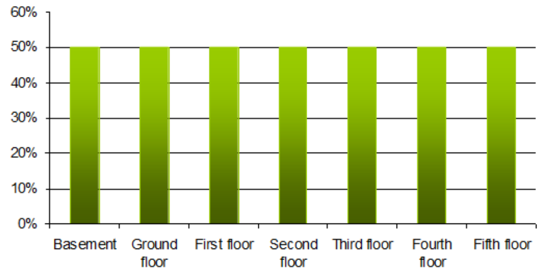

Figure 82: Maintained percentage of internal structure

b. MR C2 (1 pt- 50%, 2 pt- 75%): Construction waste management plan

This credit weighting is the same for both LEED NC and LEED CS although it is more challenging for the second case study because it includes both construction and demolition activities, and many demolition waste end in landfill. It is also worth noting that LEED V4.0 has turned it into a prerequisite which mandates its application.

Sum of total weight of salvaged materials = 2560 tons

Sum of total weight of all C&D waste= 4252.12 tons

Hence, 2560/4252.12 = 62.2% (thus, the project was eligible for 2 points under LEED CS MR C2)

6.2.3. LEED as a verification Tool

The project plans to use the LEED system as a verification tool through conducting; commissioning process and M&V plan. Additionally, the research recommends conducting LCA and POE for some important decisions.

6.2.3.1. Commissioning Process

Applying the commissioning process for this project is particular, due to the reason that it is a major renovation project for an existing building, thus commissioning process shall add some goals and features from the existing building commissioning [1] . Accordingly, it starts with the planning phase, where the current-facilities-requirements are prepared, then the "investigation phase", which is similar to an energy audit, but develops into a long-term strategic plan for a facility, then the implementation, turnover, and finally the persistence phase.

The basic phases and t goals of each phase of the EBCx process are similar to ordinary commissioning process except that it starts in early project phases with conducting some testing procedures to investigate the existing building condition and identify improvement opportunities, upon which it bases its benchmarking criteria- comparing the building performance prior and after renovation. Hence, it develops a customized Building Operation Plan which identifies specific building, system/equipment level and zoning level operational strategies, set points and schedules which shall support the building's operational needs. On doing that, it provided robust means of documentation for both building conditions, and it is clear how it shares some common goals and features with the M&V Process.

Then, during the Investigation Phase, it aims at developing a diagnostic monitoring plan and then performs comprehensive system diagnostic monitoring- which may include

[1] The author's elaboration from (QuEST, 2012), (BCA, 2008), and (Commissioning existing building, 3.0)

BAS trending, portable data logger trending, and energy and weather data collection[1]. Then a step of; Performance Assurance – to evaluate methods of measuring system performance and verifying proper implementation. Each measure should have a verification methodology appropriate to the size and complexity of the measure. The identified verification methodology is then incorporated into a Measurement and Verification (M&V) Plan. Finally, the Implementation Phase begins with the analysis, prioritization and selection of improvement measures for implementation, then testing them, as well as implementing the M&V Plan developed during the Investigation Phase, and Plan for Ongoing Commissioning.

Additionally, the Tenant Design and Construction Guidelines shall describe the sustainable design and construction features incorporated in the core & shell project. The Cx process shall include; Energy quality system, Fire Suppression System, and IAQ management. The CxA activities will be in compliance with the standards of the U.S. Commissioning Process Guides by ASHRAE and PECI[2] Inc.

6.2.3.2. Measurement and Verification

LEED for Core and Shell dedicates two credits for measurement and verification [not one as in the case for LEED NC]; Base building and Tenant sub-metering. The first credit (3 available points) is for providing infrastructure in the base building design to facilitate metering whole-building electricity use and tenant electrical end uses, as appropriate and consistent with IPMVP Volume III, Option D, and the second credit (another 3 available points) is for including a centrally monitored electronic metering network in the base building design that is capable of being expanded to accommodate future tenant sub-metering. This is to insure higher levels of quality control; not only on the scale of the whole building, but also on the scale of individual units, hence it is considered a step forward to understand the relation and different interests between the owner and the occupant .

For EA C5.1 (3 possible points); the project intends to develop and implement a measurement and verification plan consistent with Option D of the IPMVP. Nevertheless, the narrative provided has described the HVAC system and not the M and V plan as required, so a technical advice was given to the project team to include a detailed description of the Proposed M and V plan for the Base building including sub-metering and control system capabilities that will be used to assist in data collection. Also, it is worth noting that the project team does not intend to pursue exemplary performance of EA Credit 5.1[3] - which depends on the owner decision.

[1] Ongoing BAS trending, portable data loggers, spot measurements, and functional testing may be utilized pre and/or post implementation as part of the M&V process.
[2] Platform Environment Control Interface (PECI).
[3] Exemplary performance is available to projects that select either Option 1 or Option 2 AND commit to sharing whole-building energy and water use data through the Energy and Water Data Release Form in PI Form 1: Minimum Program Requirements.

M&V activities consist of the following: meter installation calibration and maintenance, data gathering and screening, development of a computation method and acceptable estimates, computations with measured data, and reporting, quality assurance, and third party verification of reports.

M&V shall be used by the owners for the following purposes (related to scope 4: Investment) : verify and provide valuable feedback about expected savings, improve engineering design and facility operations and maintenance, manage energy usage and budgets to account for variances, and this type of verification requires regular inspection and commissioning of equipment,

For EA C5.2 (4 possible points); the project shall include a centrally monitored metering system that can be expanded for future tenant sub-metering as required by LEED for Commercial Interiors Rating System EA Credit 3. The plan shall document and advise future tenants of this opportunity and means of its achievement, and it shall include a process for corrective action to ensure energy savings are realized if the results of the M & V plan indicate that energy savings are not being achieved. This plan includes monitoring and controlling system for the deep-earth water cooled heat pumps[1]- where each floor will be air conditioned by dedicated water-cooled condensers. However, the project received a technical advice from the GBCI because the narrative has not included a description of how tenant utility usage and cost will be measured and paid.

It is notable that performing M&V plan to comply with EA C5.2; tenant sub-metering has more possible points than EA C5.1; Base building. This encourages project team members to pursue this credit on a more detailed level involving future tenants as well.

6.2.3.3. Post Occupancy Evaluation

The research recommends conducting a Post Occupancy Evaluation (even though it is not required for LEED CS certification) because it is an important tool in planning the refurbishment of existing buildings, to give feedback regarding renovation scenarios, and whether the performance of the existing building satisfies occupants and explores opportunities for further development. It may also be used to identify where building design adjustments are needed to support changing practices, markets, legislation and social trends[2].

The project shall publish Tenant Design and Construction Guidelines to pursue SS C9 - which is a special credit for core and shell projects. These Guidelines will provide a

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[1] The system consists of remote controllers (one for each indoor units or group of indoor units), centralized remote controllers, one for each floor, and one integrated centralized control software. The remote controllers will monitor functions for the group of indoor units related to the floor and it will provide at least the following functions: run and stop operation for single group, switches between cool/dry/auto/fun/heat, sets the group temperature control, fun speed setting, limit the set point range, on/off time can be set, measure the intake temperature of the master unit within the group, error indication: displays a 4 digit code and the affected unit address, and finally test run function: allows each unit within the group to operate in test mode.
[2] More on Post occupancy evaluation can be found in (Mendler et al, 2 edition p.163), and http://www.postoccupancyevaluation.com/results.shtml

description of the sustainable design and construction features incorporated in the core and shell project, provide information that enables tenants to coordinate their space design and construction with the core and shell building systems, and provide information on the LEED-CI rating system and how the core and shell building contributes to achieving these credits. This credit can be directly reflect on conducting a POE after building occupancy.

6.2.3.4. Life Cycle Assessment

The research applies LCA in the decision making for the case study building in two levels; first, the building level (MR C1): For the purposes of analyzing existing building and evaluating reuse scenarios, and to determine the level of intervention, opportunities of synergies and trade-offs, and secondly, for the Material level: to capture credit environmental Impact variations, to support decision making process for material selection (MR C2). This gives a comprehensive evaluation about the whole reuse plan adopted.

a. First step LCA for floor sections and floor plans

This analysis is helpful to understand different floor compositions for the existing building. It enables decision making process regarding which floor is composed of the highest embodied energy components, and also for a single floor, which floor section(s) has the highest embodied energy to preserve, also if proposing restoration scenarios based on actual floor sections, which ones to choose (which has the lowest embodied energy)

		Total EE (MJ)	Total EC (kg CO_2e)
G.F	Section (α)	1123.12	104.51
1 F	Section (β)	394.32	40.61
2 F	Section (ϭ)	488.65	44.10
	Section (ɣ)	315.77	26.78
3 F	Section (ξ)	341.41	27.79
	Section (ϕ)	376.33	30.85
4 F	Section (ν)	507.73	44.58
	Section (x)	469.63	41.22
	Section (μ)	671.85	42.99
	Section (τ)	872.13	66.46
5 F	Section (π)	589.71	32.47
	Section (x)	469.67	41.22
	Section (ν)	495.78	43.34

Table 35: The embodied energy and embodied carbon for each $1m^2$ of each slab section

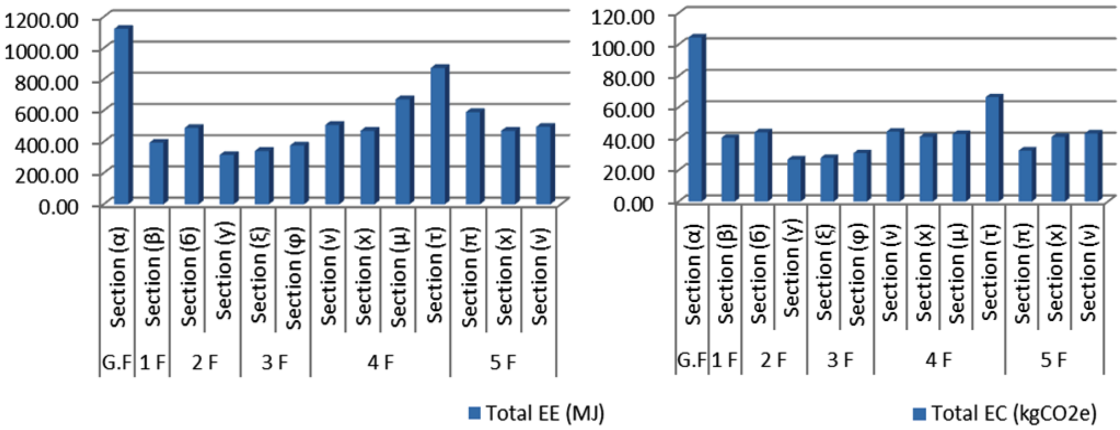

Figure 83: Comparing the values of EE and EC for 1m^2 of each slab section

Preservation scenarios should prioritise slab sections with the highest EE and EC for each square meter. The analysis shows that the highest values exist in floor section (α) in the ground floor, followed by section (τ), and section (μ) in the fourth floor, while the lowest values exist in section (y), then section (ξ) in the second and third floor respectively. Additionally, the research presents a complementary study for EE and EC for each floor- in order to evaluate reuse scenarios when comparing floor plans. It is shown that the basement floor plan had the highest values, followed by the ground and fourth floor, as shown in table (36), and represented in figure (84).

	Total EE (MJ)	**Total EC (kg CO_2e)**
Basement floor plan	339,564.29	46,843.51
Ground floor	275,330.64	27,573.49
First floor	117,047.98	12,053.88
Second floor	123,015.13	10,831.07
Third floor	111,224.40	9,076.97
Fourth floor	262,684.81	20,561.28
Fifth floor	182,939.04	15,363.42

Table 36: Total EE and EC for each floor plan

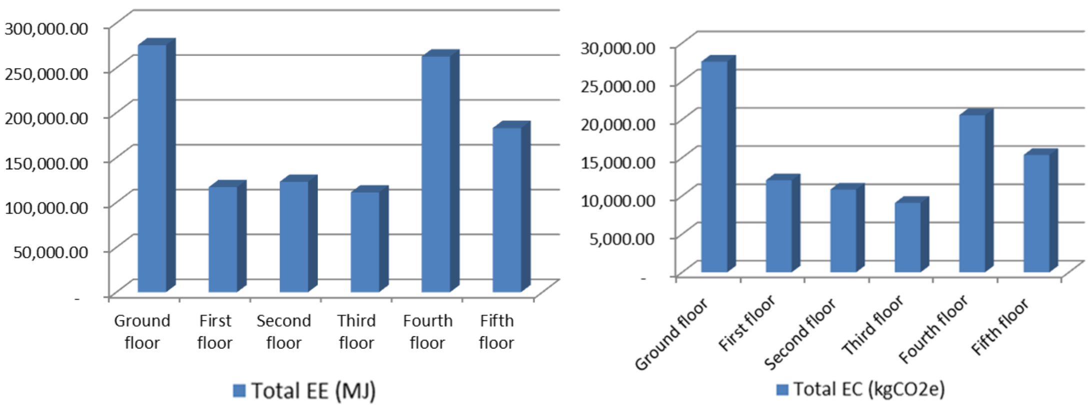

Figure 84: Total EE and EC for each floor plan

b. Using LCA for MR C1: Building Reuse

The research used LCA as a verification method for MR C1. The results presented in table (37), and figure (85), comparing the values of EE and EC for slabs, and exterior walls (for MR C1.1) and interior walls (for MR C1.2), show that maintained areas of exterior structural walls had higher values of EE and EC. The results were compared with their corresponding percentage share for MR C1, as shown in table (38), and figure (86), and the results showed that the maintained areas of slabs had higher percentage share for MR C1, but least values of EE and EC when compared to exterior and interior walls, and accordingly this requires reconsideration when attempting to draw environmental reuse scenarios complying with LEED credits.

	LCA		LEED
	EE (MJ)	**EC (kg CO_2e)**	**Maintained area in m^2**
Slabs	1,411,806.28	142,303.59	2,437.47
Exterior structural Walls	5,869,553.63	409,363.74	2,229.65
Interior structural Walls	2,800,776.95	195,336.24	1,595.88
Total Sum	**10,082,136.85**	**747,003.57**	**6,263.01**

Table 37: Comparing the values of EE, EC and maintained areas in m^2 between slabs, exterior and interior walls

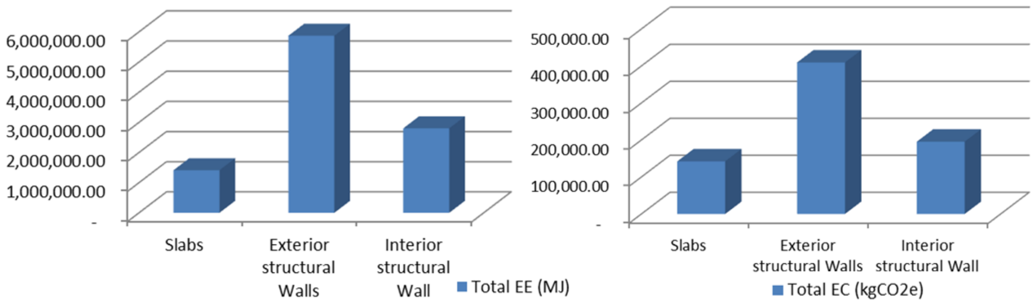

Figure 85: Comparing the values of EE, EC and maintained areas in m^2 between slabs, exterior and interior walls

	LCA		LEED
	EE (%)	**EC (%)**	**Maintained area (%)**
Slabs	14.00	19.05	38.92
Exterior structural Walls	58.22	54.80	35.60
Interior structural Walls	27.78	26.15	25.48

Table 38: Comparing the maintained areas' percentage share of EE, EC to their share in square meter for LEED calculation for slabs, exterior and interior walls

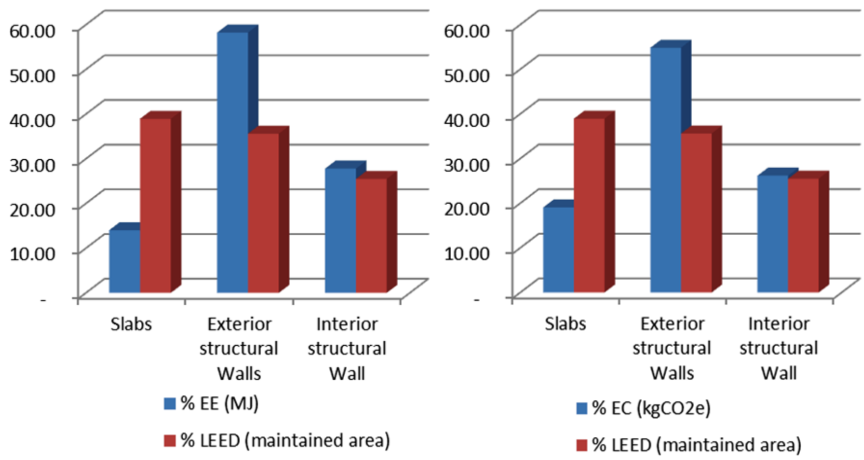

Figure 86: Comparing the maintained areas' percentage share of EE, EC to their share in square meter for LEED calculation for slabs, exterior and interior walls

c. LCA for maintained (MR C1) versus demolished scenarios

The first step for existing building restoration/ refurbishment is to draw restoration plans based on new functional requirements, then to estimate the amount of demolished materials. In this step LCA can provide guidance on how to balance between demolishing scenarios and their environmental effect. This comparison aims at completing the image of MR C1 Building Reuse, and estimating the amount of embodied energy maintained through Building Reuse; to the amount of embodied energy for demolishing.

The research used LCA to compare reuse versus demolished scenarios for the main building elements (slabs, exterior and interior walls). Exterior walls were 100% maintained, and Interior walls were 50% maintained of every floor, and since it is all made from the same material, so it shall maintain half the amount of embodied energy for interior wall construction. On the other hand, slabs require further investigation because each floor is made from different material composition, and this requires calculating the environmental impact for maintained versus demolished areas for each floor plan, as shown in table (39) and (40), and figure (87).

	Basement	**Ground**	**First**	**Second**	**Third**	**Fourth**	**Fifth**
Total EE from maintained slabs	339,564	275,331	117,048	123,015	111,224	262,685	182,939
Total EE from demolished slabs	84,891	306,073	117,048	95,872	107,249	75,545	15,771

Table 39: Comparing the values of EE for maintained slab areas, versus those demolished

	Basement	Ground	First	Second	Third	Fourth	Fifth
Total EC from maintained slabs	46,844	27,573	12,054	10,831	9,077	20,561	15,363
Total EC from demolished slabs	11,711	31,883	12,054	8,131	8,730	6,630	1,384

Table 40: Comparing the values of EC for maintained slab areas, versus those demolished

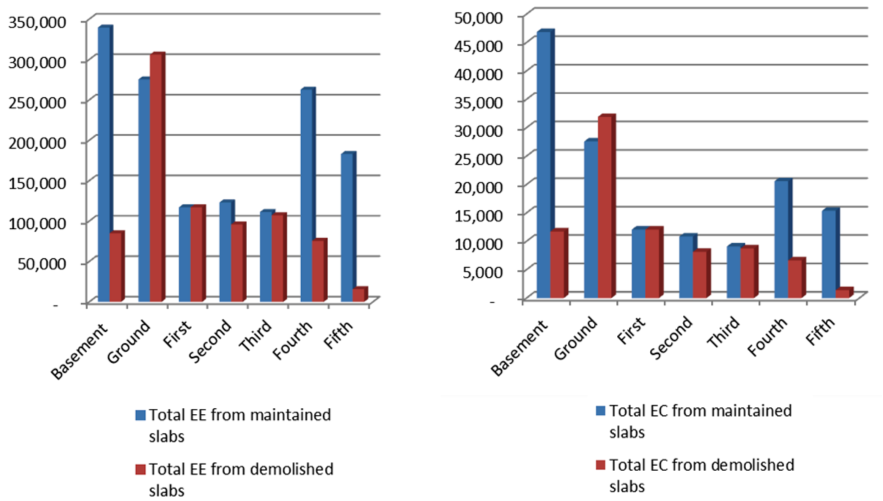

Figure 87: Comparing the values of EE, and EC for maintained slab areas, versus those demolished

This shows that the proposed reuse scenarios were more efficient for the basement, fourth and fifth floors, but less efficient for the rest of the floor plans. Accordingly, it can be concluded that acting on the ground, first, second and third floor plans shall lead to more environmentally efficient building reuse scenarios.

d. LCA for MR2: Construction waste management

The research used LCA to evaluate the environmental impact arising from construction waste management plan used to comply with MR C2, following the principle of 'avoided impact' resulting from recycling activities. The values of EE and EC for construction waste materials are calculated as shown in table (41), and then are compared to their corresponding share for MR C2 as shown in figure (88). The result shows that although bricks and concrete contribute higher in terms of weight to obtain MR C2, but they have fewer values of EE and EC when recycled, because they are converted to lower grade materials; aggregates[1], with the main aim to reduce landfill, but it does not contribute on reducing energy required to process new materials). On the other hand, steel contributes less weight to comply with MR C2, but has higher value of EE and EC,

[1] End of life scenarios for prefabricated concrete elements can be through using it as aggregates (post production recycled content), while, after reuse, they can be crushed and recycled for second use. Yet, It should be noted that the use of concrete as aggregates requires a high quota of cement, which might reduce the benefit of recycling (Hegger et alii, 2005) (Lavagna, 2008 p. 198).

because it is recycled into recycled steel, which shall eventually reduce energy used to process new steel products. This shows that more verification should be conducted for LEED MR C2.

	Brick	Reinforced concrete	Concrete	Ceramics	Plaster board/ gypsum board	Walnut stained oak wood	Glass	Steel
Weight (kg)	1,029,641	749,866	177,949	316,689	32,821	7,487	9,096	196,139
Total EE (MJ)	85,460	62,239	14,770	26,285	110,771	59,895	31,834	2,098,685
Total EC (kg CO_2e)	5,354	3,899	925	1,647	6,400	8,161	2,911	194,177

Table 41: Accounting for the environmental impact from demolished materials.

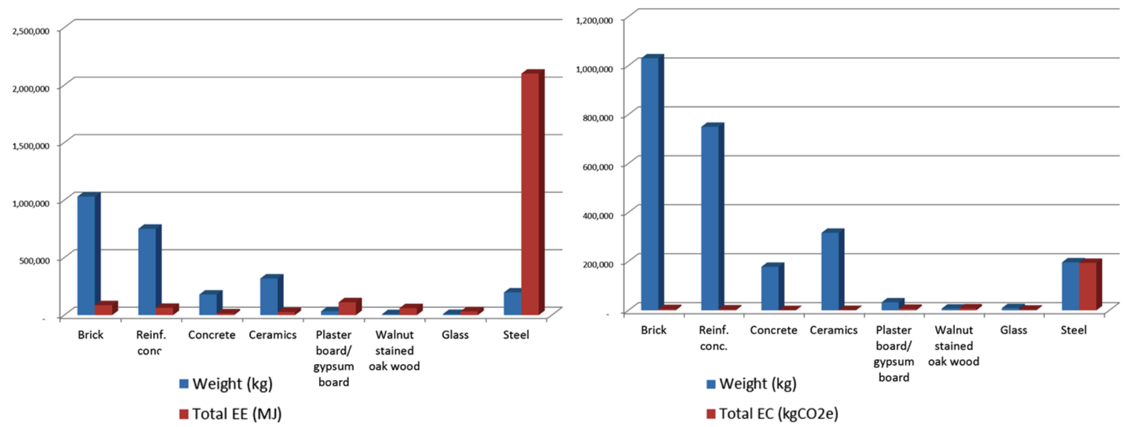

Figure 88: Comparing the environmental impact for demolished materials, to their weight required for calculating MR C2.

6.2.4. LEED as a certification Tool

6.2.4.1. Certification performance

The decision to apply for LEED CS was mainly taken in order to gain benefit of the 'Precertification' market advantage, which iteratively reflects on using LEED as guidance and decision making support tool- setting performance targets, and operational limits. Also, it includes additional number of credits and requirements compared to LEED-NC, and allows for assumptions in various credit aspects such as occupancy counts and energy modelling, along with exploring opportunities for applying dual incentives for both the owner and users. On the other hand, it may create some challenges to obtain other credits, especially those related to the building occupancy type and nature (e.g. installing meters to monitor CO_2).

6.2.4.2. Market performance

Reusing existing buildings may offer important means of avoiding unnecessary carbon outlays and help communities achieve their carbon reduction goals in the near term, and explores the sustainability value of older and historic buildings. Mixed use commercial/office buildings market encompasses the largest proportion of building types, at least in the local market as shown in previous chapters. In addition, existing building reuse/renovation receives a lot of attention in the Italian real estate market, with incentives offered to encourage investors. These two points makes up the certification prospect. In addition, selecting sustainable materials considers choosing manufacturers who provide measured and proven record of reduced emissions- thus linking the LEED certification with other international and national labelling and certification programs.

Additionally, it is important to seek early client commitment to embrace synergies between the business drivers of office building development and sustainability goals- motivated by its business case, e.g. increased productivity, high rent, as well as marketing strategies (e.g. environmental stewardship, competitive market advantage, differentiation and branding)- but also reducing risks and uncertainty coming from the use of innovative design solutions, this is why the owner was encouraged to use commissioning and M&V process to verify the expected energy savings- so eventually can bring benefit to both the owner and the occupant.

6.3. COMPARISON

LEED New Construction (case study 1) and LEED Core and Shell (case study 2) represent the major share of LEED certified projects as previously shown in chapter three. The magnitude of this segment of construction industry represents a particularly important opportunity to achieve improved sustainable performance, and the two case studies represent two different cases where each building type brings unique set of challenges and opportunities to the application of LEED system - which this section attempts to highlight, and it is important to note that this comparison, does not compare the performance of the two buildings, but tests the application of the LEED system on the management process of each project to investigate its validity for its intended use and users, and now to better investigate the contribution of applying each scope for the two case studies- the following analysis was made;

6.3.1. LEED as Guidelines and Decision Making support Tool

Building type and occupancy differ from one case to another. The first case study- being a new construction museum building- provides an open opportunity for exploring new green innovative design solutions for using energy efficient systems, and it was generally easier to comply with LEED system’s requirements. While, the second case study constitutes two additional levels of complexity; the first concerns applying LEED system on an existing building and the second concerns dealing with the historic nature of the building- also because it constitutes both demolition and construction activities that may require extreme effort from project team members for organization and operational concerns to reduce the environmental impact arising from them. This requires adopting different design, approaches, using different sustainable building practices and setting different targets. Yet, it should be noted that in both cases, much weight was laid upon each member of the design team for more research on how to properly apply LEED requirements along the management process, and accordingly, some of LEED credits have not been applicable, while others have been easier to obtain, for the first case study, more credits were obtained through the MR category and less for EA category, while for the second (although still a work in progress), but showed more compliance to EA category requirements, it also depends on the context and project type and condition.

Moreover, existing buildings require more reliance on performance based compliance paths rather than prescriptive ones, because the design in already set and the preservation/ restoration strategy is set to be case sensitive, determined according to the project situation. Also, because prescriptive guidelines may not lead to the optimum design solution or they may lead to increased cost. Hence, each project faced particular potentials and challenges to optimize energy efficiency, the palazzo project being an existing building, turned out to have very well energy performance when simulated, this is probably related to the massive walls' thickness, on the other hand, being a historic building, the project was unable to add some design requirements that would enhance its performance, for example; installing photovoltaic cells on the roof to generate renewable energy to earn EA C2: Onsite renewable energy. On the other hand, in the museum building, putting the lighting strategy was challenging considering the requirements for each exhibition zone, and the relationship between natural and artificial lighting on the artifacts, while it was easier for the palazzo project.

On the other hand, for the second case study, there were two types of impacts to consider: demolition and construction, but no consideration was paid to operational energy used for both, e.g. demolition activities may use mechanical means which require estimating its economic and environmental impact- this consideration was considered only under MR category; MR C1: Building reuse, MR C2: CWM plan.

6.3.2. LEED as a Measurement and Benchmarking Tool

Design team for both case studies have employed software management programs to better organize and control; time, budget and quality of the building process- but integrating LEED system's requirements depend on design team skill and expertise.

Measuring and benchmarking sustainable building performance differed for an existing building where there is actual measurement for building performance, versus a new construction project- where the reliance is more on predicted saving values, but practitioners for both case studies adopted the whole building energy simulation using the ASHRAE standard (Appendix G)- for complying with LEED EA credits, and prescriptive requirements for LEED MR credits. The museum project used Energy Plus v2.2, while the palazzo project used the Integrated Environmental Solution- Virtual Environment version 6.4.0.8, because of considerations related to the scope, scale, complexity as well as cost of each simulation tool. Nevertheless, it should be noted that for both cases energy simulation is mainly performed for the purpose of obtaining LEED credit, during later design stages and usually not integrated in early design decisions, maybe due to extra cost perceived or because of the required time, money and expertise.

6.3.3. LEED as a verification Tool

Verification tools and methods differ for existing buildings rather than for new construction projects in goal, scope, tools and results expected. Verifying the performance of operational energy is possible through metering; for both new construction and major renovation projects. On the other hand, verifying (embodied) energy and environmental impact may be more complex in case of major renovation projects due to the complex nature of renovation strategies which pays much concern about investigating the value of existing building elements before taking important decisions in earlier design stages, e.g. determining building reuse scenarios, while for new construction buildings it can be useful for material selection process noting the conflict with LEED's measurement metrics for MR credits- but in both cases, it is important to convey a full true image for energy use by sources as well as by end use.

Also, it is worth noting that, the museum building did not attempt to perform Enhanced building commissioning, nor M&V process, while the palazzo building applied for both fundamental and enhanced commissioning, and also attempt to comply with the two levels of M&V (the base building metering and the tenant sub metering).

6.3.3.1. Commissioning process

Commissioning process is part of the existing LEED version, yet it differs in the two cases; the first one is a new construction building, thus the scope of the commissioning process focuses on bringing building operation to the original design intent, and the project complied with the fundamental commissioning only, while the second case study is a major renovation project, thus the commissioning is a combination between ordinary commissioning processes for new construction buildings and some features for existing building commissioning to provide an on-going process to resolve operating problems, improve comfort, and optimize energy use- and the project complied with both fundamental and enhanced building commissioning process.

6.3.3.2. M&V Process

LEED EA C5 (M&V process) is already part of the existing LEED version, yet this credit was not pursued by the first case study because it was not included in earlier project phases, and would have required significant change orders to satisfy the requirements, and partly because it would have resulted in a comparatively high capital cost, and from another part, this credit is not mandatory and with few possible points. Nevertheless, some best practices were already performed by project team members, that included performing some verification activities, which are not currently considered eligible for LEED certification, but they may significantly lead to more sustainable building process within budget constraints, i.e. ensure proper recycling process[1].

Nevertheless, the second case study attempts to comply with both credits for EA C5 (5.1 for Base building with 3 possible points for CS projects), and (5.2 for tenant submetering with 4 possible points for CS projects), partly because of the comparatively more points dedicated to the compliance of this credit in LEED CS V3.0, which encouraged the owner to plan for it right from the start of the project and perform the required modifications.

6.3.3.3. Post Occupancy Evaluation (POE)

The research recommends setting goals for conducting a POE during operation phase; after all information is available and accurate in order to provide accurate feedback regarding new design solutions (materials, products, systems and services)- particularly for the first case study about energy use, renewable energy production and material recycling- and particularly for the second case study about renovation scenarios and functional requirements for the new building use and users' satisfaction. It is clear that the current version of LEED CS has more potentials to include POE rather than LEED NC because it already encourages SS C9: Tenant Design and Construction Guidelines, also because it is very much connected to LEED CI- which investigates more focused areas of sustainable building performance.

[1] LEED system reward setting recycling plan for both construction waste (under MR C2), and operational waste (under MR Pre1) - but it does not reward verifying these sustainable construction practices, through regular onsite visits.

6.3.3.4. LCA

It was clear that the current version of LEED credits' measurement criteria is not adequately reflecting the environmental performance of different materials/ building elements. This is why an additional verification step needs to be conducted to guide an in-sighted decision making process for material selection, eco-renovation scenarios as well as some sustainable construction waste management plans. Hence, the use of LCA was found flexible to cope with the different conditions for both cases according to the goals and targets of the study, system boundary, as well as LCA scenarios suggested for the process. For the first case study, it is recommended to support the decision making process for material selection in detailed design stages, while for the second case study; it is recommended to evaluate building reuse scenarios in earlier design stages.

6.3.4. LEED as a certification Tool

Using the system as a certification tool showed different perspectives in both case studies, and employing market factors such as *Signalling Messages* to distinguish environmental building performance, *Competitive advantage*, *Differentiation* and *Branding*. Yet, they may address different users and ownership[1], also the focus, methodology, application, output and impact of certification differ for new and for existing buildings[2]; both require robust, transparent procedures that are accurate and cost-effective;

First case study; LEED certification scheme was used to demonstrate compliance with national building codes and regulations which mandate certifying public building with LEED certification, and for providing an incentive for achieving a better standard compared with buildings of the same type and encourage efficient building practices beyond the minimum standards. Hence, *the second case study* is located in Milan, where the LEED certification is not mandatory, yet was making use of the 'LEED Core and Shell Precertification' to affect the market and attract more investors with the LEED brand name, long term operational benefit, as well as increases in productivity due to improving indoor environmental quality. Also, LEED certification scheme was used to help improve building efficiency compared against similar buildings and attest the building performance providing information about the environmental performance of the whole building, but

[1] It is also important to highlight the two major issues concerning 'Innovation and Design' and 'Regional Priority' and their effect related to contextual factors and certification value and price- Innovation in Design: its relation with the local green market, as well as 'Regional Priority': concerning adaptability to foreign contexts.

[2] It is important to note that more opportunities for obtaining credits were provided for historic buildings under LEED V4.0 MR C1 Building life-cycle impact reduction- Option 1- historic building reuse (5 points). This may overcome the difficulty to obtain particular credits due to the restrictions from working under existing (moreover historic) building restrictions. Eventually this shall create more incentives for existing/building reuse.

more detailed analysis of the performance of individual units is required (to avoid the problem of dual incentives)- which may eventually lead to increased investment demand[1].

Finally, it is worth noting that using different LEED versions made it easier to streamline the simulation process and obtain more credits under LEED V3.0 than LEED V2.2[2]. Another reason was owing to the development of the simulation guidelines to consider particular design cases, and raise the level for environmental assessment, i.e. developing EA under LEED V3.0 characterizes not only energy consumption, but additionally energy source and end use as well.

6.3.5. Relationships between scopes

As a result of studying all four scope, it can be concluded that both the first and the fourth scopes are related to contextual factors- applying LEED system in the Italian context, so the more effort provided in them, the more adaptable the LEED certification shall be, and easier the application of LEED in foreign contexts. It is also interesting to note the basic relations between the four scopes. They can be defined as follows;

- ☐ Consecutive (the results of one scope become the input data for another scope). For example, the guideline scope provides certain inputs to the measurement scope.
- ☐ Complementary (two scopes use the same basis for comparison but give different results because they investigate different dimensions).
- ☐ Competing (two scopes use the same basis for comparison and investigate the same dimensions but give different results because different assumptions are made about the scope of the analysis)

  For example; the measurement and verification scopes may give complementary or competing results as previously explained.

- ☐ Encompassing (a scope forms an integral part of another scope).
- ☐ Overlapping (both scopes give the same result because their methodology is identical).

  This is hopefully to be the future development of the measurement scope of the LEED system when integrating LCA in its measurement metrics.

[1] Certification of existing buildings can do more than provide ratings: it can identify measures to improve performance. (Arkesteijn and van Dijk, 2010).
[2] It is worth noting that LEED V4.0 has also differentiated between new construction, major renovation and core and shell projects- to be able to provide a flexible framework that can be applied on different building types.

6.4. VALIDATIONS & ADJUSTMENTS

6.4.1. Adaptability to other contexts: Italian context

For the first scope (guidelines); applying the LEED system to the Italian context is relatively easier than other contexts due to the high requirements for sustainable building performance mandated in national building codes and regulations. For instance, there is an existing concern and awareness in the Italian context about sustainable issues, like construction waste management, reusing and recycling scenarios. Thus, these sustainable management practices were not difficult to achieve, because they can be considered partly as best practices. Also, the improvement of the energy efficiency in buildings is, naturally, related to the European Directive (ED), and the Directive 2002/91/EC which addresses energy efficiency in buildings[1]. Also, increasing energy production from renewable sources matches with LEED Energy (green certificates). Additionally, LEED Energy and Atmosphere credit category has the highest point weighting and this matches with the national policy for energy efficiency. Hence, both LEED system and national building codes share the same objectives but different benchmarks- for instance; for scope 2 :Measurement scope; LEED measurement metrics was relatively different than national building codes or other best practices- so project team members had to educate themselves about many sustainable issues before proceeding with the LEED rating and certification requirements.

For verification scope; (particularly applying M&V plans) it should be noted that Italy is one of the world's leaders for sophisticated electricity consumption metering devices which allows using the "time of use tariff"[2]; where the price of electricity varies at different seasons as well as day times to reflect changes in the cost of producing electricity over the day, thus presents an opportunity to the customers to actively manage their consumption of electricity in line with price movements and demand patterns.

For the market scope; it was relatively easy to find green products because building products in Italy possess the CE Certificate of Conformity from a notified body[3]. Nevertheless, Comprehensive quantitative data on *Green Building* products in Italy are still developing, so the challenge was for certification and documentation requirements according to LEED certification requirements.

Moreover, the trend towards Green buildings remains positive in Italy due to some key drivers, to name a few; legislation and incentives, certification, active role of trade associations and *Green Building* clusters. Also, some incentive mechanism are awarded

[1] Under the European Energy Performance of Buildings Directive (EPBD) scheme, large buildings occupied by public authorities and institutions providing public services must display in a prominent place operational energy use on the building certificate to promote public awareness of energy efficiency (OECD/IEA, 2010).
[2] Source: (OECD/IEA, 2009).
[3] This is in accordance with EU Directive 89/106, which was transposed into Italian national law by Presidential Decree 246/93 and other subsequent decrees (Bevini, 2009).

for energy efficiency and promoting renewable energy for building sector, In addition to the above national incentives, there are certain incentives promoted on a regional basis for energy efficient construction by using EU funds (FESR) but it is worth noting that such incentives differ in size, scope and time span[1]. Additional tools are available to support innovation, technology capability development and innovative infrastructures such as smart grids, installing Photovoltaic systems[2] and Solar thermal panels[3], as well as incentives for energy efficient building renovation[4] (which may be applied on the second case study). Nevertheless, there exist some challenges to satisfy LEED system's requirements in the Italian context, for example; some certification schemes are not specified in LEED system, e.g. PEFC certified wood products, green services like commissioning is not easily available and this causes its relatively high price, but it should be noted that these problems are diminishing with time bringing more diffusion for green materials/products, systems and services in the Italian context.

Another important aspect to point out is the regional variations resulted in some differences for the stringency of applying sustainable building regulations- i.e. some cities mandate compliance with LEED certification (the first case study in Trento), while others use it as a voluntary certification scheme (the second case study in Milano- Lomobardi region). Hence, using LEED as a tool changes significantly between the two cases and this reflects on the building process. This can be traced in both case studies and their different targets and benchmarks for building performance.

The research also shows that some sustainable certification schemes are currently more important than others, e.g. energy certification. So it is recommended that the LEED system issues a detailed report for the building energy performance- not for all EA category, but only those related to the energy efficiency. This may have a significant effect on the transparency of market communications.

[1] More about Green building move in Italy can be found in (Bevini, 2009), (OECD/IEA, 2009)

[2] Applying "conto energia" measure which rewards electricity produced by homeowners and businesses through photovoltaic panels with a special rate guaranteed for 20 years including benefits for 15 years from fixed feed-in tariffs or premium tariffs lasting 20 years; users can either sell the excess energy they produce to third parties or cede it to the grid and then withdraw it from the grid when they need it (having priority access) and they can benefit from an incentive rate reduction (Bevini, 2009).

[3] It offers benefits for 15 years from fixed feed-in tariffs or premium tariffs for concentrating solar power lasting 25 years 2 R and a tax deduction of up to 55% of the expenses incurred in the installation of solar thermal panels (Bevini, 2009).

[4] It is possible to deduct 55% of the expenses incurred for the energy efficient renovation of existing buildings, both in their entirety and in their single components. This includes works on the "building envelope" and the substitution of heating systems (Bevini, 2009).

6.4.2. Applicability to different project types and rating systems

Some points should be taken into consideration, for example;

a. *Applying LEED system is affected by the project type (museum versus office building)*

It is important to consider that the museum building is developed as part of a complex of projects constituting other sustainably certified buildings; while on the other hand, the historical building is a stand-alone project. This affects energy efficiency measures used, e.g. for the museum building, a district energy unit was installed to serve the whole project, and this created a challenge when calculating the actual building energy consumption.

Also, the first case study was a new construction building so; it had more flexibility for adopting new design solutions for building structure, building envelope material, thickness, and additional shading element, as well as roof form and structure.

b. *Applying LEED system is affected by the type of development (new construction versus existing building)*

The second case study- being a historic building was subject to a lot of design restrictions, e.g. installing renewable energy on roofs or as an integrated architectural element was not allowed- so this influenced overall building energy efficiency, and the building was not able to comply with EA C2.

The type and design of floor plans affect the energy performance (particularly for the design and sizing of HVAC system , as well as lighting and control systems), for example; the Low rise- open floor plan for the Science museum differs than divided/ segregated medium rise vertical floor planning for the historic building.

Both case studies differ for their control system (lighting and HVAC)[1] regarding; design, operational hours, peak hour, occupancy schedule and use pattern, for example, the museum building is designed considering pre-set operational hours, while on the other hand, the office building is designed considering user control option to integrate thermal comfort considerations as well. In case of the office building, dimmable controls would have been a good design solution to enable individual occupant lighting control, but due to limitations on the façade design as part of the historic heritage, it was rejected.

Regarding the adaptability of design; for the second case study; HVAC and plumbing systems cannot be changed by the tenant. These limitations are particularly challenging for partial floor tenants. The first case study has more space for future expansion both internally and externally, which increases its flexible reuse in case of occupancy or functional changes; interior expansion allows for additional space

[1] Hours of operation of HVAC and lighting system differ for the two cases, this affects energy consumption statistics. This might have been obvious if applying LEED V4.0 EAc4 Demand response

requirements to be accommodated within the building floor-plate through displacement or consolidation of less critical function, while, exterior expansion involves the construction of additional building area. Consequently, flexibility should be incorporated into HVAC design to allow for changes in the building layout, use patterns and occupancy types[1]. Also, some special design features may greatly influence energy efficiency, e.g. skylights and Tropical Garden in the museum building, and hence it requires higher levels of system control.

Additionally, when comparing waste management policies for both case studies: the second case study- being an existing building under major renovation have resulted in more solid waste generated from demolition process. This puts a larger load on 'Construction & Demolition waste management' rather than new construction building type in the first case study, in order to reduce solid waste production[2].

c. *Applying LEED system is affected by the type of ownership*

Certification power is the main driving force for certification in the case of private/ for profit ownership- while in the case of public/regional ownership, certification power is coupled with compliance with building codes and regulations- and they aim at benefiting from strategies that keep operating cost to a minimum. Additionally, Ownership type generally reflects on bidding for material selection and energy systems.

d. *Applying LEED system is affected by the* type of LEED rating system

LEED Core and Shell has an advantage over LEED New Construction in the market- providing a 'Precertification statement' which attracts for profit private ownership due to its powerful marketing strategies, hence, leasing type and incentives can play a main role of whether to apply for the certification or not especially for private ownership as previously explained in chapter two. Nevertheless, it is also difficult to obtain some credits, related to occupancy nature and preferences, e.g. metering, interior finishes…etc[3]. Credits' differences between LEED NC and LEED CS were noted in order to estimate the baseline comparison. Additionally, the problem of dual incentives was considered for both types of rating systems, because LEED CS attempts to mitigate it through its structure, weighting and compliance path[4].

e. *Applying LEED system is affected by the* difference between versions for both case studies

LEED V2.2 and LEED V3.0 used for both case studies are very much similar regarding the main credit guidelines, yet, they differ in weighting assigned for some

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[1] More discussion about this issue can be found in (Mendler et al, 2 edition 95,96).
[2] It should be noted that LEED V4.0 rewards construction and demolition waste management in two levels; both as an additional prerequisite and as a credit.
[3] This is why LEED Commercial Interior was developed to complete LEED Core and Shell rating system's requirements for sustainability- but till the time of writing, it is not mandatory to apply for LEED Commercial Interior if the project is certified LEED Core and Shell.
[4] USGBC addresses these concerns through two of its rating systems: LEED for Core and Shell rewards projects that install M&V systems, and LEED for Commercial Interiors rewards projects in which tenants pay the energy bills.

credits and for the overall building score, as well as some compliance methods as previously indicated along the chapter.

6.4.3. Applying different scopes along the management process

Continuing to apply the proposed research framework on the management process of each project reveals the following points;

It is notable that during the Pre-schematic stage; Scope 4 (certification & market) affects this phase- particularly defining the type of rating system pursued, the certification level targeted, and the performance level required, and this eventually affects scope 1 (Guidelines) in order to make important decisions in early design phases- concerning the specific project goal, scope of work (among LEED Checklist), time estimation, any special expertise required as well as specifying their roles and responsibilities, and any specific tools and methods required.

While during the Schematic & design development stages; the second case study faced some challenges related to its existing condition, e.g. earning EA C2: Onsite renewable energy, because the historic nature of the building and its surrounding context, moreover, it was not quite easy to fulfil some prerequisite requirements, like MR Pre1: Storage and collection of recyclables, and dedicate a space inside the building for recycling activities. Moreover, preliminary plans for building reuse are mainly set based on functional requirements, then, it is verified at the design development stage calculating its environmental impact. It is noted that it takes a lot of time and effort to set a proper plan balancing between functional, economic and environmental requirements. This is obvious in using Scope 3: to calculate LCA from each material, and assembly for the building structure.

The following table summarizes various observations for comparing the application of the LEED system- investigating how each scope can support important activities for each stage of the building process;

PHASES	DOMINANT SCOPE(S)	ROLES AND RESPONSIBILITIES	ACTIVITIES	TOOLS & METHODS	FACTORS OF INFLUENCE	OUTCOME	SYNERGIES/TRADE-OFFS
Pre-schematic	Scope 4 (Certification)	◻ OPR: Owner & LEED AP ◻ BOD: design team ◻ Design requirements	Setting project goals, and this includes defining the type of rating and the certification level targeted.	x	◻ Context: National/ regional requirements, and market potentials ◻ Building type and occupancy ◻ Market advantage of some rating types	Performance targets	This scope has many synergies and trade-offs relations with other scopes along all phases.
Schematic	Scope 1 (Guidelines)	Owner and design team set the Organizational aspect	Determining the design approach: ◻ 1st approach: Using LEED as an End in itself ◻ 2nd approach: Using LEED as a Mean to higher sustainable goals	x	◻ Ownership & Design team awareness ◻ Time ◻ Budget	Defining & documenting the objective & approach of LEED certification: 1st approach may either lead to targeting minimum possible points (enough for certification)- or max. amount of points to attain market attraction. 2nd approach shall require more effort from team members to optimize environmental building performance	An iterative relation exists between scope 1, and scope 4 to define the certification level required.
		Design team	Defining the scope of work:	Using LEED Checklist	◻ Context ◻ Building type ◻ Budget	Determining possible points for certification	
		Design team define the Operational aspect, with the support of the LEED AP	Searching & identifying strategies to reach performance targets	LEED recommended/ required strategies & techniques.	◻ Design team competency ◻ Context ◻ Building type ◻ Budget	Determining & documenting sustainable strategies to adopt along the building process	Searching and identifying forms of incentives

	Scope 2 (Measurement & Benchmarking)	Design team, with the early contribution of the contractor and LEED AP.	For case study 2: Quantifying areas of maintained versus demolished building structure to plan for Building reuse plans according to LEED requirements.	Calculations according to LEED requirements.	□ Building type & condition.	Building reuse scenarios stating the percentage of maintained areas to comply with MR C1.	This scope shall reflect on scope 1 (Guidelines & decision making support tool), but it needs to be supported by scope 3 (verification).
	Scope 3 (Verification: LCA)	LCA specialist	For case study 2: LCA can support the decision making process under LEED MR C1 measurement metrics for building reuse plans.	Calculation and/or LCA simulation	□ LCA specialist skill □ System boundary, scope of work, & building stage. □ Functional unit	Environmental impact of maintained versus demolished building areas to support the decision making process.	Scope 3 (Verification suing LCA) may establish synergies/ trade-offs relations with scope 2 (LEED Measurement metrics).
	Scope 3 (Verification: Cx and M&V process)	Commissioning agent, and/ or M&V specialist.	For case study 2: Commissioning and Measurement & Verification methods maybe employed to investigate the current building performance- to plan for energy efficiency improvement strategies.	Energy simulation is one of the elements required to make a Commissioning or a Measurement and Verification plan.	□ Energy simulation □ Building type	Existing building performance, installation and performance testing of building systems.	This scope shall reflect back on scope 1 (Guidelines & Decision Making support tools).
Design development	Scope 1 (Guidelines & D.M)	Design team sets the Organizational aspect for optimizing the sustainable blg. Process.	Deciding on the design approach (preferably; front loading Integrated design approach), and decide on the decision making process and the software management tools, and maybe using borrowed methods, e.g. Lean philosophy.	Tailoring Project management tools and software to integrate LEED requirements.	□ Context □ Building type □ Budget	Defining and documenting the following; the general organizational framework defining the tasks, roles and responsibilities, preliminary time and budget estimations	There are not direct synergies - but it affects the decision making process and consequently other scopes as well.
		Design team sets the Operational aspect for optimizing sustainable blg. Performance.	Search & identify LEED guidelines and compliance path for optimizing energy, materials and resources efficiency	x	□ Context □ Building type □ Budget	Defining and documenting the following; tools and methods which shall be used in scope 2, the project delivery method, & material selection.	Synergies/ trade-offs exist between scope 1 (Decision making) and scope 2 (measuring & benchmarking).
	Scope 2 (Managing)	Project manager, and team managers.	Design team use software management tools to organize the organizational aspect for the sustainable building process	LEED measurement criteria – supported by LCA	□ Project management software tool □ Building type □ Context	Management software tools produce spread sheet defining the timeframe, sequence of work, as well as roles and responsibilities.	It organizes work with other scopes, and consequently changes from any scope may affect work in an iterative manner.

	Scope 2 (Measurement & Benchmarking)	MEP engineer supported by the commissioning and the LEED AP.	Design team measure and benchmark energy savings, and quantifies sustainable materials according to LEED requirements.	Whole building energy simulation for complying with LEED EA credits, and MR calculation methods for complying with MR credits.	□ Project management software tool □ Building type □ Context	Estimations of building's energy savings, and quantities to comply with EA Pre 2 and EA C1. Also estimations of sustainable materials used according to LEED requirements.	Synergies/ trade-offs exist between scope 1 (decision making), scope 2 (measuring & benchmarking) & scope 3 (verification).
	Scope 4 (Market)	Market specialist	Check availability of specified materials, products, systems and services	x	□ Budget □ Building type □ Context	Specification, procurement and documentation of specified materials, products, systems and services	Synergies with scope 1 (Guidelines) and scope 2 (Measurement & Benchmarking).
Construction	Scope 1 (Guidelines)	Contractor	Planning and documenting sustainable construction practices for labor, equipment and material procurement, delivery, storage and installation. Construction waste management plan	Project management software tools	□ Building type & condition □ Context	Organizational framework for labor, equipment and materials.	This shall reflect back on scope 2 (Measurement), and shall be affected from findings from scope 3 (Verification).
	(Measure ment & Benchmar	Contractor	Measuring & benchmarking the amount of sustainable materials according to LEED requirements.	Calculation methods	□ Contractor's skill □ Building type & condition □ Context	Diversion plans stating the amounts of materials for landfill and that for recycling to comply with LEED MR C2.	
	Scope 3 (Verification: Cx and M&V process)	Commissioning agent and M&V specialist	Verify installation & performance tests	Energy simulation software programs	□ Energy simulator skill, and cost of simulation program □ Building type, scale & complexity	Installation and performance verification testing for energy systems.	This scope reflects iteratively on scope 1 (Guidelines).

Table 42: Comparing the application of the LEED system on the building process of the two case studies

6.4.4. Potentials, Limitations & Adjustments to the proposed framework

By comparing the application of the LEED system for the two case studies, it shows that there exist some potentials and limitations for the use of the proposed framework- these can be summarized as follows;

Potentials

- It presents a defined Framework for practitioners on how to apply LEED along the whole building process: integrating whole system thinking for both process & practices. Additionally, it highlights differences in building types and contexts- which was not recognized before.
- It applies some suggestions that the research has pointed out, for example; complementing Scope 2 (Measurement) with scope 3 (Verification: LCA) to support the decision making process particularly for some phases, like for: Building Reuse plans, Material Selection process and Construction Waste management plan.
- It provides better means for managing, documenting and reporting activities and performance. This will have benefits for; practitioners, researchers & in the market.

Limitations

- **Dominance:** The framework assumes that all scopes are applied in parallel, and are weighted equally, hence, it does not investigate the dominance of one scope over the others in specific phases, for example in the pre-schematic, it was clear from analysing both case studies that scope 4 (certification and market) dominated the design approach and had many substantial effects on the rest of the scopes, as well as in other phases. Also, it does not show the dominance of using one tool or method over the other for some building types, for example; the second case study required earlier intervention through applying scope 3 (verification) to use the tools, not for verification, but above all for investigation; using the Cx process to investigate the current building state, and using LCA studies to explore the potential environmental impact in the existing building structure to enable drawing more efficient reuse scenarios.
- **Temporal effect:** The framework does not show the temporal sequence between each sub-scopes, and its synergistic or trade-offs effect, for example some activities require fast mutual feedback between two scopes in certain phases and this intensity differ according to the phase discussed, for example, in the preliminary design stages, fast mutual interrelations are required between scope 1(Guidelines), and scope 2 (Measurement), in order to make important decisions, while this intensity may slow

down the more developed the design becomes- yet, it still depends on the decision to be taken and what scopes are required to support it.

- ☐ **Iterative action:** It is true that the framework shows when some activities start in one phase and continues in others, but it does not show how the process can be iterative in a systemic manner, exploring more synergies and trade-offs relations between activities as well as between scopes and different building phases.

Adjustments

Based on the previous analysis to the potentials and limitations of the proposed research framework- the following adjustments were made;

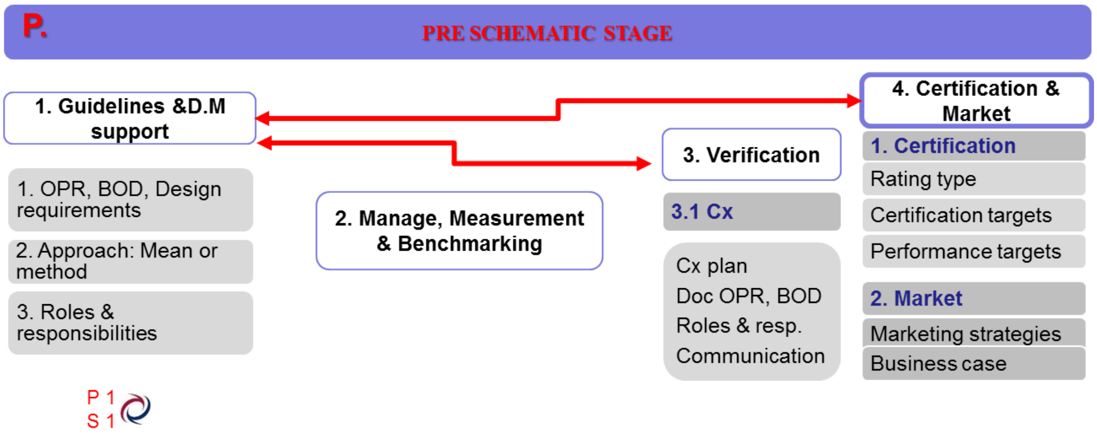

Figure 89: Adjustments for the research proposal for the pre-schematic stage

The following figure shows the dominance and temporal sequence of scope 4 (Certification & Market) on important decisions taken in the pre-schematic stage, which includes determining the type of LEED rating, as well as certification and performance targets- which is most influenced by some factors like (type of ownership, owner- user relation, and any existing incentives), as well as market signalling factors like branding of LEED certified projects, standardization of sustainable measurement criteria, as well as differentiation of LEED certification levels. Accordingly, it affects important decisions taken in scope 1 (Guidelines & decision making support tool) to develop OPR, BOD and design requirements. Scope 3 (Verification) starts by documenting all important decisions taken in the two scopes; OPR, BOD, Design requirements, roles and responsibilities of each team member as well as their communication method.

It is worth noting that this approach differ from using other Green Building Rating systems (discussed in chapter 2)- where scope 4 (Certification and market) is provided as a sort of assessment result to the building performance and not planned in advance- so it has less effect of the management process compared to LEED.

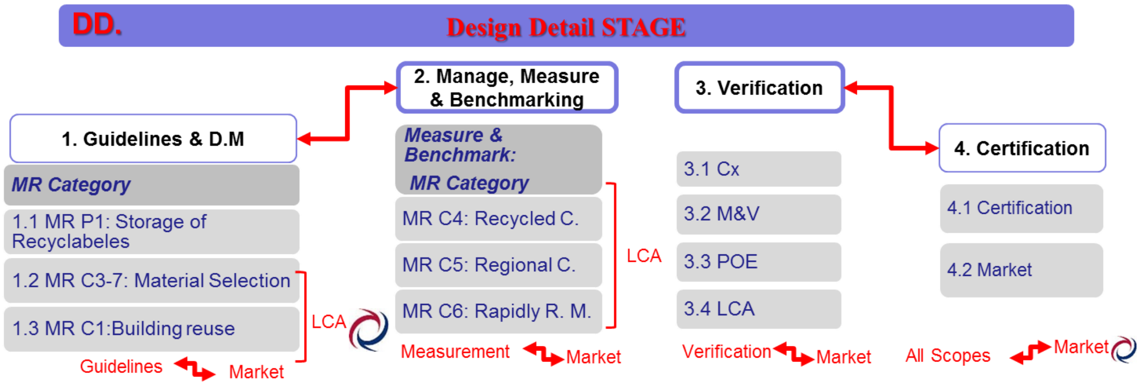

Figure 90: Adjustments for the research proposal for the Design detail stage

During the design development (also called Design Detail) stage; scope 2 (Manage, Measure & Benchmark) should be complemented by scope 3 (Verification) to support the decision making process for important activities like; Setting building reuse plans, material selection process, as well as whole building energy simulation. The results of both scopes may act as complementary to provide accurate results to the decision making process. The figure above shows the temporal sequence of activities required to support the decision making for MR category, and how scope 2 affects scope 1 , also scope 3 (Verification) affects scope 4 (Market). The figure also shows the temporal sequence and mutual interrelation of the first three scopes on the Certification & Market scope in an iterative effect, moreover it shows the iterative relation between scope 1, 2 and 3 (using LCA) for deciding on building reuse plans as well as material selection process.

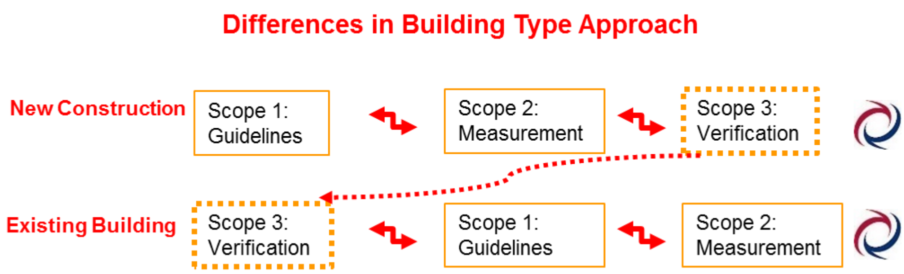

Figure 91: Differences in building type approach

Finally, a general analysis for the sequence of use of the first three scopes was illustrated in the figure above to highlight the difference between building types for both case studies. The figure shows that new construction projects typically apply scope 1; where guidelines are provided & decision making support tool are used to optimize energy as well as materials and resources efficient building performance, then scope 2 is used to provide means to manage tasks and activities, and to measure and benchmark environmental building performance. Finally, scope 3 is applied- as a quality assurance and quality control-where verification methods are used to verify the results of measuring building performance under scope 2. The process goes in an iterative manner till the optimum decision(s) are made.

On the contrary existing buildings start by applying scope 3; where verification methods are used to provide robust investigation and documentation of the existing building performance; hence Cx and M&V process are used to verify the installation and performance testing of building systems, also LCA is used to investigate the environmental impact of existing building structure to set reuse plans. The results obtained from scope 3 are used to guide decisions for scope 1- to take proper decisions for building reuse, as well as plan in advance for both demolition and construction activities, and their waste management plan. This is followed by scope 2 where LEED measurement and benchmarking criteria is used to check for credit compliance.

The management process of each case using the proposed research framework can be roughly illustrated as shown in figures (92) and (93)- where the entire building process is divided into stages and tasks take place in a temporal sequence in a scale of 1 to 5- which shows the contribution of each scope to support important activities along different stages of the building process, along with showing synergies, dominance as well as temporal sequence and dependencies between them in a typical project management spread sheet.

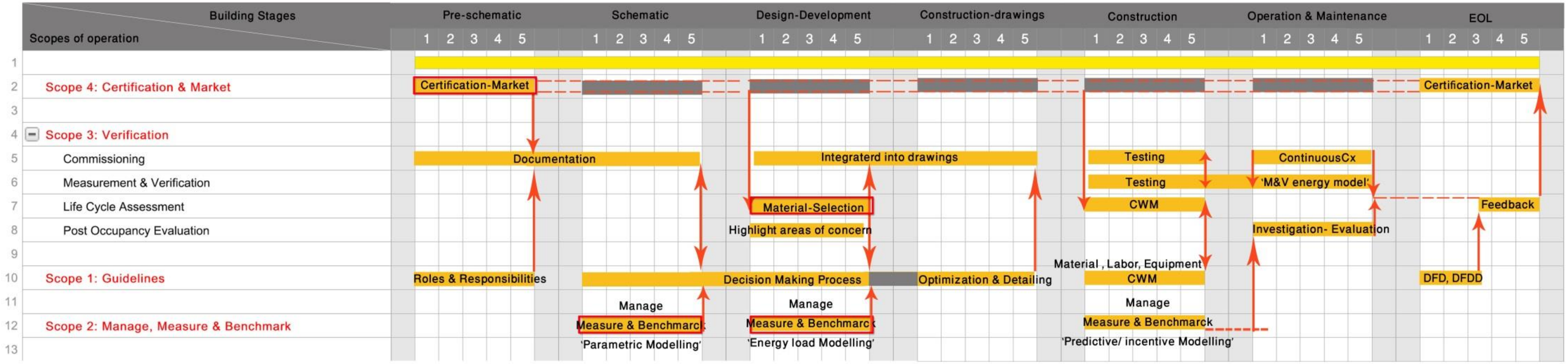

Figure 92: The proposed management framework for case study 1 (MUSE' in Tento)

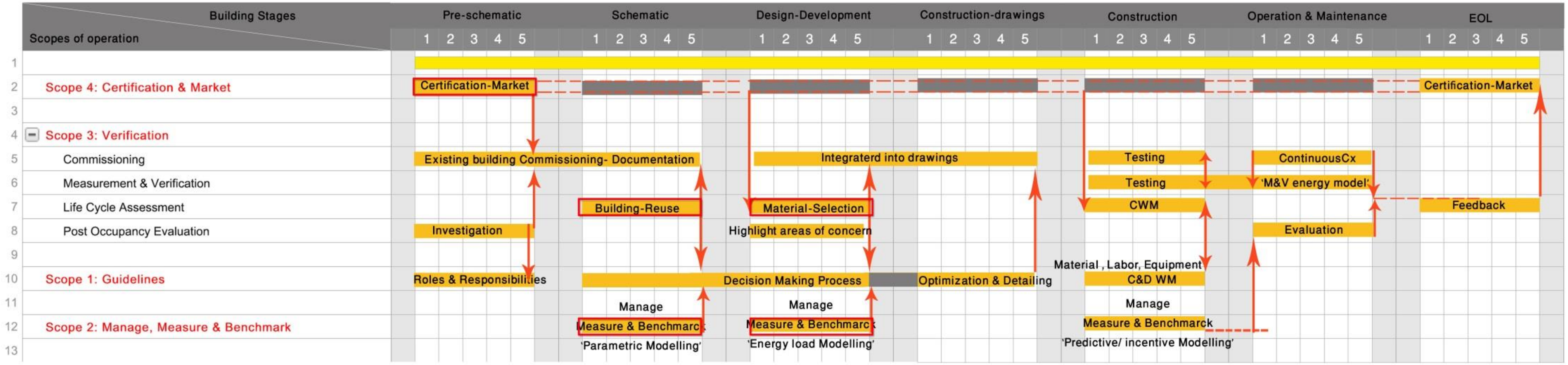

Figure 93: The proposed management framework for case study 2 (Palazzo Ricordi Berchet in Milan)

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RESULTS AND CONCLUSION

CONCLUSIONS

Applying LEED system lacks proper guidelines to use it as a tool- as a mean not as an end to sustainability in order to achieve the true sense of sustainability. These guidelines should be flexible enough to be tailored according to the project's condition(s). This requires defining better roles and responsibilities for involved parties, developing more integrated tools and models to support a more in-sighted decision making process exploring synergies, and trade-offs scenarios which shall directly or indirectly reflect on the relationships between LEED credits.

Hence, the research presents a systemic framework for applying the LEED system, based on differentiating between its mechanisms of operation into; 'Rating' and 'Verification and Certification' mechanisms. The framework was applied on both energy and materials credits- which represent almost half the total weight assigned for LEED credits and the main source of criticism for the system, due to their complex nature of assessment, which requires breaking down building elements/ materials/ products and systems into their energy and materials flows, investigating both operational and embodied energy use.

The first scope *defines the system's role as Guidelines and decision making support tool* for sustainable building process. It should cover both organizational and operational aspects- the first should include guidelines for conducting an integrated building process, and front loading important decisions for energy and resources efficiency, while the later should include prescribing sustainable strategies and guidelines to guarantee enhanced energy and resources efficiency. Although LEED system provides guidelines for sustainable management practices, but this does not cover the whole process, this creates confusion among practitioners when attempting to use the system along the building process, and results in higher cost premium resulting from a lot of change orders, as well as loss of time and money. This scope must carefully be planned to cover differences in building types, scales and complexity as well as regional differences.

The second scope defines the system's role as a *management, Measurement and Benchmarking tool* to assess sustainable building performance, support the decision making process in the first scope, and satisfy the current sustainable real estate market to provide a mean for comparing between sustainable projects. This scope should better define criteria for measuring and evaluating different sustainable criteria- this requires differentiating between source and site energy, qualitative and quantitative methods, as well as performance and prescriptive assessment criteria. It uses standard methods, so the obtained results can be the base for differentiating between the performances of different LEED projects, and can set basic understanding for comparing certified buildings under different GBRS systems. Both energy and materials credits are considered quantitative criteria, thus the current LEED version prescribes computer simulation tools as a mean to estimate operational energy savings based on predicted performance, while embodied energy may be quantified using tools as LCA- which shall be used in the next LEED version for Materials and Resources category. Yet, it is noticeable that the required energy simulation is usually outsourced due to the lack of the required skill and expertise.

The third scope explores LEED system's role as a *Verification tool* to verify sustainable building performance. Verification methods provide a degree of verification that acts as a quality assurance method for the measurement scope, and factors in the market scope. It is considered a new evolving demand for the sustainable global marketplace, and this explains why it is mostly outsourced due to the lack of expertise required to perform these analysis within team members which almost represents the major extra cost premium for green buildings. This scope includes Commissioning, Measurement and Verification, Post Occupancy Evaluation and Life Cycle Assessment. They apply standard agreed upon frameworks, but tailored according to project situation, goals and scope of verification. The methods prescribed require special expertise, time and money expenditure, which have to be balanced with the value of feedback and information obtained from them. In the same time this issue maybe the gate to control small sized and budget projects if some of these verification practices were performed by project team members, but this requires additional knowledge and training. Also this might be the chance for USGBC to show some flexibility corresponding with the project type, scale and complexity, which shall reduce the estimated cost premium especially for smaller sized and budget projects. Also, this can act as an indication towards assessing the contextual adaptation to applying the LEED system according to various contexts.

The fourth scope explores LEED system's role as a *Market tool.* Although there is no doubt about its role supporting and promoting sustainable real estate market transformation- adding the value and setting the price for LEED projects, but it is still not known how to incorporate this role when attempting to apply LEED system along the building process. There are many studies discussing the market benefit of applying the LEED system but it is not related to management practices and what practitioners need to consider during their decision making process. The research defines two interrelated subcategories to cover this scope. The first is the certification performance, which explores the value of LEED certified buildings and building products, while the second subcategory defines the market performance, which discusses means to employ marketing strategies, including branding, differentiation and standardization of LEED certified projects in the global marketplace, and discusses the business case for LEED projects, exploring its potential value, revenue and risk.

All four scopes should be applied in an iterative systemic manner to support the decision making process along various stages of the building process in an integrated process, and managed in an overlapping, complementary and iterative manner along the whole building process- considering that both first and last scopes may be closely related to any adaptation efforts to foreign contexts, while LEED's role as a measurement and verification tool for sustainable building performance draws up the standard framework of applying the LEED system. They are determined by international agreed upon standards, methods and strategies. Also, it is interesting to note that both the second and the third scopes are usually outsourced, and they represent an addition to the overall project's budget, thus, their drawbacks should be overcome by the value of benefits obtained from them which can be better managed using risk assessment and risk management.

It is worth noting that following this framework opens up new horizons for exceeding LEED system requirements; the first scope identifies new opportunities for improving both the organizational as well as the operational framework for a sustainable building process. The second scope points out opportunities for standardizing measurement metrics to enable international comparison with other GBRS. The third scope identifies opportunities to exceed LEED system's verification methods according to project situation. While, the fourth scope investigates LEED certified buildings and building products. Above all, it opens up opportunities to integrate the four scopes together to improve the sustainable project management approach.

Then the research employs the previously explained framework to set a sustainable management framework for LEED projects, and tests this comprehensive step by step 'Know How' of applying LEED for important activities in each stage. The testing criterion investigates differences in building types, contexts, as well as differences in rating systems and versions. It employs the same logic for prescribing sustainable management practices including; specification and documentation activities, selecting a project delivery method, and setting a comprehensive material selection plan. It is worth noting that comparability of the building performance is not possible, not only due to different rating types, versions, and accordingly different credits and weighting, but also due to the fact the different building conditions control earning or losing credits, and this does not indicate performance, for example; MR C1: Building Reuse, thus it can only be possible for existing buildings with reuse plans, and not applicable on new construction buildings. This concept of (Not Applied) should be introduced to the weighting process, to give a fair comparability base for building performance. Also, LEED defines certain thresholds for each sustainable criterion, but the project may contain some sustainable materials, but not be able to reach these thresholds for a number of credits- this again does not reflect the true environmental building performance. Finally, a set of validations and adjustments are made to the proposed research framework, which includes showing; dominance of some scopes in certain stages, temporal sequential and / iterative effect of some scopes and stages- pointing out synergies and trade-offs. Hence, adjustments were made to the proposed framework and the final result is presented in the form of project management spreadsheets for each case study using the poposed research framework.

DISCUSSION

Potentials of the proposed framework can be summarized in the following points;

(a) It presents a defined framework for practitioners on how to apply LEED integrating whole system thinking for both Process & Practices, and highlights difference in building types and contexts, but still more and more work is required by working groups of experts that have managed LEED projects for various building types and contexts.

(b) It applies some suggestions that the research has pointed out, for using scope 3 (Verification: Life Cycle Assessment) to support the decision making process under Scope 2 (LEED Measurement)- particularly for some activities, like; Building Reuse plans, Material Selection process, and Construction Waste management plan, and

(c) It provides better means for managing, documenting and reporting activities and performance. This will have benefits for; practitioners, researchers & in the market

d) Contextual adaptations of the LEED system into foreign contexts. This requires working on the first scope: LEED's role as a guideline and decision making support tool, as well as fourth scope: LEED as a Certification tool.

e) Finally, working on the second scope to provide standard framework for measurement metrics to enable direct comparison between LEED and non LEED certified green buildings- accordingly this shall unify efforts aiming at raising sustainable building performance, and reduce much of the confusion in the sustainable real estate market.

DIRECTIONS FOR FUTURE RESEARCH

Using the research framework to adjust LEED system's structure and weighting mechanism

A major problem for the LEED rating system is that credits' scores are mixed together, not identifying the logic behind credit weighting, i.e. for different measurement metrics; qualitative and quantitative criteria, performance and prescriptive criteria, as well as for verification and certification criteria, and then the result is reduced to a single score, leaving questionable assumptions and generalizations. Thus LEED's current structure of assessment does not allow an adequate reflection of the building's environmental performance. Additionally, some weighting assigned for some credits is based on subjective justification, which does not provide a consistent base for reporting the final environmental building assessment. Hence, the suggested research framework may be used to differentiate LEED credits into four main categories; (1) Guidelines, (2) Measurement and Benchmarking, (3) Verification, and (4) Certification & Market. Accordingly, the certification shall report points scored by the project for each category, to better reflect the sustainable status of the project.

USGBC may be able to better adjust its assessment method, online submission and certification methodology and draw future development plans for credits' weighting process based on the methodological framework explained in the research. In this way, the whole category is divided into credits for each scope identified in the research and assigned a weighting, so that documentation and reporting activities are performed in a transparent manner. In this way, rating system can continuously update its weighting system for qualitative metrics- raising the bar according to research and market demand. Also, it shall allow direct comparison for different building performance based on quantitative measurement metrics, and finally, additional points (exemplary points) are assigned for using better verification methods to verify sustainable building performance, and eventually improve the credibility and reliability of the system's results in the global market place.

Using the research framework to develop new management software

The same logic can be used to develop new management software programs to apply the LEED system considering both the environmental as well as the economic aspects- accounting for both synergies and trade-offs between mechanisms and scopes of actions, and also considering; project phases, sequence and interrelation between tasks, roles and responsibilities assigned for design team members, and accordingly streamline the decision making process- and present robust mean of managing, documenting and reporting sustainable building performance.

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APPENDIX A: COMPARING LEED ITALIA TO ITACA

The research presents a direct comparison between ITACA and LEED Italia. It is important to note that when comparing ITACA against LEED system, we discuss the rating mechanism only, because ITACA provides no certification mechanism for Green building performance.

Source: the author's elaboration from: LEED reference guide 2009, and (ENERBUILD WP6.1, 2010)

Table 43: Comparing Protocollo Itaca and LEED Italia

Criteria of analysis	Sub criteria	Protocollo Itaca	LEED Italia
Tool developer		ITACA, iiSBE Italia, ITC CNR	Before 2008 was USGBC but after that GBCI Tool developer: USGBC, it issues and develops the rating system, while certification and professional credentiality of personnel, Before 2008 was done by USGBC but after that by GBCI
		Issued by iiSBE ITALIA on the base of a MOU between Regione Piemonte and ITACA, the Federal Association of Italian Regions.	LEED NC 2009 is the only prototype followed by LEED Italia till the time of writing of the research, but projects can also apply for any other LEED rating system through open channels with USGBC e.g. LEED EBOM, LEED Schools, LEED CS, LEED Home, LEED ND, LEED CI.
Origin		It is a balance between (performance based systems) and (design strategies). Developed mainly for public use.	It is a more performance based system. Developed primarily to be applied in the *Real estate market.*
Users		Designers Consultants Construction companies Public institutions Researchers.	Designers Consultants Construction companies Investors Public institutions Consumers/end users Researchers.

Involvement	**Scale of involvement**	Building Site	Building Site
	Project phase involvement	Design Construction Refurbishment	Pre-design Design Construction In addition to credits based on plans for post occupancy. Operation, Refurbishment and maintenance for existing buildings has specific rating system called LEED EBOM which is not yet in LEED Italia but can be registered through LEED GBCI.
Building use		Residential dwellings Retail	LEED NC was designed primarily for new commercial office buildings but it is also applied on many other building types e.g. offices, institutional buildings (libraries, museums, churches…etc.), hotels and Residential dwellings of four or more habitable stories, dealing mainly with new construction and major renovation of existing buildings. Other types of buildings are not yet included in LEED Italia but can be registered through LEED GBCI.
Type of criteria	**No. of environmental criteria.**	13	36
	No. of social criteria.	7	10
	No. of economic criteria.	0	4

Structure of assessment system	**No. of mandatory criteria**	20	8
Structure of the assessment system	**No. of quantitative criteria..**	45%	77%
Structure of assessment system	**Number of hierarch levels**	3 (issues, categories of criteria and sub criteria).	2 (issues and criteria)
	Major weight categories	Availability of the technical documentation for maintenance operations.	Energy performance optimization

		Rating system ranges from -1 to +5 **Negativo:** -1.00 : global score **Sufficiente:** 0.00: Standard **Buono:** +3.00: Best practices **Ottimo**:+5.00: Ideal	Credits are distributed according to potential environmental impacts and human benefits of each credit. ☐ All LEED Italia credits are worth a minimum of 1 point. ☐ All LEED Italia credits are positive, whole numbers; there are no fractions or negative values. ☐ All LEED Italia credits receive a single, static weight, without variations based on project location (although this is considered a criticism for LEED rating system but it has been mitigated adding the new credit category of Regional Priority credits). LEED Italia rating system has 100 base points; Innovazione nella Progettazione and Priorità Regionale credits provide opportunities for up to 10 bonus points.
	Neighbourhood development	a specific version of Protocollo ITACA is under development	A version of LEED Italia for neighbourhoods is under development.
	Operation stage	Does not rate operation of a building	A building must be engaged in a contract with USGBC and/or GBCI to present data regarding the optimum use of energy and water after completion (according to the sixth requirement in LEED's Minimum Program Requirements 2009).
Certification process	**Main aim of certification**	The certification process is basically a *self-assessment validated by iiSBE Italia.* at the moment, it is used only in the context of policies aimed to provide incentives for sustainable buildings. This means that the certification is not available on the market and private buildings cannot be labelled. The main stakeholder interested are the social housing companies	*The certification is a self-assessment validated by design team, checked and verified by:* USGBC (before 2008) and now GBCI, as well as administration of credentiality of LEED AP. Assessment and ranked certification by GBCI on an international level stating that a building is sustainable, for: Policies and national incentives Real estate marketing, since buildings as well as building owners receive a labelled certificate and is published on the USGBC website.

	Steps	- Self assessment carried out by the **design team** - The Protocollo ITACA technical documents are sended to **iiSBE Italia**- **iiSBE Italia** start a validation process. Possible audit on specific criteria- iiSBE Italia at the end of the validation process issues the certificate at the **design stage. -** iiSBE Italia assess the conformity of the building at the **as built stage** to the validated Protocollo Itaca at the design stage - **iiSBE Italia** issues the final certification.	It is also a self assessment method by the design team through filling in an online template letters and uploading all necessary documentation to LEED Online, then it is revised and confirmed or denied by the USGBC giving the certification. It is divided into two principal phases, and all credits into two main categories (design phase and construction phase). Narrative and documents (pre-requisites; obligatory, and credits: minimum number of LEED credits): project registration in LEED-Online. The Design phase review is optional
	Cost	For Free	**Registration fee** is a flat fee paid up front at the time of registration. The rates are: 725 € for GBCI Members and 970 € for Non-Members.**Cost of Registration:** Depends on area of the project, membership to USGBC and expedite (as shown in the table below).
	N.B. The cost of certification doesn't include the cost for developing the technical documents requested by the certification process. Simulations, modelling, commissioning, measurements could have a cost superior to the certification one. This cost is contained as much the assessment system is linked to the national/regional regulations and technical standards.		
	Output of the certification	A statement by **iiSBE Italia** on the performance reached by the building at the **as built phase.** No levels of certification.	A formal letter of certification from USGBC **Levels of certification:** Certified 40–49 points Silver 50–59 points Gold 60–79 points Platinum 80 points and above

	Connection to legislation and technical standards	Mandatory in the Piedmont Region. **Regulations** There are not regulations based on Protocollo ITACA Regione Piemonte 2009. **Standards** All the criteria included in the assessment systems are totally linked to the *national technical standards of UNI.* *Incentives or granting* **schemes** The Protocollo ITACA Regione Piemonte 2009 is actually employed (mandatory) in two incentive programs for social housing (10.000 apartments by 2012) and for private single houses (Hosing plan). On the base of the score reached it's possible to receive a financial contribution up to 10.000 euro per apartment or a construction volume bonus.	Mandatory for Trento region. International standards, but modified for the national context, e.g. EPA, CEE, ASTM, ASHRAE, IESNA, UNI, DPR, IPMVP, ISO, GEV, SCAQMD, state of California standard, . The Autonomous **Province of Trento**, since 2008, has imposed the adoption of LEED rating system for assessing sustainability of buildings for the construction of **new province owned buildings**. Incentives are given according to the law n. 825/2007 of the Province for Energy consumption lower than 60 kWh/m2 a year (energy class B).N.B. national incentives till now have been offered for energy savings only and not for applying a sustainable rating and certification system.

And now the research presents a comparison between ITACA and LEED Italia 2009 for new construction

Protocollo Itaca list of criteria	LEED NC
1. Site quality 5% *Site conditions* 1.1.2 Level of urbanization of site **2. Resource consumption 70%** *Non-renewable Primary energy expected for whole life cycle 55%* 2.1.2 U value of the envelop 2.1.3 Net Energy for heating 2.1.4 Primary Energy for heating 2.1.5 Solar radiation control 2.1.6 Thermal mass *Renewable energy 20%* 2.2.1 Sanitary hot water from renewable sources 2.2.2 Electric energy from P.V. *Eco-compatible materials 15%*	**1. Sustainable Sites 26 Possible Points 26%** *Pre 1 Construction Activity Pollution Prevention Required* C 1 Site Selection Cr 2 Development Density and Community Connectivity C 3 Brownfield Redevelopment C 4.1 Alternative Transportation—Public Transportation Access C 4.2 Alternative Transportation—Bicycle Storage and Changing Rooms C 4.3 Alternative Transportation—Low-Emitting and Fuel-Efficient Vehicles C 4.4 Alternative Transportation—Parking Capacity C 5.1 Site Development—Protect or Restore Habitat C 5.2 Site Development—Maximize Open

2.3.1 Materials from renewable sources 2.3.2 Re-used and recycled materials *Potable water 10%* 2.4.2 Potable water for indoor uses **3. Environmental loads 5%** *Equivalent Co2 emissions* 3.1.2 Emissions in the operation **4. Indoor environmental quality 15%** *Hygrothermal Wellbeing* 4.2.1 Air temperature *Visual wellbeing* 4.3.1 Day lighting *Electromagnetic pollution* 4.5.1 Magnetic fields – 50 Hz **5. Service quality 5%** *Performance maintenance during operation* 5.2.1 Technical documentation 5.4.1 Quality of the clable system 5.4.2 Video control 5.4.3 Anti intrusion: control of access and safety 5.4.4 Systems integration	Space C 6.1 Storm water Design—Quantity Control C 6.2 Storm water Design—Quality Control C 7.1 Heat Island Effect—Nonroof C 7.2 Heat Island Effect—Roof C 8 Light Pollution Reduction **2. Water Efficiency 10 Possible Points 10%** *Pre 1 Water Use Reduction Required* C 1 Water Efficient Landscaping C 2 Innovative Wastewater Technologies C 3 Water Use Reduction **3. Energy and Atmosphere 35 Possible Points 35%** *Pre 1 Fundamental Commissioning of Building Energy Systems Required* *Pre 2 Minimum Energy Performance Required* *Pre 3 Fundamental Refrigerant Management Required* C 1 Optimize Energy Performance C 2 On-site Renewable Energy C 3 Enhanced Commissioning C 4 Enhanced Refrigerant Management C 5 Measurement and Verification C 6 Green Power **4. Materials and Resources 14%** *Pre 1 Storage and Collection of Recyclables Required* C 1.1 Building Reuse—Maintain Existing Walls, Floors and Roof C 1.2 Building Reuse—Maintain Existing Interior Non-structural Elements C 2 Construction Waste Management C 3 Materials Reuse C 4 Recycled Content C 5 Regional Materials C 6 Rapidly Renewable Materials

	C 7 Certified Wood **5. Indoor Environmental Quality 15 Possible Points 15%** *Pre 1 Minimum Indoor Air Quality Performance Required* *Pre 2 Environmental Tobacco Smoke (ETS) Control Required* C 1 Outdoor Air Delivery Monitoring C 2 Increased Ventilation C 3.1 Construction Indoor Air Quality Management Plan—During Construction C 3.2 Construction Indoor Air Quality Management Plan—Before Occupancy C 4.1 Low-Emitting Materials—Adhesives and Sealants C4.2 Low-Emitting Materials—Paints and Coatings C 4.3 Low-Emitting Materials—Flooring Systems C 4.4 Low-Emitting Materials—Composite Wood and Agrifiber Products C 5 Indoor Chemical and Pollutant Source Control C 6.1 Controllability of Systems—Lighting C 6.2 Controllability of Systems—Thermal Comfort C 7.1 Thermal Comfort—Design C 7.2 Thermal Comfort—Verification C 8.1 Daylight and Views—Daylight C 8.2 Daylight and Views—Views **6. Innovation in Design 6 Possible Points 6%** C 1 Innovation in Design C 2 LEED Accredited Professional **7. Regional Priority 4 Possible Points 4%** C1 Regional Priority

APPENDIX B: Research Survey

Practitioners' evaluation of applying the LEED rating system in the Italian context

The researchers used an online web-based questionnaire along with conducting ten interviews with LEED practitioners in the Italian context to investigate the practical perspective from applying the LEED rating system in the Italian context. They were carried in the period from May to July 2012

The Online Questionnaire

The online questionnaire was carried on a sample of 150 LEED practitioners, with the following link http://www.esurveyspro.com/Survey.aspx?id=bdab1d67-cbc2-40ac-817e-0f39672266bc, according to the previously published names on the electronic site for the Green Building Council www.usgbc.org/LEED/Accredited_Pros/accredited_pros_directory.asp (accessed May 2012). It received a percentage of 18% responses, with (63%) completed responses and (37%) incomplete ones. The studied sample included several specializations, e.g. designing & Planning, Research & Development, Management and Consultancy, Engineering & Construction and Others as shown in figure (94) and included a range of different LEED specializations (but mainly dominated by LEED AP for NC as shown in figure (95).

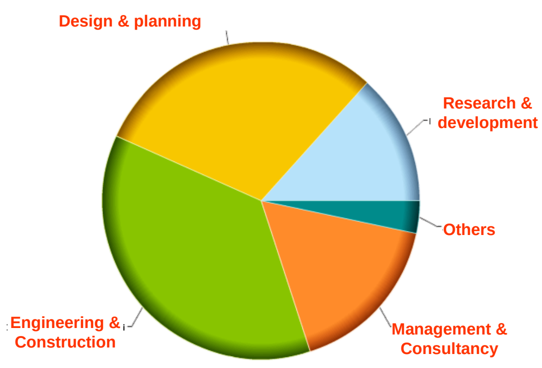

Figure 94: Different survey sample specialization

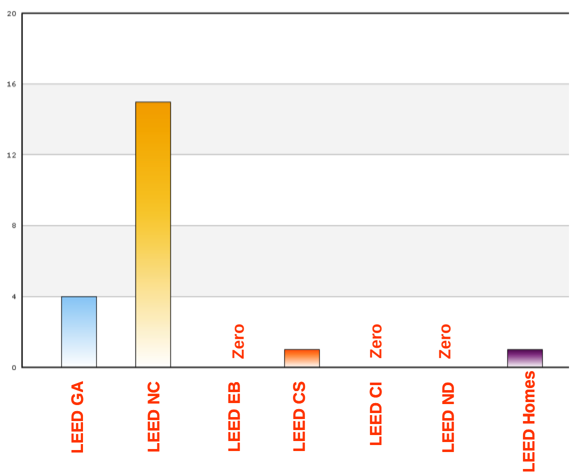

Figure 95: different survey LEED sample specialization

Questionnaire Design

The questionnaire included 26 questions (including 3 open ended ones and the rest single and multiple choices answer). They aim at qualitatively assess the application of the LEED system in the Italian context according to main arguments derived from the literature review, while the open ended questions were added to highlight additional areas of concern.

The questionnaire was divided into five parts

A. Applying the LEED system in the Italian context
B. Applying the LEED system in the building process
C. Applying LEED credit categories
D. Investigating LEED system's market in the national context
E. General Questions

It is organized in a hierarchical order, first relating LEED system application to the wider contextual scope of building industry in Italy, then shifting to more detailed levels of project application, then discussing issues related to credits' application and finally adding the market scope.

Assessment Method

The assessment used a simple calculation method where responses were categorized to provide a final scoring for LEED system from the two perspectives, LEED Rating mechanism (R) and LEED Certification Mechanism (C). LEED Rating Mechanism investigated the ability of the LEED system to define, measure, and evaluate sustainable building performance, while LEED certification Mechanism investigated the role and position of LEED certification providing a competitive market advantage, in addition to any related market issues. Positive values were assigned to indicate relative pros of the LEED process, while negative values indicated relative cons for each of the obtained results.

The score obtained from each response was registered as; score: (R) or (C), depending on its category. Scores ranged from (-1 to +1) where Negative One (-1) indicated that 100% of respondents agreed on the existence of such drawback in applying the LEED system, while Positive One (+1) indicated the contrary.

It is important to mention that percentages of responses for each question were treated independently; meaning that if the sample of study were 30 people but the question received only 20 responses, then those 20 responses represented the 100% scale that determined the range of weighting from (-1 to +1) for this specific question and so on. Questions with multiple response choices were treated in the same way. Some responses were not included in the scoring process but maintained meaningful significance in the final assessment of the LEED system.

Section A- Applying the LEED system in the Italian context

The aim of this section of the questionnaire is to investigate LEED practitioners' building industry experience of applying the LEED system related to the Italian context, covering the following points:

- ❑ Why choosing to apply the LEED system as a green building system (Multiple response question)
- ❑ How much easy do practitioners perceive applying the LEED process (Single response question) [(a)]
- ❑ If the LEED rating system is higher or lower than national norms (Single response question) [(b)]
- ❑ How much is it expected for the LEED system to increase sustainable building performance (Single response question) [(c)]

NOTES;

[(a)] Easiness is a relative term that implicitly indicated extra effort, time and cost, in addition to compliance with local building codes and regulations.

[(b)] National norms in Italy vary among regions but this question required a generalized response.

[(c)] The question implied comparison against the conventional building process following national norms and directives.

Section B- Applying the LEED system in the building process

The aim of this section is to investigate LEED practitioners' project experience of applying the LEED system in the Italian context, covering the following points:

- ❑ LEED management process and dealing with LEED online (Single response question) [(d)]

- ❑ Integrating LEED in the ordinary building process (Single response question) [(e)]
- ❑ Extra cost estimated for obtaining the LEED certification (Single response question) [(f)]
- ❑ What costs more during the LEED process (Multiple response question)
- ❑ If applying the LEED system enhances Green education among project team members (Single response question)
- ❑ Currently, If it is easy to obtain materials Green according to LEED specification (Single response question)

NOTES;

[(d)] This is a general question but a more detailed study would require filtering responses relative to easiness and cost. When assessing complexity of the LEED process, it might be useful to filter out responses depending on practical experience and number of LEED projects conducted. Dealing with LEED online could also be filtered to indicate various versions of LEED and improvement of LEED online process.

[(e)] Project management is discussed relative to time and cost, it is important to consider the conditions to which the project was realized, including when and how was the decision taken to apply the LEED system i.e. the earlier it is to integrate green features in the design process, the less change procedures and accordingly less time, effort and cost associated.

[(f)] Extra cost includes both hard and soft costs. Hard cost includes cost of obtaining Green according to LEED requirements, documentation and certification cost as well as the rest of LEED requirements like energy simulation, commissioning…etc., while soft cost includes extra time, effort or special expertise of design team members to satisfy LEED requirements. Thus, it holds a negative value in the scoring process.

Section C- Applying LEED credit categories

The aim of this section is to investigate in more detail practitioners' experience regarding obtaining LEED credits covering the following points;

- ❑ Which credit categories have higher potentials to obtain better results and which have the least ones (Multiple response question)
- ❑ Calculation requirements in the LEED process (Single response question)
- ❑ Simulation requirements in the LEED process (Multiple response question related to cost and easiness)
- ❑ Which credit categories provide future payback (Multiple response question) and after how long (Single response question)

Section D- LEED market in the national context

The aim of this section is to investigate practitioners' LEED market experience, covering the following points:

- ❑ If the national market is ready for the LEED certification (Single response question)
- ❑ If LEED system helps diffuse green products & technologies in the market (Single response question)
- ❑ Energy and Atmosphere category status regarding the national energy market (Single response question)
- ❑ What are the barriers for the diffusion of the LEED in the Italian market (Multiple response question)
- ❑ Suggestions for the development of the LEED system in the Italian market (Open ended

question)

Section E- General Questions

This section starts with an open end question asking respondents to list what they perceive as advantages and disadvantages of applying the LEED system and their opinions regarding the development of LEED International, in addition to a final question for additional comments.

In-person Interviews

The research cited additional ten in-person interviews with LEED practitioners in the Italian context. They agreed with many of the conclusions indicated by the questionnaire in addition to stressing some issues related to;

1) LEED system provides a robust framework, but it is still a difficulty to achieve an integrated building process using LEED system's guidelines, 2) using new tools to support a sustainable decision making process is still in its infancy (e.g. computer simulation models are used for verification instead of experimenting design options, and LEED online does not act as a guideline, it only provides letter templates for data uploading), 3) Currently, the Italian market is still not ready for the LEED certification because it is still not easy to find green materials, products & services according to LEED requirements but by time, the market is gaining more acceptance for the LEED system owing to the system's market attracting force and more green building elements are provided satisfying LEED requirements. They also pointed out challenges for obtaining individual credits as shown in table (44)

Credit	Challenge
SS pre1 Construction activity pollution prevention	This requirement is not included in the Italian code but it is a prerequisite in the LEED scorecard
SS C 3 Brownfield development	Incentives and technical requirements vary from one region to another, thus the feasibility of this credit should be analyzed case by case.
SS C4 Alternative transportation	It is relatively easy in the Italian context owing to the proximity of public me ns of transportation and promoting cleaner transportation alternatives, but particularly C4.4 (reduce parking and encourage car share services) is considered easier to achieve for office and institutional buildings compared to multifamily buildings
SS C6 Storm water Management	This is considered a difficult credit to obtain for many practitioners due to the calculation procedures and C6.2 (Quality Control) has been found expensive.
SS C8 Light pollution reduction	It depends on client's decision. Some regions take it into consideration but LEED requirements are considered more stringent.
WE pre1 and C1Water Use Reduction	Achieving 40% reduction in water use can be done by using efficient irrigation and landscape practices, but it is difficult to achieve 100% reduction which requires reuse of rainwater or treated grey water that are considered expensive technologies if not supported by local incentives.
WE C2 Water Efficient Landscaping	This credit depends on project type, context and incentives offered. High first-costs associated with on-site sewage treatment and/or grey water treatment and reuse, but some regions require the reuse of stormwater.
EA P1 and EA C3 Commissioning	Commissioning services are considered relatively expensive in the Italian context.
EA C1 Optimize	This credit depends on building type and context. It requires an expert contribution to perform the simulation process whom vary in their fees

Energy Performance	depending on the context and technical expertise. Using LEED U.S. (conforming with ASHRAE) is easier to achieve than LEED Italia (conforming with UNI norms).
EA C2 On site Renewable Energy	This credit requires high initial cost, although promoting renewable energy is a national target providing incentives for photovoltaic energy production, but they are not enough to satisfy the required threshold for project energy demand as required by LEED.
EA C4 Enhanced Refrigerant Management	It is easier for institutional or high-rise multifamily buildings due to HVAC specification.
EA C5 Measurement and Verification	It is mandated by the national legislations but it is considered more difficult for multifamily houses because it necessitates metering each residential unit.
EA C6Green Power	Regulations and incentives to achieve credit requirements differ among regions.
MR C7 Certified Wood	Depends on the context and availability of certified wood with considerable prices. Forest Stewardship Council (FSC) certified wood products is currently available in the Italian context but it is important to note that there are other types of certified wood products (PEFC) in the Italian context as well.
IEQ C1 Outdoor Air delivery Monitoring	Depends on the project type and budget; first-costs is considered an obstacle for multifamiliy buildings installing CO2 monitors for residential unit.
IEQ C2 Increased Ventilation	It is easier to implement in mechanically ventilated buildings because they are carefully planned to achieve increased ventilation rates.
IEQ C5 Indoor Chemical and Pollutant Source Control	It requires the use of MERV 13 filters across air handling units which may not be feasible for mid-rise multifamily buildings.

Table 44: Individual credit review according to LEED practitioners in the Italian context

It can be concluded that the practical review of applying the LEED system in the Italian context has revealed some drawbacks related to the inefficient use of the system mainly dominated by its market power and certification prestige, thus, practitioners continue to adopt a short-term rather than a long-term perspective seeking easily achieved credits.

Limitations of the study

The main objective of this study is to present an overall assessment for the LEED rating system in the Italian context, pointing out areas of concern for future development, this is why the nature of the questions were general but filtering the questions to more detailed levels would indicate more accurate results but it is outside the scope of this study. The survey was carried on practitioners in the Italian context, thus it represents opinions of LEED practitioners in the Italian context only. The questions which included the structure of LEED system were generalized but excluding LEED ND and LEED for Homes due to their peculiar nature.

Areas of Concern

The results obtained where specific to certain factors;

Sample of study; The introduction of LEED in Italy is relatively new, so the sample of study among LEED practitioners registered on the GBCI website, represented only a few number compared to other markets (150 LEED accredited). Respondents ranged from various professional backgrounds which generalize the results obtained, but the majority being LEED NC practitioners, while LEED EB, LEED CI and LEED ND practitioners were not represented in the sample of study. Practitioners' responses came from all over Italy, thus, the survey puts in mind the diversity of norms from one region to another. They represented their expertise (in years and practical application) through working in various LEED versions, projects with different owners, scales, types, programs, location and project certification level. It is important to mention, that respondents' sample lacked differentiation between experienced and less experienced practitioners, but due to the recent introduction of LEED system, this filtration was skipped to the point of view of the researchers.

Weighting of responses; all questions held equal range of weighting (from -1 to +1) but assigning different weights to questions would change the results obtained. Scores weighting was assigned according to the subjective point of view of the researchers. Using different score values might lead to different conclusions.

APPENDIX C: EA & MR CREDIT COMPLIANCE FOR CASE STUDY (1) SCIENCE MUSEUM

i. Energy credits' calculations for LEED compliance Pre1, C1, C2, C6

Table 45: Section 1.1 - General Information

Simulation Program	EnergyPlusV2-2-0	Quantity of Stories	5
Principal Heating Source	Fossil Fuel	Weather File	Trento Meteonorm,Italy (Trento.epw)
Energy Code Used	ASHRAE 90.1-2004 Appendix G	Climate Zone	4c
New Construction Percentage	100%	Existing Renovation Percentage	0%

Table 46: Section 1.2 - Space Summary

Building Use (Occupancy Type)	Conditioned Area (sf)	Unconditioned Area (sf)	Total Area (sf)
Museum/galleries	46537	5681	52,218
Office	24358	594	24,952
Libraries/Cafeteria	7133	0	7,133
Auditorium seating area	2160	0	2,160
WC	2255	417	2,672
Staircase/Corridor	6093	14472	20,565
Warehouse	0	1016	1,016
Storage/Multiuse-assembly	24080	2964	27,044
mechanical	1413	14677	16,090
greenhouse	6713	0	6,713
Parking	0	43971	43,971
Total	120,742	83792	204,534

Table 47: Section 1.4 - Comparison of Proposed Design Versus Baseline Design Energy Model Inputs including descriptions for:

Model Input Parameter	Proposed Design Input	Baseline Design Input
Exterior Wall Construction	Mass construction, marble, sp 0.03m, air gap, sp 0025m, corkboard, sp 0.140 m, thermal brick, sp 0.260m, plaster, sp 0.015m, U=factor=0.192 W/m2K	Steel Frame construction, U-factor=0.705 W/m2K
Roof Construction	Office 's roof, gravel, sp 0.08m, bitumen, sp 0.002m, concrete , sp 0.07m, Polyurethane board, sp 0.04m, concrete, sp 0.05m, oriented strand board, sp 0.03m, corkboard, sp 0.12m, U=0.246 W/m2K Exposition's roof, Polyethylene, sp 0.002m, cork board, sp 0.12m, plywood, sp 0.01m corkboard, sp 0.06m, plywood, sp 0.01m, acrylic, sp 0.009m U=0.208 W/m2K	insulation entirely above deck, U-Factor=0.360 W/m2K
Floor/Slab Construction	Exposition's floor, wooden floor, sp 0.015m , chipboard, sp 0.03m, polyethylene HD, sp 0.005m, concrete sp 0.4m, U=1,375W/m2K	Steel Joist, U-factor=0.705 W/m2K Unheated slab-on grade floor, F-factor=0.73 W/mK
Window-to-gross wall ratio	30%	30%
Fenestration type	1-Office:Wood frame, Double Pane low-e glass 2-Lobby:Steel frame, Double Pane low-e glass 3-Esposition area: Aluminium frame, Double Pane low-e glass	1-North Orientation 2-South, East, West Orientation
Fenestration U-factor	1-1.67 2-3.22 3-3.09	1-3.24 2-3.24
Fenestration SHGC - North	1-0.58 2-0.58 3-0.58	1-0.39

Fenestration SHGC - Non-North	1-0.58 2-0.58 3-0.58	2-0.39
Fenestration Visual Light Transmittance	1-0.67 2-0.67 3-0.67	1-0.65 2-0.65
Shading Devices	1-Automatic Shade Roll 2-Automatic Shade Roll 3-Automatic Shade Roll	None
Shading Devices	1-Automatic Slatted blind 2-Automatic Slatted blind 3-Automatic Slatted blind	None
Interior Lighting Power Density (W/sf)	Average: 0.76 W/sf	1.1 W/sf (Building Area Method)
Day lighting Controls	None	None
Other Lighting Control Credits	None	None
Exterior Lighting Power (kW)	3.5	5.6
Process Lighting (kW)	None	None
Receptacle Equipment Power Density (W/sf)	2.09	2.09
Primary HVAC System Type	Museum/Galleries: Constant air volume unit and heating and cooling radiant panels Reception areas: Constant air volume Classroom (age 9 plus): Constant air volume with reheat Office: Constant air volume unit and heating and cooling radiant panels, Fan coil Conference/Meeting: Constant air volume unit and heating and cooling radiant panels Cafeteria: Constant air volume unit and fan coils	Table G3.1.1B System 7-packaged rooftop variable air volume with reheat (VAV-R) Supply Air Temperature Reset higher 2.3?C under minimum cooling load conditions

	Libraries: Constant air volume unit and heating and cooling radiant panels Auditorium sitting area: Constant air volume with reheat Storage room: Fan coil Warehouse: Fan Coil Lobbies: Constant air volume	
Other HVAC System Type	NONE	NONE
Fan Supply Volume	UTA01: Supply 0.51 m3/s; Return 0.51 m3/s UTA02: Supply 1.6 m3/s; Return 1.2 m3/s UTA03: Supply 7.0 m3/s; Return 5.4 m3/s UTA04: Supply 0.9 m3/s; Return 0.6 m3/s UTA05: Supply 0.2 m3/s; Return 0.2 m3/s UTA06: Supply 0.9 m3/s; Return 0.9 m3/s UTA07: Supply 1.9 m3/s; Return 1.5 m3/s UTA08: Supply 2.0 m3/s; Return 1.8 m3/s UTA09: Supply 1.4 m3/s; Return 0.8 m3/s UTA10: Supply 1.0 m3/s; Return 0.8 m3/s UTA11: Supply 2.4 m3/s; Return 1.8 m3/s UTA12: Supply 0.7 m3/s; Return 0.7 m3/s	-01VAV: 70,943cfm (33.49m3/s) (mean value Baselines) -02VAV: 12,601 cfm (5.95 m3/s)(mean value Baselines) -03VAV: 17,542 cfm (8.28 m3/s)(mean value Baselines) -04VAV: 2,564 cfm (1.21 m3/s)(mean value Baselines) -05VAV: 6,081 cfm (2.87 m3/s)(mean value Baselines) -06VAV: 21,229 cfm (10.02 m3/s)(mean value Baselines) -09VAV: 9,174 cfm (4.33 m3/s)(mean value Baselines) -10VAV: 21,186 cfm (10.00 m3/s)(mean value Baselines) -11VAV: 26,398 cfm (12,46 m3/s)(mean value Baselines) -12VAV: 6,271 cfm (2.96

		m3/s)(mean value Baselines) -13VAV: 2,542 cfm (1.20 m3/s)(mean value Baselines) -14VAV: 2,924 cfm (1.38 m3/s)(mean value Baselines)
Fan Power	UTA01: Supply 0.49 kW; Return 0.39 kW UTA02: Supply 1.8 kW; Return 0.7 kW UTA03: Supply 7.8 kW; Return 3.9 kW UTA04: Supply 0.92 kW; Return 0.43 kW UTA05: Supply 0.09 kW; Return 0.13 kW UTA06: Supply 0.6 kW; Return 0.4 kW UTA07: Supply 1.7 kW; Return 1.0 kW UTA08: Supply 2.1 kW; Return 0.9 kW UTA09: Supply 1.3 kW; Return 0.5 kW UTA10: Supply 0.5 kW; Return 0.6 kW UTA11: Supply 2.2 kW; Return 1.2 kW UTA12: Supply 0.8 kW; Return 0.5 kW	-01VAV: (Supply+return) 81.31 bhp (64.8 kW) -02VAV:(Supply+return)15.12 bhp (12.5 kW) -03VAV: (Supply+return)21.05 bhp (17.2 kW) -04VAV:(Supply+return)3.08 bhp (2.67 kW) -05VAV:(Supply+return)7.30 bhp (6.15 kW) -06VAV:(Supply+return)25.38 bhp (20.7 kW) -09VAV:(Supply+return)11.01 bhp (9.2 kW) -10VAV:(Supply+return)25.33 bhp (20.6 kW) -11VAV: (Supply+return)31.20 bhp (25.3 kW) -12VAV: (Supply+return)7.53 bhp (6.3 kW) -13VAV: (Supply+return)3.05 bhp (

		2.7 kW) -14VAV: (Supply+return)3.51 bhp (3.0kW)
Economizer Control	For UTA02, UTA07, UTA08; in cooling mode when the outside air enthalpy is less than exhaust air enthalpy	For All VAV-R High limit shutoff=24?C
Demand Control Ventilation	None	None
Unitary Equipment Cooling Efficiency	Fan Coil 4 pipe, Radiant panel	Cold Coils
Unitary Equipment Heating Efficiency	Fan Coil 4 pipe, Radiant panel, radiator	Hot Coils
Chiller parameters	-Purchased Cooling	-Purchased Cooling
Chilled water loop & pump parameters	-Primary Constant volume pump, 15.4 kW, Chilled water supply temperature: 7?C, return temperature: 12?C -Secondary variable volume pump, loop radiant panel 7.2 kW, chilled water supply temperature:16?C, return temperature: 18?C -Secondary variable volume pump, loop FC, 7.0 kW, chilled water supply temperature:7?C, return temperature: 12?C -Secondary variable volume pump, loop Cold Coil UTA, 9.2 kW, chilled water supply temperature:7?C, return temperature: 12?C	-Primary Constant volume pump, 28.00 kW (mean value) -Secondary Constant volume pump, 28.00 kW(mean value) -Chilled water design supply temperature: 6.7?C -Chilled water design return temperature: 13?C Temperature reset based on outside temperature
Boiler parameters	-Purchased Cooling	-Purchased Heating
Hot water loop & pump parameters	-Primary Constant volume pump, 13.2 kW, Hot water supply temperature:50?C, return temperature: 45?C	--Primary Constant volume pump 12.00 kW(mean value) -Hot water design supply

	-Secondary variable volume pump, loop radiant panel 5.0 kW, Hot water supply temperature: 37?C, return temperature: 34?C -Secondary variable volume pump, loop FC, 4.6 kW, Hot water supply temperature:50?C, return temperature: 45?C -Secondary variable volume pump, loop Cold Coil UTA, 5.2 kW,Hot water supply temperature:50?C, return temperature: 45?C Temperature reset based on outside temperature	temperature: 82?C -Hot water design return temperature: 54?C Temperature reset based on outside temperature
Cooling tower parameters	None	None
Condenser water loop & pump parameters	None	None

Table 48: Section 1.5 - Energy Type Summary

Energy Type	Utility Rate Description	Units of Energy	Units of demand
Electricity	0.177	kWh	kW
Purchased Heating	0.108	kWh	kW
Purchased Cooling	0.149	kWh	kW

Table 49: Section 1.6 - On-Site Renewable Energy- Renewable Energy Source Summary

Renewable Source	Backup Energy Type	Annual Energy Generated	Rated Capacity (price)	Renewable Energy Cost (dollar)
Photovoltaics panels	Electricity	45331.7 (kWh)	46.6 kW	8024.35

Table 50: Baseline Performance - Performance Rating Method Compliance

End use	process	Baseline design energy type	Units of annual energy & peak demand	Baseline (0º rotation)	Baseline (90º rotation)	Baseline (180º rotation)	Baseline (270º rotation)	Baseline design
Interior lighting		Electricity	Energy use (kWh)	306,790.1	306,790.1	306,790.1	306,790.1	306,790.1
			Demand	130	130	130	130	130

			(kW)					
Exterior lighting		Electricity	Energy use (kWh)	12,731.6	12,731.6	12,731.6	12,731.6	12,731.6
			Demand (kW)	5.6	5.6	5.6	5.6	5.6
Space heating		Purchased heating	Energy use (kWh)	311,653.5	312,816.2	292,080.9	316,085.8	308,159.1
			Demand (kW)	2,149	2,185	2,113	2,144	2,147.8
Space cooling		Purchased cooling	Energy use (kWh)	407,540	418,252	410,941	416,821	413,388.5
			Demand (kW)	992	1,140	959	1,060	1,037.8
Pumps		Electricity	Energy use (kWh)	130,085	129,948.2	127,938.5	124,379	120,087.7
			Demand (kW)	40	38.7	39.7	38.5	39.2
Evaporative cooling		Electricity	Energy use (kWh)	0	0	0	0	0
			Demand (kW)	0	0	0	0	0
Fans- interior		Electricity	Energy use (kWh)	88,107.8	95,523.8	88,719.6	91,689.2	91,010.1
			Demand (kW)	191.5	191.1	191.8	189.9	191.1
Fans- parking garage		Electricity	Energy use (kWh)	0	0	0	0	0
			Demand (kW)	0	0	0	0	0
Service water heating		Purchased heating	Energy use (kWh)	18,943.6	18,944.4	18,995.5	18,934.4	18,954.5
			Demand (kW)	23	23	23	23	23
Receptacle equipment		Electricity	Energy use (kWh)	300,772.6	300,772.6	300,772.6	300,772.6	300,772.6
			Demand (kW)	90	90	90	90	90
Domestic hot water pressurization		electricity	Energy use (kWh)	546.7	546.7	546.7	546.7	546.7
			Demand (kW)	8	8	8	8	8
Refrigeration		electricity	Energy use (kWh)	1,332	1,332	1,332	1,332	1,332
			Demand (kW)	29	29	29	29	29
Domestic hot water recirculation		electricity	Energy use (kWh)	20.1	20.1	20.1	20.1	20.1

			Demand (kW)	0.3	0.3	0.3	0.3	0.3
Cooking bar		electricity	Energy use (kWh)	130	130	130	130	130
			Demand (kW)	12	12	12	12	12
Elevators & escalators		electricity	Energy use (kWh)	32,203	32,203	32,203	32,203	32,203
			Demand (kW)	52.5	52.5	52.5	52.5	52.5
Collection area. Greenhouse,		electricity	Energy use (kWh)	618,610.3	618,610.3	618,610.3	618,610.3	618,610.3
			Demand (kW)					
Baseline energy totals		Total annual energy use (MBtu/year)		7,607	7,672	7,547	7,646	7,618
		Total process energy (MBtu/year)						3,252

Note: Process Cost equals at least 25% of Baseline Performance, as required for showing credit compliance.

Table 51: Baseline Energy Costs

Energy type	Baseline cost ($) (0° rotation)	Baseline cost ($) (90° rotation)	Baseline cost ($) (180° rotation)	Baseline cost ($) (270° rotation)	Baseline Building Performance ($)
Electricity	263,978	263,850	263,706	263,601	263,783
Purchased Heating	35,707	35,833	33,599	36,185	35,331
Purchased Cooling	60,728	62,325	61,235	62,111	61,599
Total Baseline Costs	360,413	362,008	358,540	361,897	360,713

Table 52: Performance Rating table (1)- Performance Rating Method compliance

End use	process	Proposed design energy type	Proposed design units	Proposed building results	Baseline building units	Baseline building results	Percentage savings
Interior lighting		Electricity	Energy	212,080	Energy use	306,790.1	30.9

			use (kWh)		(kWh)		
			Demand (kW)	90	Demand (kW)	130	30.7
Exterior lighting		Electricity	Energy use (kWh)	8,103.4	Energy use (kWh)	12,731.6	36.4
			Demand (kW)	3.5	Demand (kW)	5.6	42.1
Space heating		Purchased heating	Energy use (kWh)	131,143.5	Energy use (kWh)	308,159.1	57.4
			Demand (kW)	802	Demand (kW)	2,147.8	62.7
Space cooling		Purchased cooling	Energy use (kWh)	345,205.7	Energy use (kWh)	413,388.5	16.5
			Demand (kW)	710.6	Demand (kW)	1,037.8	31.5
Pumps		Electricity	Energy use (kWh)	59,727.9	Energy use (kWh)	128,087.7	53.4
			Demand (kW)	56	Demand (kW)	39.2	-43.6
Evaporative cooling		Electricity	Energy use (kWh)	2,372.4	Energy use (kWh)	0	0
			Demand (kW)	2	Demand (kW)	0	0
Fans- interior		Electricity	Energy use (kWh)	72,499.4	Energy use (kWh)	91,010.1	20.3
			Demand (kW)	35	Demand (kW)	191.1	81.7
Fans- parking garage		Electricity	Energy use (kWh)	0	Energy use (kWh)	0	0
			Demand (kW)	0	Demand (kW)	0	0
Service water heating		Purchased heating	Energy use (kWh)	18,954.5	Energy use (kWh)	18,954.5	0
			Demand (kW)	23	Demand (kW)	23	0
Receptacle equipment		Electricity	Energy use (kWh)	300,772.6	Energy use (kWh)	300,772.6	0
			Demand (kW)	90	Demand (kW)	90	0
Domestic hot water pressurization		electricity	Energy use (kWh)	546.7	Energy use (kWh)	546.7	0
			Demand (kW)	8	Demand (kW)	8	0
Refrigeration		electricity	Energy use (kWh)	1,332	Energy use (kWh)	1,332	0
			Demand (kW)	29	Demand (kW)	29	0
Domestic hot water recirculation		electricity	Energy use (kWh)	20.1	Energy use (kWh)	20.1	0
			Demand (kW)	0.3	Demand (kW)	0.3	0
Cooking bar		electricity	Energy use (kWh)	130	Energy use (kWh)	130	0
			Demand (kW)	12	Demand (kW)	12	0
Elevators &		electricity	Energy	32,203	Energy use	32,203	0

escalators			use (kWh)		(kWh)		
			Demand (kW)	52.5	Demand (kW)	52.5	0
Collection area. Greenhouse,		electricity	Energy use (kWh)	618,610.3	Energy use (kWh)	618,610.3	0
			Demand (kW)		Demand (kW)		
Energy totals		Total annual energy use (MBtu/year)		6,154		7,618	19.2
		Total process energy (MBtu/year)		3,252		3,252	0

Table 53: Performance Rating table (2)- Performance Rating Method compliance

End use	process	Proposed design energy type	Proposed design units	Proposed building results	Baseline building units	Baseline building results	Percentage savings
Exterior lighting		Electricity	Energy use (kWh)	1,406	Energy use (kWh)	12,731.6	89
			Demand (kW)	4.2	Demand (kW)	5.6	26.3
Space heating		Natural gas	Energy use (kWh)	591,157	Energy use (kWh)	434,655.5	-36
			Demand (kW)	591.2	Demand (kW)	2,046.3	71.1
Space cooling		Natural gas	Energy use (kWh)	703,782	Energy use (kWh)	69,307.2	-91.5
			Demand (kW)	463.7	Demand (kW)	411.4	-12.7
Pumps		Electricity	Energy use (kWh)	10,364	Energy use (kWh)	98,769.5	89.5
			Demand (kW)	31.1	Demand (kW)	102	69.5
Heat rejection		Electricity	Energy use (kWh)	0	Energy use (kWh)	20,367.6	0
			Demand (kW)	0	Demand (kW)	33.7	0
Fans- interior		Electricity	Energy use (kWh)	12,580	Energy use (kWh)	90,385.2	86.1
			Demand (kW)	37.8	Demand (kW)	191.1	80.4
Fans- parking garage		Electricity	Energy use (kWh)	0	Energy use (kWh)	0	0
			Demand (kW)	0	Demand (kW)	0	0
Service water heating		Natural gas	Energy use (kWh)	32,459	Energy use (kWh)	18,955.2	-71.2
			Demand (kW)	32.5	Demand (kW)	60	46.1
Receptacle equipment		Electricity	Energy use (kWh)	52,192	Energy use (kWh)	300,772.6	82.6
			Demand (kW)	156.8	Demand (kW)	90	-74.3
Domestic hot		electricity	Energy	95	Energy use	546.7	82.6

water pressurization			use (kWh)		(kWh)		
			Demand (kW)	-3	Demand (kW)	8	96.3
Refrigeration		electricity	Energy use (kWh)	231	Energy use (kWh)	1,332	82.7
			Demand (kW)	-7	Demand (kW)	29	98
Domestic hot water recirculation		electricity	Energy use (kWh)	3	Energy use (kWh)	20.1	85.3
			Demand (kW)	0.01	Demand (kW)	0.3	0
Cooking bar		electricity	Energy use (kWh)	23	Energy use (kWh)	130	82.4
			Demand (kW)	0.1	Demand (kW)	12	0
Elevators & escalators		electricity	Energy use (kWh)	5,588	Energy use (kWh)	32,203	82.6
			Demand (kW)	16.8	Demand (kW)	52.5	68.2
Collection area. Greenhouse,		electricity	Energy use (kWh)	618,638.6	Energy use (kWh)	618,638.6	0.000047
			Demand (kW)		Demand (kW)		
Energy totals		Total annual energy use (MBtu/year)		7,047		6,843	-3
		Total process energy (MBtu/year)		2309		3,252	29

Table 54: Energy Cost and Consumption by Energy type- Performance Rating Method compliance

Energy type	Proposed Design		Baseline Design		Percentage savings	
	Energy use	Cost	Energy use	Cost	Energy use	Cost
Natural gas	1,327,398 (kWh)	120,793	434,655 (kWh)	39,556	-205.4	-205.4
Electricity	737,921 (kWh)	130,612	1,570,945 (kWh)	274,716	53	52.5
Purchased Heating	0 (kWh)	0	0 (kWh)	2,047	0	0
	0	0	0		0	0
Subtotal (Model outputs)	7,047 (MBtu/year)	251,405	6,843 (MBtu/year)	316,319	-3	20.5
Onsite Renewable energy	Energy generated	Renewable energy cost				
Photovoltaic panels	45,331 (kWh)	8,023	(subtracted from model results to reflect proposed building performance)			
		0	(subtracted from model results to reflect proposed building performance)			
	Energy savings	Cost savings				
	Proposed design		Baseline design		Percentage savings	

	Energy use	Cost	Energy use	Cost	Energy	Cost
Total	6,892 (MBtu/year)	243,382	6,843 (MBtu/year)	316,319	-0.7	23.1

ii. District Energy systems

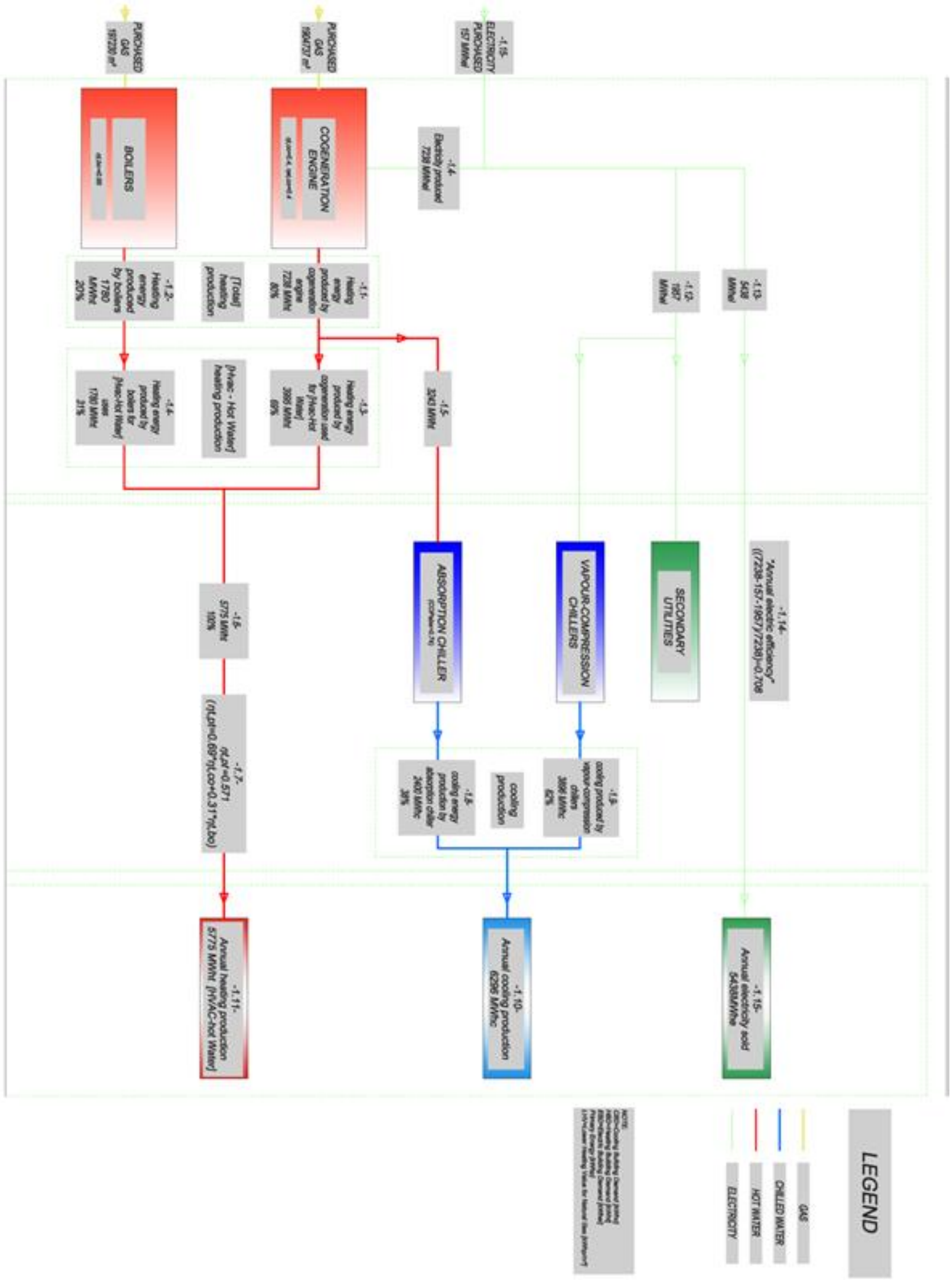

Figure 96 District Energy System for the project

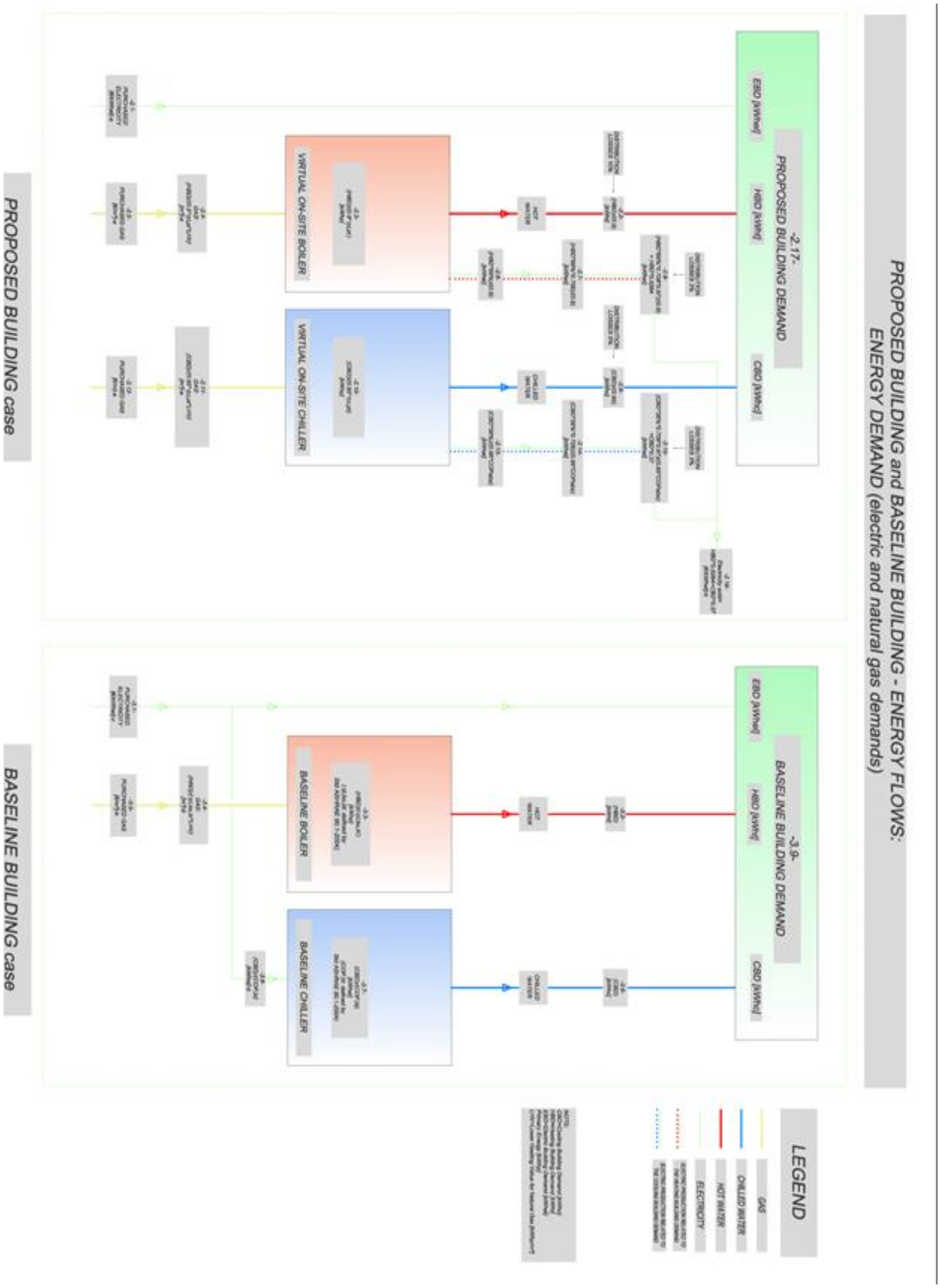

Figure 97: District Energy System for the project-Proposed versus Baseline case

iii. Materials credits' calculations for LEED compliance

Table 55: MR Credit 2.1/2.2: Construction Waste Management

MATERIAL	***Recycled***	***Landfill***
European Waste Code	(ton)	(ton)
CONCRETE (CER 17 01 01)	224,98	0,00
MIXED MATERIAL: cement, bricks, tiles and ceramics (CER 17 01 07)	490,94	0,00
MIXED WASTE (CER 17 09 04)	0,00	33,72
WOOD (CER 17 02 01)	111,68	0,00
GLASS (CER 17 02 02)	4,13	0,00
IRON AND STEEL (CER 17 04 05)	50,83	0,00
PACKAGING IN MIXED MATERIALS (CER 15 01 06)	0,00	24,57
CARDBOARD (CER 15 01 01)	22,56	0,00
PLASTIC PACKAGING (CER 15 01 02)	12,86	0,00
PLASTERBOARD (CER 17 08 02)	16,27	0,00
TOT.	934,25	58,29
RECYCLED PERCENTAGE	94,13%	

Table 56: MR Credit 4.1/4.2: Recycled Content:

Material Name	**Manufacturer**	**Material Cost* ($)**	**Post-Consumer Recycled Content (%)**	**Pre-Consumer Recycled Content (%)**	**Recycled Content Information Source**
Reinforcing steel - FERALPI	ALTOLAGO	1573145	98	0	Manufacturer documentation
Reinforcing	ALTOLAGO	361398	96	0	Manufacturer

steel - STEFANA					documentation
Reinforcing steel - IRO	ALTOLAGO	127552	98	0	Manufacturer documentation
Reinforcing steel - FERRIERE NORD	ALTOLAGO	42517	89	0	Manufacturer documentation
reinforcing steel - ALFA ACCIAI	ALTOLAGO	21259	98	0	Manufacturer documentation
Cast in place concrete - mix1	CORONA CALCESTRUZZI	144584	0	44.36	Manufacturer documentation
Cast in place concrete – mix2	CORONA CALCESTRUZZI	955000	0	43.79	Manufacturer documentation
Cast in place concrete – mix3	CORONA CALCESTRUZZI	167978	0	45.10	Manufacturer documentation
Cast in place concrete – mix5 beam	CORONA CALCESTRUZZI	566366	0	43.31	Manufacturer documentation
Cast in place concrete – mix5- elevation	CORONA CALCESTRUZZI	127413	0	43.31	Manufacturer documentation
Cast in place concrete – mix7	CORONA CALCESTRUZZI	13204	0	39.86	Manufacturer documentation
Cast in place concrete – mix6	CORONA CALCESTRUZZI	115448	0	48.24	Manufacturer documentation
Laminated steel	ARCELOR MITTAL	588976	54	46	Manufacturer documentation
Metal sheet	DUFERCO	1143307	25	0	Default value
Glass roofing and facade	GUARDIAN	818350	6.2	0.61	Manufacturer documentation
Zinc titanium	ZINTEK	912372	60	20	Manufacturer documentation
Aluminium profiles	METRA	956840	0	60	Manufacturer documentation

Table 57: Combined calculation for MR Credits

Mill	***Quantity of rebar supply***	***% of postconsumer recycled content***	***number and date of IGQ validation***	***Mill site***	***Distance from the project site***	***% of raw materials collected within 805km from the project site(*)***
FERALPI SPA	74%	98 %	C055 27-11-2008	Lonato (BS) zip code 25017	130 km *(81 miles)*	92 %
STEFANA SPA	17%	96 %	C068 01-03-2011	Nave (BS) zip code 25075	170 km *(106 miles)*	79 %
IRO	6%	98 %	C062 18-10-2010	Odolo (BS) zip code 25076	170 km *(106 miles)*	87 %
FERRIERE NORD SPA	2%	89 %	C063 15-12-2010	Osoppo (UD) zip code 33010	300 km *(186 miles)*	72 %
ALFA ACCIAI SPA	1%	98 %	C057 21-04-2010	Brescia (BS) zip code 25134	135 km *(84 miles)*	91 %

Product Name	Manufacturer	Total Product Cost* ($)	Percentage Compliant (%)	Compliant Product Value	Harvest Distance**(mi)	Manufacture Distance**(mi)	Harvest /Manufacture Location Info Source
Reinforcing steel - FERALPI	ALTOLAGO	1573145	92	1447293.4	1	81	Manufacturer documentation
Reinforcing steel - STEFANA	ALTOLAGO	361398	79	285504.42	1	106	Manufacturer documentation
Reinforcing steel - IRO	ALTOLAGO	127552	87	110970.24	1	106	Manufacturer documentation
Reinforcing steel - FERRIERE NORD	ALTOLAGO	42517	72	30612.24	1	186	Manufacturer documentation

reinforcing steel - ALFA ACCIAI	ALTOLAGO	21259	91	19345.69	1	84	Manufacturer documentation
Cast in place concrete - mix1	CORONA CALCESTRUZZI	144584	100	144584	65.9	8.7	Manufacturer documentation
Cast in place concrete – mix2	CORONA CALCESTRUZZI	955000	100	955000	87	8.7	Manufacturer documentation
Cast in place concrete – mix3	CORONA CALCESTRUZZI	167978	100	167978	87	8.7	Manufacturer documentation
Cast in place concrete – mix5 beam	CORONA CALCESTRUZZI	566366	100	566366	87	8.7	Manufacturer documentation
Cast in place concrete – mix5-elevation	CORONA CALCESTRUZZI	127413	100	127413	87	8.7	Manufacturer documentation
Cast in place concrete – mix7	CORONA CALCESTRUZZI	13204	94	12411.76	87	8.7	Manufacturer documentation
Cast in place concrete – mix6	CORONA CALCESTRUZZI	115448	100	115448	87	8.7	Manufacturer documentation
Wall finishes Botticino stone	GEIMAR	753628	100	753628	53.7	56	Manufacturer documentation
Glass roofing and facade	GUARDIAN	818350	36.36	297552.06	445	330	Manufacturer documentation
Zinc titanium	ZINTEK	912372	80	729897.6	1	124	Manufacturer documentation
Glue laminated wood - roof A	STRATEX	15997	100	15997	285.46	94.32	Manufacturer documentation
Glue laminated wood - roofs B-C	STRATEX	38508	100	38508	20.62	94.32	Manufacturer documentation
Glue laminated	STRATEX	167662	100	167662	330.38	94.32	Manufacturer documentati

wood - roofs D-E-F-G and wooden facade							on

Material Name / Description	**Manufacturer**	**Total Material Cost* ($)**	**The Rapidly Renewable Criteria(% by Weight)**	**Compliant Product Value(Total Material Cost X Percentage Of Qualifying Product)**
Cork panels for insulation 40mm	Corkpan	9065	100	9065
Composite panels: cork component	Tecnosugheri	146598	100	146598
Cork panels for roof insulation	Tecnosugheri	110842	100	110842
Raised floor laminated finishing bamboo	Crespi	37324	4.55	1698.242
Bamboo Flooring	Maccani	198118	100	198118
Bamboo handrails	Icras	33238	100	33238
Bamboo handrails base	Icras	13849	100	13849
Bamboo stair treads	Icras	80576	100	80576
Bamboo stair landing	Icras	45324	100	45324

Product Name	Vendor	Product Cost ($)*	Wood Component Percentage (%)	FSC Certified Wood Percentage (%) of Wood Component	FSC Chain-of-Custody Certificate Number from Vendor Invoice
Glue laminated wood - roof A	STRATEX	15997	100	100	ICILA-COC-000135
Glue laminated wood - roofs B-C	STRATEX	38508	100	70	CILA-COC-000135
Glue laminated wood - roofs D-E-F-G and wooden facade	STRATEX	167662	100	100	CILA-COC-000135
Hardwood planking panel	STRATEX	24135	100	0	
Wood windows	STAHLBAUPICHLER - LUCHESA	64587	100	0	
Raised floor laminated finishing bamboo	CRESPI	37324	100	0	

Bamboo flooring	MACCANI	198118	100	100	TT-COC-003884
Bamboo handrails	ICRAS	33238	100	0	
Bamboo handrails base	ICRAS	13849	100	0	
Bamboo stair treads	ICRAS	80576	100	0	
Bamboo stair landing	ICRAS	45324	100	0	
Ipè wood handrails	ICRAS	5036	100	0	
Ipè wood stair treads	ICRAS	18130	100	0	
Ipè wood stair landing	ICRAS	17122	100	0	
Wood doors fire resistant	NINZ	64369	80	0	
Wood doors	TRE P	5124	100	0	

iv. LCA Calculations

Using the Inventory of Carbon and Energy (ICE) V 2.0, 2011

Assumption:

FOR MR C4; the same percentage of post consumer and preconsumer material content based on cost (according to LEED requirements) were taken to indicate the material post consumer/preconsumer recycled content- based on quantity to simlify LCA calculations

FOR MR C5; the same percentage of regional material content based on cost (according to LEED requirements) were taken to indicate the material regional mater content- based on quantity to simlify LCA calculations

Table 58: LCA calculation

Notes			total price of material/ products ($)			**LCA Calculations**						
	03200 renforcing steel	TOTALE Ferro tondino d'armatura- TOTAL Iron rod reinforcement				euros	euro/kg	kg	EE (MJ/kg)	EE of virgin material (MJ)	EC-kgCO2e/kg	EC of virgin material (kgCO2e)
[ICE V 2.0 Steel- Bar and rod, recycled]		fornitura FERALPI	1,573,145.00		74%	1,249,519.83	0.60	2,089,498.04	8.80	18,387,582.78	0.45	940,274.12
[ICE V 2.0 Steel- Bar and rod, recycled]		fornitura STEFANA	361,398.00		17%	287,051.85	0.60	480,019.82	8.80	4,224,174.38	0.45	216,008.92
[ICE V 2.0 Steel- Bar and rod, recycled]		fornitura IRO	127,552.00		6%	101,312.42	0.60	169,418.76	8.80	1,490,885.11	0.45	76,238.44
[ICE V 2.0 Steel- Bar and rod, recycled]		fornitura FERRIERE NORD	42,517.00		2%	33,770.81	0.60	56,472.93	8.80	496,961.75	0.45	25,412.82
[ICE V 2.0 Steel- Bar and rod, recycled]		fornitura ALFA ACCIAI	21,259.00		1%	16,885.40	0.60	28,236.45	8.80	248,480.80	0.45	12,706.40
								2,823,646.00		24,848,084.83		1,270,640.70
Note: the values of concrete (without refinforcement) are used because renforcement is calculated above.	**03300 cast in place concrete**				m3		density (kg/m3)	kg	EE (MJ/kg)	MJ	EC-kgCO2e/kg	kgCO2e
[ICE V 2.0 Concrete 16/20 MPa]		Magrone per fondazioni dosato a 250 (mix 1: cls non strutturale Rck20)	144,584.00		1,435.50		2,400.00	3,445,200.00	0.70	2,411,640.00	0.10	344,520.00
[ICE V 2.0 Rc Concrete 25/30 MPa]		CLS Rck30 per fondazioni Drytech (mix 2 C25/30 S4 Drytech, XC2)	955,000.00		7,623.50		2,400.00	18,296,400.00	0.78	14,271,192.00	0.113	2,067,493.20

[ICE V 2.0 Rc Concrete 32/40 MPa]		CLS Rck 37 per elevazioni Drytech (mix 3 C30/37 S5 Drytech, XC3)	167,978.00		1,202.00		2,400.00	2,884,800.00	0.88	2,538,624.00	0.132	380,793.60
[ICE V 2.0 Rc Concrete 32/40 MPa]		Cls Rck 37 per travi cordoli solai e solette (mix 5, S5 XC3)	566,366.00		4,454.00		2,400.00	10,689,600.00	0.88	9,406,848.00	0.132	1,411,027.20
[ICE V 2.0 Rc Concrete 32/40 MPa]		Cls Rck 37 Pilastri (mix 5, S5 XC3)	127,413.00		1,002.00		2,400.00	2,404,800.00	0.88	2,116,224.00	0.132	317,433.60
[ICE V 2.0 Rc Concrete 40/50 MPa]		Cls Rck 50 Pilastri e setti (mix 7 C45/55 S5 XC4)	13,204.00		92.00		2,400.00	220,800.00	1.00	220,800.00	0.151	33,340.80
[ICE V 2.0 RC Concrete 25/30 MPa]	**03500 cementitious deck and underlayment**	Cls Rck 30 Pavimento industriale antiusura sp. 50mm (mix 6 C25/30, S5, XC2)	115,448.00		986.00		2,400.00	2,366,400.00	0.78	1,845,792.00	0.113	267,403.20
								40,308,000.00		32,811,120.00		4,822,011.60
	05100 structural metal framing							kg	EE (MJ/kg)	MJ	EC-kgCO2e/kg	kgCO2e
[ICE V 2.0 Steeel- Section recycled]		ACCIAIO LAMINATI (Stahlbaupichler - Arcelor Mittal)	588,976.00					159,120.00	10.00	1,591,200.00	0.47	74,786.40
[ICE V 2.0 Steeel- Section recycled]		ACCIAIO LAMIERE (Stahlbaupichler - Duferco)	1,143,307.00					308,880.00	10.00	3,088,800.00	0.47	145,173.60
[ICE V 2.0 Aluminium general recycled]		ALLUMINIO PROFILI FACCIATE (Stahlbaupichler - Metra)	956,840.00					50,000.00	8.80	440,000.00	0.45	22,500.00
										5,120,000.00		242,460.00
	05300 metal deck		thickness (m)	m2	m3		density kg/m3	kg	EE of virgin material (MJ/kg)	Total EE of virgin material (MJ)	EC-of virgin material (kgCO2e/kg)	Total EC-of virgin material (kgCO2e)

Titan Zinc is not affected by environmental factors and stays unaltered with time. Besides, it is fully recyclable, without any environmental effect		ZINCO-TITANIO MANTO COPERTURA (Stahlbaupichler - Zintek)	0.01	3,660.00	29.28		7.20	210.82				
thickness assumed 8 mm alloy of zinc(99.86%), titanium (0.06%), and copper (0.08%). Thus EE and EC was calculated based on these percentages- thickness was assumed 8 mm, density from http://www.lcp.sg/PDF/architectural/Rheinzink%20specification.pdf							Zinc	21,052.09	9.00	189,468.77	0.52	10,947.08
[ICE V 2.0 recycled; Zinc, Titanium and Copper]							Titanium	12.65	258.00	3,263.43	14.70	185.94
							Copper	16.87	16.50	278.28	0.84	14.17
										193,010.48		**11,147.19**
	06100 rough carpentary				m3		density kg/m3	kg	EE (MJ/kg)	MJ	EC-kgCO2e/kg	kgCO2e
[ICE V 2.0 Laminated Veneer Lumber]		ORDITURA PORTANTE IN LEGNO LAMELLARE - Copertura A (Stahlbaupichler - Stratex)			10.86		420.00	4,561.20	9.50	43,331.40	0.62	2,827.94
[ICE V 2.0 Laminated Veneer Lumber]		ORDITURA PORTANTE IN LEGNO LAMELLARE - Coperture B-C (Stahlbaupichler - Stratex)			26.14		420.00	10,978.80	9.50	104,298.60	0.62	6,806.86
[ICE V 2.0 Laminated Veneer Lumber]		ORDITURA PORTANTE IN LEGNO LAMELLARE - Coperture D-E-F-G e facciata lignea (Stahlbaupichler - Stratex)			113.82		420.00	47,804.40	9.50	454,141.80	0.62	29,638.73
										601,771.80		39,273.53
	07200 thermal protection		thickness	m2	m3		density kg/m3	kg	EE (MJ/kg)	MJ	EC-kgCO2e/kg	kgCO2e

[ICE V 2.0 Cork]		ISOLAZIONE CON PANNELLO ISOLANTE IN SUGHERO Corkpan - sp.30 mm	0.03	2,320.00	69.60		200.00	13,920.00	4.00	55,680.00	0.19	2,644.80
[ICE V 2.0 Cork]		ISOLAZIONE CON PANNELLO ISOLANTE IN SUGHERO Corkpan - sp. 70 mm	0.07	1,440.00	100.80		200.00	20,160.00	4.00	80,640.00	0.19	3,830.40
[ICE V 2.0 Cork]		ISOLAZIONE CON PANNELLO ISOLANTE IN SUGHERO Corkpan - sp.60 mm	0.06	4,876.50	292.59		200.00	58,518.00	4.00	234,072.00	0.19	11,118.42
[ICE V 2.0 Cork]		ISOLAZIONE CON PANNELLO ISOLANTE IN SUGHERO Corkpan - sp. 80 mm	0.08	4,588.50	367.08		200.00	73,416.00	4.00	293,664.00	0.19	13,949.04
[ICE V 2.0 Cork]		ISOLAZIONE CON PANNELLO ISOLANTE IN SUGHERO Corkpan - sp. 40 mm	0.04	400.00	16.00		200.00	3,200.00	4.00	12,800.00	0.19	608.00
[ICE V 2.0 Cork] assumed 7 cm thickness		PANNELLO COMPOSITO_SUGHERO (Stahlbaupichler - Stratex)	0.07	4,100.00	287.00		200.00	57,400.00	4.00	229,600.00	0.19	10,906.00
[ICE V 2.0 Cork] assumed 7 cm thickness		PANNELLI IN SUGHERO PACCHETTO COPERTURA Corkpan	0.07	3,100.00	217.00		200.00	43,400.00	4.00	173,600.00	0.19	8,246.00
										1,080,056.00		51,302.66
	08800 glazing		thickness	m2	m3		density kg/m3	kg	EE (MJ/kg)	MJ	EC-kgCO2e/kg	kgCO2e

[ICE V 2.0 Glass, Primary glass]- thickness was assumed 34 mm, and desnsity of glass (Lavagna 2008)		VETRO COPERTURE E FACCIATE (Stahlbaupichler - Guardian)	0.03	5,000.00	170.00		2.50	425.00	15.00	6,375.00	0.91	386.75
										0.02		0.03
	09600 flooring			m2	m3		density kg/m3	kg	EE (MJ/kg)	MJ	EC-kgCO2e/kg	kgCO2e
EE of bamboo assumed 15 MJ/ton , EE and EC of Bamboo, referred to (www.symbioticengineering.com) (not including transportation)- and LCB Method v3.0, desnity of bamboo assumed 350 kg/m3. It is worth noting that if the transportation energy of bamboo was included , results might have changed.		PAVIMENTO SOPRAELEVATO FINITURA BAMBOO (Crespi - incidenza bamboo 4,55%)	0.03	1,220.00	36.60		350.00	12,810.00	0.02	192.15	0.085	1,088.85
		PAVIMENTO IN BAMBOO FSC (Maccani)	0.02	5,426.26	81.39		350.00	28,487.87	0.02	427.32	0.085	2,421.47
assumed dimensions 0.03*0.02		CORRIMANO CONTINUO SAGOMATO IN BAMBOO (Icras) - in m long	1,100.00		0.66		350.00	231.00	0.02	3.47	0.085	19.64
assumed dimensions 0.03*0.02		BASE PARAPETTI IN BAMBOO (Icras)- in m long	460.00		0.28		350.00	96.60	0.02	1.45	0.085	8.21
											0.085	
assumed dimensions 0.3*0.02*1.2		PIANEROTTOLI IN BAMBOO (Icras)		150.00	0.01		350.00	2.52	0.02	0.04	0.085	0.21
										624.42		3,538.38
	09700 wall finishes		thickness	m2	m3		density kg/m3	kg	EE (MJ/kg)	MJ	EC-kgCO2e/kg	kgCO2e
[ICE V 2.0 Stone- Marble] assumed thickness 2 cm,		pietra BOTTICINO_rivestimento (Geimar)	0.02	6,108.00	122.16		2,680.00	327,388.80	2.00	654,777.60	0.13	42,560.54

MR C4 : Recycled Content Materials
Assumption: for simplification, the same percentage of post consumer and preconsumer material content based on cost (according to LEED requirements) were taken to indicate the material post consumer/preconsumer recycled content- based on quantity to simlify LCA calculations

Note: for LCA there is no differentiation between post and pre consumer content

Table 59: LCA for MR C 4 compliant LEED materials

		LCA Calculation										LEED Calculation		
	Weight of material complied (kg)	**EE (MJ/kg)**	**EE of virgin material (MJ)**	**EC- kgCO2e/kg**	**EC of virgin material (kgCO2e)**	**EE (MJ/kg)**	**EE of recycled material (MJ)**	**EC- kgCO2e/kg**	**EC of recycled material (kgCO2e)**	**total avoided EE (MJ)**	**total avoided EC (kgCO2e)**			**[price of post consumer + 1/2 price of preconsumer] $**
fornitura FERALPI	2,047,708.08	29.20	59,793,076.01	2.77	5,672,151.39	8.80	18,019,831.13	0.45	921,468.64			98.00	-	1,541,682.00
fornitura STEFANA	460,819.02	29.20	13,455,915.48	2.77	1,276,468.69	8.80	4,055,207.41	0.45	207,368.56			96.00	-	346,942.00
fornitura IRO	166,030.39	29.20	4,848,087.31	2.77	459,904.17	8.80	1,461,067.41	0.45	74,713.67			98.00	-	125,001.00
fornitura FERRIERE NORD	50,260.90	29.20	1,467,618.41	2.77	139,222.71	8.80	442,295.96	0.45	22,617.41			89.00	-	37,840.00
fornitura ALFA ACCIAI	27,671.73	29.20	808,014.39	2.77	76,650.68	8.80	243,511.19	0.45	12,452.28			98.00	-	20,834.00
			80,372,711.61		7,624,397.64		**24,221,913.09**		**1,238,620.56**	**56,150,798.52**	**6,385,777.09**			**2,072,299.00**
	% of total credit compliance of the total						85.06		84.58	72.55	69.78			48.76
	Notes; the % of recycled materials was assumed for aggregates													
	Weight of material complied (kg)	EE (MJ/kg)	EE of virgin material (MJ)	EC- kgCO2e/kg	EC of virgin material (kgCO2e)	EE (MJ/kg)	EE of recycled material (MJ)	EC- kgCO2e/kg	EC of recycled material (kgCO2e)	total avoided EE (MJ)	total avoided EC (kgCO2e)			[price of post consumer + 1/2 price of preconsumer]
Magrone per fondazioni dosato a 250 (mix 1: cls non strutturale	1,528,290.72	0.70	1,069,803.50	0.10	152,829.07	0.08	126,848.13	0.01	7,947.11			-	44.36	32,069.00

Rck20)														
CLS Rck30 per fondazioni Drytech (mix 2 C25/30 S4 Drytech, XC2)	8,011,993.56	0.78	6,249,354.98	0.113	905,355.27	0.08	664,995.47	0.01	41,662.37			-	43.79	209,097.00
CLS Rck 37 per elevazioni Drytech (mix 3 C30/37 S5 Drytech, XC3)	1,301,044.80	0.88	1,144,919.42	0.132	171,737.91	0.08	107,986.72	0.01	6,765.43			-	45.10	37,879.00
Cls Rck 37 per travi cordoli solai e solette (mix 5, S5 XC3)	4,629,665.76	0.88	4,074,105.87	0.132	611,115.88	0.08	384,262.26	0.01	24,074.26			-	43.31	122,647.00
Cls Rck 37 Pilastri (mix 5, S5 XC3)	1,041,518.88	0.88	916,536.61	0.132	137,480.49	0.08	86,446.07	0.01	5,415.90			-	43.31	27,591.00
Cls Rck 50 Pilastri e setti (mix 7 C45/55 S5 XC4)	88,010.88	1.00	88,010.88	0.151	13,289.64	0.08	7,304.90	0.01	457.66			-	39.86	2,632.00
Cls Rck 30 Pavimento industriale antiusura sp. 50mm (mix 6 C25/30, S5, XC2)	1,141,551.36	0.78	890,410.06	0.113	128,995.30	0.08	94,748.76	0.01	5,936.07			-	48.24	27,846.00
			14,433,141.33		2,120,803.58		**1,472,592.30**		**92,258.79**	**12,960,549.02**	**2,028,544.78**			**459,761.00**
	% of total credit compliance of the total						5.17		6.30	16.75	22.17			10.82
	Weight of material complied (kg)	EE (MJ/kg)	EE of virgin material (MJ)	EC-kgCO2e/kg	EC of virgin material (kgCO2e)	EE (MJ/kg)	EE of recycled material (MJ)	EC-kgCO2e/kg	EC of recycled material (kgCO2e)	total avoided EE (MJ)	total avoided EC (kgCO2e)			[price of post consumer + 1/2 price of preconsumer]
ACCIAIO LAMINATI (Stahlbaupichler - Arcelor Mittal)	159,120.00	38.00	6,046,560.00	3.03	482,133.60	10.00	1,591,200.00	0.47	74,786.40			54.00	46.00	453,512.00
ACCIAIO LAMIERE (Stahlbaupichl	77,220.00	38.00	2,934,360.00	3.03	233,976.60	10.00	772,200.00	0.47	36,293.40			25.00	-	285,827.00

er - Duferco)														
ALLUMINIO PROFILI FACCIATE (Stahlbaupichler - Metra)	30,000.00	29.00	870,000.00	2.77	83,100.00	8.80	264,000.00	0.45	13,500.00			-	60.00	287,052.00
			9,850,920.00		799,210.20		**2,627,400.00**		**124,579.80**	**7,223,520.00**	**674,630.40**			**1,026,391.00**
	% of total credit compliance of the total						9.23		8.51	9.33	7.37			24.15
ZINCO-TITANIO MANTO COPERTURA (Stahlbaupichler - Zintek)	Weight of material complied (kg)	EE (MJ/kg)	EE of virgin material (MJ)	EC-kgCO2e/kg	EC of virgin material (kgCO2e)	EE (MJ/kg)	EE of recycled material (MJ)	EC-kgCO2e/kg	EC of recycled material (kgCO2e)	total avoided EE (MJ)	total avoided EC (kgCO2e)			[price of post consumer + 1/2 price of preconsumer]
	168.65											60.00	20.00	638,660.00
Zinc	16,841.67	72.00	1,212,600.14	4.18	70,398.17	9.00	151,575.02	0.52	8,757.67					
Titanium	10.12	361.00	3,653.02	20.60	208.45	258.00	2,610.75	14.70	148.75					
Copper	13.49	57.00	769.06	3.81	51.41	16.50	222.62	0.84	11.33					
			1,217,022.22		**70,658.04**		**154,408.38**		**8,917.75**	**1,062,613.83**	**61,740.28**			638,660.00
	% of total credit compliance of the total						0.54		0.61	1.37	0.67			15.03
	Weight of material complied (kg)	EE (MJ/kg)	EE of virgin material (MJ)	EC-kgCO2e/kg	EC of virgin material (kgCO2e)	EE (MJ/kg)	EE of recycled material (MJ)	EC-kgCO2e/kg	EC of recycled material (kgCO2e)	total avoided EE (MJ)	total avoided EC (kgCO2e)			[price of post consumer + 1/2 price of preconsumer]
VETRO COPERTURE E FACCIATE (Stahlbaupichler - Guardian)	28.94	15.00	434.14	0.91	26.34	11.50	**332.84**	0.59	**17.08**	101.30	9.26	6.20	0.61	53,234.00
	% of total credit compliance						0.00		0.00	0.00	0.00			1.25

	of the total													
Sum Total							28,476,646.62		1,464,393.98	77,397,582.68	9,150,701.81			4,250,345.00

MR C5: Regional Materials
In order to adjust the comparison, LCA should be calculated for all materials contributing or not to LEED credit, but due to lack of sufficient data, it was only conducted on those credits contributing to LEED requirements.
Assumption: for simplification, the same percentage of regional material content based on cost (according to LEED requirements) were taken to indicate the material regional mater content- based on quantity to simlify LCA calculations

Table 60: LCA for MR C 5 compliant LEED materials

	Weight of regional material content (t)	Assumed Mean of transportation [Lavagna, 2008 p.175]	Distance from project site (km)	EE from transportation (kgkm)	EC from transportation		percentage regional materials (%)	price of percentage regional of toal product price ($)
fornitura FERALPI	1,922.34	Train(s)	130.00	74,471.38	3,423.68		92.00	1,447,294.00
fornitura STEFANA	379.22	Train(s)	170.00	19,211.07	883.19		79.00	285,505.00
fornitura IRO	147.39	truck 40t	170.00	70,209.81	4,134.41		87.00	110,971.00
fornitura FERRIERE NORD	40.66	1 truck 40 t	300.00	34,179.22	2,012.70		72.00	30,613.00
fornitura ALFA ACCIAI	25.70	1 truck 32 t	135.00	12,872.90	773.55		91.00	19,345.00
				210,944.38	**11,227.54**			**1,893,728.00**
% of total credit				26.85	26.92			31.64
	Weight of regional material content (t)	Assumed Mean of transportation [Lavagna, 2008 p.175]	Distance from project site (km)	EE from transportation	EC from transportation		percentage regional materials (%)	price of percentage regional of toal product price ($)
Magrone per fondazioni dosato a 250 (mix 1: cls non strutturale Rck20)	3,445.20	Train(s)	20.00	20,533.39	943.98		100.00	144,584.00
CLS Rck30 per fondazioni Drytech (mix 2 C25/30 S4 Drytech, XC2)	18,296.40	Train(s)	20.00	109,046.54	5,013.21		100.00	955,000.00
CLS Rck 37 per elevazioni Drytech (mix 3 C30/37 S5 Drytech, XC3)	2,884.80	Train(s)	20.00	17,193.41	790.44		100.00	167,978.00

Cls Rck 37 per travi cordoli solai e solette (mix 5, S5 XC3)	10,689.60	Train(s)	20.00	63,710.02	2,928.95		100.00	566,366.00
Cls Rck 37 Pilastri (mix 5, S5 XC3)	2,404.80	Train(s)	20.00	14,332.61	658.92		100.00	127,413.00
Cls Rck 50 Pilastri e setti (mix 7 C45/55 S5 XC4)	207.55	Train(s)	20.00	1,237.01	56.87		94.00	12,412.00
Cls Rck 30 Pavimento industriale antiusura sp. 50mm (mix 6 C25/30, S5, XC2)	2,366.40	Train(s)	20.00	14,103.74	648.39		100.00	115,448.00
				240,156.72	**11,040.76**			**2,089,201.00**
% of total credit				30.56	26.47			34.90
ZINCO-TITANIO MANTO COPERTURA (Stahlbaupichler - Zintek)	Weight of regional material content (t)	Assumed Mean of transportation [Lavagna, 2008 p.175]	Distance from project site (km)	EE from transportation	EC from transportation		percentage regional materials (%)	price of percentage regional of toal product price ($)
	0.17						80.00	
Zinc	16.84	1 truck 16 t	200.00	17,474.92	1,071.13			
Titanium	0.01	1 truck 16 t	200.00	7,510.45	0.64			
Copper	0.01	1 truck 16 t	200.00	10,013.93	0.86			
				34,999.29	**1,072.63**			**729,898.00**
% of total credit				4.45	2.57			12.19
	Weight of regional material content (t)	Assumed Mean of transportation [Lavagna, 2008 p.175]	Distance from project site (km)	EE from transportation	EC from transportation		percentage regional materials (%)	price of percentage regional of toal product price ($)
ORDITURA PORTANTE IN LEGNO LAMELLARE - Copertura A (Stahlbaupichler - Stratex)	4.56	1 truck 16 t	260.00	6,152.51	377.12		100.00	15,997.00
ORDITURA PORTANTE IN LEGNO LAMELLARE - Coperture B-C (Stahlbaupichler - Stratex)	10.98	1 truck 16 t	260.00	14,809.08	907.73		100.00	38,508.00
ORDITURA PORTANTE IN LEGNO LAMELLARE - Coperture D-E-F-G e	47.80	1 truck 40t	260.00	64,482.40	3,952.47		100.00	167,662.00

facciata lignea (Stahlbaupichler - Stratex)								
				85,443.99	**5,237.31**			**222,167.00**
% of total credit				10.87	12.56			3.71
VETRO COPERTURE E FACCIATE (Stahlbaupichler - Guardian)	Weight of regional material content (t)	Assumed Mean of transportation [Lavagna, 2008 p.175]	Distance from project site (km)	EE from transportation	EC from transportation		percentage regional materials (%)	price of percentage regional of toal product price ($)
	0.15	1 truck 16 t	240.00	190.50	11.68		36.00	**297,552.00**
% of total credit				0.02	0.03			4.97
	Weight of regional material content (t)	Assumed Mean of transportation [Lavagna, 2008 p.175]	Distance from project site (km)	EE from transportation	EC from transportation		percentage regional materials (%)	price of percentage regional of toal product price ($)
pietra BOTTICINO_rivestimento (Geimar)	327.39	1 truck 16 t	126.00	214,010.13	13,117.81		100.00	**753,628.00**
% of total credit				27.24	31.45			12.59
				Sum EE for credit	Sum EC for credit			sum price of regional materials
Sum Total				785,745.02	41,707.74			5,986,174.00

Table 61: LCA for MR C 6 compliant LEED materials

								LCA Calculation				LEED Calculation	
	07200 thermal protection		thickness	m2	m3	density kg/m3	kg	EE (MJ/kg)	Sum EE for credit (MJ)	EC-kgCO2e/kg	Sum EC for credit kgCO2e	Percentage compliant	Material cost
[ICE V 2.0 Cork]		ISOLAZIONE CON PANNELLO ISOLANTE IN SUGHERO Corkpan - sp.30 mm	0.03	2,320.00	69.60	200.00	13,920.00	4.00	55,680.00	0.19	2,644.80	100.00	39,432.00
[ICE V 2.0 Cork]		ISOLAZIONE CON PANNELLO ISOLANTE IN SUGHERO Corkpan - sp. 70 mm	0.07	1,440.00	100.80	200.00	20,160.00	4.00	80,640.00	0.19	3,830.40	100.00	57,108.00

[ICE V 2.0 Cork]		ISOLAZIONE CON PANNELLO ISOLANTE IN SUGHERO Corkpan - sp.60 mm	0.06	4,876.50	292.59	200.00	58,518.00	4.00	234,072.00	0.19	11,118.42	100.00	165,767.00
[ICE V 2.0 Cork]		ISOLAZIONE CON PANNELLO ISOLANTE IN SUGHERO Corkpan - sp. 80 mm	0.08	4,588.50	367.08	200.00	73,416.00	4.00	293,664.00	0.19	13,949.04	100.00	207,969.00
[ICE V 2.0 Cork]		ISOLAZIONE CON PANNELLO ISOLANTE IN SUGHERO Corkpan - sp. 40 mm	0.04	400.00	16.00	200.00	3,200.00	4.00	12,800.00	0.19	608.00	100.00	9,065.00
[ICE V 2.0 Cork] assumed 7 cm thickness		PANNELLO COMPOSITO_SUGHERO (Stahlbaupichler - Stratex)	0.07	4,100.00	287.00	200.00	57,400.00	4.00	229,600.00	0.19	10,906.00	100.00	146,598.00
[ICE V 2.0 Cork] assumed 7 cm thickness		PANNELLI IN SUGHERO PACCHETTO COPERTURA Corkpan	0.07	3,100.00	217.00	200.00	43,400.00	4.00	173,600.00	0.19	8,246.00	100.00	110,842.00
									1,080,056.00		51,302.66		736,781.00
% of total credit									99.96		46.10		71.60
	09600 flooring			m2	m3	density kg/m3	kg	EE (MJ/kg)	MJ	EC-kgCO2e/kg	kgCO2e		
desnity of bamboo assumed 350 kg/m3. It is worth noting that if the transportation energy of bamboo was included , results might have changed.		PAVIMENTO SOPRAELEVATO FINITURA BAMBOO (Crespi - incidenza bamboo 4,55%)	0.03	1,220.00	36.60	350.00	12,810.00	0.02	8.84	0.085	50.09	4.60	1,698.00
		PAVIMENTO IN BAMBOO FSC (Maccani)	0.02	5,426.26	81.39	350.00	28,487.87	0.02	427.32	0.085	2,421.47	100.00	198,118.00
assumed dimensions 0.03*0.02		CORRIMANO CONTINUO SAGOMATO IN BAMBOO (Icras) -in m long	1,100.00		0.66	350.00	231.00	0.02	3.47	0.085	19.64	100.00	33,238.00
assumed dimensions 0.03*0.02		BASE PARAPETTI IN BAMBOO (Icras)- in m long	460.00		0.28	350.00	96.60	0.02	1.45	0.085	8.21	100.00	13,849.00

assumed dimensions 0.3*0.02*1.2		PIANEROTTOLI IN BAMBOO (Icras)		150.00	0.01	350.00	2.52	0.02	0.04	0.085	0.21	100.00	45,324.00
									441.11		2,499.62		292,227.00
% of total credit									0.04		4.65		28.40
Total Sum									1,080,497.11		53,802.28		1,029,008.00

Table 62: LCA for MR C 2 compliant LEED materials

Notes									**LCA Calculations**		**LEED Calculation**
		Recycled (kg)	**Landfill (kg)**		EE (MJ/kg)	MJ	EC-kgCO2e/kg	kgCO2e	% embodied energy of whole credit	% embodied carbon of whole credit	% material weight (kg) of whole credit
[ICE V 2.0 Aggregates]	**CONCRETE (CER 17 01 01)**	224,980.00	0,00		0.08	18,673.34	0.01	1,169.90	0.92	0.97	24.08
MISSING DATA: quantities of each material ??? ASSUMED proportions	**MIXED MATERIAL: cement, bricks, tiles and ceramics (CER 17 01 07)**	490,940.00	0,00								
[ICE V 2.0 Aggregates]	**CONCRETE**	98,188.00			0.08	8,149.60	0.01	510.58	1.32	1.40	34.59
[ICE V 2.0 Aggregates]	**BRICKS**	245,470.00			0.08	20,374.01	0.01	1,276.44	1.00	1.06	26.27
[ICE V 2.0 Aggregates]	**TILES**	98,188.00			0.08	8,149.60	0.01	510.58	0.40	0.43	10.51
[ICE V 2.0 Aggregates]	**CERAMICS**	49,094.00			0.08	4,074.80	0.01	255.29	0.20	0.21	5.25
Note: excluded from calculations	**MIXED WASTE (CER 17 09 04)**	-	33,720.00								
[ICE V 2.0 Timber;BUT assumed half values for EE and EC]	**WOOD (CER 17 02 01)**	111,680.00	-		5.00	558,400.00	0.36	40,204.80	27.53	33.50	11.95
[ICE V 2.0 Subtracting secondary from Primary glass]	**GLASS (CER 17 02 02)**	4,130.00	-		3.50	14,455.00	0.32	1,321.60	0.71	1.10	0.44
[ICE V 2.0 Subtracting recycled steel from general recycled steel]	**IRON AND STEEL (CER 17 04 05)**	50,830.00	-		10.70	543,881.00	0.99	50,321.70	26.81	41.93	5.44
Note: excluded from calculations	**PACKAGING IN MIXED MATERIALS (CER 15 01 06)**	-	24,570.00								

[ICE V 2.0 Paperboard-general for construction use ;BUT assumed half values for EE and EC]	**CARDBOARD (CER 15 01 01)**	22,560.00	-		12.40	279,744.00	-	-	13.79		2.41
[ICE V 2.0 plastics-general ;BUT assumed half values for EE and EC]	**PLASTIC PACKAGING (CER 15 01 02)**	12,860.00	-		40.25	517,615.00	1.66	21,283.30	25.52	17.73	1.38
[ICE V 2.0 plaster board ;BUT assumed half values for EE and EC]	**PLASTERBOARD (CER 17 08 02)**	16,270.00	-		3.38	54,911.25	0.20	3,172.65	2.71	2.64	1.74
									100.00	100.00	100.00
		934,250.00	58,290.00	992,540.00		Sum embodied energy of salvaged materials (avoided		Sum embodied carbon of salvaged materials			
		94.13	5.87	% according to LEED calculations (by weight)		2,028,427.61		120,026.83			

APPENDIX D: EA & MR CREDIT COMPLIANCE FOR CASE STUDY (2) PALAZZO RICORDI BERCHET

i. Building floor plans and sections

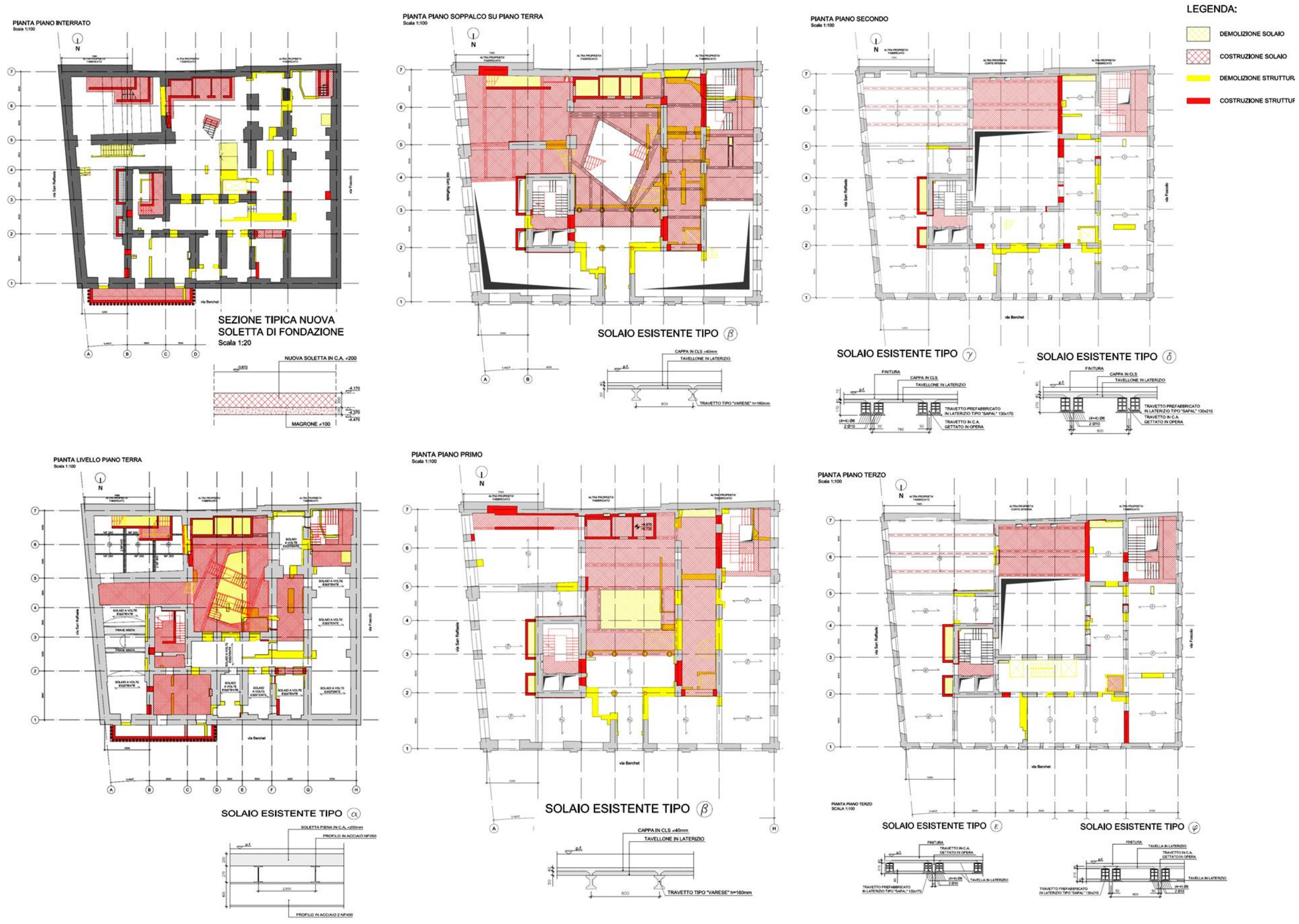

Figure 98: Diagrams showing building reuse scenarios versus new construction intervention scenarios- 1

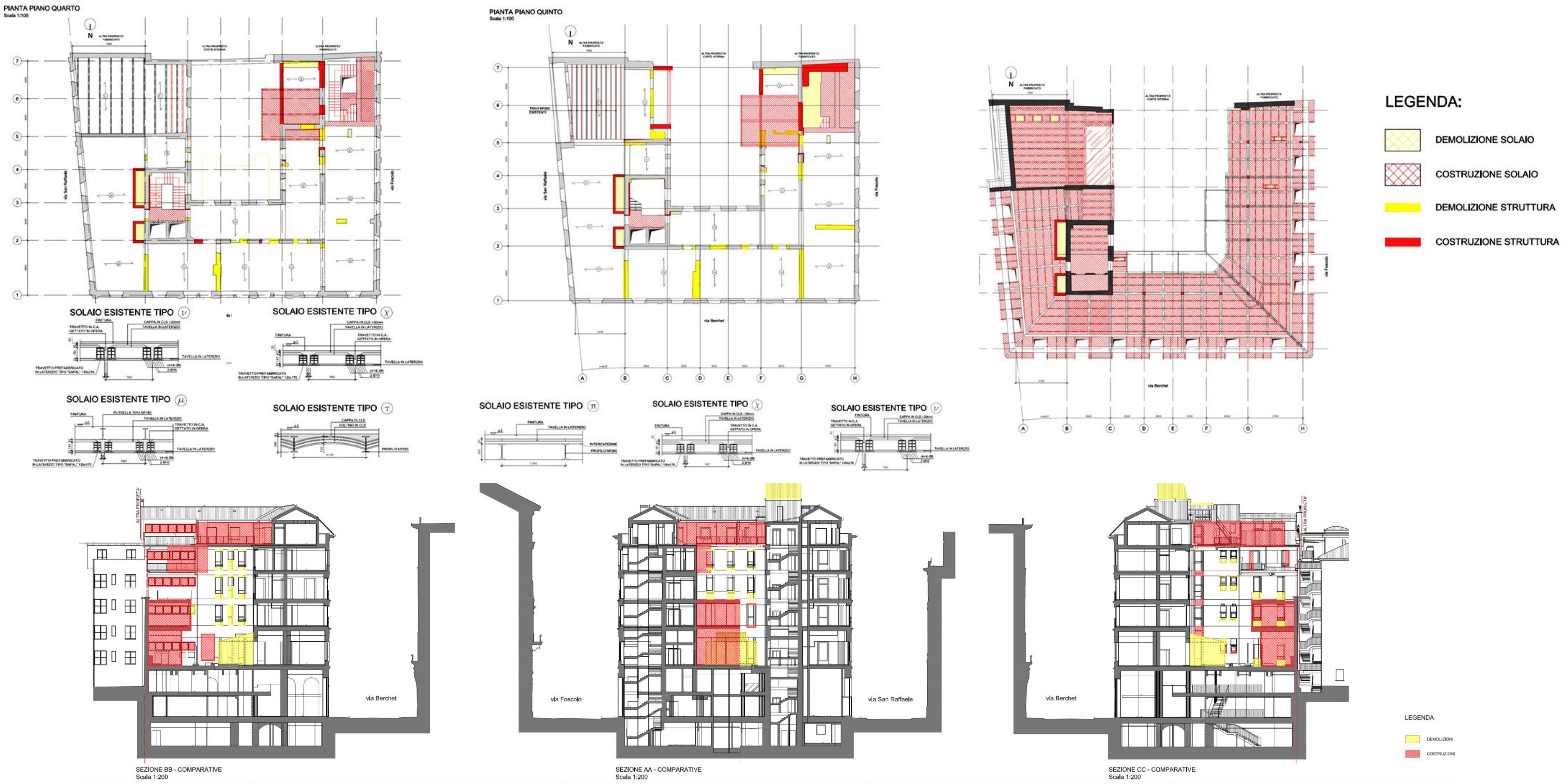

Figure 99: Diagrams showing building reuse scenarios versus new construction intervention scenarios- 2

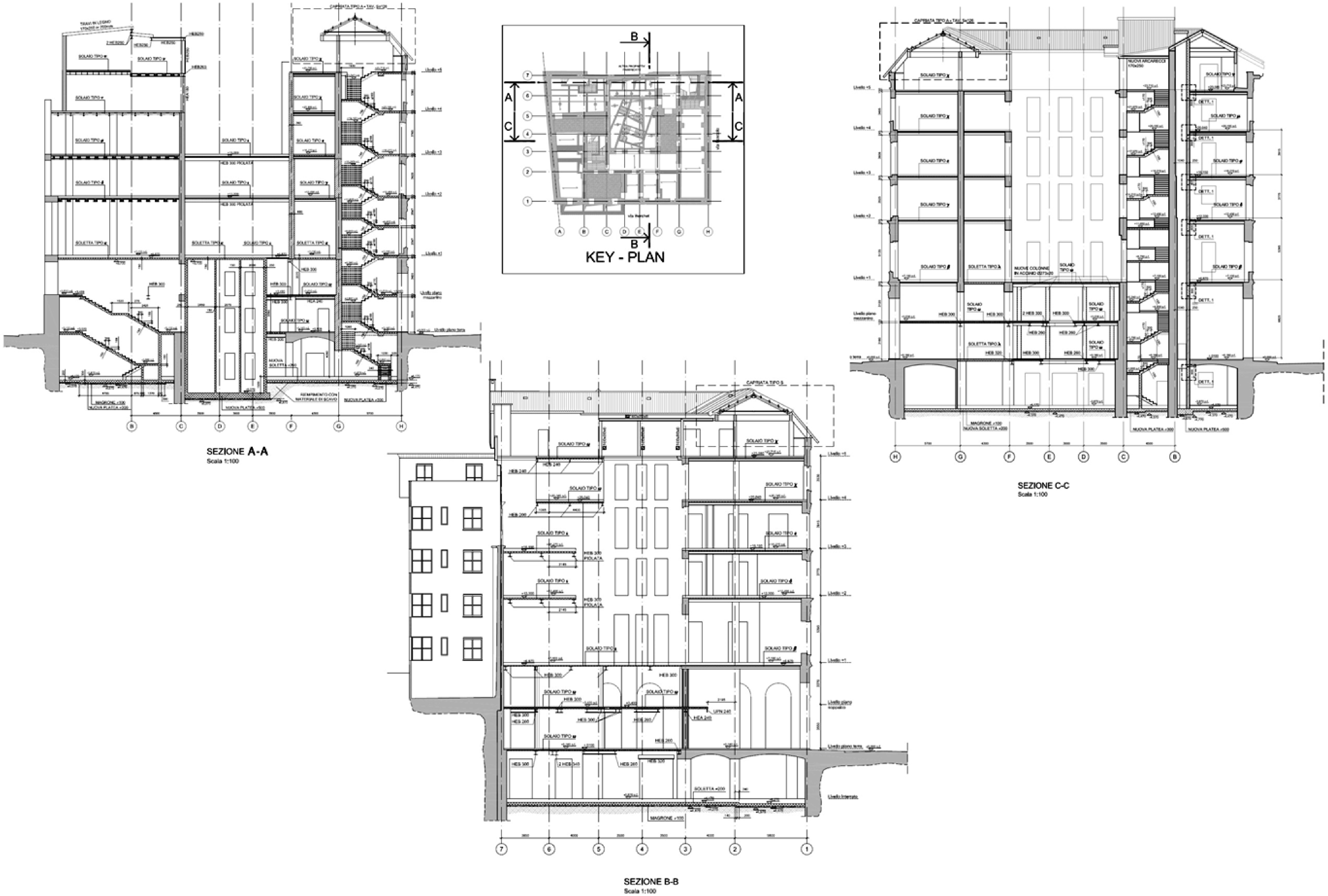

Figure 100: Diagrams showing building reuse scenarios versus new construction intervention scenarios-3

ii. Energy credits' calculations for LEED EA compliance

New construction percentage: 3.48 %
Percentage energy cost savings: 35 %
EA Credit 1 Points Documented: 16 points

Table 63: Target Finder

Energy	Design	Target	Median building
Energy performance Rating (1-100)	97	84	50
Energy reduction (%)	63	40	0
Source energy use intensity (kBtu/Sq.Ft./yr)	141	226	376
Site energy use intensity (kBtu/Sq.Ft./yr)	42	68	113
Total annual source energy (kBtu)	6,507,207	10,438,793	17,397,988
Total annual site energy (kBtu)	1,948,266	3,125,387	5,208,979
Total annual energy cost ($)	85,651	137,400	229,000
Pollution emissions			
CO2-eq. emissions (metric tons/year)	291	467	779
CO2-eq. emissions reduction (%)	63	40	0

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Table 64: General information

Simulation program	Integrated environmental solutions virtual environment version 2012
Energy code	ASHRAE 90.1-2007 Appendix G
Model data	Floor area: 4290.17
	Building floor area: 3525.92
	Building volume: 18158.56
	Number of conditioned rooms: 87
	Number of floors: 8
Heating calculation data	Principal heating source: electricity Heating degree days: 4,507
Cooling calculation data	Principal cooling source: electricity Cooling degree days: 3,335
Climate zone	ASHRAE 90.1: ZONE 4 Milan/ WEC

Construction	Total gross square footage: 59,555 Gross square footage used in the energy model, if different than gross square footage above: 59,266 New construction gross square footage: 2,073 New construction: 3.48 % Existing renovated gross square footage: 57,482 Existing renovation percentage: 96.52 % Existing unrenovated percentage: 0 %

Table 65: Facility charcateristics

Space type	Gross floor area (sq.ft.)
Retail	17,846
Office	28,405
Total gross floor area	46,251

Table 66: EA P2 & EA C1: Energy Type Summary

Energy type	Utility company name	Utility rate & description of rate structure	Baseline virtual rate (dollar per unit energy)	Units of energy	Units of energy	Units of demand
Electricity	Autorita' per l'energia	Flat rate	0.1921	0.1921	kWh	kW
Natural gas		Flat rate	0	0	kWh	kW

Table 67: Estimated design energy[1]

Energy source	Units	Estimated total annual energy use	Energy rate ($/unit)
Electricity grid purchase	kWh	571,004	0.150/ kWh

Table 68: Energy use summary & energy savings

Energy type	Units	Baseline design	Proposed design
Electricity	kWh	885,633.38	574,270.96
Natural gas	kWh	0	0
Totals	MMBtu	3,021.78	1,959.41

Table 69: Space Summary

Building use (occupancy type)	Space usage	Space size	Regularly occupied	Unconditioned area (GSF)	Typical hours in

[1] Source: Data adapted from DOE-EIA

	type		GSF		operation (per week)
Active storage	Retail	2,906.28	2,906.28	0	35.2
Conference/ meeting/ multipurpose	Office	1,216.33	1,216.33	0	48.6
Electrical/ mechanical	Retail / office	2,960.1	312.15	2,647.94	47.45
Elevators- equipment	Retail / office	312.15	312.15	0	47.45
Inactive storage	Retail / office	452.08	118.4	333.69	35.2
Lobby	Office	2,303.49	2,303.49	0	48.6
Office- open plan	Office	18,094.28	18,094.28	0	48.6
Restrooms	Retail / office	3,078.5	3,078.5	0	48.6
Retail- sales area	Retail	9,612.25	9,612.25	0	46.3
Stairs- active	Retail / office	5,242.06	0	5,242.06	0
Void/ plenum	Retail / office	1,022.58	0	1,022.58	0
Total		47,200.1	37,953.83	9,246.27	
Percentage of total (%)			80.41	19.59	

Table 70: Advisory messages

Advisory messages	Proposed building	Baseline building	Differences (proposed design minus baseline design)
Number of hours heating loads not met	0.0	37.3	
Number of hours cooling loads not met	0.0	0.5	
Total	0	37.8	-37.8
Number of warning messages	0	0	
Number of error messages	0	0	
Number of default overridden	0	0	
Unmet load hours compliance	Y		

Baseline design and proposed design unment load hours each may not exceed 300
Unmet load hours for the proposed design may not exceed the baseline design by more than 50 hours

Table 71: Comparison of proposed versus baseline design

Model input parameter HVAC	Proposed		Baseline	
	Description	Performance SCop/SSEER Cfm/SFP/kW	Description	Performance SCop/SSEER Cfm/SFP/kW
Primary HVAC	VRV/VRF system	Heating mode: 3.45 COP Cooling mode: 5.45 EER	System type 8: VAV with PFP boxes	
Other HVAC				
Fan supply power	Constant flow for main air handling unit 1 speed fans for zone level units		VSD Control	
Fan power				
Economiser control	None		None	
Demand control ventilation	None		Yes	
Unitary equipment cooling efficiency				
Unitary equipment heating efficiency				
Chiller	Water- cooled chiller	5.45	1 water cooled screw chiller	4.45
Chilled water loop and pump				
Boiler	Water- cooled chiller	3.45	Electric	0.99
Hot water loop and pump				
Cooling tower	Not applicable		Axian fan cooling power with 2 speeds fan	
Condenser water loop and pump	Condensing water loop	36.4 kW	Water loop	349 W/l/s

Table 72: ASHRAE 90.1 Section 6: HVAC (Air- Side)

Model input parameter/ Energy Efficiency Measure	Baseline case	Proposed case
Primary HVAC Type	8. VAV with PFP Boxes	VRF/VRV systems
Other HVAC Type	None	None

Semi- conditioned space HVAC Type	None	None
Semi- conditioned area (Gross SF)	-	-
Semi- conditioned Heating Capacity (Btuh)	-	-
Total Cooling Capacity	475 kW	309 kW
Unitary Cooling Capacity Ranges	528 kW	-
Unitary cooling efficiency	4.45	5.45
Total heating capacity	309 kW	156 kW
Unitary Heating Capacity Ranges	-	-
Unitary Heating efficiency	100%	3.45
Fan System operation		
Outdoor Air Design Min Ventilation	9034 cmf	9034 cmf
HVAC Air- side Economizer Cycle	-	-
Economizer High limit shutoff	-	-
Design Airflow Rates (Conditioned space)	9034 cmf	9034 cmf
Total system Fan power (conditioned)	37 kW	15.42 kW
Total supply fan power	30.9 kW	11.53 kW
Total return/ relief fan power	0 kW	0 kW
Total exhaust fan power (tied to AHUs)	-	-
Pressure Drop adjustments	-	-
Zone terminal boxes fan power	6.10 kW	3.89 kW
Unconditioned Total fan power	-	-
Unconditioned Total fan flow	-	-
Semi- conditioned Total fan power	-	-
Semi- conditioned Total fan flow	-	-
Exhaust Air Energy Recovery	None	75%
Demand Control Ventilation	-	-
Supply air temperature reset parameters	Higher by 2.3 ºC on minimum cooling conditions	Higher by 2.3 ºC on minimum cooling conditions
Thermal energy storage	None	None
Other		

Table 73: ASHRAE 90.1 Appendix G: HVAC (Water side)

Model input parameter/ Energy Efficiency Measure	Baseline case	Proposed case
The project has district heating	N	N
The project has district cooling	N	N
Number of chillers	1	15
Chiller part load controls	Screw chiller	Part load curve chiller
Chiller capacity (per chiller)	475 kW	Min: 22.4 kW; max; 56 kW; mean: 41.3 kW
Chiller efficiency	4.45	5.4
Chilled water loop supply temperature	6.67 ºC	6.67 ºC
Chilled water (CHW) Loop Delta-T	6 ºC	6 ºC
CHW Loop Temp Reset parameters	7 ºC at 27 ºC and above, 12 ºC at 16 ºC and low	7 ºC at 27 ºC and above, 12 ºC at 16 ºC and low
CHW Loop configuration	Variable speed	-
Number of primary CHW Pumps	1	0 (VRF system)
Primary CHW Pump Power	69.74 W/l/s	-
Primary CHW Pump Flow	17.07 l/s	-
Primary CHW Pump speed control	-	-
Secondary CHW Pump Power	278.97 W/l/s	-
Secondary CHW Pump Flow	17.07 l/s	-
Secondary CHW Pump Speed Control	-	-
Number of cooling towers/ fluid coolers	1	-
Cooling tower fan power	6,192 kW	-
Cooling tower fan control	Two speed fan	-
Condenser water leaving temperature	29.44 ºC	No temperature dependence
Condenser water (CW) Loop Delta-T	5.56 ºC	-
CW Loop Temp Reset Parameters	21 ºC constant	
CW Loop configuration	Constant speed	Variable speed
Number of CW Pumps	1	1
CW Pump power	310,00 W/l/s	36.4 kW
CW Pump flow	25,08 l/s	-
CW Pump speed control	-	-
Number of boilers	0 (electrical energy)	15
Boiler part load controls	-	Generic heat source
Boiler capacity (per	309.6 kW	Min: 25 kW; max: 63 kW;

boiler)		mean: 45.9 kW
Boiler efficiency	100%	3.45
Boiler water loop supply temperature	-	Heating system is modelled as a generic heat source as indicated in IES VE 6.4 VRF/VRV guide
Hot water or steam (HHW) Loop Delta-T	-	
HHW Loop Temp Reset parameters	-	
HHW Loop configuration	-	
Number of primary HHW pumps	-	
Primary HHW Pump Power	-	
Primary HHW Pump flow	-	
Primary HHW Pump speed control	-	
Secondary HHW Pump Power	-	
Secondary HHW Pump flow	-	
Secondary HHW Pump speed control	-	
Thermal energy storage capacity	-	
Thermal energy storage control sequence	-	
Thermal energy storage charge Temp	-	
Thermal energy storage chiller efficiency	-	
Water- side Economizer	None	None
Water- side Energy Recovery	None	None
Other		VRF/ VRV system is modelled as indicate in IES VE 6.4 guide

Table 74: ASHRAE 90.1 Section 7: Service Water Heating

Model input parameter/ energy efficiency measure	Baseline case	Proposed case
SHW Equipment type	Electric source	Ground water heat pump with booster
SHW Storage tank capacity		
SHW Heating input capacity	2 kW	12.5 kW
Equipment efficiency	90 %	189 %
Temperature controls	-	-
SHW Energy recovery	-	-
Other		Equipment efficiency is calculated considering both heat pump and booster electrical absorption

Table 75: Table EA P2-4 Baseline Performance - Performance Rating Method Compliance

	process	Baseline design energy type	Units of annual energy & peak demand	Baseline (0º rotation)	Baseline (90º rotation)	Baseline (180º rotation)	Baseline (270º rotation)	Baseline design
Interior lighting		Electricity	Energy use (kWh)	167,265.1	167,265.1	167,265.1	167,265.1	167,265.1
			Demand (kW)	47.76	47.76	47.76	47.76	47.76
Exterior lighting		Electricity	Energy use (kWh)	26,001.66	26,001.66	26,001.66	26,001.66	26,001.66
			Demand (kW)	5.13	5.13	5.13	5.13	5.13
Space heating		Electricity	Energy use (kWh)	270,254.4	270,254.4	270,254.4	270,254.4	270,254.4
			Demand (kW)	329.94	329.94	329.94	329.94	329.94
Space cooling		Electricity	Energy use (kWh)	63,560.5	63,560.5	63,560.5	63,560.5	63,560.5
			Demand (kW)	92.82	92.82	92.82	92.82	92.82
Pumps		Electricity	Energy use (kWh)	4,983.05	4,983.05	4,983.05	4,983.05	4,983.05
			Demand (kW)	5.43	5.43	5.43	5.43	5.43
Heat rejection		Electricity	Energy use (kWh)	32,860.36	32,860.36	32,860.36	32,860.36	32,860.36
			Demand (kW)	13.91	13.91	13.91	13.91	13.91
Fans-interior		Electricity	Energy use (kWh)	101,306.5	101,306.5	101,306.5	101,306.5	101,306.5
			Demand (kW)	46.93	46.93	46.93	46.93	46.93
Fans-parking garage		Electricity	Energy use (kWh)	0	0	0	0	0
			Demand (kW)	0	0	0	0	0
Service water heating		electricity	Energy use (kWh)	10,356.92	10,356.92	10,356.92	10,356.92	10,356.92
			Demand (kW)	1.96	1.96	1.96	1.96	1.96
Receptacle equipment		Electricity	Energy use (kWh)	124,823	124,823	124,823	124,823	124,823
			Demand (kW)	36.66	36.66	36.66	36.66	36.66
Interior lighting process		electricity	Energy use (kWh)	0	0	0	0	0
			Demand (kW)	0	0	0	0	0

Refrigeration equipment		electricity	Energy use (kWh)	0	0	0	0	0
			Demand (kW)	0	0	0	0	0
Cooking		electricity	Energy use (kWh)	0	0	0	0	0
			Demand (kW)	0	0	0	0	0
Industrial process		electricity	Energy use (kWh)	130	130	130	130	130
			Demand (kW)	12	12	12	12	12
Elevators & escalators	x	electricity	Energy use (kWh)	84,221.79	84,221.79	84,221.79	84,221.79	84,221.79
			Demand (kW)	26.66	26.66	26.66	26.66	26.66
Baseline energy totals		Total annual energy use (MBtu/year)		3021.78	3021.78	3021.78	3021.78	3021.78
		Total process energy (MBtu/year)						713.26
		Process energy modelling compliance						N

Table 76: EA Performance Rating Method Compliance

End use	process	Proposed design energy type	Units of annual energy & peak demand	Baseline building results	Proposed building results	Percentage savings
Interior lighting		Electricity	Energy use (kWh)	167,265.1	167,265.1	0
			Demand (kW)	47.76	47.76	
Exterior lighting		Electricity	Energy use (kWh)	26,001.66	15,426.9	40.67
			Demand (kW)	5.13	3.04	
Space heating		Electricity	Energy use (kWh)	270,254.4	25,980.5	90.39
			Demand (kW)	329.94	70.39	
Space cooling		Electricity	Energy use (kWh)	63,560.5	35,756.2	43.74
			Demand (kW)	92.82	43.19	
Pumps		Electricity	Energy use (kWh)	4,983.05	0	100
			Demand (kW)	5.43	0	
Heat rejection		Electricity	Energy use (kWh)	32,860.36	6,937.11	78.89
			Demand (kW)	13.91	9.84	
Fans- interior		Electricity	Energy use (kWh)	101,306.5	109,487	-8.08
			Demand (kW)	46.93	23.14	
Fans- parking garage		Electricity	Energy use (kWh)	0	0	0
			Demand (kW)	0	0	
Service water		electricity	Energy	10,356.92	4,372.75	57.78

heating			use (kWh)			
			Demand (kW)	1.96	1.04	
Receptacle equipment		Electricity	Energy use (kWh)	124,823	124,823	0
			Demand (kW)	36.66	36.66	
Interior lighting process		electricity	Energy use (kWh)	0	0	0
			Demand (kW)	0	0	
Refrigeration equipment		electricity	Energy use (kWh)	0	0	0
			Demand (kW)	0	0	
Cooking		electricity	Energy use (kWh)	0	0	0
			Demand (kW)	0	0	
Industrial process		electricity	Energy use (kWh)	0	0	0
			Demand (kW)	0	0	
Elevators & escalators	x	electricity	Energy use (kWh)	84,221.79	84,221.79	0
			Demand (kW)	26.66	26.66	
		Total annual energy use (MBtu/year)		3021.78	1959.41	
		Total process energy (MBtu/year)		713.26	713.26	

Table 77: EA Energy Use summary & energy savings

Energy type	Units	Baseline design	Proposed design
Electricity	kWh	885,633.38	574,270.96
Natural gas	kWh	0	0
Totals	MMBtu	3,021.78	1,959.41

Table 78: EA Energy Use summary: Total Building Energy Use Performance

Energy type	Units	Baseline case		Proposed case			
Section 1.6 Energy Use		Process	Section 1.6 Energy Use	Section 1.6 Energy Use	Section 1.7 Energy Use	Section 1.8 Energy Use	Total Energy Use
Electricity	kWh	209,044	885,633.38	574,270.96	0	0	574,270.96
Natural gas	kWh	0	0	0	0	0	0
Totals	MMBtu	713.26	3,021.78	1,959.41	0	0	1,959.41
Energy use savings							35.16 %

Table 79: Proposed Tenant Electricity Used

	Units	Total building	Tenant use	Tenant use %
Lighting	kWh	182,692.1	167,265.11	91.56
HVAC	kWh	178,161.29	178,161.29	100

Service Water Heating	kWh	4,372.75	4,372.75	100
Receptacles	kWh	124,823.03	124,823.03	100
Miscellaneous	kWh	84,221.79	0	0
Total	kWh	574,270.96	474,622.18	82.65
Core & Shell electricity use	kWh	99,648.78		

Table 80: EA: Energy Cost summary: Total Building Energy Cost Performance (Baseline Case)

Energy type	Baseline cost ($) (0 º rotation)	Baseline cost ($) (90 º rotation)	Baseline cost ($) (180 º rotation)	Baseline cost ($) (270 º rotation)	Baseline building performance
Electricity	170,130.17	170,130.17	170,130.17	170,130.17	170,130.17
Natural gas					
Totals	170,130.17	170,130.17	170,130.17	170,130.17	170,130.17

Table 81: EA: Energy Cost summary: Total Building Energy Cost Performance (manual cost input)

Energy type	Units	Baseline case		Proposed case			
Section 1.6 Energy Use		Process	Section 1.6 Energy Cost	Section 1.6 Energy Cost	Section	Section	Total energy cost
Electricity	$	40,157.35	170,130.17	110,317.45	0	0	110,317.45
Natural gas	$	0	0	0	0	0	0
Totals	$	40,157.35	170,130.17	110,317.45	0	0	110,317.45
Baseline process energy cost as percentage of total energy cost (%)			23.6	Energy cost savings			35.16 %
EA Credit 1 points documented							16

Section 1.9 B- Reports & metrics

Table 82: EA Energy Use Intensity

	Baseline EUI	Proposed EUI
Electricity (kWh/sf)		
Interior lighting	2.809	2.809
Space heating	4.538	0.436
Space cooling	1.067	0.6
Fans- interior	1.701	1.838
Service water heating	0.174	0.073
Receptacle equipment	2.096	2.096
Miscellaneous	2.486	1.791
Total	14.871	9.643
Natural gas (kBtu/sf)		
Space heating	0	0

Service water heating	0	0
Total energy use intensity (kBtu/sf)		
Total	50.739	32.901

Table 83: EA End Use Energy percentage

	Baseline case	Proposed case	End use energy savings (%)
Interior lighting	18.889	29.131	0
Space heating	30.516	4.522	78.462
Space cooling	7.175	6.222	8.933
Fans- interior	11.439	19.061	-2.62
Service water heating	1.17	0.757	1.932
Receptacle equipment	14.095	21.737	0
Miscellaneous	16.717	18.574	13.294

GBCI Comments on the energy simulation results

The GBCI found that it was unclear what improvements have been made to the building envelope in the proposed design, and if the baseline case existing construction have been modelled for spaces that were conditioned prior to renovation and new construction. Hence, it was required that project team provide a description for each construction and the insulation R-value noting if insulation is continuous or installed in the framing cavity[1]. Additionally, the baseline case does not need to be rotated; hence the simulation results for the baseline case with the same orientation as the proposed case may be used to determine the project's savings. Also, new equipment must be modelled in the baseline case with the minimum efficiencies as described by the reference standard- not the performance characteristics of the replaced equipment.

Reviewing the energy simulation report; the GBCI noted that during the Input summary; regarding the additional wall, roof, and floor insulation is not sufficient to substantiate the reported assembly performance for the existing walls in the proposed case, hence the U-values used represent the glazing only without accounting for the heat transfer through the framing. Thus, the GBCI required that the project team provide additional information to confirm that the framed assembly U-value was used for the proposed case windows (showing that the whole framed window assembly has been tested by NFRC[2]; verifying that LBNL Windows 5 calculations have been provided for the whole framed assembly; or verifying that the frame effects are captured within the energy modelling. Also, commented that it was mistakenly modelling the venetian blinds on

[1] It should be noted the nominal R-value for cavity insulation must be adjusted as described in Appendix A to develop an assembly U-value that accounts for the heat transfer through the structure.
[2] The National Fenestration Rating Council (NFRC) is a non-profit organization which provides performance ratings on windows, doors, and skylights. NFRC administers a certification and labeling program overseeing energy-efficiency of windows, doors, and skylights. The NFRC helps determine how well a product performs in regards its energy efficiency.

glazed façade and roof lights in the proposed case, although it is prohibited to model manual fenestration shading devices, while automatic ones need to be supported by a narrative with their description, describing how they are controlled and how they are simulated in the model. Also, exterior lighting was not modelled- although any end use load component must be modelled for both baseline and proposed cases, also checking different value inputs for receptacle equipment for both baseline and proposed cases although the simulation results show identical electric demands and consumption for this end use, also it was mistakenly simulating an electric boiler in the baseline case for space heating, but the baseline HVAC system has electric resistance reheat- so no boiler for space heating should be modelled in the baseline case, and the narrative description for HVAC system control provided indicates that the proposed VRF systems having water cooled condensers- but the proposed model did not include any pumps. Also, it was unclear whether the simulation software program (IES-VE) was able to model VRF systems directly or other methods were used, and how the performance curved were obtained, also the input summary indicates that the same heating and cooling efficiencies have been used for VRF HVAC systems and service hot water heat pump in the proposed case, which is according to the GBCI, is unlikely, also the simulation results show space heating savings of 92.9%, space cooling savings of 100%, and service water heating savings of 78.5% of the proposed case, but these savings do not appear to be substantiated by the reported energy efficiency measures, and the elevator equipment has been modelled using 0.2 W/m^2, and the annual electric consumption only represents 0.13 % of the total annual energy consumption, which according to the GBCI appears to be low. Another comment was given for the space summary (292 m^2 for warehouse and material storage); stating that it was an inappropriate space use classification for this type of building.

Also, reviewing HVAC modelling with ASHRAE 90.1-2007 standard, indicates that identical supply and outside airflows have been modelled in both cases, but it is unclear if one baseline HVAC system has been modelled for each floor as required by section G3.1.1- unless an exception applies which is not explained, additionally, insufficient information has been provided for the baseline case HVAC system to determine if they are modelled with the minimum primary airflows (30%) and zone fan airflow (50% of peak primary) and power (0.35 W/cfm) as described by the standard reference- also, it is unclear if the proposed HVAC system have been modelled as designed and if the system fan power for the proposed case includes the fan power for the VRF units as well as the energy recovery ventilators. Also, the design indicates that the proposed design uses a groundwater heat pump with booster for the service hot water heater but insufficient data is reported for its capacity and whether or not it meets the minimum efficiency requirement, also noting that the demand from this end use is low and should be justified, and it is also not clear if the baseline service water heater of this system was sized and modelled with the appropriate efficiency in accordance with the reference standard. It is also unclear how the proposed case lighting can exceed the baseline case while roughly using the same electricity, it is also required to verify that the lighting inputs for the proposed case reflects the lighting system as designed, while for the baseline case reflects the ASHRAE allowances and LEED modelling protocol for Core and Shell projects noting that identical schedules must be used for both cases, and any savings associated with occupancy sensor lighting controls must be reported and modelled with the appropriate lighting power adjustment factor, and savings demonstrated using a schedule change must be submitted using the exceptional calculation method and reported separately in the form.

iii. LCA Calculations

Calculating the embodied energy from maintained area for LEED MRC 1: Building Reuse

Basement plan/ Pianta piano interrato

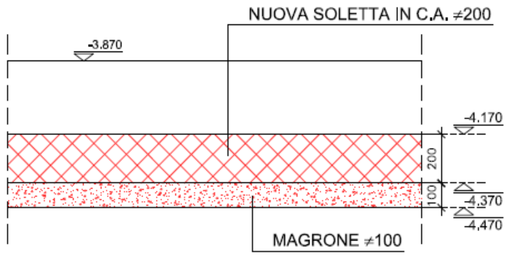


Figure 101: New foundation slab section

Consist of two layers; reinforced concrete and lean concrete
RC= 426.16 * 0.2= 85.23 m^3
Lean concrete= 426.16 * 0.1= 42.62 m^3

Ground floor plan/ Pianta livello piano terra

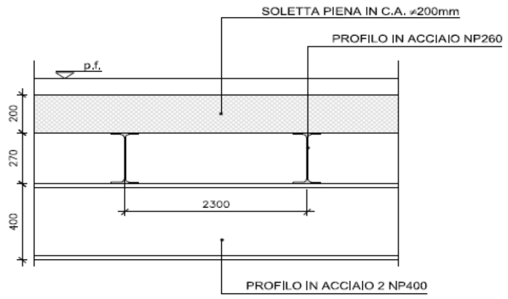


Figure 102: Existing slab type (α)

Consists of slab for existing vault, and another special area (α) of two types of NP steel sections.
For area (α) = 72.5 m^2
RC = 72.5*0.2= 14.5 m^3
While the rest of the maintained area= 210.4 m^2 (solaio a volte esistente)- assumed from reinforced concrete with slab thickness= 20 cm
RC = 210.4*0.2= 42.08 m^3
Thus, adding them to get the total RC = 56.58 m^2 of reinforced concrete
To calculate the steel used for the beams;
Thus, using 15 m long of NP 260 (from the tables= 41.9 kg/m long)= 628.5 kg
And 9 m long of NP 400 (from the tables= 92.5 kg/m long)= 832.5 kg
Adding them to get the total steel for NP beams= 1461 kg of steel

Mezzanine floor plan/ Pianta piano soppalco su piano terra
All new construction and No maintained area

First floor plan/ pianta piano primo

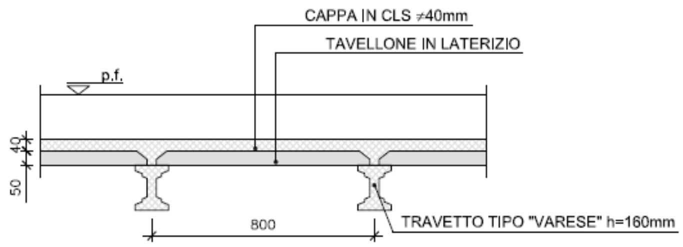


Figure 103: Existing slab type (β)

Total Area (β) = 296.84 m^2 consist of varese beam, brick layer and upper layer of reinforced concrete.
First; to calculate the 'Varese' beams, which is made from prefabricated reinforced concrete- typical Italian method of construction:
For 1 m^2 = 1.25 (0.16*0.16*1) = 0.032 m^3 of reinforced concrete
Thus, for the whole area= 296.84 * 0.032= 9.5 m^3 of prefabricated reinforced concrete
Additionally, calculating the upper reinforced concrete layer RC #400= 0.04 * 296.84= 11.87 m^3 of reinforced concrete
Last; Calculating Bricks
296.84* 0.05 = 14.842 m^3 of bricks

Second floor plan/ Pianta piano secondo

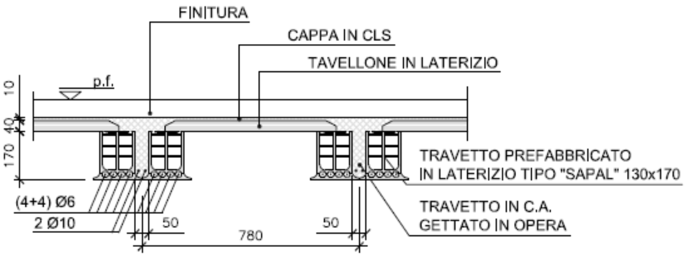


Figure 104: Existing slab type (γ)

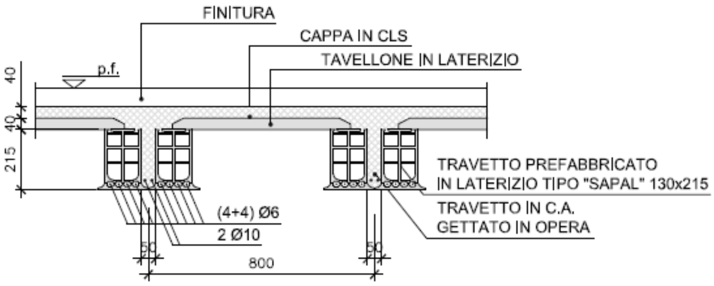


Figure 105: Existing slab type (σ)

Consist of two types of slab sections; (σ) and (γ)
Maintained area (σ) = 150 m^2
Maintained area (γ) = 157.45 m^2
For area (σ) :
In situ reinforced concrete for the slab= 0.04 * 150= 6 m^3
In situ reinforced concrete for the beams= 150* [1.25 (0.05*0.255)] = 2.4 m^3
Thus, total reinforced concrete= 8.4 m^3
Bricks= 0.04* 150= 6 m^3
SAPAL bricks = 150* [2*1.25 (0.13*0.215)]= 10.5 m^3
Thus, total bricks= 16.5 m^3
Steel bars:
Thus, in 0.8 m exists number of 8 bars Ø 6
number of 2 Ø 10
Thus, in 1 m^2 long exists number of 10 bars Ø 6
number of 2.5 Ø 10
Weight of 1 steel bar Ø 6= 0.222 kg per 1 m long,
Weight of 1 steel bar Ø 10= 0.617 kg per 1 m long
and since I have it only in one direction, then these values shall be applicable for 1m^2 of the slab section.
in order to count the number of steel bars per 1 m^2:
Thus, total weight of steel for each 1 m^2 = (10 *0.222)+ (2.5*0.617)= 3.76 kg for each m^2

Total weight of steel in area (ϭ)= 7.375*150= 564.38 kg

For area (ϒ):
In situ reinforced concrete for the slab= 0.01*157.45=1.57 m^3
In situ reinforced concrete for the beams= 157.45 *[1.28(0.05*0.21)]= 2.11 m^3
Thus, total reinforced concrete= 3.68 m^3
Bricks= 0.04* 157.45= 6.3 m^3
SAPAL bricks = 157.45* [2*1.28 (0.13*0.17)] = 8.9 m^3
Thus, total bricks= 15.2 m^3
Steel bars:
Weight of 1 steel bar Ø 6= 0.222 kg per 1 m long
Weight of 1 steel bar Ø 10= 0.617 kg per 1 m long
And in order to count the number of steel bars per m^2:
1 m2 contains 10 Ø 6
2.56 Ø 10
Thus, total weight of steel for each 1 m^2 = (10.25 *0.222)+ (2.56*0.617)= 3.85 kg for each m^2
Total weight of steel in area (ϭ)= 3.85 *157.45= 606.97 kg
Thus, adding (ϭ) and (ϒ)
Thus, total reinforced concrete= 8.4+ 3.68= 12.08 m^3
Thus, total bricks= 16.5+ 15.2= 31.7 m^3
Total weight of steel = 564.38+ 606.97= 1171.35 kg

Third floor plan/ pianta piano terzo

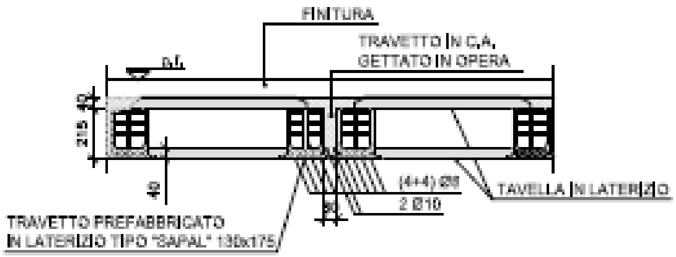


Figure 106: Existing slab type (ξ)

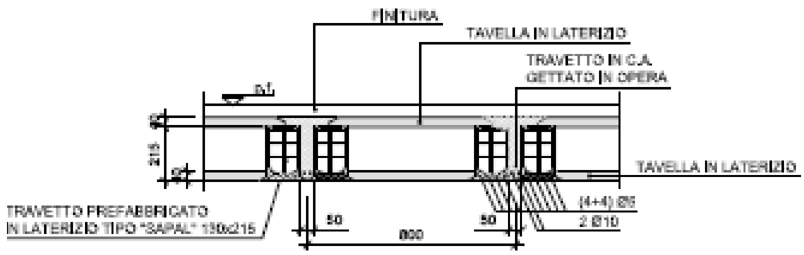


Figure 107: Existing slab type (ϕ)

Consist of two types of slab sections; (ξ) and (ϕ)
Maintained area (ξ) = 204.93 m^2
Maintained area (ϕ) = 109.64 m^2
For area (ξ) :
In situ reinforced concrete for the beams = 204.93 * [1.25 (0.05*0.255)]= 3.27 m^3
Bricks= 2*0.04* 204.93 = 16.4 m^3
SAPAL bricks = 204.93 * [2.5 (0.13*0.175)]= 11.65 m^3
Thus, total bricks= 28 m^3
Steel bars:
Weight of 1 steel bar Ø 6= 0.222 kg per 1 m long
Weight of 1 steel bar Ø 10= 0.617 kg per 1 m long

And in order to count the number of steel bars per m^2:
1 m contains 10 Ø 6
2.5 Ø 10
Thus, total weight of steel for each 1 m^2 = (10 *0.222)+ (2.5*0.617)= 3.76 kg for each m^2
Total weight of steel in area (ξ)= 3.76*204.93= 771 kg
For area (ϕ) :
In situ reinforced concrete for the beams= 109.64 * [1.25 (0 .05*0.255)]= 1.75 m^3
Bricks= 2*0.04* 109.64 = 8.8 m^3
SAPAL bricks = 109.64 * [2.5 (0.13*0.215)]= 7.66 m^3
Thus, total bricks= 16.46 m^3
Steel bars:
Weight of 1 steel bar Ø 6= 0.222 kg per 1 m long
Weight of 1 steel bar Ø 10= 0.617 kg per 1 m long
And in order to count the number of steel bars per m^2:
1 m contains 10 Ø 6
2.5 Ø 10
Thus, total weight of steel for each 1 m^2 = (10 *0.222)+ (2.5*0.617)= 3.76 kg for each m^2
Total weight of steel in area (ϕ)= 3.76*109.64= 412.5 kg
Thus, adding (ξ) and (ϕ)
Thus, total reinforced concrete= 3.27 +1.75=5 m^3
Thus, total bricks= 28+ 16.46= 44.46 m^3
Total weight of steel = 771+ 412.5= 1183.5 kg

Fourth floor plan/ pianta piano quarto

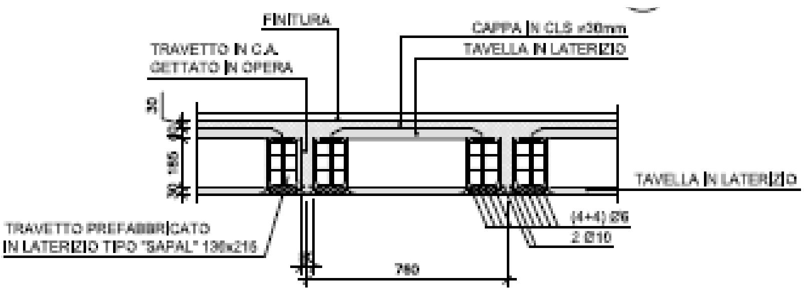


Figure 108: Existing slab type (v)

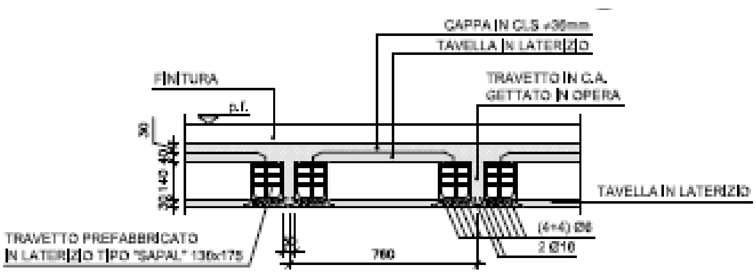


Figure 109: Existing slab type (x)

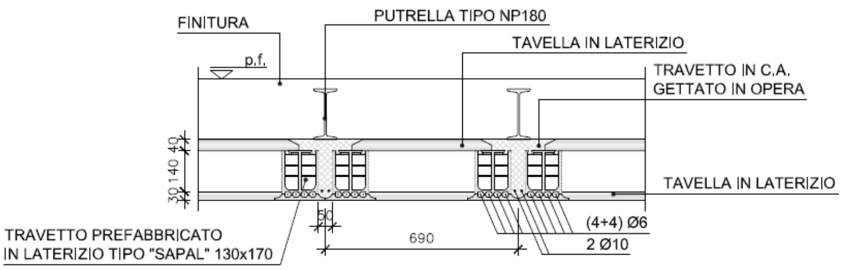


Figure 110: Existing slab type (µ)

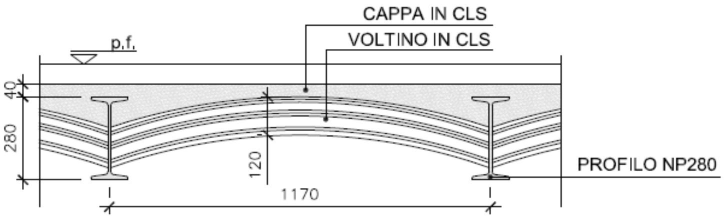


Figure 111: Existing slab type (т)

Consist of four types of slab sections; (v) (*x*), (µ) and (т)
Maintained area (v) = 120.5 m^2
Maintained area (*x*) = 127.75 m^2
Maintained area (µ) = 104.7 m^2
Maintained area (т) = 81.6 m^2
For area (v):
In situ reinforced concrete for the slab= 0.03 * 120.5 = 3.6 m^3
In situ reinforced concrete for the beams= 120.5 * [1.3 (0 .05*0.255)]= 2 m^3
Thus, total reinforced concrete= 5.6 m^3
Bricks= (0.04* 120.5) + (0.03*120.5)= 8.4 m^3
SAPAL bricks = 120.5* [2*1.3* (0.13*0.215)]= 8.85 m^3
Thus, total bricks= 17.25 m^3
Steel bars:
Weight of 1 steel bar Ø 6= 0.222 kg per 1 m long
Weight of 1 steel bar Ø 10= 0.617 kg per 1 m long
And in order to count the number of steel bars per m^2:
1 m2 contains 10.5 Ø 6
2.63 Ø 10
Thus, total weight of steel for each 1 m^2 = (10.5*0.222)+ (2.63 *0.617)= 3.95 kg for each m^2
Total weight of steel in area (ϭ)= 3.95*120.5= 475.98 kg
For area (*x*):
In situ reinforced concrete for the slab= 0.03 * 127.75 = 3.8 m^3
In situ reinforced concrete for the beams= 127.75 * [1.3 (0 .05*0.210)]= 1.74 m^3
Thus, total reinforced concrete= 5.54 m^3
Bricks= (0.04* 127.75) + (0.03*127.75)= 8.94 m^3
SAPAL bricks = 127.75 * [2.63* (0.13*0.175)]= 7.64 m^3
Thus, total bricks= 16.6 m^3
Steel bars:
Weight of 1 steel bar Ø 6= 0.222 kg per 1 m long
Weight of 1 steel bar Ø 10= 0.617 kg per 1 m long
And in order to count the number of steel bars per m^2:
1 m2 contains 10.5 Ø 6
2.63 Ø 10
Thus, total weight of steel for each 1 m^2 = (10.5 *0.222)+ (2.63 *0.617)= 3.95 kg for each m^2
Total weight of steel in area (ϭ)= 3.95*127.75= 505 kg
For area (*µ*):
In situ reinforced concrete for the beams= 104.7 * [1.45 (0 .05*0.17)]= 1.29 m^3
Bricks= (0.04* 104.7) + (0.03*104.7)= 7.32 m^3
SAPAL bricks = 104.7 * [2.89* (0.13*0.175)]= 6.9 m^3
Thus, total bricks= 14.22 m^3
Steel bars:
Weight of 1 steel bar Ø 6= 0.222 kg per 1 m long
Weight of 1 steel bar Ø 10= 0.617 kg per 1 m long
And in order to count the number of steel bars per m^2:

1 m contains 11.6 Ø 6
2.9 Ø 10
Thus, total weight of steel for each 1 m^2 = (11.6*0.222)+ (2.9*0.617)= 4.36 kg for each m^2
Total weight of steel bars (ϭ)= 4.36*104.7 = 457 kg
I-beams NP 180:
Every 0.69 exist 1 steel NP beam, thus in 16 m, exist 23 rows- each row is around 6 m long
Thus total steel length is = 23*6= 138 m long
, and each is 21.9 kg,
Total weight of steel beams= 3022.2 kg
For area (ד):
In situ reinforced concrete = slab + triangles
Nearly; for 1 m exist Area of two triangle= 2* ½ (0.585)*0.1= 0.0585 m^2 , therefore for 1m2= 0.0585+0.04=0.0985 m3.
Therefore total concrete= 0.0985* 81.6= 8 m^3 of reinforced concrete
Steel NP 280= 9.5 (no. of steel beams) *7.5 (length of each beam)= total 71.25 m long *47.9 (weight of one kg/m)= 3412.88 kg
Therefore total
Total reinforced concrete =5.6+ 5.54+1.29+8 = 19.85 m^3
Total bricks =17.25+16.6+14.22 = 87.92 m^3
Steel bars = 475.98+ 505+457= 1437.98
Steel beams= 3022.2+3412.88= 6435.08 kg

Fifth floor plan/ pianta piano quinto

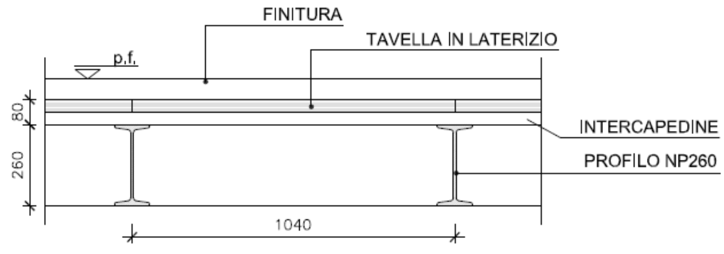


Figure 112: Existing slab type (π)

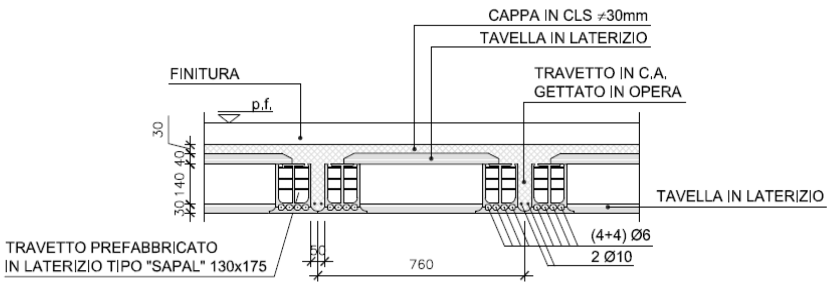


Figure 113: Existing slab type (x)

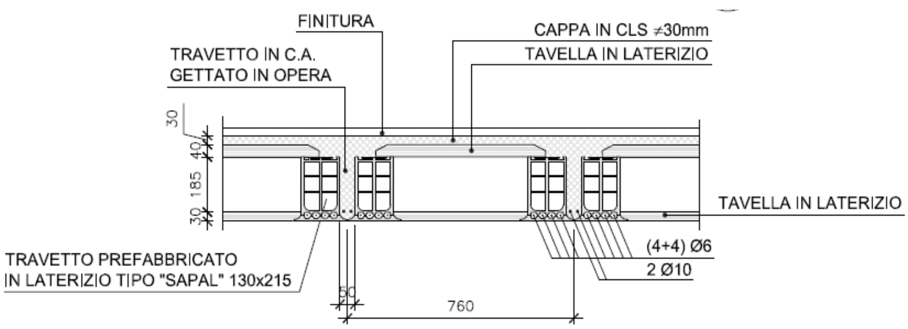
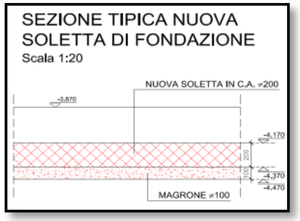
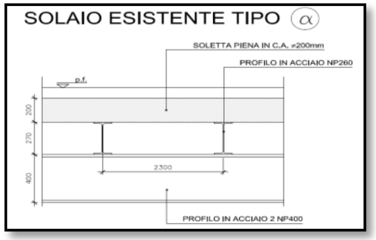


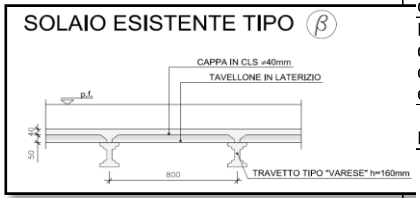
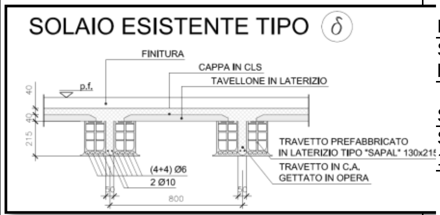
Figure 114: Existing slab type (v)

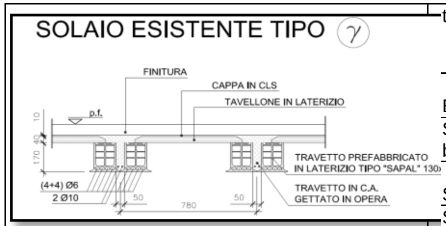
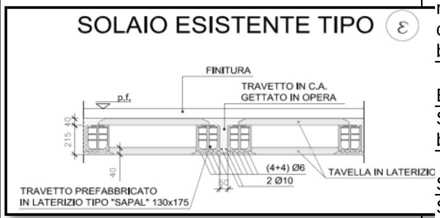
Consist of three types of slab sections; (v) (*x*), and (π)
Maintained area (v) = 100 m^2
Maintained area (*x*) = 240 m^2
Maintained area (π) = 35 m^2
For area (π):
Steel NP 260= (5) beams*7.5 (long) =37.5 m long *41.6 kg/m= 1560 kg
Bricks= 0.08*35=2.8 m^3
For area (*x*):
Reinforced concrete=(0.03*240)+ [240 (1.31) (0.05*0.21)]= 10.5 m^2
Brick layers= [0.04*240] + [0.03*240]= 16.8
SAPAL= 240*2.63 (0.13*0.175)= 14.36 m3
Thus, total bricks= 31.16 m^3
Steel bars:
Weight of 1 steel bar Ø 6= 0.222 kg per 1 m long
Weight of 1 steel bar Ø 10= 0.617 kg per 1 m long
And in order to count the number of steel bars per m^2:
1 m contains 10.52 Ø 6
2.63 Ø 10
Thus, total weight of steel for each 1 m^2 = (10.52 *0.222)+ (2.63 *0.617)= 4 kg for each m^2
Total weight of steel bars (ϭ)= 4*240= 960 kg
For area (*v*):
Reinforced concrete=(0.03 *100) + [100*1.31 (0.05*0.215)]= 4.4 m^3
Bricks= (0.04*100) +(0.03*100)= 7 m^3
SAPAL= 100* (2.63) (0.13*0.215)= 7.36 m^3
Thus, total bricks= 14.36 m^3
Steel bars:
Weight of 1 steel bar Ø 6= 0.222 kg per 1 m long
Weight of 1 steel bar Ø 10= 0.617 kg per 1 m long
And in order to count the number of steel bars per m^2:
1 m contains 10.52 Ø 6
2.63 Ø 10
Thus, total weight of steel for each 1 m^2 = (10.52*0.222)+ (2.63*0.617)= 4 kg for each m^2
Total weight of steel bars = 4*100= 400 kg
Thus, total=
Reinforced concrete=10.5+ 4.4= 14.9 m^2
Bricks= 2.8+ 31.16+ 14.36=48.32 m^3
Steel bars= 960+400=1360
Steel beams= 1560

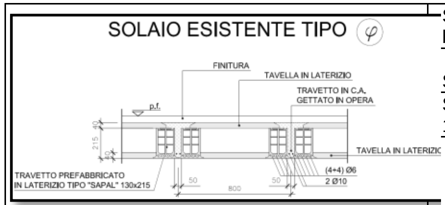
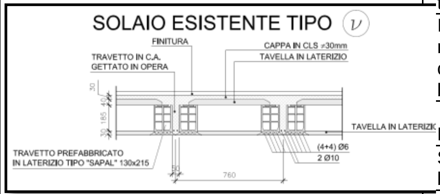
Using the Inventory of Carbon and Energy (ICE) V 2.0, 2011

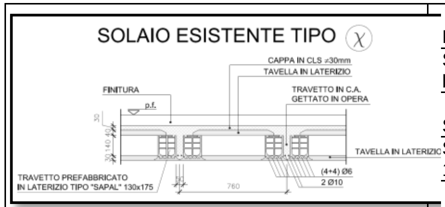
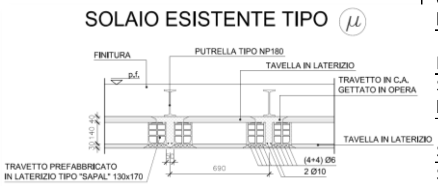
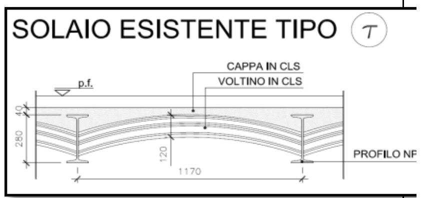
Table 84: Calculating the EE and EC contained for 1 m2 for different slab sections

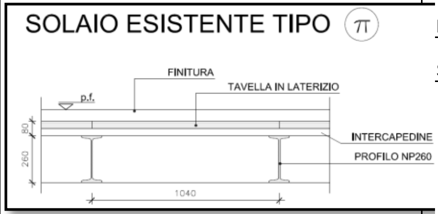
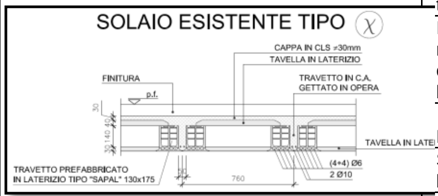
Basement floor plan	**Material**	**quantity**	**Unit**	**Density kg/m3**	**Total weight (kg)**	**EE (MJ/kg)**	**SUM EE (MJ)**	**EC (kgCO2e/kg)**	**SUM EC (kgCO2e)**	**Total section area**			**Total EE of section**	**Total EC of section**
	Lean Concrete	0.2	m3	2400	480	0.70	336.00	0.13	62.40					
	Reinforced Concrete	0.1	m3	2400	240	1.92	460.80	0.20	47.52					
							796.80		**109.92**	426.16			339,564.29	46,843.51
Ground floor	**Material**	**quantity**	**Unit**	**Density kg/m3**		**EE (MJ/kg)**	**SUM EE (MJ)**	**EC (kgCO2e/kg)**	**SUM EC (kgCO2e)**		**Total EE of section**	**Total EC of section**	**Total EE of floor**	**Total EC of floor**
	Reinforced Concrete	0.2	m3	2400	480	1.92	921.60	0.20	95.04					
	Steel beams NP 260	8.67	kg	7800	8.67	10.00	86.69	0.47	4.07					
	Steel beams NP 400	11.48	kg	7800	11.48	10.00	114.83	0.47	5.40					
							1,123.12		**104.51**	72.5	81,426.00	7,577.07		
													275,330.64	27,573.49
	Additionally;													
	Reinforced Concrete	0.2	m3	2400	480	1.92	921.60	0.20	95.04					
							921.60		**95.04**	210.4	193,904.64	19,996.42		
First floor	**Material**	**quantity**	**Unit**	**Density kg/m3**		**EE (MJ/kg)**	**SUM EE (MJ)**	**EC (kgCO2e/kg)**	**SUM EC (kgCO2e)**					

	Reinforced concrete	0.04	m3	2400	96	1.92	184.32	0.20	19.01					
	Prefabricated concrete'Varese beam'	0.032	m3	2500	80	1.50	120.00	0.18	14.40					
	Brick layer	0.05	m3	600	30	3.00	90.00	0.24	7.20					
							394.32		**40.61**	296.835			117,047.98	12,053.88
Second floor	**Material**	**quantity**	**Unit**	**Density kg/m3**		**EE (MJ/kg)**	**SUM EE (MJ)**	**EC (kgCO2e/kg)**	**SUM EC (kgCO2e)**		**Total EE of section**	**Total EC of section**	**Total EE of floor**	**Total EC of floor**
	In situ reinforced concrete for slabs	0.04	m3	2400	96	1.92	184.32	0.20	19.01					
	In situ reinforced concrete for beams	0.0159375	m3	2400	38.25	1.92	73.44	0.20	7.57					
	Brick layer	0.04	m3	600	24	3.00	72.00	0.24	5.76					
	SAPAL bricks	0.069875	m3	600	41.925	3.00	125.78	0.24	10.06					
	Steel bar Ø 6	2.22	kg	7800	2.22	8.80	19.54	0.45	1.00					
	Steel bar Ø 10	1.5425	kg	7800	1.5425	8.80	13.57	0.45	0.69					
							488.65		**44.10**	150	73,296.75	6,614.49	123,015.13	10,831.07
	Material	**quantity**	**Unit**	**Density kg/m3**		**EE (MJ/kg)**	**SUM EE (MJ)**	**EC (kgCO2e/kg)**	**SUM EC (kgCO2e)**					
	In situ reinforced concrete for the slab	0.01	m3	2400	24	1.92	46.08	0.20	4.75					
	In situ reinforced concrete for	0.01	m3	2400	32.26	1.92	61.93152	0.20	6.386688					

	the beams													
	Bricks	0.04	m3	600	24	3.00	72.00	0.24	5.76					
	SAPAL bricks	0.056576	m3	600	33.9456	3.00	101.84	0.24	8.15					
	Steel bar Ø 6	2.2755	kg	7800	2.2755	8.80	20.02	0.45	1.02					
	Steel bar Ø 10	1.57952	kg	7800	1.57952	8.80	13.90	0.45	0.71					
							315.77		**26.78**	157.45	49,718.38	4,216.57		
Third floor	**Material**	**quantity**	**Unit**	**Density kg/m3**		**EE (MJ/kg)**	**SUM EE (MJ)**	**EC (kgCO2e/kg)**	**SUM EC (kgCO2e)**				**Total EE of floor**	**Total EC of floor**
	In situ reinforced concrete for beams	0.0134375	m3	2400	32.25	1.92	61.92	0.20	6.39				111,224.40	9,076.97
	Bricks	0.08	m3	600	48	3.00	144.00	0.24	11.52					
	SAPAL bricks	0.056875	m3	600	34.125	3.00	102.38	0.24	8.19					
	Steel bar Ø 6	2.22	kg	7800	2.22	8.80	19.54	0.45	1.00					
	Steel bar Ø 10	1.5425	kg	7800	1.5425	8.80	13.57	0.45	0.69					
							341.41		**27.79**	204.93	69,964.13	5,694.72		
	Material	**quantity**	**Unit**	**Density kg/m3**		**EE (MJ/kg)**	**SUM EE (MJ)**	**EC (kgCO2e/kg)**	**SUM EC (kgCO2e)**					
	In situ reinforced concrete for beams	0.0159375	m3	2400	38.25	1.92	73.44	0.20	7.57					
	Bricks	0.08	m3	600	48	3.00	144.00	0.24	11.52					

	SAPAL bricks	0.069875	m3	600	41.925	3.00	125.78	0.24	10.06					
	Steel bar Ø 6	2.22	kg	7800	2.22	8.80	19.54	0.45	1.00					
	Steel bar Ø 10	1.5425	kg	7800	1.5425	8.80	13.57	0.45	0.69					
							376.33		**30.85**	109.64	41,260.27	3,382.24		
Fourth floor	**Material**	**quantity**	**Unit**	**Density kg/m3**		**EE (MJ/kg)**	**SUM EE (MJ)**	**EC (kgCO2e/kg)**	**SUM EC (kgCO2e)**				**Total EE of floor**	**Total EC of floor**
	In situ reinforced concrete for the slab	0.03	m3	2400	72	1.92	138.24	0.20	14.26					
	In situ reinforced concrete for beams	0.016575	m3	2400	39.78	1.92	76.38	0.20	7.88					
	Bricks	0.07	m3	600	42	3.00	126.00	0.24	10.08					
	SAPAL bricks	0.0735085	m3	600	44.1051	3.00	132.32	0.24	10.59					
	Steel bar Ø 6	2.331	kg	7800	2.331	8.80	20.51	0.45	1.05					
	Steel bar Ø 10	1.62271	kg	7800	1.62271	8.80	14.28	0.45	0.73				262,684.81	20,561.28
							507.73		**44.58**	120.5	61,180.93	5,371.51		
	Material	**quantity**	**Unit**	**Density kg/m3**		**EE (MJ/kg)**	**SUM EE (MJ)**	**EC (kgCO2e/kg)**	**SUM EC (kgCO2e)**					
	In situ reinforced concrete for the slab	0.03	m3	2400	72	1.92	138.24	0.20	14.26					
	In situ reinforced concrete for beams	0.01365	m3	2400	32.76	1.92	62.90	0.20	6.49					

	Bricks	0.07	m3	600	42	3.00	126.00	0.24	10.08					
	SAPAL bricks	0.0598325	m3	600	35.8995	3.00	107.70	0.24	8.62					
	Steel bar Ø 6	2.331	kg	7800	2.331	8.80	20.51	0.45	1.05					
	Steel bar Ø 10	1.62271	kg	7800	1.62271	8.80	14.28	0.45	0.73					
							469.63		**41.22**	127.75	59,995.28	5,265.54		
	Material	**quantity**	**Unit**	**Density kg/m3**		**EE (MJ/kg)**	**SUM EE (MJ)**	**EC (kgCO2e/kg)**	**SUM EC (kgCO2e)**					
	In situ reinforced concrete for beams	0.012325	m3	2400	29.58	1.92	56.79	0.20	5.86					
	Bricks	0.07	m3	600	42	3.00	126.00	0.24	10.08					
	SAPAL bricks	0.0657475	m3	600	39.4485	3.00	118.35	0.24	9.47					
	Steel bar Ø 6	2.5752	kg	7800	2.5752	8.80	22.66	0.45	1.16					
	Steel bar Ø 10	1.7893	kg	7800	1.7893	8.80	15.75	0.45	0.81					
	Steel beam NP 180	33.2301815	kg	7800	33.23018147	10.00	332.30	0.47	15.62					
							671.85		**42.99**	104.7	70,342.54	4,500.71		
	**Material**	**quantity**	**Unit**	**Density kg/m3**		**EE (MJ/kg)**	**SUM EE (MJ)**	**EC (kgCO2e/kg)**	**SUM EC (kgCO2e)**					

	In situ reinforced concrete	0.0985	m3	2400	236.4	1.92	453.89	0.20	46.81					
	Steel beams NP 280	41.82450 98	kg	7800	41.824509 8	10.00	418.25	0.47	19.66					
							872.13		**66.46**	81.6	71,166.0 6	5,423.5 2		
Fifth floor	**Material**	**quantity**	**Un it**	**Densi ty kg/m3**		**EE (MJ/k g)**	**SUM EE (MJ)**	**EC (kgCO2e/ kg)**	**SUM EC (kgCO2 e)**				**Total EE of floor**	**Total EC of floor**
	Bricks	0.08	m3	600	48	3.00	144.00	0.24	11.52				182,939.0 4	15,363.4 2
	Steel NP 260	44.57142 86	kg	7800	44.571428 57	10.00	445.71	0.47	20.95					
							589.71		**32.47**	35	20,640.0 0	1,136.4 0		
	Material	**quantity**	**Un it**	**Densi ty kg/m3**		**EE (MJ/k g)**	**SUM EE (MJ)**	**EC (kgCO2e/ kg)**	**SUM EC (kgCO2 e)**					
	In situ reinforced concrete for the slab	0.03	m3	2400	72	1.92	138.24	0.20	14.26					
	In situ reinforced concrete for beams	0.01365	m3	2400	32.76	1.92	62.90	0.20	6.49					
	Bricks	0.07	m3	600	42	3.00	126.00	0.24	10.08					
	SAPAL bricks	0.059832 5	m3	600	35.8995	3.00	107.70	0.24	8.62					
	Steel bar Ø 6	2.33544	kg	7800	2.33544	8.80	20.55	0.45	1.05					
	Steel bar Ø 10	1.62271	kg	7800	1.62271	8.80	14.28	0.45	0.73					
							469.67		**41.22**	240	112,720. 66	9,892.6 9		

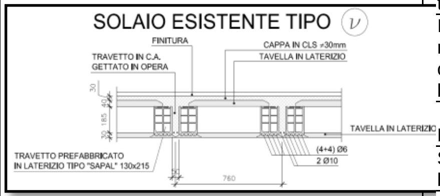
	Material	quantity	Unit	Density kg/m3		EE (MJ/kg)	SUM EE (MJ)	EC (kgCO2e/kg)	SUM EC (kgCO2e)					
	In situ reinforced concrete for the slab	0.03	m3	2400	72	1.92	138.24	0.20	14.26					
	In situ reinforced concrete for beams	0.013975	m3	2400	33.54	1.92	64.40	0.20	6.64					
	Bricks	0.07	m3	600	42	3.00	126.00	0.24	10.08					
	SAPAL bricks	0.0735085	m3	600	44.1051	3.00	132.32	0.24	10.59					
	Steel bar Ø 6	2.33544	kg	7800	2.33544	8.80	20.55	0.45	1.05					
	Steel bar Ø 10	1.62271	kg	7800	1.62271	8.80	14.28	0.45	0.73					
							495.78		**43.34**	100	49,578.38	4,334.33		
Total EE and EC of slabs													1,411,806.28	142,303.59

Table 85: LCA for external wall structure

	External Walls (Masonary)							
		Side facing Berchet st.	**Side facing Foscolo st**	**Side facing San Raffaele st**	**Side facing neighbouring property**			
	H=25 m	25.00	25.00	25.00	25.00			
	Width in m	30.60	26.00	26.80	31.38			
	Wall thick= 0.6 m	0.60	0.60	0.60	0.60			
	in m3	459.00	390.00	402.00	470.70	2,869.50	**2,229.65**	total maintained exterior wall areas
	total openings (m2)	639.85						
	total openings (m3)	383.91						

	sum m3 of walls	1,337.79						
	Masonary 1700 kg/m3	1,705,682.25	kg	Brick volume assumed 3/4 total wall volume				
	Lime Mortar 1500 kg/m3	501,671.25	kg	Note: mortar assumed 1/4 of total wall volume				
	EE (MJ/kg)	**Total EE of walls (MJ)**		EC (kgCO2e/kg)	**Total EC of Walls (kgCO2e)**			
Masonary	3.00	5,117,046.75	MJ	0.24	409,363.74	kgCO2e		
Lime Mortar	1.50	752,506.88	MJ	-	-	kgCO2e		
		5,869,553.63			**409,363.74**			

Table 86: LCA for internal wall structure

	Interior Structural Walls (Masonry)					
		Sum Total wall length (m)	Floor Height (m)	maintained %	Maintained area m2	
	Basement	152.16	3.86	0.50	293.67	
	Ground f.	17.50	3.15	0.50	27.56	
	Mezzanine f.		3.19	-	-	
	First f.	138.90	5.13	0.50	356.28	
	Second f.	138.90	3.56	0.50	247.24	
	Third f.	138.90	3.72	0.50	258.35	
	fourth f.	138.90	3.35	0.50	232.66	
	Fifth f.	128.20	2.81	0.50	180.12	
	total material area	1,595.88	m2			
	Total wall volume- assuming Wall average thickness 0.4 m	638.35	m3			

	Masonary 1700 kg/m3	813,900.99	kg	Brick volume assumed 3/4 total wall volume		
	Lime Mortar 1500 kg/m3	239,382.65	kg	Note: mortar assumed 1/4 of total wall volume		
	EE (MJ/kg)	**Total EE of walls (MJ)**		EC (kgCO2e/kg)	**Total EC of Walls (kgCO2e)**	
Masonary	3.00	2,441,702.98	MJ	0.24	195,336.24	kgCO2e
Lime Mortar	1.50	359,073.97	MJ	-	-	kgCO2e
		2,800,776.95	**MJ**		**195,336.24**	**kgCO2e**

Table 87: Comparing reuse versus demolished scenarios for each element

Slabs (Reinforced concrete, Masonry, Steel deck)										
	Basement	**Ground**	**Mezzanine**	**First**	**Second**	**Third**	**Fourth**	**Fifth**	**SUM**	
Full area m2	532.70	615.02	341.62	593.67	611.06	628.71	595.41	408.58	**4,326.77**	
Maintanined area m2	426.16	282.91	-	296.84	307.45	314.57	434.55	375.00	**2,437.47**	
Demolished area (m2)	106.54	332.11	-	296.84	303.61	314.14	160.86	33.58		

Table 88: Comparing materials' EE and EC for demolished areas for each floor

		EE and EC for demolished areas for each floor		
		Demolished area (m2)	EE	EC
assumed resembling the new slab construction	**Basement**	106.54	84,891.07	11,710.88
assumed continuous slab on vault	**Ground**	332.11	306,073.31	31,882.64
	Mezzanine	-	-	-
Assumed demolished areas of section (β)	**First**	296.84	117,047.98	12,053.88
Assumed demolished areas of section (γ)	**Second**	303.61	95,871.69	8,130.79

Assumed demolished areas of section (ξ)	**Third**	314.14	107,248.97	8,729.52
Assumed demolished areas of section (x)	**Fourth**	160.86	75,544.74	6,630.25
Assumed demolished areas of section (x)	**Fifth**	33.58	15,771.50	1,384.15
		1,547.68		

The first step for existing building restoration/ refurbishment is to draw restoration plans based on new functional requirements, then to estimate the amount of demolished materials. In this step LCA can provide guidance on how to balance between demolishing scenarios and their environmental effect; not in weight but in embodied energy. This comparison aims at completing the image of MR C1 Building Reuse, and estimating the amount of embodied energy maintained through Building Reuse; to the amount of embodied energy for demolishing. It also determines and prioritises the amount of demolished materials to be able to draw conversion plans. This gives comprehensive evaluation about the whole reuse plan adopted. Thus in managing this type of project, LCA can be used to evaluate a) Demolished: maintained areas, b) scenarios of demolishing , and c) scenarios of reuse. conversion plans. This gives comprehensive evaluation about the whole reuse plan adopted. Thus in managing this type of project, LCA can be used to evaluate a) Demolished: maintained areas, b) scenarios of demolishing , and c) scenarios of reuse.

Assumptions for the calculation method

PR.P.L1.02: assumed percentage of mix to be brick: reinforced concrete: brick: steel to be 35:55:10, and (assuming common 25 cm brick slab)

PR.P.L1.03: Reinf. conc.: 91.15 m2 * 0.30= 13.6725 m3 (assuming 30 cm conc. Stair slab)

A.02.04.015: Ceramics: 206.35 m2 * 0.0127 = 2.620645 m3 (assuming ceramic 12 mm)
A.02.04.016: Ceramics: 2,965.81 m2 * 0.0127 = 37.66566 m3 (assuming ceramic 12 mm)
A.02.04.017 Ceramics: 2,297.22 m * 0.03* 0.3 = 20.67498 m3 (assuming marble 300*600*30 mm)
PR.P.L1.04: Plaster board/ gypsum board: 2,735.08 m2 * 0.02 m= 54.7016 m3 (sections of plaster board)
A.02.04.021: Concrete: 2,965.81 m2 * 0.04 = 118.6324 m3 (as stated 4 sm thick)
PR.P.L1.05: Glass: 606.37 m2 * 0.006= 3.63822 m3
PR.P.L1.06: Plaster: 2,640.62 m2 * 0.03 (as stated in the BOQ)= 79.2186 m3, and 2,640.62 m2 * 0.03 (as stated in the BOQ)= 79.2186 m3- assumed all area with the same thickness
PR.P.L1.07: Partition wall (wood, glass, drywall): 217.01 m2 *0.046 = 9.98246 m3
PR.P.L1.84: Brick: 822.7 m2 * 0.04 m = 32.908 m3- assumed brick thickness 4 cm
Ceramics: 3516.743 m2

Notes
Reinf. conc.: cement density assumed 2400 kg/m3
stair slab thickness assumed 15 cm
Ceramics: ceramic thickness assumed 1/5 inch = 0.0127 m and density ranging bet. 2790 - 3070 kg / m3 will be assumed 2900 Kg/m3
Plaster board/ gypsum board: assuming the density of gypsum board = 600 kg/m3
Plaster: assuming density of plaster = 849 kg/m3
Partition wall (wood, glass, drywall): assuming thickness of the partition wall 46 mm as in openings schedule , assuming desnsity of 750 kg/m3 for walnut stained oak (rovere tinto noce)
Glass: assuming 6 mm thickness of glass as in openings schedule and 2500 kg/m3 p.35 tech. specs
tempered glass 2400 kg/m3

Table 89: LCA for different materials used in the project

	Brick	Reinf. conc.	Ceramics	Plaster board/ gypsum board	Walnut stained oak wood	Glass	Steel	Concrete		
PR.P.L1.01	434.46	353.31								
PR.P.L1.02	138.303	88.011					25.146			
PR.P.L1.03		27.35								
A.02.04.015			2.62							
A.02.04.016			37.67							
A.02.04.017			68.92							
PR.P.L1.04				54.70						
A.02.04.021								118.63		
PR.P.L1.05						3.64				
PR.P.L1.06										
PR.P.L1.07					9.98					
PR.P.L1.84	32.91									
sum in m3	605.67	468.67	109.20	54.70	9.98	3.64	25.15	118.63		
Density kg/m3	1,700.00	1,600.00	2,900.00	600.00	750.00	2,500.00	7,800.00	1,500.00		
									Total Sum of salvaged construction waste	
in kg	1,029,640.70	749,865.60	316,688.79	32,820.96	7,486.85	9,095.55	196,138.80	177,948.60	2,519,685.85	kg

	[ICE V 2.0 Aggregates]	[ICE V 2.0 Aggregates]	[ICE V 2.0 Aggregates]	[ICE V 2.0 plaster board ;BUT assumed half values for EE and EC]	[Internet BUT assumed half values for EE and EC]	[ICE V 2.0 Subtracting secondary from Primary glass]	[ICE V 2.0 Subtracting recycled steel from general recycled steel]	[ICE V 2.0 Aggregates]		
EE (MJ/kg)	0.08	0.08	0.08	3.38	8.00	3.50	10.70	0.08		
Total EE (MJ)	85,460.18	62,238.84	26,285.17	110,770.74	59,894.76	31,834.43	2,098,685.16	14,769.73	2,489,939.01	MJ
EC (kgCO2e/kg)	0.01	0.01	0.01	0.20	1.09	0.32	0.99	0.01		
Total EC (kgCO2e)	5,354.13	3,899.30	1,646.78	6,400.09	8,160.66	2,910.58	194,177.41	925.33	223,474.28	kgCO2e
Notes		stair slab thickness assumed 15 cm	ceramic thickness assumed 1/5 inch = 0.0127 m a		assuming thickness of the partition wall 46 mm as in openings schedule for walnut stained oak (rovere tinto noce)	soda lime silicate glass assuming 6 mm thickness of glass as in openings schedule				