MSc Program
Environmental Technology & International Affairs

Energy performance assessment of existing buildings: A case study of LEED for an office building in Austria

A Master's Thesis submitted for the degree of
"Master of Science"

supervised by
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Vienna, 24/10/2014

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Affidavit

I, **MITCHELL SCHOUCHANA**, hereby declare

1. that I am the sole author of the present Master's Thesis, "ENERGY PERFORMANCE ASSESSMENT OF EXISTING BUILDINGS: A CASE STUDY OF LEED FOR AN OFFICE BUILDING IN AUSTRIA", 126 pages, bound, and that I have not used any source or tool other than those referenced or any other illicit aid or tool, and
2. that I have not prior to this date submitted this Master's Thesis as an examination paper in any form in Austria or abroad.

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I. Abstract

About a third of world energy consumption takes place in buildings. Although policy efforts aimed at improving energy efficiency in buildings have been around at least since the 70s, these policies have mainly been applied to new constructions. Nevertheless, substantive gains in energy efficiency are possible in already existing buildings. In fact where public policy has failed to have an impact, voluntary Green Building certification systems have emerged offering a whole building approach to improvements in energy efficiency and environmental sustainability.

However, as this thesis will explain, each certification system has adopted different forms of energy performance assessment. One of these, known as benchmarking, involves assessing the energy performance of one building in relation to other similar buildings. This is the method advocated by the American Green Building certification system: Leadership in Energy and Environmental Design (LEED). As LEED has grown in popularity and become an internationally used certification system, it has allowed projects outside the United States to either be benchmarked against similar buildings in the US or to use a local benchmark for their energy performance assessment.

This thesis investigates the most coherent strategy for existing office buildings in Austria wishing to perform best in the energy performance assessment component of LEED for Existing Building (LEED EBOM) version 3. In the process, this thesis highlights the problems related with applying a national system of assessment abroad and therefore the need to adopt the system to local conditions. This thesis concludes, based on presently available data, that existing office buildings in Austria perform best when benchmarked against US buildings rather than if the local benchmark were to be used.

Keywords: Green Building, energy performance assessment, LEED, Austria

II. Table of Contents

III. Acronyms and abbreviations

AC	Alternative Current
ASHRAE	American Society of Heating and Refrigerating and Air-conditioning Engineers
BEM	Building Energy Modeling
BMS	Building Management System
BREEAM	Building Research Establishment Environmental Assessment Methodology
BTU	British thermal unit
CAD	Computer Aided Design
CBECS	Commercial Building Energy Consumption Survey
CDD	Cooling Degree Days
CEN	European Committee for Standardizazion
CEREN	Centre d’étude économique et de recherche sur l’énergie (centre for economic studies and research on energy)
CIR	Credit Interpretation Ruling
CO_2	Carbon Dioxide
DC	Direct Current
DES	District Energy System
DF	Daylight Factor
DGNB	Deutsches Gütesiegel nachhaltiges Bauen (German Sustainable Building Council)
DH	District Heating
DOE	Department of Energy
DPE	Diagnostic de Performance Energétique (Energy Performance diagnostic)
EAC1	Energy and Atmosphere Credit 1
EAC4	Energy and Atmosphere Credit 4
EAP2	Energy and Atmosphere Prerequisite 2
EBOM	Existing Buildings: Operations & Maintenance
EC	European Community
EIA	Energy Information Administration
EPA	Environmental Protection Agency
EPBD	Energy Performance Building Directive
EPC	Energy Performance Coefficient
EStar	Energy Star
EU	European Union
EUI	Energy Use Intensity
f2	Square feet
HDD	Heating Degree Days
HQE	Haute Qualité Environnementale (High Environmental Standard)
HVAC	Heating, Ventilation and Air Conditioning
ISO	International Organisation for Standardization
KWh	Kilowatt hour

kBTU	Thousand British Thermal Unit
LEED	Leadership in Energy and Environmental Design
m2	Square meter
MWh	Megawatt hour
NBC	National Building Code
NC	New Construction
SAVE	Specific Actions for Vigorous Energy Efficiency
SBC	Standard Buildng Code
TM46	Technical Memorandum 46
TRACI	Tools for the Reduction and Assessment of chemical and other environmental Impacts
UBC	Uniform Building Code
UK	United Kingdom
US	United States
USGBC	United States Green Building Council
V3	Version 3
V4	Version 4
y	Year

IV. Acknowledgments

This thesis was undertaken in cooperation with the company Clean Energy Solutions, an energineering consultency firm that provided me with supervision, ressources and case study material. My thanks especially go to Ivan Krofak and Klaus Kogler for being so suportive during the 6 months I spent with them for this thesis.

My gratitude also goes to every single person who has supported me during these past two years studying at the Diplomatic Academy of Vienna and at the TU Wien. I would especially like to thank my thesis supervisor Professor Dr. Hans Puxbaum for encouraging me throughout my studies and providing me with sufficient guidance for writing my thesis.

I finally would like to thank my study friends from the ETIA program for being who they are and for having been a great source of inspiration and support in difficult time

1. Introduction

This section explains what motivated this thesis before defining the problem statement, the objectives, the research questions and the methodology as well as outlining the expected results.

1.1. Motivation

As unsustainable practices of human development have sprung to our attention, so has the need for more sustainable production and consumption of energy. Naturally, a large share of our final energy consumption takes place in our homes and workplaces. According to Eurostat, energy consumption in residences and services is 39.8% of total final energy consumption in the European Union (EU) (European Environmental Agency, 2013). According to the International Energy Agency, world final consumption taking place in buildings is 32% (International Environmental Agency, n.d.). Subsequently the concepts of energy efficiency and energy conservation in buildings have become a focus of national and international policies. Techniques to measure energy efficiency in buildings first emerged with the installations of the first Heating, Ventilation and Air Conditioning (HVAC) systems in Europe and in the United States (US). The purpose of these techniques was to determine the size of the HVAC systems. These techniques typically involved estimating peak loads and annual energy use through various calculations, which precisions were constrained throughout history by knowledge of gas laws, heat transfer and thermodynamics. The advent of Computer technology allowed Building Energy Modeling (BEM) to assess with some high measure of precision the energy performance of a building, new and existing. This, in turn, gave a clear indication of the building’s energy efficiency. Nevertheless, as energy consumption is invariably dependent on other physical and functional characteristics of a building such as the envelope or the occupancy patterns, the need to use more comprehensive methods of evaluation became apparent. These were driven primarily by more stringent building standards as well as the growth of Green Building labels (BEMBOOK, 2013).

One way in which measurements of building energy consumption play an essential role is in complying with the requirements of “green building” labels also called certification programs, rating systems or rating schemes. Buildings submit their measurements for assessment by the rating scheme. The organism in charge of certifying the building then attributes the building a certain rating based on its energy consumption. The rating then carries some benefits such as increasing the marketability of the building (Leonardo Academy Inc., 2008). The Leadership in Energy and Environmental Design (LEED) is one of these rating schemes and will be the focus of this thesis.

Although LEED certifications are voluntary, consensus based and market driven, many States in the US now require them for public projects and/or state buildings (Green Building Pages, 2002). As buildings are one of the most important areas where energy consumption takes place, research ought to focus on improving energy efficiency and energy conservation in buildings. This thesis will therefore contribute to research efforts going in this direction in two ways: firstly by focusing on the energy performance assessment component of the LEED certification for existing buildings and secondly by looking at how it applies in Austria and more generally in Europe.

1.2. Relevance and problem statement

Two of the main challenges faced with bringing measures of energy efficiency and energy conservation to the building sector are both the lack of incentives for stakeholders to outweigh the initial investment (Greg Kats, 2003) as well as the lack of applied knowledge. It is this gap, which LEED, a rating system officially set up by the United States Green Building Council (USGBC)[1] in 1998, has been committed to bridge.

The assessment of a building's energy performance is a key feature of any Green building certification. However, the measure of a building's efficiency in primary energy consumption varies from country to country and very often from region to region. This is because it is mostly dependent on local characteristics (Leipziger, 2013). The calculation of a building's efficiency in primary energy consumption is what is at issue with the application of LEED standards abroad. One of the main challenges of the LEED certification is for instance to objectively rate the energy performance of buildings highly reliant on District Heating (DH) connections. The main problematic is thus how LEED can adapt its requirements to accommodate foreign regions with different characteristics and already well-entrenched energy performance rating systems.

1.3. Objective of the study

This study will look at different strategies in order for office buildings in Austria to comply and try to perform best in the energy performance assessment component of the LEED certification for existing buildings. Energy performance assessment is covered under the Energy and Atmosphere category of LEED. This category contains many different credits[2]. This thesis will focus on one of these credits, which is the Energy and Atmosphere Credit 1 – optimize energy performance (EAC1) of the LEED for Existing Buildings: Operations & Maintenance version 3 (v3) certification (LEED EBOM). There are many versions of LEED EBOM. The latest one is LEED EBOM version 4 (v4). This thesis will focus solely on LEED EBOM version 3 which will be still in use until the 1st of June 2015 and is the version certifying the case study building. The main strategies for projects applying for the

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[1] Chapter 5.1. gives a brief description of the USGBC

[2] See annex 15.1. for a list of all Energy and Atmosphere credits

EAC1 of LEED EBOM will be explained. In the process of analyzing the different possible approaches for achieving the credit, this study will identify the relevant approaches for buildings outside of the US and determine the recommended approach to follow for existing office buildings in Austria. A case study of a building in Austria in the process of being certified will demonstrate the approach to follow in so far as its application to the Austrian context.

Understanding how Green Building Labels such as LEED assess the environmental sustainability and energy efficiency of existing buildings is crucial to improving the huge potential for savings in energy and subsequent Carbon Dioxide (CO_2) emissions in our increasingly populous building stock.

An additional objective of this thesis is to provide an understanding for stakeholders wishing to apply the energy performance assessment component of a foreign Green Building label to existing buildings in their own country. This thesis is thus part of a wider effort aimed at gaining a uniform understanding of the use of Green Building labels and energy performance assessment methods internationally; the goal of which is to troubleshoot local barriers to the application of technical methods coming from abroad. This might in some circumstances also involve adapting the technical method to a different environment.

This study will be relevant for a variety of stakeholders both in the energy efficiency and sustainable buildings fields. It will be of immediate relevance to LEED project leaders working on existing office buildings in Austria and possibly in Europe. Furthermore it will be potentially useful for any researcher, private and institutional investor, standard bearing institution and other stakeholder wishing to apply a method of energy performance assessment abroad.

1.4. Research questions and scope of the work

This thesis will be tackling a number of prescient issues.

First and foremost this thesis will explain the how and why of how energy performance assessments came to be standard. This question will be tackled by reviewing historical developments in this field as a well as comparing the emergence of energy efficiency norms in the US and Europe. The point of this question is to find out the contexts in which energy efficiency became a national objective both in the US and in Europe, thus defining to some significant extent the crafting of respective Green Building labels and energy performance assessments.

Secondly, after introducing the notion of Green Building certification and after providing an overview of different rating systems, this thesis will underline what are the fundamental concepts defining energy performance assessments. These will be further illustrated through a comparison of the US assessment with other systems of assessment in Europe.

Thirdly, after introducing LEED and LEED EBOM, this thesis will provide a detailed analysis of the energy performance assessment component of LEED. The analysis will form the basis for determining the best strategy to follow out of the available compliance paths offered under EAC1.

Lastly, based on a detailed analysis of the energy performance assessment component of LEED and of the possible compliance paths under EAC1, this thesis will try to determine specifically what are the compliance options for a building in Austria and what is the best strategy (or compliance path) in order to perform best in EAC1 of LEED EBOM. In other words, the purpose of this question is to understand the dynamics behind applying a technical method abroad: on the one hand can local barriers be troubleshot in order to be assessed as fairly as possible by the foreign assessment system?; on the other hand shall the assessment system adapt to local conditions?.

1.5. Methodology

This thesis comprises a literature review first providing a historical overview of building energy consumption measurements and later on in the thesis an understanding of the challenges of applying the energy performance component of LEED EBOM in Europe.

The thesis will provide a short comparison of LEED with some other Green Building labels in Europe in order to compare and understand the differences in their category weightings and energy performance assessment components. This comparison will be based on official information from the relevant labels as well as peer reviewed research.

A critical review, based on documentation from the USGBC, Energy Star (EStar) and the US Energy Information Administration (EIA), will also be performed. This review will cover LEED, the two most recent versions of LEED EBOM, the credit explanation of the EAC1 of LEED EBOM, the EAC1 section of the additional compliance guides for LEED EBOM with all relevant addendas, the credit interpretations, the assessment tool on which EAC1 relies on namely EStar Portfolio Manager (PM) and the Commercial Building Energy Consumption Survey (CBECS) data set from which PM has made a statistical analysis forming the basis of the LEED EBOM EAC1 assessment. Whenever available, other statistical data sets from Germany, France, the United Kingdom (UK) and Austria will be analyzed in parallel to the American CBECS. This comparison will help us determine average energy consumption figures across the different building stocks, which will have implications for the strategy chosen.

A case study of an existing office building in Austria, used as reference building, will be undertaken. This case study will provide an empirical basis for validating the chosen strategy and implementing it.

1.6. Expected results

This thesis will outline and justify the most coherent strategy to adopt for existing office buildings in Austria when applying for the EAC1 of LEED EBOMv3. A provisional score for the case study building before engineering energy saving measures have been applied will be determined. This score will be compared to hypothetical scores in Germany, France and the UK based on differences in average energy consumption figures in the respective building stocks. Prospective energy saving measures will be outlined. However, no energy gains from those measures will be determined in this thesis as they have not yet been implemented and therefore no energy performance improvements could be measured. Finally the reference building is expected to be the first building in Austria to achieve LEED platinum certification.

2. Historical development of energy performance assessments in buildings

This section will provide a literature review on the history of energy performance assessments in buildings. After firstly outlining the science involved and explaining the earliest forms of measurements, the introduction of Computer Aided Design (CAD) will be discussed. In a second part, the American and European developments since CAD will be separately reviewed and their differences highlighted. This particular part will serve to understand fundamental differences in the European and American building sectors thereby posing many challenges to the adoption of LEED in Europe. In a final part, the emergence of European regulations will be outlined before concluding by the implication of globalisation on the internationalisation of voluntary certifications.

2.1. The fundamental sciences

The study of energy performance assessments includes all methods aimed at improving peak load and annual energy use calculations for all energy end uses involved. Methods for improving heat and cooling load calculations are based on principles drawn from gas laws, heat transfer and thermodynamics (Mao, Haberl, Fibpsa, & Baltazar, 2013).

The discovery of the Ideal Gas law[3] in 1834[4] reflected a better understanding of the behavior of gases. This allowed for the thermodynamic principles of moist air to be determined and thus became important for sizing HVAC systems (Mao, Haberl, Fibpsa, & Baltazar, 2013). The 18th and 19th century saw advancements in heat

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[3] $PV=nRT$ where P is the absolute pressure of the gas, V is the volume of the gas, n is the amount of substance of gas (measured in moles), R is the ideal or universal gas constant (8.3 J/MolK), and T is the absolute temperature of the gas (measured in Kelvin).

[4] The ideal gas law was discovered in 1834 by physicist and engineer Benoît Paul Émile Clapeyron (1799 -1864). The discovery is drawn from the previous works of five scientists: Robert Boyle - Boyle's law (1662) "PV=k", Jacques Charles - Charles' law (1787) "V/T=k", John Dalton – Dalton's law (1801) "Ptotal=P1+P2…+Pn", Joseph Louis Gay-Lussac - Gay-Lussac's law (1809) "P/T=k" and Amedeo Avogadro - Avogadro's law (1811): "V/n=a"

transfer, which is the process of moving heat from one object to another. These discoveries were crucial for providing the basic theories for peak load and annual energy use calculations (Mao, Haberl, Fibpsa, & Baltazar, 2013). In 1884, Ludwig Boltzmann combined his work with that of Joseph Stephan to propose the ‘Stefan Boltzmann Law[5], which allows through the use of the Stephan-Boltzmann constant[6] to perform the radiative heat transfer calculation. Finally, the three first laws of thermodynamics[7] proposed in the 19th and early 20th century set the foundations of peak heating and cooling loads for buildings as well as annual energy use calculations (Mao, Haberl, Fibpsa, & Baltazar, 2013).

2.2. Beginnings of measurements

The science of measuring a building’s energy consumption started making sense with the introduction of heating and cooling in buildings. Later on, the large scale introduction of electric lighting enabled improvements in the measurements of lighting loads as well as in the development of technologies to record energy consumption.

2.2.1. Measurements for heating and cooling

The need to thoroughly measure energy in buildings came about with the installations of the first HVAC systems. A turning point was when Mitalas and Stephenson developed the thermal Response Factor Method in 1967 allowing for dynamic heat transfer equations to be solved by digital computer without having to solve the separate differential equations for each wall type (D.G.Stephenson, 1967). By 1972 there were only two different ways to determine peak cooling loads from the impact of thermal mass in buildings: the direct use of the sol-air temperature

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[5] $J{*}k^bT^4$ where J is the total emitted energy of a black body, k^b is the Boltzmann constant, T is the temperature in Kelvin

[6] The Boltzmann constant is $k^b = 5.670373\times10^{-8}$ W m^{-2} K^{-4}

[7] The first law of thermodynamics – conservation of energy was demonstrated in 1843 by James Prescott Joule through the equivalence of heat and mechanical work. The second law of thermodynamics introducing the term of entropy was presented by Rudolf Clausius in 1850. The third law of thermodynamics, which states that if the temperature of a system is absolute zero then the entropy is also zero, was proposed in 1906 by Walther Nernst.

equations of 1944 and the use of Equivalent Temperature Differential Tables first outlined by Steward in 1948.

These calculation breakthroughs, linked to the development of engineer institutions and their published guides came a long way from the initial “rule of thumb” methods used for sizing HVAC systems and paved the way for the establishment of standards and regulations in the building industry.

2.2.2. Measurements for lighting loads

Measurements of lighting loads came about with both acquired knowledge in daylighting practices as well as the advent of meters accompanying the introduction of electrical lighting.

The first important concept introduced in this field is the Daylight Factor (DF). This was the ratio of illumination from daylight measured at a certain point on a surface and coming from a sky of assumed luminance distribution. DF became the subject of much research. These research efforts contributed in turn to explaining the three fundamental components of the DF: the sky component[8], the external reflected component[9] and the internal reflected component[10] (Sandeep & Jeff, 2009).

Daylighting calculations became intrinsic to simulating the electricity consumption from lighting of a new construction during the day as well as influencing the illuminance of lighting at night and the insulation of the building enveloppe. Moreover such calculations can also help in retrofitting existing buildings.

2.2.3. History of metering

The perfection of building energy load calculations formed the basis for the energy consumption measurements of new constructions based solely on the building design, thus enabling appropriate sizing of HVAC systems but also appropriate

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[8] Light from a delineated sky area as perceived from the point of view of the observer

[9] These are reflections taking place beyond the receiving system (eg: clouds or obstructions)

[10] These are reflections taking place inside the receiving system (eg: building or room)

changes in daylighting designs if necessary. However, an additional component of building energy consumption still required attention. This was the consumption variations of electrical energy consumption from human behavior and later on plug loads. The measurement of human consumption through the use of meters was key to assigning a price to electricity, thereby incentivizing saving behaviors and energy efficiency gains in electrical equipments.

Only once electrical energy became widely sold, did people start paying careful attention to the cost of lighting. In the late 19th century and early 20th century many different types of meters were invented such as the electric meter, the pendulum meter and motor meters. All these systems ran with Direct Current (DC). One of the major inconveniences of DC was that bigger systems could not be erected unless voltages could be changed within the system. A solution to this problem came in 1884 when Gaulard and Gibbs invented the secondary generator (Spintelligent (Pty) Ltd, 1996). This invention was then perfected into the early 20th century and allowed Alternative Current (AC) systems to be developed. With the advent of the AC, new meters had to be invented. Shortly after the AC ampere-hour meter was patented by Bláthy in 1889. This meter displayed consumption in watt-hours and was the precursor of the induction meter (Spintelligent (Pty) Ltd, 1996).

Over the years no major technological improvements were made to the induction meter until the introduction of electronic meters and remote metering, which in coordination with computers helped optimized consumption readings.

2.3. Advent of Computer Aided Design (CAD) and its implication for Building Energy Modelling (BEM)

Since many of the calculations of a building’s energy performance were timely, the use of computers became a logical development in this field. This section will analyze the changes brought by computers to modeling energy consumption in buildings.

The benefits of CAD were essentially about gains in modeling time, integration of many different building components in order to analyze their interactions, reduction of the margin for calculation errors and increased capacity for repetition using different inputs. CAD really paved the way for both theoretical and practical applications of building physics through simulations. Initial simulations presented no coupling between the various calculations. In other words, an equation for calculating heat envelope loss would not take into account the effect that a higher loss of the building envelope might have on other components. The designer was therefore required to estimate the limits of each equation based on knowledge of sub system interactions (Clarke & Hirsch, 1986). However, by the late 60s several hourly energy simulation programs were being developed by utilities (Kusuda, 1999). In time, these began to dominate the building sector in the 70s and 80s and continue to this day. After being perfected by higher capacity processors they allowed simulation models to assume that all quantities are entirely variable and dependent on each other over space and time. In other words, no process can be dealt with independently; thus, the simulation approach.

2.4. Development of energy performance assessment in the US

The advent of CAD sped up the research and development of energy performance assessments in buildings around the world. However in terms of the private sector actors involved in its application, the programs used and the standards created, varied from the US to Europe. This section will provide a chronological overview of the main American developments.

In addition to advances in the Research & Development of energy performance assessments in buildings, some crucial policies gave incentives for such research to spill over into the private sector. The oil crises of the 70s shifted research funding from nuclear engineering and aerospace to energy efficiency (Kusuda, 1999). The past decade has seen more stringent building standards and a growth in voluntary certification programs. Indeed in 1998 the USGBC created LEED, the first comprehensive rating system for Green Buildings in the US. LEED emerged as a certification for buildings in the late 90's as a response to the building industry's need for clear definitions and measurements of 'green buildings' (BEMBOOK, 2013). However it was not until the introduction of Standard 90.1 Appendix G – Performance Rating method from the American Society of Heating and Refrigerating and Air-conditioning Engineers (ASHRAE) in 2004 that a turning point in the building industry was reached. ASHRAE provided a rating method for non residential structures already exceeding ASHRAE Standard 90.1 Code that required the use of simulation (BEMBOOK, 2013). In other words building performance was no longer only being evaluated in accordance with a standard but also in comparison to other similar buildings. LEED incorporated the Appendix G in its later versions for new buildings in the Energy and Atmosphere Credit 1 (EAC1), which became one of the most important credits for any LEED certification. In 2005 the US Energy Policy Act included ASHRAE standard 90.1 as a benchmark for achieving tax credits[11].

The initial boost for the development of energy performance assessments in buildings in the US came from a shift in public funding from space and nuclear energy to energy efficiency. The development of BEM thereafter was very much driven by competition in the private sector. Many companies competed against each other to provide the best BEM programs. In turn, competition improved standards, engineering practices, technologies and energy policies.

2.5. Evolution of US building codes

Countries usually adopt a single national building code. However, the US building code is based on what is decided by the regional and/or local authority. In the past,

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[11] Information can be found at: http://www.lightingtaxdeduction.org/standard.html

there were up to 5000 different building codes. Over the past 75 years, three models became the basis for all local codes: the Uniform Building Code (UBC), the Standard Building Code (SBC) and the National Building Code (NBC).

Although there are many codes for structural prerequisites to sustain different winds, climates, and earthquakes, there are few energy building codes. The first reference to an energy code was made in 1979 by Chapter 52, Appendix A of the 1979 UBC (ASHRAE, 2009). The UBC of 1991 has provisions for operation and maintenance in existing buildings (ICBO, 1991). The SBC of 2007 has energy and conservation provisions and includes among others inspections of envelope insulation, r values, HVAC and water equipments (Building Code Standard Committee, 2004). Recently the UBC, SBC and NBC merged to form the International Code Council which paved the way for the International Energy Conservation Code which currently provides minimum design and construction requirements for energy efficiency in many States.

2.6. Development of the main building energy performance assessments in Europe

This part will delve into the recent history of energy performance assessments in Europe. The evolution of regulations and the techniques used in the UK, France, Germany and Austria will serve to illustrate the European achievements. Unlike literature on the US developments in this field, there is no literature summing up the European historical developments of energy performance assessments. Therefore this part will highlight, in each of the countries, selected codes dedicated to providing energy standards. This part will conclude with the recent evolution of regulations at the European level.

2.6.1. Main building energy standards in the UK

Right about the time when the ASHRAE adopted the NBS state guidelines for building energy consumption, the Charted Institution of Building Services Engineers in the UK adopted energy efficiency requirements in the form of energy targets in 1976. These energy targets were adopted for both new constructions and existing buildings. Although these energy targets were criticized for being speculative, it was already understood that future targets would be drawn from surveys of energy consumption in existing buildings (Hui, 1996). The next important legislation to be passed was in 2005 following the Energy Performance of Building Directive (EPBD), introducing the first performance based code. Since then, the code was updated in 2010 and requires for new constructions: a mandated reference building simulation, air tightness requirements, thermal bridging requirements, renewable energy requirements as well as pre occupancy commissioning.

The enforcement status is mandatory and undertaken locally through post occupancy control as well as the accreditation of applicants. There are no penalties for none compliance (GBPN, 2013).

2.6.2. Main building energy standards in France

Prescriptive building energy efficiency requirements go back to 1955. From the onset France focused its energy standards on the whole building rather than focusing in on specific parts. In 1974 it introduced thermal standards for residential buildings. In 1976 it introduced another set for non residential buildings. The updated legislation of 1988 sets mandatory thermal insulation and air conditioning standards in non residential buildings according to different climatic zones (Hui, 1996). In 2005 France got in line with the EPBD. The Régulation Thermique was amended in 2012 with the aim of making the already compliant buildings 40 % more efficient.

The enforcement of French standards is mandatory. Enforcement is done locally, by a third party inspection and accreditation of the applicant is necessary. Penalties for non compliance include a fine and the refusal of permit to occupy (GBPN, 2013).

2.6.3. Main building energy standards in Germany

In Germany thermal standards and design guidelines have been around long before the 70's. The 1976 Energieeinsparungsgesetz (Energy Saving Act) laid the foundation for the 1977 Wärmeschutzverordnung (Thermal Insulation Ordinance) and the 1978 Heizungsanlagen – Verordnung (Heating Appliances Ordinance). Part of what these standards introduced along with some other air conditioning requirements were specified standards for energy and load calculations. The most recent standard is the Energieeinsparverordnung (Energy Saving Ordinance) of 2009 (Hui, 1996).

The enforcement of German standards is mandatory but only requires the accreditation of the applicant for compliance. Non compliance however is punishable by the construction permit refusal and the refusal of the occupation permit (GBPN, 2013).

2.6.4. Main building energy standards in Austria

The Austrian standards had prescriptive requirements since the 70's. However these requirements were not set at the national level but at the regional level instead among each of the 9 Bundesländer (regions). The 2006 code introduced the first nationwide standard and its 2011 amendment in the form of the Richtlinie 6 includes air tightness testing, thermal bridging considerations, Energy Performance Contracting and incentive schemes such as an energy performance certificate. The clauses for energy performance, however, are voluntary and present low requirements (GBPN, 2013).

The standards are mandatory. Their enforcement is done at the local and central level, by a third party and requires accreditation of the applicant. Failure to meet these conditions results the refusals of both the construction and occupancy permits (GBPN, 2013).

2.6.5. The evolution of European regulations

Post war Europe emerged in a context of economic and resource scarcity. The focus of European policy at that time was supply side economics. It is out of this context that the European Coal and Steel Treaty came into force in 1954. The aim of this treaty was twofold; firstly to increase the production of steel and coal and secondly to encourage trade within a common market which became reality in 1958 with the Rome Treaty. In 1973 after the first oil crisis and after the first European Community (EC) enlargement, Denmark put the issue of demand management of energy on the table and Ireland advocated against nuclear energy at a time when major investments in that area were being made (David, 2007).

Although in terms of core energy policies, these voices were not being heard, some small minute developments in energy labeling were taking place. By the end of the 90's it was clear that Europe was paving the way in terms of energy efficiency requirements in consumer good products. EU legislation in this field had two consequences: it set the foundations for the reduction of plug loads in buildings and created a precedent for the wider use of labels and other peer review as well as benchmarking practices.

Nevertheless, EU legislation in core energy policies was slower to make an impact. In 1987 a proposal for a directive on an EC system for energy audits in buildings was made. However, it was rejected by the Council of Ministers. The Council of Ministers was primarily voicing the interests of Member States. Moreover, energy was considered at that time to be an exclusive sovereign issue. Nevertheless, the Single European Act of 1987 made environmental policy increasingly the business of the EC. It stipulated that decisions of environmental policy no longer required unanimity from the Council of Ministers for adoption such as is required for energy policy but a qualified majority sufficed. This allowed the European Commission to rescue the 1987 directive by embodying it in an environmental policy package, which became known as Specific Actions for Vigorous Energy Efficiency (SAVE). The SAVE Directive was watered down through negotiation between the Parliament and the Council. However, in 1989 it introduced the notions of: energy certification of buildings, third party financing of energy savings in the public sector, thermal insulation in buildings, boiler inspections and energy audits for industries among other issues (David, 2007). Eventually as the EU was itself known internationally as the leader in global warming politics, many of the issues noted in SAVE were redrafted to be given more legislative power. A proposal by the European Commission followed and became the Energy Performance Building Directive (EPBD) 2002/91/EC in 2002 (David, 2007).

2.7. The Implications of globalisation

Although the process of evaluating a building's performance was arguably defined in the US in the 60s and 70s (BRSIA), many developments also took place in Europe during that time. However in contrast to the US where the private sector played a larger part, in Europe developments in this field were largely left to public institutions. Consequently, instead of seeing developments in different fields converge towards one comprehensive form of evaluation as had been the case in the US, in Europe each field of expertise further specialized in their own direction.

Meanwhile, in addition to cooperation in research that had been ongoing since the 19th century, international organizations and standards in building performance evaluations were starting to emerge. First the International Energy Agency adopted in 1977 its first annex[12] aimed at stimulating research and providing useful information for decision making in the field of building energy efficiency. This was

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[12] Energy Conservation in Buildings and Community Systems (ECBCS)

followed by 35 annexes. In 1987 the International Building Performance Simulation Association was founded to promote the science and application of building performance simulation[13]. In addition to these, a few European initiatives picked up around that time.

Although these developments were limited to research and standards and left national markets relatively protected, the signing of the GATT in 1995 marked the end of protectionism and opened the markets to competition. The voluntary code on technical barriers to trade (TBT) was strengthened and binding to all WTO members. Nevertheless, it remained difficult for an importing country to evaluate the quality of an exported product (IRCC, 2010). Therefore a performance based approach became welcomed by the markets.

Only recently with the introduction of the EPBD in the EU and the emergence of the USGBC as an international player in the building certification industry, has the urge in Europe to develop and adopt more comprehensive methods of building performance evaluation been felt. Labeling a whole building as opposed to its constituent parts is an approach that allows all aspects of a building's environmental footprint to be taking into account. This is precisely the purpose of a Green Building rating system.

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[13] http://www.ibpsa.org/downloads/IBPSA-Regionalization-Guide.pdf

3. Green Building Rating systems

This section outlines the basic trends in the Green Building Industry before looking at the incentives for adopting a Green standard.

3.1. Recent developments of the Green Building Industry

Although ‘Green Building’ research has been ongoing for a while, the use of the term in the building industry required a number of major developments in the 90’s, culminating with the Energy Policy Act of 2005 in the US and the EPBD of 2002 in the EU. Since then, the Green Building Industry has been growing at a rapid pace. Supported by new technologies, renewable energy and energy efficiency policies, the projected annual growth rates for Green Buildings as of 2007 was, depending on the sector, between 20% and 65% (McGraw-Hill Construction Research and Analytics, 2007). In addition to this, governmental entities have enforced the adoption of Green Standards in governmental building (Prum & Kobayashi, 2014). The assumption is that more stringent standards are projected to reach the private sector. Crucially, there has been a shift from greening new buildings to greening existing buildings (Dirksen & McGowan, 2008).

Why apply for a Green Building certification?

Even though the topic ‘Green Buildings’ no longer goes unnoticed, there is a reluctance from investors to adopt processes which are environmentally sustainable and resource efficient over the life time of a building. This is partly due to a misunderstanding of the benefits that come with sustainable development. The advantages of building green are typically of three types: social, economical and environmental[14].

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[14] Source: http://www.tosca-life.info/sustainability/definitions

The social rationale consists of improving one’s image (a company may choose to do so and become a model for others) as well as enhancing the occupant’s comfort among others.

The economic reasoning is firstly to meet the increasing demand for Green Buildings. Secondly, it is to increase the value of the building by increasing the return on investment through an extension of the building’s life cycle and an increase in worker’s productivity (Greg Kats, 2003). These effects subsequently increase the price of rents. Lastly, the new building is a new product, which will therefore attract new demand.

The environmental advantages relate to reducing the consumption of natural resources, the emissions of carbon, the amount of solid waste and also to the improvement of the quality of drinking water.

3.2. Comparison of different Green Building Rating Systems

Green Building certification has certainly allowed for national Green industries to market themselves and extend their reach in any given country they have been based. However, it is progressively becoming an international business battleground for the different manufacturers of Green Building related technologies. This is because the certification represents the marketing arm of the Green Building industry [15] and as LEED becomes popular abroad, it competes with other certifications and thus other manufacturers. This section will provide a brief comparison of LEED with other certification systems in Europe.

The LEED credits represent different topics of sustainability which LEED covers and rates through its system. However, the topics dealt with and their weighting as to the

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[15] http://www.usatoday.com/story/news/nation/2012/12/10/green-schools-construction-leed/1753823/

overall score (which is a measure of sustainability) are subject to change depending on the rating system applied (Liu, Nolte, Patapova, Michel, & Rückert, 2010).

The systems that are popular internationally are the Building Research Establishment Environmental Assessment Methodology (BREEAM) and LEED. All other systems are mainly working nationally. Some of these systems might have just started to operate internationally. Systems, other than LEED from the US and BREEAM from the UK, operating in European countries include Haute Qualité Environnementale (HQE) from France and the German Deutsches Gütesiegel nachhaltiges Bauen (DGNB) among others (Liu, Nolte, Patapova, Michel, & Rückert, 2010). The level of certification is more or less similar for all systems and can be observed in table 1.

Table 1: Labels and their levels of certification (LEED, BREEAM, DGNB, HQE)

Certification	LEED	BREEAM	DGNB	HQE
Best possible performance	100 points (+10 points for innovations)	100% (+10% for innovations)	100%	Achieve a 'very high performance' level in all 14 categories
Certification levels	Platinum: 80 points or more	Outstanding	Gold : 80% or more	Minimum requirement: 'Very high Performance' level in 3 categories, 'high performance' level in 4 categories, 'minimum performance' level for all other categories
	Gold: 60-79 points	Excellent	Silver: 65% to 79,9%	
	Silver: 50-59 points	Very Good	Bronze: 50% to 64,9%	
	Certified: 40-49 points	Good		
		Pass		

Source: Sawyer 2013

Each Green Building label has rating systems that apply to different building typologies and functions (Liu, Nolte, Patapova, Michel, & Rückert, 2010) whether they be new constructions for schools, hospitality, data centers or existing buildings, residential and commercial. LEED and BREEAM have developed many versions applicable to different building types and functions. In addition to slight differences in the level of certification awarded as well as with the types and functions of buildings rated by each certification, the biggest difference lies in the scope of topics (or credits) covered by each certification and the weighting given to each topic (or credit) overall. Table 2 shows the categories dealt with by each certification and the weighting awarded.

Table 2: Certification categories and weightings

LEED		BREEAM		DGNB		HQE	
Categories	**Weighting**	**Categories**	**Weighting**	**Categories**	**Weighting**	**Categories**	**Weighting**
Sustainable Sites	23,60%	Land Use & Ecology	9%	Environmental Quality	22,50%	Immediate environmental surroundings	20,35%
Water Efficiency	9,10%	Water	5,45%	Economical Quality	22,50%	Materials	13,08%
Energy and Atmosphere	31,90%	Energy	17,27%	Socio Cultural and Functional Quality	22,50%	Building Sites	5,81%
Materials & Resources	12,70%	Materials	11,36%	Technical Quality	22,50%	Energy Management	7,85%
Indoor Environmental Quality	13,60%	Health & Wellbeing	13,64%	Process Quality	10%	Water Management	8,14%
Innovation in Design	5,50%	Transport	7,27%	Site Quality	Rated Seperately	Waste Management	2,91%
Regional Priority	3,60%	Waste	6,82%			Operation and Maintenance	6,10%
		Pollution	9%			Thermal comfort	5,23%
		Management	10,91%			Accoustic Comfort	2,91%
		Innovation	9,00%			Visual Comfort	8,14%
						Olfactory Comfort	2,91%
						Air Quality	4,65%
						Sanitary Indoor Quality	8,72%
						Water Qual.	3,12%

Source: Sawyer 2013

Table 2 shows that the priorities for each certification are different. Germany for instance already has rules for minimum energy efficiency requirements in its legislation. Therefore DGNB does not have to focus on Energy. France’s HQE lends very little importance to energy. This might be due to a strong production of nuclear energy. Energy is however the main priority for both LEED and BREEAM. In addition to credit weighting, each certification has credit prerequisites, which are requirements necessary to get certified. Failing to meet just one of these requirements, prevents certification.

Although there are some differences between the various systems, the general structures are very similar. In fact BREEAM, which is 23 year old, is said to have influenced the early developments of LEED (Sleeuw, 2011)

4. The energy performance assessment component of Green Building rating systems

A crucial component of Green Building certifications is assessing the energy performance of a building. This thesis will emphasize the basic characteristics of the LEED rating system as a method for assessing energy performance. One reason for focusing on energy performance assessment is that this aspect carries the most points in the LEED certification. In other words performing well in the credit relating to energy performance assessment brings the project one step closer to the aimed certification level. Moreover it is also an indication of good performance in some other Energy and Atmosphere credits such as for instance the Energy and Atmosphere prerequisite 2: minimum energy performance (EAp2). A further more fundamental reason why this thesis is focusing on energy performance assessments is because of the significant potential for nearly zero cost energy savings from control system settings in existing buildings. Modifying control system settings to save on energy requires knowledge of the peak loads as well as annual energy use. These have in the US for the recent past been calculated based on hour by hour building simulations. However, in Europe many of the existing buildings have had their HVAC systems sized based mainly on peak load calculations. However, as this is gradually changing, this thesis will after first briefly comparing building energy use around the world, provide an overview of approaches from other rating systems in Europe for assessing energy performance in existing buildings. This comparison will firstly highlight some specific characteristics of the LEED energy performance assessment tool and secondly help understand potential alternative compliance paths for achieving the best energy performance under LEED.

4.1. Fundamentals for evaluating energy performance

Any assessment is inevitably making a comparison and thus either rewarding or penalizing a performance. An Energy performance assessment system must therefore have both a clear indicator of building energy efficiency and a reference in order to justify any of its assessments. Challenges may arise when a building is being assessed by a rating system which bases its assessment on relative rather than absolute indicators of building energy efficiency. Therefore not only should the purpose and objectives of a rating system be examined when trying to comprehend a rating system but one should also pay careful attention to the mechanisms or assessment methods used by the rating system to meet its own objectives and abide by its purpose. This sub-section firstly comprises a brief overview of some building energy efficiency indicators before delving into indicators of relative building energy efficiency and a short analysis of the datasets that are used as reference for the assessment.

4.1.1. Indicators of Building energy efficiency

Although it is of common knowledge that world energy demand and more specifically energy consumption in the building sector is ever increasing, what is less clear however is whether the energy efficiency of buildings is improving. There is subsequently the need to use efficiency metrics to attempt correct measurements. A traditional measure of energy performance is for instance the energy consumption per unit of economic activity (Hinge, Bertoldi, & Waide, 2004). However since the type of building does not determine the economic output and since most studies ignore or simply do not know the deadweight loss arising from the long term environmental degradation of an economic output as well as perhaps misinterpreting social priorities in the process, energy consumption per unit of economic activity does not tell you much about the energy efficiency of a building relative to its unexploited energy saving potential. Another more popular indicator is the energy use per unit of area, also known as Energy Use Intensity (EUI) (Hinge, Bertoldi, & Waide, 2004). Unfortunately this indicator still fails to take major performance factors into account such as weather, occupancy, assigned comfort and indoor air qualities among others. These factors can distort the energy performance of a building. Normalized EUI is the indicator which energy performance assessment systems typically aim for. The EUI is usually expressed as either Kilowatt hour/square meter/year (kWh/m2/y) or 1000 British Thermal Units/square feet/year (kBTU/f2/y) (Hinge, Bertoldi, & Waide, 2004).

4.1.2. Standards used for evaluating performance

Building energy efficiency indicators are central to energy performance assessments but do not by themselves reflect their purpose and objectives. Depending on the purpose of the energy performance assessment, the standards used for evaluating energy performance are likely to be different. Although evaluation standards are numerous, there are only two comparability metrics (Leipziger, 2013). The first one is comparing the building's energy performance to a single unique value. This is known as an absolute standard. The second comparability metric consists in comparing the energy performance of the assessed building to other performers. This is known as a relative standard.

The choice of standard is dependent on the purpose and objectives of the energy performance assessment system. The purposes and objectives will themselves depend on the type of actor in charge of setting up the standards. Typical purposes may include environmental protection in the case of States wishing to reduce their stocks of CO_2. In this case special attention will be spent on trying to avoid any hindrance to national economic development. Pursuant to their purpose, States set objectives such as meeting a policy, regulation or standard for which absolute standards are more applicable. This is because absolute standards usually reflect the intention of a given policy (Leipziger, 2013). As an example of this, the energy performance assessment rating of Denmark is fixed to the energy consumption rates of a building, designed to the standards established by the Danish Building Regulation (Leipziger, 2013). The rating systems of Germany and France also use absolute standards for existing buildings whereas the rating systems of the UK and of the US use relative standards.

In the case of a private actor, however, purposes will basically include increasing long term profits and short term turnover when possible. This is the case of the USGBC, who in view of its purposes have set the objectives of providing standards enabling voluntary applicants to try and achieve the best environmental performance and concomitantly the best energy performance relative to others. This approach inevitably requires the use of relative standards. There are two ways of developing relative standards. One way is to make a statistical average from a building energy use dataset. Another way is to simulate, through calculation, how a reference building would perform under minimum standard requirements and for average performance (Leipziger, 2013).

4.1.3. Building energy use surveys

Having a relative standard to which a given building must abide by, provides a useful overview of the overall energy usage of this given building and where it might unlock saving potentials. Nevertheless since the simulated and real building energy consumption might differ, building energy use datasets are key to providing a breadth and depth of data that may be used for benchmarking purposes. Such datasets are very few worldwide as the process of data gathering is somewhat resource intensive, timely and faces many challenges such as non responses[16]. Examples of such datasets include the CBECS from the US, Technical Memoranda 46: Energy Benchmarks (TM46) from the UK (Leipziger, 2013) and a survey undertaken by the centre for economic studies and research on energy (CEREN)

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[16] A non response is an in scope sample building, eligible for interview, for which no information is obtained.

financed by the French Energy Agency (ADEME) from France (Hinge, Bertoldi, & Waide, 2004). Each of these datasets may help draw up relative standards to which buildings can then be benchmarked. For example, figures from Energy Star (EStar), a US energy efficiency program and label, and CBECS show that whilst an average EStar existing office building achieves an EUI of 194 kWh/m2 per year (Hinge, Bertoldi, & Waide, 2004), an average CBECS building achieves an EUI of 293 kWh/m2 per year. Therefore a building built to an EStar standard performs much better than an average office building in the US.

4.2. Comparison of different national energy performance assessment tools

A comparison of energy performance assessment tools, respectively used in the UK, France, Germany and the US highlights a number of characterizing criteria, which are outlined in table 3.

Table 3: Classification of energy performance assessment tools by country

Country			USA	UK	FRANCE	GERMANY
Program			Estar	EPC	DPE	Energieaus-weis
Tool/method			Portfolio Manager	SBEM	3CL, Comfie or DEL6	Various
Building Type	Public		✓		✓	✓
	Non Residential		✓	✓	✓	✓
	Residential Single Family				✓	✓
	Residential Multifamily		✓		✓	✓
Assessment Type	Calculated			✓	✓	✓
	Measured		✓		✓	✓
Energy Type	Total		✓	✓	✓	✓
	Delivered		✓			✓
	Final				✓	
Floor Area	Gross		✓	✓		
	Rentable					
	Conditioned		✓	✓	✓	✓
	Unconditioned		✓	✓	✓	✓
Energy Uses	Lighting		✓	✓	✓	✓
	Mechnalical Ventilation		✓	✓	✓	✓
	Domestic Hot Water		✓	✓	✓	✓
	Heating		✓	✓	✓	✓
	Cooling		✓	✓	✓	✓
	Plug/Process Loads		✓		✓	✓
Baseline	Absolute Standard				✓	✓
	Relative Standard	Statistical	✓			
		Simulated to Average		✓		
		Simulated to Code		✓		

Source: Leipziger, 2013

These criteria include among others the building types to which the tools apply, the types of measurement adopted in order to quantify energy consumption, the definitions for determining what measured energy use is, the measurement type for the floor area to which the energy assessment extends, the type of end-uses the assessment comprises and the standard of comparison used in order to determine the score (Leipziger, 2013). Each of these elements will be clarified in this section.

Quantifying energy consumption to a reasonable degree of estimation is possible for all types of buildings. In fact it should be feasible for anything that can be defined as a single system. However, trying to assess the energy performance is a different exercise that in many ways presents many subjective aspects. As a simple illustration of this, a newer building with better insulation, lighting, plug in and HVAC systems might perform more poorly than an older less well designed building if the buildings are not normalized for their occupancy patterns. Moreover the normalizations of these patterns are themselves subject to interpretation. Therefore the assessment design is crucial for limiting the biases in terms of energy performance.

4.2.1 Differences in building type definitions

One of the most important characteristics in any assessment is the building type. In all countries compared in this section, their most popular national energy performance assessment tools include distinctions between building types. The primary distinction is between 'new' and 'existing' buildings. It is typically the first characteristic used to define a building type. The reason for this is because unlike an existing building, a new building usually does not have the option of relying on utility bills for energy performance assessment (Leipziger, 2013) either because the building is still under construction or because the consumption duration is way too short to allow for any useful assessment. Definitions of what constitutes 'new' and 'existing' buildings are rooted in law. These definitions vary from country to country but buildings remain generally 'new' for one to two years after construction before then becoming an 'existing' building. In Australia for example the law explicitly states that an 'existing' building must have been occupied for at least two years (Leipziger, 2013). The purpose for this distinction is to allow 'new buildings' to be subjected to newer requirements as with for instance most energy efficiency policy prerogatives in Europe. Once these energy performance requirements are met, a building will be granted an efficiency label which is valid for a certain amount of time before needing to be renewed (Leipziger, 2013). The validity period of the efficiency label and thus the period before renewal also vary depending on the country. Moreover it will also be decisive in determining whether a building should be subject to the ‘new’ or ‘existing’ building assessment system. The validity period of the efficiency label de facto determines whether a building is considered as ‘new’ or ‘existing’ with regards to its energy performance assessment when being labeled. In the US for instance, EStar requires a new building to renew its label after one year. LEED EBOM however only require a ‘new building’ to be recertified within 5 years.

As the building function clearly determines energy consumption patterns, a performance assessment must first distinguish between three main groups: public, residential and non residential buildings. As an illustration of this a typical warehouse with no cooling or heating will require much less energy than a residential building. Therefore a performance comparison between the two buildings’ absolute energy consumption values would conclude that warehouses are performing better than residences. However since residences cannot be substituted for warehouses the assessment compares them respectively among their building type groups. Public buildings tend to be subject to more stringent requirements than other building types. Although these requirements vary on a country by country basis, the recent EPBD law tries to set uniform standards for energy performance in public buildings. However, as the directive does not define what is meant by ‘public’, it allows a lot of room for member states to interpret the directive when transposing it into national law. Subsequently each country has its own definition for what constitutes a ‘public building’. For example, whilst in China ‘public buildings’ include all non residential buildings, in France they only include buildings occupied by a government body (Leipziger, 2013). A distinction between building types is thus essential to any performance assessment. However, as this section illustrate, each performance assessment tool has its own unique way of making this distinction.

4.2.2. Differences in energy consumption quantification

Another characteristic of energy performance assessments has to do with how the total energy consumption of the building is measured. There are two ways of quantifying this value: calculation and measurement (Leipziger, 2013).

The calculated method will vary between rating systems but will usually apply to new constructions although it might also sometimes apply to existing buildings. It will vary in accordance with the technique used for modeling the building's energy consumption. These techniques are often rooted in two different energy calculation philosophies: dynamic versus normative (Kim, Augenbroe, & Suh, 2013). This distinction is akin to said calculation methods using either standardized or customized set of building energy use characteristics (Leipziger, 2013). An example of energy use characteristic would be for instance heating or lighting. An equation might thereby help simulate energy consumption from heating. Dynamic modeling required by LEED New Construction, adapted from the ASHRAE 90.1 calculation, first requires the use of software that can perform BEM[17]. BEM basically models energy consumption using algorithms[18] which simulate energy consumption. Such algorithms vary in complexity depending on a multiplicity of factors such as the energy use characteristic being measured, the definitions of energy consumption and the energy fuels being used among other factors. The simulated energy consumption from the designed building is then compared to a reference building called a baseline. This baseline is created using the data from the designed building but with the assumptions of the appendix G from the ASHRAE 90.1 standard (Kim, Augenbroe, & Suh, 2013). This method shared by most other rating systems, will deliver results that vary in accordance with the accredited simulation tool (or software) used for the energy evaluation. Other rating systems might also decide to

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[17] The history of BEM is described in the first part of this thesis

[18] The basic science underpinning the algorithms of BEM are described in the first part of this thesis

use normative calculations. The International Organization for Standardization (ISO) is for instance using this approach. The ISO-CEN (European Committee for Standardizazion) standard 13970 does not require modeling and therefore there is no room for a modeler's bias. This method first consists in defining an Energy performance coefficient (EPC), which is found by dividing the calculated energy use of the proposed design by an industry wide reference value for energy use per building type and location (Kim, Augenbroe, & Suh, 2013). Once the EPC has been determined, then a set of monthly energy use calculations defined by the standard assuming different usage scenarios and different estimates of HVAC system efficiencies based on the HVAC design allow calculation of the energy consumption (Kim, Augenbroe, & Suh, 2013).

Measurement is the other method for quantifying the energy consumption of a building. This is done by recording the energy consumption with meters. The data can then be obtained either directly from privately owned meters or indirectly from utility owned meters through actual utility bills. In this method, the data must then be normalized for use characteristics (Leipziger, 2013). In other words, a use such as heating might be influenced by factors which tend to consistently characterize it. Such factors include among others weather, number of workers and operating hours (ENERGY STAR, 2013$_1$). To illustrate this, a building located in a geographical area with more Heating Degree Days (HDD)[19] will usually require more heating than a similar building with the same other use characteristics. Therefore energy consumption quantification for the purpose of measuring energy performance will require this specific use characteristic (ie: heating loads) to be formulated as a normalized function of HDD in order to provide a fair performance benchmark (Hinge, Bertoldi, & Waide, 2004). It is of course these normalizations which vary

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[19] Heating Degree Days are a measure to help decide the heating and cooling requirements for a building. To calculate the heating degree days for a particular day, find the day's average temperature by adding the day's high and low temperatures and dividing by two. If the number is above 65, there are no heating degree days that day. If the number is less than 65, subtract it from 65 to find the number of heating degree days.

between rating systems. For instance, average Heating Degree Days are higher in Austria than in France. The weather normalization is therefore likely to differ in each country's rating system. Moreover, the types of use characteristics being normalized may also vary. In Germany's Energieausweis only weather is normalized and the only use it normalizes is heating. In contrast EStar normalizes all energy uses (Leipziger, 2013).

As a whole there are often mismatches between calculated energy consumption of buildings, which construction are based on their respective thermal energy codes and measured energy consumption (Hinge, Bertoldi, & Waide, 2004). As a result the measurement method is often prioritized by systems that rate existing buildings.

4.2.3. Differences in energy consumption definitions

A central characteristic of any energy performance assessment will be the definition the rating system attributes to consumption. In other words at which points in the energy supply chain is energy consumption measured? There are in theory three different ways of accounting for energy consumption in buildings namely final, delivered and total energy consumption.

Final energy consumption is a measure of the actual consumption from a building's end uses (Leipziger, 2013). Final energy consumption differs from another way of accounting for energy consumption that is called site energy consumption. Site energy consumption also known as delivered energy consumption measures energy consumption from the building's system boundary thus taking into account losses within the building's own delivery system. This method however, ignores the loss of energy that occurs before the energy reaches the building's system boundary. These losses are due to the lack of efficiency in the systems generating and supplying the energy to the building (ENERGY STAR, 2013_1). The losses therefore occur at the energy production stage or at the transmission stage. Losses in the production stage are due to for instance the energy consumed for producing electricity. Losses in the transmission stage are due to a number of reasons such as for instance a poor part load performance of the system, a high parasitic energy consumption or thermal losses in energy conversion processes among other reasons (USGBC, 2012). The third way of accounting for a building’s energy consumption is to sum up all of the possible losses in the production or delivery of energy to a given building and add to this the overall building’s delivered energy consumption. This amounts to the building’s source energy consumption also known as total energy consumption (Leipziger, 2013). The source-site energy conversion ratio is the key unit for measuring the difference between site and source energy. According to Seppänen, 2.5 is a common ratio used throughout EU member states for electricity source-site conversion ratio (Seppänen, 2013). In the US, this ratio stands presently at 3.14. The simulated impact of the source-site energy conversion ratios of France, Austria, Germany, the UK and the US on the average site EUI of the buildings stocks in those countries and the subsequent implication it has on the strategy chosen will be looked at in the results‘ section.

The definition chosen to quantify energy consumption in a building reflects the objective of a rating system. If the rating system is measuring site energy then the performance burden lies solely on the individual buildings. If is adopting source energy as a definition of energy consumption then the whole energy supply chain has an impact on the building’s performance. Moreover, any improvements in energy efficiency taking place from the building’s system boundary and moving upwards in the supply chain is likely to involve government led guidelines, standards or regulations. Most rating systems and indeed all four rating systems analyzed in this thesis use source energy consumption, sometimes in addition to site or final energy consumption (Leipziger, 2013).

4.2.4. Differences in floor area measurements

Once the definition of quantified energy consumption is decided, a definition of the space to which the defined and quantified energy applies must be determined. Of course the definition of the space changes the relative value of the EUI of a building which uses a specific rating system when compared with the same building using a different rating system with a different definition of floor area.

The typical floor areas considered in a building rating system are composed of conditioned and unconditioned spaces. Conditioned space is subject to mechanical heating and/or cooling, unconditioned is not (Leipziger, 2013). Apart from a few exceptions such as the French rating system Diagnostic de Performance Energétique (DPE) which only considers conditioned space for energy performance in residential buildings , most and all of the rating systems analyzed in this thesis use conditioned and unconditioned space to assess the energy performance of existing buildings (Leipziger, 2013). Therefore most rating systems will define floor area as the gross floor area which includes all the area contained within a building up to the outside face of its external walls (Leipziger, 2013). Nevertheless, some rating systems such as the German Energieausweis use the net floor area or a variation of it. The net floor area is the gross floor area minus the walls. Energieausweis defines floor area as all area mechanically cooled or heated minus the interior and exterior walls (Leipziger, 2013). Another type of floor area definition is rentable floor area which is the space in a building used for generating revenue by a service or a business. This type of floor area is rarely used by rating systems.

Accommodating industrial or sectoral practices is one of the major factors in determining which floor area definitions are chosen by any given rating systems. Therefore, among rating systems, floor area definitions tend to align with the building type to which the rating system applies.

4.2.5. Differences in type of end-uses assessed

The types of end-uses being assessed will have a substantial influence on the overall energy performance of a building. Typically end-uses include cooling, heating, domestic heating water, lighting, mechanical ventilation, plug loads and process loads (Leipziger, 2013). Process loads include energy uses which are not essential to a building‘s function such as elevators, appliances and industrial equipment whereas plug loads refer to equipment which is powered through AC outlets[20]. Therefore end-uses can practically be divided between those that are necessary for building operations and those that are dependent on occupant behavior (Leipziger, 2013). Whilst ratings that quantify energy consumption by measurement usually include all energy uses, ratings using calculation might exclude occupant behavior dependent end uses such as lighting and plug loads. Among the rating systems analyzed in this thesis, the US EStar rating, the French DPE and the German Energieausweis include all energy end-uses. However, the UK Energy Performance Certificate, which uses a calculation method for quantifying energy consumption in buildings, does not include plug nor process loads in its end-uses (Leipziger, 2013).

As building codes differ among countries and are reflective of their socio-economic development, building energy performance will also inevitably differ. In order to adapt to differences in performances among countries, energy performance assessment systems native to one country but wishing to compete in the private market internationally might therefore have to adopt alternative relative standards to certify buildings native to another country.

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[20] According to the US Department of Energy, ASHRAE and the Center for the Built Environment at UC-Berkeley.

5. The LEED certification and its global reach

This section provides a short overview of LEED before underlining how at present LEED has become porminent on the global stage.

5.1. Basic overview of LEED

LEED stands for Leadership in Energy and Environmental and was set up in 1998 by a committee established by the United States Green Building Council (USGBC). The committee reflected the diversity of members of the USGBC. To date, there are 12800 member organisations and 193000 LEED professionals[21]. Although LEED is not a norm but a voluntary compliance standard, it has become through intensive marketing reflective of the interest of its members. Members express their intrests through, for instance, public comment periods before the adoption of a new version of LEED certification and by voting for the adoption of any new versions (Renewable Choice Energy). LEED is therefore a movement in the sociological sense of the word. One central reason for focussing on LEED is that it is a method which is open, voluntary and uses mechanisms of compliance such as benchmarking and rewarding which allow for public peer reviewing.

The LEED certification comprises multiple versions, each addressing specific building typology, sectors and project scope in its own unique rating system[22].

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[21] http://www.usgbc.org/about

[22] This information can be found at http://www.usgbc.org/

Table 4: LEED rating systems

Rating systems	Description	Building typology or project scope
Building Design and Construction	Applies to buildings that are being newly construction or going through a major renovation	• New Construction • Core & Shell • Schools • Retail • Hospitality • Data Centers • Warehouses & Distribution Centers • Healthcare
Interior Design and Construction	Applies to projects that are a complete interior fit-out	• Commercial Interiors • Retail • Hospitality
Building Operations and Maintenance	Applies to existing buildings that are undergoing improvement work or little to no construction	• Existing Buildings • Schools • Retail • Hospitality • Data Centers • Warehouses & Distribution Centers
Neighborhood Development	Applies to new land development projects or redevelopment projects containing residential uses, nonresidential uses, or a mix. Projects can be at any stage of the development process, from conceptual planning to construction	• Plan • Built Project
Homes	Applies to single family homes, low-rise multi-family (one to three stories), or mid-rise multi-family (four to six stories)	• Homes and Multifamily Lowrise • Multifamily Midrise

Source: USGBC website

The goal of these rating systems is to attempt to compel building owners or tenants to evaluate the environmental performance of their building. Buildings acquire LEED certification by demonstrating, according to their relevant rating systems, compliance with a certain level of certification. The LEED rating systems are designed to evaluate the environmental performance of a building through its design, construction and operation. The environmental performance is rewarded from the lowest level to the highest level of certification as follows: Certified 40-49 points, Silver 50-59 points, Gold 60-79 points, Platinum 80 points and above (USGBC, 2009_1).

LEED certifications exist for new and existing commercial, institutional and residential buildings. Reference guides have been drafted for each type of LEED certification. Each LEED certification includes five fundamental environmental categories: sustainable sites (the environmental surroundings of the building), water efficiency, energy and atmosphere, materials and resources and Indoor environmental air quality (USGBC, 2009_1). In addition to these, a category for innovation in design and operations covers all measures that are not dealt with within the five fundamental categories. A number of credits make up each of the categories. For example, the credit studied in this thesis namely Energy and Atmosphere Credit 1 (EAC1) is one of the credits from the Energy and Atmosphere category. Each credit carries a different weight in the overall certification. This weight is represented with points. In other words, some credits have more points than others do. The allocation of points between credits is done by modeling the potential environmental impacts and benefits of each credit (USGBC, 2009_1). LEED uses Tools for the Reduction and Assessment of chemical and other environmental Impacts (TRACI), a model from the US Environmental Protection Agency (EPA), as well as considerations from the National Institute of Standards and Technology in order to weigh the credits (USGBC, 2009_1). Each LEED certification has 100 base points plus 10 for innovations and 1 credit is equivalent to a minimum of 1 point (USGBC, 2009_1).

5.2. LEED Abroad and in Austria

LEED certification has become popular around the world as shown by Table 4. China counts more than 1600 LEED projects, the EAU and Brazil both have more than 500 LEED projects.

Table 5: LEED projects in selected countries around the world

Country	Total LEED projects	LEED certified projects	LEED Platinum Certified	% of projects certified
China	1606	483	52	30%
UAE	658	90	9	14%
Brazil	533	133	3	25%
Canada	523	363	13	70%
India	443	194	72	44%
Mexico	368	94	11	26%
Germany	276	83	17	30%
Chile	251	58	1	23%
Turkey	248	54	7	22%
South Korea	199	49	8	25%
Spain	170	63	10	37%
Italy	164	52	6	32%
Finland	134	70	11	52%
Columbia	127	36	1	28%

Source: US Green Building Council LEED Project Directory

In Europe, the existence of national Green Building certifications has slowed down the expansion of LEED certification. In Austria, LEED is becoming a competitor with other rating systems such as Österreichische Gesellschaft für Nachhaltige Immobilienwirtschaft for certifying Green Buildings. To date there are 10 LEED certified buildings in Austria, 3 of which are certified with Platinum but all of which are new constructions. Only one building in Austria is certified with LEED for existing buildings[23].

As this section illustrates, LEED is now an internationally recognized label set up by the USGBC. There are many examples of professional networks such as the USGBC providing benchmarking information for peer review (Dixon, Le Grand, & Smith, 2003). This is for instance the case in many health care systems. Whether peer reviewing causes market forces or is the cause of them is a chicken and egg question. What is sure is that such mechanisms are intrinsic to the market and provide platforms between the private markets and public policy spheres. The risk is that the need for business overtakes the fundamental principles of the USGBC networks of professional. There are for instance already some shortfalls and criticisms about the LEED rating system such as the lack of emphasis on life cycle cost analysis, the lack of building performance verification means, price increases in LEED certified buildings which are not justified from an energy performance perspective and low standards just to mention a few. Therefore, in order for its cost saving and environmental protection mandate to be followed through, its evolution ought to be monitored and matched by government standards.

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[23] US Green Building Council LEED Project Directory

6. LEED for existing buildings

The presence of large building stocks in Europe is a tremendous asset in terms of wealth and in terms of contributing to the wealth of future generations. However, it can be a detriment in terms of meeting environmental standards as most existing buildings have a larger environmental footprint than new constructions. Unlike the US which still has a growing building stock and a growing commercial building stock because of a steadily increasing population, many European countries such as Germany have a declining population and thus the focus of building codes and standards ought to be for existing buildings rather than just new constructions (Amecke, Deason, Hobbs, Novikova, Xiu, & Shengyuan, 2013). Standards for evaluating and rewarding the environmental performance of existing buildings are therefore necessary. Considering that existing buildings can achieve much savings and efficiencies without any significant capital investment (USGBC, 2009$_1$), LEED Existing buildings: Operation and Maintenance (LEED EBOM) contributes to efforts aimed at increasing energy conservation. Indeed, it is estimated that energy reductions of 10% or more are possible with little to no cost. These typically involve zero cost control systems modifications. Another 30% of energy consumed in existing commercial and industrial buildings is estimated to be wasted. In addition to a cost reduction for end users of energy consumed, focusing on energy efficiency gains in existing buildings means that the CO_2 concentration can be reduced with immediate effect. Energy efficiency and reduction of CO_2 are two of the main objective of the EU 2020[24] plan and therefore additional reasons for focusing on existing buildings.

This section will first elaborate on the purpose and objectives of LEED EBOM. In a second part, this section will draw a comparison between LEED EBOM v3 and

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[24] http://ec.europa.eu/news/economy/100303_en.htm

LEED EBOM v4. The characteristics of energy performance assessments under LEED EBOM will then be introduced by offering a brief comparison to other types of energy assessments. Finally it shall be explained why this thesis is focusing on office buildings.

6.1. Brief overview of LEED EBOM

LEED EBOM was first designed to include a whole range of commercial and institutional existing buildings (USGBC, 2009_1). In addition to these, it includes residential buildings of 4 or more habitable stories (USGBC, 2009_1). Applications for LEED EBOM are accepted for purposes of building operations, processes, systems upgrades, minor space-use changes and minor facility alterations or additions. They furthermore include previous buildings certified under LEED New Construction (NC) (USGBC, 2009_1).The objective of the certification is to encourage building owners and operators to reduce the environmental impact of their buildings over the buildings' functioning lifecycles by adopting the sustainable practices required (USGBC, 2009_1).

By definition LEED EBOM focuses on issues of operation and maintenance whereas LEED NC refers to the adoption of measures during the construction phase. Although this means in practice that the areas covered by the credits are somewhat similar in both certifications, there are some minor area differences to be noted as well as major differing types of measures. In most categories the areas covered in NC carry on to EB sometimes under a slightly different title, with a different credit weighting and/or with a different measure. In some cases the credits only apply to NC or EB. In other cases the credit exists for both but the requirements differ. NC typically refers to the use of materials or resources, the choice of design or location and modeling. EB typically refers to management programs, audits, replacement of parts, reporting, recording and cleaning. There are of course issues, typical to one of the certifications that might be also covered by the other. An example of this is

LEED EBOM Sustainable Sites Credit 1 that rewards 4 points for buildings design and construction previously certified under LEED NC (USGBC, 2009_1).

6.2. Novelties of LEED EBOM v4

LEED is continuously evolving through its improvements and development cycles. LEED certifications typically evolve in scope and stringency. This evolution is tied in with technological improvements, market expansion, improved understanding of building physics and the increased importance of environmental priorities (Renewable Choice Energy). The new LEED EBOM v4 introduced this year covers more existing building certification types and adopts more stringent requirements. It therefore includes provisions for rating data centers, warehouse and distribution centers as well as hospitality buildings. In addition to this it includes a section for International projects including metric conversions as well as updated advanced energy design guides (GBRI, 2013). The reference standard for minimum energy performance is updated from ASHRAE 90.1.2007 to ASHRAE 90.1.2010. A new category is added: Location and Transportation[25]. Under LEED EBOM v4, the Materials and Resources as well as the Water Efficiency categories loose points overall to both the Energy and Atmosphere and the Indoor Environmental quality categories. A new prerequisite for sustainable sites is introduced under LEED EBOM v4: Site Management Policy. The minimum energy performance requirement for LEED EBOM v4 goes from having a performance which is better than 69% of similar buildings to 75% better. Utility owned meters are required. Data regarding energy performance must be shared with the USGBC for 5 years[26] (GBRI, 2013).

As concerns were raised over the stringency of LEED EBOM v4, the USGBC announced that project teams would be allowed to register for either LEED EBOM

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[25] This category includes the alternative transportation credits from the sustainable sites category of the previous LEED certifications

[26] 5 years is also the maximum amount of time allowed before recertification is required

v4 or LEED EBOM v3 until June 1rst 2015 (Renewable Choice Energy). Considering that recertification is required at least once every 5 years, buildings will have up until 2020 – 2021 to recertify under LEED EBOM v4.

6.3. The importance of certifying existing office buildings

This thesis will be focusing on existing office buildings. There are two reasons for this: firstly because the reference building in the case study is an office building that provides the empirical basis to this research and secondly because office buildings represent a substantial and essential fraction of the building stock as well as being prime for LEED certification. 26% of the total energy use in all types of buildings takes place in office buildings. Office buildings also represent 23% of all non-residential floor space[27] in Europe[28]. Moreover, existing office buildings are prime for LEED certification for two reasons. Firstly because of the marketing incentive LEED presents which encourages offices to be active in seeking Green Building certification. Secondly there has been a growth in the service sector worldwide and in countries such as China, Malaysia, Indonesia, Korea and Thailand energy use in the commercial sector has increased 4.5 to 7 times between 1980 and 2000 (Hinge, Bertoldi, & Waide, 2004). This has prompted an international focus on energy efficiency in buildings among other environmental measures and has thus created a large market for ensuring energy efficiency in the commercial sector. Additionally, as data from the case study building was accessible for the purpose of this thesis, this also logically motivated this thesis' focus on office buildings.

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[27] http://www.wsed.at/fileadmin/redakteure/WSED/2012/download_presentations/01_Economidou.pdf

[28] The EU, Switzerland and Norway

7. Review of the LEED EBOM energy performance assessment tool

The LEED EBOM energy performance assessment tool is called Portfolio Manager (PM). It is a freely accessible software created by the Energy Star program of the Environmental Protection Agency (EPA) and the Department of Energy (DOE). The particularities of the assessment tool which are the use of recorded energy data, the full normalization of the building's energy consumption and the benchmarking of the building against other buildings will be analyzed in this section. However, as PM relies first and foremost on a statistical analysis of the Commercial Building Energy Consumption Survey (CBECS) as the backbone for the generation of its normalization factors and its benchmarking system, This section will first explain what is CBECS and briefly look at the characteristics of its dataset before thoroughly analysing PM in a second part.

7.1. Characteristics of CBECS

The CBECS is known as the most comprehensive building energy consumption survey to date (Hinge, Bertoldi, & Waide, 2004). Its dataset acts as the reference for the production of a relative standard of assessment. In the case of the US the relative standard of assessment is PM. The entity in charge of gathering the data forming the backbone of PM's benchmarking is the EIA of the US' DOE that collects the data every four year through this survey. The last two CBECS surveys have not been published - the 2007 survey for quality of data reasons and the 2011 because it was suspended - parts of the CBECS for 2015 have already been published and the whole survey is expected for next year[29]. This thesis will therefore rely on the CBECS of 2003. In order to fully understand the basic data underpinning PM, this section will briefly overview the methods adopted by the survey before undertaking a

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[29] This information and additional information about the CBECS can be found at: http://www.institutebe.com/Building-Performance-Management/data-matters.aspx

concise statistical analysis of the data for professional office buildings built in the last 25 years. In a last part the energy consumption figures from other surveys in France, the UK, Germany and Austria will be briefly looked at in order to provide a comparison with the figures oft he CBECS.

7.1.1. CBECS Methodology

The CBECS of 2003 set three main conditions that a building had to abide by in order to eligible for the surveying. The first condition was that the building had to be 'a structure intended for human access that is totally enclosed by walls, which extend from the foundation to the roof'[30]. The second condition was that more than 50% of the building floor space must have been devoted to activities other than residential, agricultural or industrial[31]. The third condition was that in order to be eligible for the CBECS 2003, a building had to measure more than 1000 square feet[32] (US Energy Information Administration). Once a building abides by these three basic criteria, the building manager or owner is eligible for an interview. Before the interview takes place, a questionnaire is designed. The designing of the questionnaire in 2003 included a variety of topics such as the building's physical characteristics, the building's use patterns, type of energy using equipments, types of energy used, amount of energy used and energy expenditures[33]. After the questionnaire was designed, it was pretested[34] by trained supervisors and interviewers. The interviews were conducted using Computer Assisted Personal

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[30] The only accepted exception to this definition are enclosed structures built on pillars

[31] Commercial Buildings on manufacturing sites are also considered out of scope

[32] The only exception are establishments within malls which have no minimum square footage

[33] Topics of the questionnaire include among others: building activity, size, vintage, operating hours, number of workers, ownership, occupancy patterns, heating equipment, cooling equipment, refrigeration equipment, lighting equipment, office equipment, conservation features, energy management practices, types of energy used for heating, types of energy used for cooling, types of energy used of water heating, types of energy used for cooking types of energy used for manufacturing, types of energy used for electricity generation.

[34] 71 questionnaires were administered by interviewers with building's and establishments of different primary activities and sizes

Interviewing which means that the interviewee answers by computer but an interviewer is present to guide the interviewee through. Once the interviews were conducted, several methods for minimizing interview non responses were undertaken. For instance, whereby possible, interviewers refused conversation by the interviewee were changed by another interviewer and an attempt at a second interview was made. In other cases interviewers performing poorly were discharged of some work. All the mechanisms used for minimizing non responses converted 25% of initial non responses to completes (US Energy Information Administration). Once the data was collected it was processed. During this phase data is typically edited. For instance one or more pieces of information might be missing in an otherwise completed interview. In this case another similar building is chosen to furnish the values for the missing items. Characteristics for determining similarity are in this case: activity, floor space, vintage and census region (US Energy Information Administration).

7.1.2. CBECS data characteristics

This next section will highlight some of the characteristics of the CBECS dataset in order to illustrate its strength but also limits as a fundamental source of information for EStar PM.

There 976 office buildings in the CBECS. The average EUI for these buildings is 293 kwh/m2/y.

These 976 office buildings are composed of banks, government buildings, buildings for mixed use and other office buildings for professional use as illustrated by table 6.

Table 6: EUI for different office building types according to floorspace

Building type/Building characteristics	N. of buildings	average EUI (1000 BTU/f2/y)	average EUI (kwh/m2/y)
Banks	67	96	303
Government buildings	149	110	347
Mixed Use buildings	164	90	284
Professional Buildings	520	90	284
Other	76		270
Total	976		293

Source: CBECS, 2003

Table 6 shows that although a total of 976 office buildings exist in the CBECS data set, only 900 appears when we add the totals for banks, government, mixed use and professional buildings. This means that for 76 office buildings in the data set, there office building type is not specified. Table 6 also shows that, whilst on the one hand, difference in EUI are negligible between banks, professional and mixed use office buildings, on the other hand government office buildings have a much higher EUI. Further analysis of the data shows that although the EUI tends to increase as the building size increases across the office building data set as observed in table 7, this difference is minimal and does not take place in the case of office buildings with mixed use. Climate, however, is an important factor in influencing the EUI.

Table 7: EUI for professional office buildings according to climate[35]

CBECS data 2003 for office buildings				
Building type/Building characteristics	**Climate**	**N. of buildings**	**average EUI (1000 BTU/f2/y)**	**average EUI (kwh/m2/y)**
Professional Buildings	N/A			
	≤ 2000 CDD, ≥ 7000 HDD	9	120	379
	≤ 2000 CDD, 4000 - 7000 HDD	50	98	309
	≥ 2000 CDD, ≤ 4000 HDD	9	50	158
	N/A			

Source: CBECS 2003

Table 7 shows that climates with extreme HDDs and CDDs will on average require more energy consumption then temperate climates.

Another important factor in offices is the number of computers present. The more the number of computers increases, the more the EUI tends to increase.

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[35] Climate in this case is a function of both HDD and CDD values

Table 8: EUI for professional office buildings according to the number of computers

CBECS data 2003 for office buildings				
Building type/Building characteristics	**N. of Computers**	**N. of buildings**	**average EUI (1000 BTU/f2/y)**	**average EUI (kwh/m2/y)**
Professional Buildings	N/A			
	1 to 10	273	84	265
	10 to 50	81	98	309
	50 to 100	24	100	315
	100-250	13	118	372
	250 and more	7	104	328
	N/A			

Source: CBECS 2003

However, as illustrated by table 8, there is an exception to this rule. Professional office buildings with a very high number of computers tend to perform better on average than professional office buildings with slightly less computers.

Office occupancy also carries a lot of weight in terms of increasing the EUI.

Table 9: EUI of professional buildings in accordance with weekly opening hours

CBECS data 2003 for office buildings				
Building type/Building characteristics	**Weekly opening hours**	**N. of buildings**	**average EUI (1000 BTU/f2/y)**	**average EUI (kwh/m2/y)**
Professional Buildings	N/A			
	1-48hrs	174	84	265
	49-84hrs	273	83	262
	85hrs and more	73	127	401
	N/A			

Source: CBECS 2003

This trend is illustrated by table 9 where professional office buildings with 85 weekly opening hours or more clearly have a much higher EUI than professional office buildings with less than 85 weekly opening hours.

All factors highlighted above have on average a substantial influence on the EUI of the sample. The CBECS dataset contains a multiplicity of other factors. When too many factors are taken into consideration, the sample is rendered statistically insignificant and thus prone to outlier data bias. In other words, out of the 976 buildings in the CBECS dataset, it is possible to find at least one building for any combination of factors which acts as an outlier.

7.1.3. Analysis of the data characteristics

These tables have helped illustrate two aspects that characterize the EStar PM data set. Firstly, the limits of the CBECS data set in terms of providing large peer groups for PM benchmark can be observed. This point in particular explains one of the methods used by PM. For instance PM applies a multivariate linear regression analysis to all the characteristics of the CBECS building data set in order to normalise all factors that might prejudice the energy performance of building. This method will be further analysed in the following section.

Although the characteristics of a building to be benchmarked in PM will most likely never be exactly matched in the CBECS data set, coefficients resulting from these regressions will allow the energy use of a hypothetical building with characteristics very similar to that of the real building to be predicted (Scofield, 2014). However, even with these regressions, uncertainties of +35 have been found in EStar scores. Although this applies to EStar score overall and not specifically to office buildings, the limited size of the sample used in the PM regression data set of office buildings suggests a high probability of accidental correlation (Scofield, 2014). Secondly, these tables have shown how the influence variables such as floorspace, weekly opening hours, number of personal computers and climate might have. It is therefore logical that these factors are subject to normalization in PM.

Further analysis of the CBECS data can deduce that the main factors influencing a building’s EUI in the data set are user behavior factors, the shape of the building and other factors which are not present such as shell and core insulation material.

7.1.4. CBECS comparison with other national surveys

The German survey of energy consumption in existing office buildings was requested by the ministry for economics and technology. The survey was undertaken for 2007 through to 2010 by subcontracted institutions. It is a survey of the energy requirements for the operation of over 2000 selected companies. These surveys based on telephone interviews are supplemented by data analyses based on market wide knowledge of building typologies and activities (Schlomann, Kleeberger, Pich, Gruber, & Schiller, 2013).

Table 10: Energy consumption in existing commercial buildings in Germany (per year)

Economic activity	Banking and insurance	Public services	Non Profit Organizations	Small Offices	Other
Number of buildings	123	75	55	124	133
Average number of workers/building	13 (10 full time; 3 part time)	58 (44 full time; 13 part time)	14 (6 full time; 8 part time)	10 (7 full time; 2 part time)	18 (9 full time; 8 part time)
Average floor space/ building	546 m2	2481 m2	597 m2	259 m2	532 m2
Average energy consumption/person	7840 Kwh	7687 Kwh	13025 Kwh	6217 Kwh	7407 Kwh
Average energy consumption/m2	187 Kwh	180 Kwh	305 Kwh	240 Kwh	251 Kwh

Source: IREES (Insitut für Ressourceneffizienz und Energiestrategien), BASE-ING. GmbH, GfK Retail and Technology GmbH, Lehrstuhl für Energiewirtschaft und Anwendungstechnik von der Technische Universität München, Fraunhofer-Institut für System- und Innovationsforschung, 2007 to 2010

The average EUI for each economic activity is calculated by using the energy consumption per worker which is provided by the survey and multiplying it by the number of workers before dividing it by the floor space. The average EUI for the overall German office building stock is about 210 Kwh/m2/y. If we exclude public buildings where the average EUI is 180 Kwh/m2/y, then the average EUI is 237 Kwh/m2/y.

In Austria a survey of 12000 companies in the service sector was undertaken by Statistik Austria, a non for profit organization with public rights. Together the surveyed companies represent 9.6% of the all companies in the service sector (STATISTIK AUSTRIA, 2011).

Table 11: Average site EUI of existing private office buildings in Austria in 2008

Electricity consumption	144 Kwh/m2/y
Consumption from all other fuels	83 Kwh/m2/y
Total	227 Kwh/m2/y

Source: STATISTIK AUSTRIA, Energiestatistik, 2008

In Austria the average EUI for offices in 2008 was 227 Kwh/m2/y. This value excludes public buildings where the average EUI is 182 Kwh/m2/y. Both represent 11.3% and 11.2% of final energy consumption in the commercial sector respectively. Therefore the average of both EUIs can be considered as the average EUI for existing public and private office building in Austria in 2008. This average stands at about 205 Kwh/m2/y.

In France the institution in charge of undertaking the survey for the energy consumption of existing office building is the Centre d'Études et de Recherches Économiques sur l'Énergie (CEREN). They undertake their survey based on raw data from the National Institute of Statistics and Economic Studies. Unfortunately access to this data is restricted and the CEREN only shares its data on a commercial basis.

The same problem is encountered in the UK. The Technical Memorundum 46 from the Chartered Institute of Buildings Services Engineers provides energy benchmarks for commercial existing buildings but data can only be accessed on a commercial basis.

To sum up, data restrictions in Europe do not allow access to the same breathe and depth of data as in the US. In some cases the average EUI for the office building stock is not even publicly available, as in the UK and in France. The data for Germany and Austria does allow a comparison of the average EUI for the office building stocks (without government buildings) of those countries with that of the US.

Table 12: The average site EUI of existing private office buildings in the US, Germany and Austria

Countries	United States	Germany	Austria
Average EUI in the Existing office building stock (government/public buildings excluded) in Kwh/m2/y	285	237	227

Source: US, German and Austrian surveys

Nevertheless data for the average EUI in relation to specific factors such as climate or occupancy patterns is not publicly available in both the German and Austrian surveys. A comparison of these EUIs in relation to such factors, which form the basis of Portfolio Manager, would allow a much more accurate comparison of how the average existing office building performs in each country, according to its country respective survey. Unfortunately such a comparison will not be available in following section as statistical analyses of surveys in Europe for the purpose of creating a local system of benchmarking are either not yet available or have not yet been made public.

7.2. Characteristics of Portfolio Manager (PM)

The LEED EBOM guide requires the use of EStar's PM, an open source tool set up by the EStar program of the EPA and the DOE of the US dedicated to assessing the energy performance, water efficiency and carbon emissions of buildings. The first step when using PM is to plug in the building's consumption data, operational use details and cost information. PM will then compare the performance of the building with the performance of other similar buildings. This section will elaborate on the specific characteristics of PM for assessing performance. In so doing, we will review the eligibility to PM, the use of EUI as an evaluation unit, the methodologies behind the design of the EStar PM score for office buildings as well as the source-site energy conversion factors.

7.2.1. Eligibility to Portfolio Manager

There are three eligibility criteria for PM which will be further explained in this section.

The first eligibility criteria set by EStar is that the property type of the project building must be one that is listed in EStar. The list of eligible property types is as follows:

- Bank branch
- Barracks
- Financial office
- K-12 school
- Supermarket/grocery store
- Wholesale club/supercenter
- Hospital (general medical & surgical)
- Medical office
- Senior care community
- Hotel
- Residence hall/ dormitory
- Office
- Courthouse
- Wastewater treatment plant
- Worship facility

- Retail store
- Data center
- Distribution center
- Non-refrigerated warehouse
- Refrigerated warehouse

A building is defined as one of the property types on the list if at least 50% of the building's gross floor area can be defined as one of the eligible property types, if no more than 25% of its gross floor area is defined by a property type which is not in the list and if the combined space of both the enclosed and unenclosed garage space does not exceed the gross floor area of the building.

This first eligibility criterion obviously leaves some space for uncertainty. For instance, if at least 50% of the gross floor area can be defined as a hospital, then the building will be benchmarked against other hospital type properties. Because hospitals overall have a higher EUI[36], if the rest of the building is most similar to a non refrigerated warehouse property type, which typically register very low average EUIs, then the building will have better chances at performing very well in PM.

The second eligibility criterion is definition requirements to be considered for a property type. These definitions can be seen in the table below.

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[36] Inpatient Health Care buildings in the US have an average site EUI of 786Kwh/m2 according to CBECS

Table 13: Property type definition requirements for Portfolio Manager

Property type	Definition requirements
All buildings	• Be at least 5,000 square feet. There are four exceptions to this rule: 1. Banks may be as small as 1,000 square feet 2. Religious worship facilities may be as small as 1,000 square feet 3. Hospitals must be at least 20,000 square feet 4. Data centers do not have a square-foot minimum • Be in operation at least 30 hours per week. There are two exceptions to this rule: 1. This doesn't apply to buildings that are not asked for hours of operation, such as hotels and hospitals 2. This doesn't apply to religious worship facilities. • Have at least 1 worker during the main shift, when this is asked.
Hospitals	• Have at least 1 bed set up and staffed for use
Municipal wastewater treatment plants	• Have an average daily wastewater flow greater than 0.6 million gallons per day (MGD) • Have an average influent biological oxygen demand (BOD5) level greater than 30 and less than 1000 • Have an average effluent BOD5 level greater than 0
Offices, bank branches, financial offices, and courthouses	• Have at least 1 Personal Computer (PC)
Residence halls/ dormitories and barracks	• Have at least 5 rooms
Retail stores	• Have at least one cash register • Have an exterior entrance to the public • Be a single store only
Senior care facilities	• Not have an average number of residents that exceeds the resident capacity
Religious worship facilities	• Have at least 25 seats and no more than 4,000 seats

Source: ENERGY STAR, 2013[7]

As observed from the table above a building cannot be rated under PM if it does not have a minimum gross floor area of 5000 f2 or 465 m2. These definition requirements are designed to limit differences between the building being evaluated under PM and the peer group to which it is being benchmarked.

The third eligibility criterion is constituted of requirements regarding the energy data recorded and then inputted into PM. The energy data must first of all reflect all energy uses of the property. Secondly at least twelve consecutive months of energy data must be entered for all active meters and all fuel types (ENERGY STAR, 2013_7).

7.2.2. Evaluation unit for existing office buildings

As the EUI by property type is dependent on the reference data surveyed, the aim for a given project team benchmarking its building using PM will be to approximate its building with the most similar building from the CBECS (ENERGY STAR, 2013_2). In order to protect confidentiality of information all building identifiers are removed and any characteristics that could potentially lead to building identification in CBECS are masked[37]. As a result, the surveyed building presenting the most similarities to the building being benchmarked is unknown to the project team. Therefore any attempt by the project team to try and benchmark their building inputting characteristics in PM, which they believe to be the closest approximation to the most similar surveyed building ought to therefore be considered as a faithful representation of the building. The EStar technical reference recommends benchmarked buildings to focus on the primary function of the building as a way of reaching this approximation and thereby avoid mentioning additional uses unless necessary. The project team is therefore allowed to compare different benchmarking scenarios using every reasonably possible combination of building uses in order to determine which scenario generates the best score in PM without misrepresenting a building's main function.

Whilst with CBECS data, the mean EUI values for buildings according to specifically selected characteristics can be obtained, PM uses a median EUI as a recommended benchmark metric (ENERGY STAR, 2013_2). The reason for that is to

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[37] http://www.eia.gov/consumption/commercial/data/2003/index.cfm?view=methodology

prevent any single building in a limited reference data set to significantly distort the mean EUI value in such a way that it is either much higher or much lower than the majority of the buildings in the data set. In other words, a building performing extremely well or extremely poorly will have no more influence on the average value in median terms than any other building performance in the data set. Moreover, a data set may become limited in PM if too many building function characteristics are inputted.

Median EUIs for US and Canadian office buildings using PM can be observed in Table 14.

Table 14: Median Source and Site EUI in Canada and the US

Countries\Median EUIs	Source EUI (Kwh/m2/y)	Site EUI (Kwh/m2/y)
USA	467	212
CANADA	364	255

Source: ENERGY STAR 2013[3]

What Table 14 clearly depicts is that although the average Canadian office building uses more site energy than the average American office building, it also uses less source energy. One explanation could be that the average Canadian office building uses more primary energy as source of heating (eg: natural gas) than the average American office building. In any case the fuel type is an important component of the PM score as it can considerably alter the source-site energy conversion of the overall EUI of the building.

7.2.3 EStar Score for existing office buildings in the US

In order to produce a score, PM first uses EUI data from CBECS which is already normalized for some building characteristics such as floor space, office building type, number of personal computers, hours of operation per week, HDD, Cooling Degree Days (CDD) and geographical area. This data is then further normalized for the building's business activities. The normalization of the building's business activities is derived using an equation, which is itself the produce of a statistical analysis of the CBECS reference data. The result of normalizing all relevant factors is the predicted EUI of the building. This can also be interpreted as the mean energy consumption for buildings with similar operational characteristics to the building being benchmarked. The difference between the actual and predicted EUI is the basis for the score. The score is expressed in a percentile ranking of performance (ENERGY STAR, 2013_1). For instance a benchmarked building having an actual EUI equal to the predicted EUI is a building which performs identically to the national mean EUI for buildings with similar characteristics. In this specific case, the score would be the 50th percentile.

The technical reference explains how the statistical analysis of the CBECS reference data is carried out. To sum up, it is firstly explained that the CBECS reference data for office building is filtered using basically three types of filters: 1) already incorporated CBECS filters which act as eligibility criteria for a PM benchmark[38], filters due to a lack of data in the CBECS[39] and analytical filters (ENERGY STAR, 2013_1). An analytical filter either eliminates outlying data points because some extreme value may skew the analysis or eliminates a subset of data because it may have a completely different behavior than the rest of the data. An illustration of this is the non inclusion of office buildings smaller than 5000 f2 in PM. Interestingly analytical filters, although not designed for the purpose of defining eligibility to PM, may act as such. The filters bring the total number of office

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[38] Such filters include: at least 1 personal computer, at least 30 hours/week of operation and at least 10 months per year, at least 50 % of floor space must be for office activity purposes.

[39] These include: properties must be less than 1'000'000 f2, a propane quantity use of less than 1000 and less than 10% of total source energy, no use of chilled water.

buildings down from 755 to 498 (ENERGY STAR, 2013_3). Out of these 498 buildings an analysis is performed using a weighted ordinary least squares regression which, by minimizing the sum of squared vertical distances between the various business activity characteristics observed responses from the dataset and between the responses predicted by their linear approximation, produces an equation which allows the estimation of its dependent variable (the EUI) based on its independent variables[40] (business activity characteristics, climate).

The regression equation must predict the EUI of the building being benchmarked so that it can then be compared to its actual EUI for an EStar score. The difference between actual and predicted EUI being the basis for the score, the objective of the regression equation is to account for the operational characteristics to such an extent and to such a precision that the difference between actual and predicted EUI can only be attributed to elements which are independent from those elements which ought to be normalized. This is done in order to reflect a fair and objective performance. Such elements which should not be normalized are for instance lighting technology used, window technology used, HVAC system used or the thermodynamic design applied among others. In other words, the independent variables in the equation must account for all normalized factors and their inclusion in the regression must reflect as much as possible the effect of these factors. PM has actually estimated in its technical reference the precision of its regression equation. It is determined by a coefficient of determination (R2), that when re-calculated in units of source energy[41] (primary and secondary energy) accounts for 79.1% of the variation of source energy of offices (ENERGY STAR, 2013_3). In other words, 20.9% of the differences between predicted and actual source EUI, averaged

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[40] These business characteristics are composed of 27 independent variables. Such variables include for example: floorspace, operation, number of computers, number of walk-in refrigeration units, percentage of heated and cooled floorspace as well as HDD and CDD just to name a few.

[41] Unit of source energy = Unit of energy consumed + energy required to produce, and transport the unit of energy consumed

out over the whole building sample, cannot be attributable to factors taken into account by the equation. Although this difference is an excellent result for a statistically based energy model (ENERGY STAR, 2013_3), it does not tell us how much of this difference is due to factors that ought to be normalized or factors that ought not to.

Applying PM to the European context means subjecting European Buildings to a benchmark based on a statistical analysis of the CBECS. However precise the statistical analysis developed by PM may be, it is still based on a survey of buildings in the US and therefore might not reflect specificities of the European context, which when interpreted by PM might distort the variation in the EUI of offices due to factors which ought to be normalized but which are not included in R2.

7.2.4 Source Energy as a unit of evaluation

As previously mentioned source EUI is the unit of evaluation. However unlike site energy, source energy cannot be metered. Indeed source energy includes energy expended further up the energy supply chain such as in production and in transmission in order to produce the required site energy. Therefore source-site conversion ratios are necessary to estimate the source energy from the site energy being metered. In this section we will review the outcome of using source rather than site energy and the methodology adopted by PM to calculate the source-site conversion ratios. Throughout this review, special attention will be paid to how the assessment of buildings in Europe might be affected.

The reason why the EStar program opts for using source over site energy as a unit of energy performance assessment, boils down to understanding the program[42]'s

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[42] The Energy Star program was set up in 1992 by the Environmental Protection Agency and the Department of Energy.

purpose[43]. The purpose is to encourage the increased prioritization of energy efficiency in the private market through the introduction of a labeling system. The key words underlying the purpose of the EStar program are: energy efficiency. Moreover since the focus of attention is buildings, the assessment deals with a building's energy efficiency. Therefore what is being assessed is the building itself. Any assessment which breaks with this focus on energy efficiency such as an energy performance rating based on impacts to the environment is arguably irrelevant to achieving the purpose of the EStar program. We might subsequently ask ourselves how source energy as a unit of assessment is contributing to the purpose of measuring energy efficiency.

A quick look at the technical reference from PM demonstrates two benefits of using source energy. Table 10 highlights these benefits. First of all if two identically built buildings consuming the same fuel type, one using an efficient heating system and the other an inefficient heating system, were compared to each other, then a source energy measure would magnify disparity in performance between the buildings already noticed in a site energy measure. Secondly, it accounts for performance disparities between fuel types. For example if comparing in table 10 the site energy of Building A with an efficient gas heating system to Building E then Building E with the inefficient electric heating system might perform better than the building with the most efficient heating system respective to its fuel type (ENERGY STAR, 2013_4). This assessment would be somewhat unfair as the building performing best is the one with an inefficient heating system for its respective fuel type. However, using source energy as a unit of assessment for the same scenario, the building with the most efficient heating system for its respective fuel type suddenly perform much better than the other building (ENERGY STAR, 2013_4).

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[43] Information about the purposes of the Energy Star Program can be found at: http://www.energystar.gov/about/

Table 15: Hypothetical comparison of heating scenarios in American buildings

	Building A	Building B	Building C	Building D	Building E
Heating Fuel	Natural Gas	Natural Gas	Electric	Electric	Electric
Heating System	Gas-fired Boiler 90% combustion efficiency 80% system efficiency	Gas-fired Boiler 70% combustion efficiency 55% system efficiency	Geothermal COP=4.0	Air Source Heat Pump COP=2.5	Electric Resistance Heat COP=1
Heat to Space (BTU)	1000	1000	1000	1000	1000
Site Energy (MBtu)	1250	1818	250	400	1000
Source Energy (MBtu)	1313	1909	785	1256	3140

Source: Energy Star Portfolio Manager Technical Reference for source energy

Even though source energy is a far more accurate indicator of the total energy consumed than site energy as demonstrated in the PM technical reference, there might be downsides when comparing the source energy consumption of fuel type to achieving the purpose of the EStar program: encouraging the private sector to prioritize energy efficiency in buildings. If for historical reasons more efficient heating systems have been developed for one specific fuel type such as boilers running from natural gas, then buildings that have the most efficient natural gas fired boilers might not perform as well as similar buildings using efficient heating systems running on electricity even though both groups of similar buildings might have state of the art heating systems within their respective fuel types. As a result at any given level of heating system efficiency, one fuel type may be favored by the assessment over another. For example, the PM technical reference demonstrates that for identically built buildings heating the same space, inefficient heating systems running on natural gas perform better than inefficient heating systems running on electricity. Conversely efficient heating systems running on electricity perform better than efficient heating systems running on natural gas. Taking a step back we might realize that buildings from a region or a country with energy systems more reliant on one fuel type might be de facto disadvantaged if technological advancements in heating systems relying on that fuel are not as advanced as technological advancements in heating systems for other fuels. As a matter of fact electricity accounts for 62% of energy use in the CBECS and of the energy use from all EStar certified buildings, 78% is electricity (ENERGY STAR, 2013_4). Of course in reality a single building will use a mixture of fuel types. However, the same CBECS survey shows that 30% of the buildings rely on energy use that is of 100% from electricity and out of the EStar certified buildings 26% rely on energy use that is of 100% electricity (ENERGY STAR, 2013_4).

The methodology adopted by PM in calculating the source-site conversion ratios is important to avoiding assessing factors which a building's system cannot control. Therefore efficiencies, which are happening outside of the building system's boundaries such as primary fuel efficiency and equipment used for primary to secondary fuel conversion, are normalized. There are three problems encountered when assessing these efficiencies. Firstly they vary on a geographical basis. Secondly, it is fairly difficult to trace back the geographical origin of a kWh as energy systems are typically interconnected such as they are in the electricity grid. Thirdly, as per the purpose of the EStar program, the unit of evaluation is the building. Therefore, in order to normalize these efficiencies while still using source energy as the assessment unit, PM uses national average source-site ratios. This serves the goal of the EStar Program which is to promote private sector led building energy efficiency at a national level[44]. As the building is the sole unit of evaluation, energy from renewable sources such as wind or sun purchased from the electricity grid does not impact the source energy or score calculations in PM (ENERGY STAR, 2013_4). A second reason mentioned in the technical reference for why that is, is due to the grid's interconnectedness. According to the technical reference, the interconnectedness of the grid has the effect of not allowing a specific production method to be allocated to a specific building (ENERGY STAR, 2013_4). Because source-site energy conversions take into account factors which are time dependent, they are reviewed every 3 to 5 years.

Calculations of source-site energy conversion vary according to fuel types and include factors such as quality of fuels, primary to secondary efficiency conversion and distribution efficiency (ENERGY STAR, 2013_4). The table below shows all calculations by fuel types.

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[44] Information about the purposes of the Energy Star Program can be found at: http://www.energystar.gov/about/

Table 16: Explanation of Source-Site Conversion Ratio in PM

Energy type	Definition	losses incurred	Data source	Calculation	Ratio
Electricity purchased from the grid	Secondary energy generated from fossil fuels, nuclear plants, renewables and fed into the grid	primary to electricity conversion, grid transportation	Electricity flow diagram found in the Annual Energy Review from the EIA	(Primary Energy / (Net Generation - Transmission losses - Distribution losses))	3.14
On site electricity from solar or wind	Energy produced on site by solar panels or wind turbines	No losses	Not needed	NA	1
Natural Gas	Primary energy converted on site into heat or electricity	pipeline transmission and distribution	Natural Gas Annual	((Delivery to consumers + Pipeline and distribution losses + Plant fuel) / Delivery to Consumers)	1.05
Fuel Oil	Primary energy converted on site into heat or electricity	Storage, distribution and dispensing	None. Considered to be analogous to studied losses in highway diesel fuel.	(100 % of End Use - Proportion of losses in fuel distribution and storage - proportion of losses in fuel dispensing) / 100	1.01
Propane	Primary energy converted on site into heat or electricity	storage, distribution and dispensing	None.	Considered to analogous to fuel oil losses.	1.01
District Steam	Secondary energy in the form of steam generated from primary fuels	primary to steam conversion, delivery	Reference in a report called: District Energy Services: Commercial Data Analysis for EIA's National Energy Modeling System	(source-site conversion ratio for CHP x market share of CHP systems) + (source-site conversion ratio for conventional steam systems x market share of conventional systems)	1.2
District Hot Water	Secondary energy in the form of steam and hot water generated from primary fuels	primary to hot water conversion, delivery	Reference in a report called: District Energy Services: Commercial Data Analysis for EIA's National Energy Modeling System	100 / (weighted efficiency from CHP and conventional systems combined) x (1 - % of distribution losses) x (1 - % of pumping energy required)	1.2
District Chilled Water	Secondary energy in the form of chilled water generated from electrcity or natural gas	energy conversion processes (natural gas to chilled water, primary to electricity and electrcity to chilled water), distribution	Reference in a report called: District Energy Services: Commercial Data Analysis for EIA's National Energy Modeling System	(source -site conversion ratio for electric chillers x market share of electric chillers) + (source-site conversion ratio for natural gas chillers x market share of natural gas chillers)	1
Wood	Primary energy converted on site to heat or electricity	Storage, transportation and delivery	Not needed	Losses are not considered	1
Coal	Primary energy converted on site to heat or electricity	Storage, transportation and delivery	None	No direct quantifiable losses are observed therefore no losses are considered	1
Other	Other fuels used on site (eg: waste biomass)	No losses considered	None	Not possible to quantify losses	1

Source: Energy Star Technical Reference for source-site ratios by energy type in the US, 2013

As seen from the table 16, the highest ratio is for electricity and as previously mentioned the vast majority of buildings in the US have heating systems that run on electricity. The first question that needs to be addressed is whether using different source-site ratios, as might be the case in other countries, might translate in significant variations in overall building performances?

7.2.5. Country comparisons of Source-Site Conversion Ratios

A comparison of source-site conversion ratio among different selected countries shows the extent of variance in these ratios (ENERGY STAR, 2013$_6$), (DEFRA, 2005) (Centre Scientifique et Technique du Bâtiment, 2011).

Table 17: Source site energy conversion ratios in selected countries

Countries	Electricity	Natural Gas	Oil	Coal	Wood
Austria	3.51	1.3	1.33	1.54	1.22
France	2.58	1	1	1	0.6
Germany	2.6	1.1	1.1	1.1	0.2
UK	2.8	1.15	1.19	1.07	1.1
Canada	2.05	1.02	1.01	1	1
US	3.14	1.05	1.01	1	1

Source: Energy star 2013, DEFRA 2005, Centre Scientifique et Technique du Bâtiment 2011

Table 18: Electricity mix in selected countries

Countries	Fossil fuels	Nuclear	Hydro	Geo/wind/solar/other
Austria	20%	0%	73%	7%
France	5%	77%	14.5%	3.5%
Germany	62.5%	16%	3.5%	18%
UK	66.5%	20.5%	3%	10%
Canada	22.5%	14.5%	60.5%	2.5%
US	65%	19%	9%	7%

Source: International Energy Agency 2014

Table 17 demonstrates the large variances between countries in source-site conversion ratios for these main fuel types. Explanations for these variances are not always obvious as illustrated by table 18 which shows that the electricity mix is not a factor significant enough for explaining these variances. Indeed, Canada which has a similar electricity mix profile to Austria has the lowest source-site conversion ratio for electricity whereas Austria has the highest. One possibility for this could be simply different methodologies for calculating source-site conversion ratios and perhaps more specifically different definitions of what constitutes primary energy. Another possibility could be larger transportation losses for Austrian energy. It can also be deduced from Table 17 that if a performance evaluation was performed on a building in Austria running on electricity, then the building in Austria would have a lower EUI using the American source-site conversion ratio rather than using the Austrian ratio. However, since the standard used by PM is a relative one, which is comparing performance with other buildings, then although using the American source-site conversion ratios would result in a better performance in absolute terms, in relative terms it would not change anything.

Table 19: Hypothetical comparison of heating scenarios in Buildings in Austria[45]

	Building A	Building B	Building C	Building D	Building E
Heating Fuel	**Natural Gas**	**Natural Gas**	**Electric**	**Electric**	**Electric**
Heating System	Gas-fired Boiler 90% combustion efficiency 80% system efficiency	Gas-fired Boiler 70% combustion efficiency 55% system efficiency	Geothermal COP=4.0	Air Source Heat Pump COP=2.5	Electric Resistance Heat COP=1
Heat to Space (BTU)	1000	1000	1000	1000	1000
Site Energy (MBtu)	1250	1818	250	400	1000
Source Energy (MBtu)	1625	2363	878	1404	3510

Source: ENERGY STAR 2013$_4$, DEFRA 2005

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[45] Extrapolated from table 16 using source-site ratios from table 17

Table 20: Hypothetical percent gain calculation between different fuel type heating scenarios of table 15 and 19

Comparisons	Calculation	Austria (table 19)	US (table 15)
Very efficient natural gas system (A) versus very efficient electrical system (C)	Source EUI of scenario A / Source EUI of scenario C	Performance of Building C is 85% better than Building A	Performance of Building C is 67% better than Building A
Very efficient natural gas system (A) versus efficient electrical system (D)	Source EUI of scenario A / Source EUI of scenario D	Performance of Building D is 16% better than Building A	Performance of Building D is 4.5% better than Building A
Unefficient electrical system (E) versus average efficiency natural gas system (B)	Source EUI of scenario E / Source EUI of scenario B	Performance of Building B is 49% better than Building E	Performance of Building B is 65% better than Building E

Source: ENERGY STAR 2013$_4$, DEFRA 2005

Nevertheless in comparison to similar buildings running on other fuel types the building might perform comparatively better with the source-site ratios of one country than with the ratios of the other. As seen in Table 20, buildings in Austria with highly efficient heating systems running on electricity tend to perform 85% better than their efficient natural gas counterparts whereas in the US they will only perform 67% better. Moreover, buildings in Austria with inefficient heating systems running on natural gas tend to perform 49% better than their inefficient electricity counterparts whereas in the US the same buildings will perform 65% better. Furthermore with a 3.51 source-site conversion ratio for electricity, any building with an inefficient electric heating system will be disadvantage from a EUI source performance perspective.

After having looked at firstly the CBECS, this section showed the limits of the of the database in terms of providing the sufficient breadthe and depth of data for allowing PM's regression analyses of the buildings independent variables to be precise. The section then explained the principles used by PM for EUI, reviewed the methodology as well as the statistical analysis forming the basis of the EStar PM score for offices before looking at methods and calculation for source energy forming the basis of the source EUI unit of evaluation in PM. By going through these various components of PM, we highlighted the importance of factors such as heating systems, fuel types, source-site energy conversion ratios and the statistical analysis of nationwide building performance surveys such as the CBECS in influencing the final performance of a building within PM. In addition to this, we observed how a variation in these factors can change an assessment tool such as PM. These insights into the fundamentals of PM underline how a building essentially foreign to the PM framework might be evaluated in an inconsistent manner. However, these insights still fail to explain how important are these inconsistencies and whether these inconsistencies are due to source-site conversion ratios, different heating systems with different efficiencies and therefore different fuel types used or due to buildings being built to different building standards. Although this thesis will not delve into the causes of these inconsistencies, this section provided a detailed overview of what might be some of the reasons why buildings outside the US are not assessed objectively when benchmarked in PM.

8. Energy and Atmosphere Credit 1: description and explanation

The two credits responsible for energy performance assessment under LEED EBOM are the Energy and Atmosphere Prerequisite number 2 (EAP2) and the Energy and atmosphere credit 1 (EAC1). As EAP2 is a minimum requirement for LEED certification, the thesis will focus on the credit description of EAC1 even though minimum performance for EAP2 will also be discussed. This section will explain how and why points are rewarded in accordance with their energy performance. This section will first present the rationale for applying to EAC1. The requirements for the implementation of EAC1 will then be laid down before outlining and explaining the guide's credit description and briefly discussing the issues to take into consideration. In a fifth part, the exception for projects outside the US will be underlined.

8.1. The rationale

The rationale given by the USGBC for the Energy and Atmosphere credit 1 of LEED EBOM v3 covers two of the three important advantages of applying for Green Building Certification, namely the environmental and economic advantages. It states firstly that energy efficiency is one of the strategies for managing the environmental burdens from energy consumption. Secondly, it argues that improving energy efficiency will reduce overall operating costs. To support this argument, the USGBC cites an EPA estimate that for every 1 dollar invested in energy upgrades, there will be a 2-3$ average increase to the asset value of a building (USGBC, 2008).

8.2. Implementation requirements

The credit description introduces some terms and rules that ought to be clarified in order to understand to full intent of the credit. One such term is 'performance period', which is a period in which the ongoing operations and maintenance practices necessary for the LEED credit and prerequisites are tracked. The performance periods start after project registration and the LEED application must be submitted no later than 60 days after the end of the latest performance period. A performance period may not have any gaps longer than seven contiguous days. All the performance periods must overlap and terminate within 30 days of each other. For EAP2 and EAC1, the performance periods must be between 12 and 24 months (USGBC, 2008). Performance periods for all other prerequisites and credits must be a minimum of 3 months and may be extended up to 24 months. The performance period of EAP2 must be between 3 and 36 months (Leppo, 2009).

In order to earn points for EAC1, buildings must be equipped with meters measuring the energy use during the minimum 12 months performance period. All meters, whether belonging to the owner, organization managing the building or the tenants must have been calibrated according to the manufacturer's recommended intervals except for meters owned by third parties such as utilities or governmental entities. Compliance with EAC1 first requires an EStar score. This score appears after inputting performance period data into PM to be normalized and translated into a source EUI value. The EUI value is then benchmarked against a data set, which is in all but one possible EAC1 options at least partly based on the CBECS data set. The resulting EStar score is used to determine the points rewarded in EAC1. It is noteworthy to mention that earning an EStar label, awarded when an EStar score of 75 or higher is achieved, is no requirement of LEED (USGBC, 2008).

8.3. Credit description

This list of possible compliance paths in EAC1[46] can be summarized in the table below:

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[46] Please see Annex 15.2. for official credit description

Table 21: Basic summary of the EAC1 credit compliance paths

Option 1	Approach 1	Eligible to PM	Benchmarked in PM	0 to 18 points
Option 2	Approach 2,3,4	Not eligible to PM	Creation of own benchmark	0 to 18 points

Source: USGBC, 2008

A more complex explanation of the compliance paths is given below:

1rst Approach: If the building is eligible for a PM[47] rating, use PM to compare actual metered energy consumption of the chosen building with the energy performance of other similar buildings in the EStar data set. This approach is equivalent to case 1 option 1. An EStar score of 69 would mean that the building performs better than 69% of the similar buildings in the EStar data set. This score is the minimum required for LEED certification by the EAP2. A score short of 69 would not achieve EAP2 and would mean that the project building does not meet the baseline requirements for LEED certification. A score between 71 and 95, such as 85 would mean that the building is performing better than 85% of the similar buildings in the EStar data set. As seen by the table in the credit description such a performance would yield 13 points. Projects that are eligible for PM rating must use this approach.

If the building is not eligible for a PM rating based solely on property type identification, you may still benchmark the building using this approach by identifying the building as ‘other’. Based on the inputted uses of the building, PM will then determine the property type and benchmark the building accordingly. This same approach would be equivalent to case 2 option 1.

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[47] For PM eligibility criteria please see chapter 7.1.1.

2nd Approach: If the building is not eligible for a PM rating and you do not wish to use approach 1, you may still be benchmarked for 0 points under EAC1 or the equivalent of EAP2. This would be equivalent to case 2 option 2a. This approach is successful if, by imputing one year of energy use data into PM, the resulting weather-normalized source EUI is equivalent to an EStar score of 19 above the national median. This score expresses a value which is at least better than 19% of values above the national median for similar buildings. In this case, the national median is taken from the average source EUI for the closest building type[48] in the 2003 CBECS data set and is called the 'streamlined baseline' in the credit description. An offline calculator is also made available by LEED to convert the PM weather normalized source EUI into a percentile level representing a reduction from the streamlined baseline. The distribution of performance levels that is used to express the project building's score in comparison with the baseline is that of a distribution of performance for all CBECS buildings extrapolated to the national building stock. Therefore although the score is meant to express a performance in comparison to similar buildings, in reality the project building is compared to all commercial buildings in the US, as extrapolated from the CBECS data set, which are above the baseline. The baseline might of course end up being above or below the CBECS extrapolated national median. Interestingly, the EStar score of 19 above the national median would be equivalent, in relative percentile terms, to a regular EStar score of 59, below the minimum required 69 under approach 1. However, since we do not know where the baseline lays in comparison to any median value in the EStar data set for any given EStar building type, we cannot compare both of these values in absolute real terms.

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[48] CBECS has more building type options than PM. However, if the project building type cannot be found from the CBECS list of available building types, then the closest building type to the project building might be 'all other' building type under CBECS.

3rd Approach: If the building is not eligible for a PM rating and you do not wish to use approach 1 nor approach 2 or If the building is not eligible for a PM rating and you do not wish to use approach 1 and by using approach 2 you failed to meet EAP2, you may still try to benchmark the project building by using approach 3. This approach is equivalent to case 2 option 2b. In this approach the project team must enter a minimum of 3 consecutive years of historical energy data into PM. The historical data must fall within 6 years of the beginning of the performance period[49]. The historical data, once entered into PM, is normalized for weather. The ensuing weather normalized source energy intensity is entered into LEED's offline calculator where a baseline is determined. This baseline is an estimated average from the historical data's average weather normalized source energy intensity as well as national EUI values from the CBECS 2003 data set for buildings of the closest building type (USGBC, 2008). The performance period energy use data of the project building is then entered into PM and the resulting value is benchmarked against the baseline. The score reflects a value which expresses the percentage of buildings with a performance which is under that of the project building but over that of the baseline. Although this distribution of performance might be different to the distribution of performance that might occur in a sample representative of the project building's building type, in the absence of such a sample the formula for a distribution of performance of the whole CBECS data set is used. The minimum score that must be achieved is an EStar of 19 above the national median. This complies with EAP2 and is equivalent to 0 points under EAC1. The maximum number of points possible under EAC1 using this approach is 9 points, equivalent to an EStar score of 30 or more above the national median.

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[49] If major energy efficiency improvements were made in the recent past, the best strategy for the project team might be, if possible, to use the energy use data from the first 3 consecutive years of this 6 years interval.

4rth Approach: If the project building is not eligible for a PM rating and only if the project building cannot use approaches 1, 2 or 3, then this approach can be used. Historical energy use data composed of 3 consecutive years of the project building's energy use data taken from within 6 years of the performance period in addition to a minimum of 2 years of energy use data from at least 3 other similar buildings must be collected and entered into PM. All data is normalized for weather to generate EUI values for each of the different buildings and on a year by year basis. These EUI values are inputted into the offline calculator provided by LEED to draw an average weather normalized source EUI. This value in addition to national EUI values from the CBECS 2003 data set for buildings of the closest building type helps generate the baseline. The performance period of the project building is benchmarked against this baseline. An EStar score of 19 above the national median complies with EAP2 and scores 0 points in EAC1. To achieve the maximum 18 points in EAC1, an EStar score of 45 above the national median must be attained.

8.4. Exception for projects outside the US

Projects outside the US have the possibility to follow all the approaches outlined in the credit description as long as they fulfill the respective requirements. Being a project outside the US is not a reason for not being eligible to a PM rating. Therefore unless a building outside of the US is ineligible for option 1 because for instance it is not one of the building types rated by PM, then option 1 must be used.

Although weather normalization in PM is feasible for nearly all locations around the world[50], a project building from Europe using PM will still be benchmarked against American energy use data. Moreover the change in benchmarking score based on building characteristics will be dependent on the US relation between building

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[50] The National Oceanic and Atmospheric Administration collect daily data called Global Summary of Days (GSOD) from over 10000 weather stations around the world. EPA has computed 10 year climate normals from GSOD daily data, using the average of reported data from 2001-2010, which are used by PM for weather normalization.

characteristics and energy use as recorded by the CBECS sample and statistically analyzed by EStar PM. For all these reasons, case 2 option 1 allows project buildings from outside the US to use a local benchmark in order to obtain EAC1 points. This compliance option is detailed in section 9.1.

9. Alternative Compliance paths

As the previous section illustrates there are many reasons why an assessment of European buildings by an American assessment system, using relative standards based on characteristics of the American building stock and the American building industry, is not purely objective. Therefore the USGBC has tried to adapt the LEED model to foreign contexts by offering options for alternative compliance based on references guides for alternative compliance paths as well as credit interpretation processes.

9.1. European and global Alternative Compliance Paths

Both the LEED EBOM alternative compliance paths for Europe and the LEED EBOM with Global alternative compliance paths introduce more details about the implementation of case 2, option 1 for projects wishing to use a local benchmark. The use of a local benchmark must fulfill a number of conditions, all of which are outlined below (USGBC, 2013):

- The local benchmark must be based on source energy data
- This data must come from a national or regional agency
- A proof that the benchmark represents a statistically significant sample of energy use data from buildings of the project's building type must be submitted
- A proof that the benchmarking process is repeatable must be submitted
- The benchmark should include at least 30 buildings of the project's building type
- The data should be weather normalized
- The data should account for internal and external loads
- The local benchmark should be managed by a reputable source

It is furthermore mentioned that projects are encouraged to submit a Credit Interpretation Request (CIR) prior to using a local benchmark. The reference guide also advises when normalizing the weather factor under EStar PM to choose the city representative of the closest weather station if the weather station for the exact project location cannot be found (USGBC, 2013).

9.2. Compliance through standards of the International Organisation for Standardization

As per the EAC1 credit requirements, the building must have meters to measure all energy uses continuously for a minimum of 12 months. The calibration of the meters must be done in accordance with the manufacturer's recommendations except if they belong to a third party. The LEED EBOM with alternative compliance paths for ISO 50001[51]: 2011 Energy Management systems allows for the use of ISO 50001:2011 - 4.6.1 Monitoring, Measurement and Analysis for rules on meter calibration. It also allows for the use of ISO 50001: 2011 – 4.4.3 Energy Review for documentation requirements for energy data collection (USGBC, 2009,2).

9.3. Addenda for District Heating exceptions

In addition to these alternative compliance paths, the USGBC put together an addendum for LEED EBOM buildings using DH. Given that DH networks are very popular in Europe, it is important to see what LEED understands by a DH system and how that affects EAC1. This addendum explains this. The USGBC understands a DH system as a thermal energy system where some part of the system extends beyond the LEED project site (USGBC, 2012). In EAC1 a building will meter the energy served by a DH system. This site energy would then be converted to source energy in PM. If, however, some or all of the Dystrict Energy System (DES) is

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[51] International Organization for Standardization created a standard for establishing, implementing, maintaining and improving an energy management system

owned by the building, then the energy use from the DES can be metered as source energy directly. Project served by a third party DES system are not allowed to do so (USGBC, 2012).

9.4. Description of the credit interpretation process

If project teams have questions they would like to raise regarding the technical specifics of the LEED requirements, there a process which they can follow in order to obtain technical guidance from the USGBC. This process is called a Credit Interpretation Request (CIR). Firstly, an inquiry is made by the project team about a specific issue applying to the project's certification. In most cases this issue will be relevant to other types of LEED certifications. Once the inquiry is made, the USGBC reviews the inquiry and rules on it. The ruling can be a clarification, a refusal or acceptance of an alternative technical method relative to the assessment. The CIR can be made at any time and must be between 600 to 5000 characters. A CIR cannot challenge either the credit language or the minimum threshold established by the credit. A positive ruling for the project team's CIR is never guaranteed. Out of the 16 CIRs related to EAC1 available online, about 10 were positive rulings for the project team although some of them came with restrictions.

9.5. Credit Interpretations related to EAC1

CIRs with positive rulings include among others the use of alternative methods for calculating domestic hot water use and energy savings from Energy Star equipment[52], space[53] exemptions, new calculation methods for energy savings from servers[54], exceptional energy modeling methodologies[55] and confirmation on an understanding of methodology used[56].

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[52] LEED Interpretation ID#5235 made on 06/30/2009

[53] LEED Interpretation ID#2532 made on 03/02/2009

[54] LEED Interpretation ID#2441 made on 01/14/2009

CIRs regarding European projects mostly deal with the use of an alternative compliance path for documenting the energy consumption of buildings linked to the complex DH systems of Europe[57]. However, this only applies to LEED Design and New Construction (NC). As per the ruling, projects in Europe may in lieu of using option 2 of EAC1 for NC, use a method developed by the Sweden Green Building Council and approved by the USGBC known as ‘Treatment of European District Energy Systems in LEED’.

9.6. Analysis of the Alternative compliance paths

The strategy the USGBC has adopted for adapting its EAC1 rating system to the European context is essentially allowing it to apply its own rating system. The use of a local benchmark found in the global and European alternative compliance path reference guide essentially points to that. As for alternative options for other EA credits, the LEED reference guides for alternative options also allow for alternative paths to be chosen. For instance in the case of EAC4 (the use of renewable energies), a project can account for the use of offsite renewable energies if it can be proved through LEED validated Renewable Energy Certificates. Very often, however, this requires transparency from part of the supplier which in some European countries is difficult to achieve.

The use of a local benchmark for EAC1 is also very difficult to achieve in practice. The main reason for this is because databases for energy consumption in buildings exist only at a national level in Europe. Moreover, these databases are either not disclosed to the public or are withheld by private companies who only disclose the data for commercial purposes. Therefore there is presently no central European database equivalent to CBECS in the US from which a European style benchmark

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[55] LEED Interpretation ID#2416 made on 02/03/2009

[56] LEED Interpretation ID#2620 made on 06/04/2009

[57] LEED Interpretation ID#10241 and ID#10243 made on 10/01/2012

could be created. Furthermore the creation of any database for the sole purpose of a LEED certification would require other buildings (at least 30) to disclose their own energy consumption and building characteristics as well as additional resources for collection, analysis of the data and creation of the benchmark.

It is therefore not surprising that most projects in Europe opt for using the EStar PM benchmark.

10. The strategy when applying for EAC1 in Austria

This section first explains the rationale for developing the assumption that will form the basis of the strategy. The rationale is based on on an understanding of the various compliance paths available in EAC1 and of the assessment method used. In a second part the assumption will be made based on the relevant research. In a third part the proposed strategy is outlined and the choice of that strategy is justified.

10.1. The rationale

The best strategy for existing office buildings in Austria boils down to the choice of two compliance paths under EAC1. The first option is to benchmark the project building in PM against other similar buildings in the US. The second option is to benchmark the project building against similar buildings in Austria using or creating a local benchmark.

The ensuing question is to know which benchmark would allow the poject building to perform best in EAC1. The answer to this question is complex. It would require firstly a detailed comparison of the energy performance of the two building stocks for buildings similar to the project building. Secondly, it would require normalization factors adapted to each respective building stock.

Normalization factors such as the ones in PM are dependent on statistical regression analysis from building energy performance surveys such as CBECS. As such a survey is not publicly available in Austria and as no statistical analysis of this survey to determine relevant normlization factors has been made, accounting for normalization factors will not form part of the rationale for the proposed strategy.

The first requirement, however, which is a comparison of the energy performance of the two building stocks is possible albeit with limited data. This comparison will form the basis for the assumption.

10.2. The assumption

Due to data limitations, this thesis concludes that at present the best means for comparing the building stocks of Austria and the US, is based on a comparison of the average EUI in both existing office building stocks. This specific comparison can be observed in the following table.

Table 22: Average site EUI of the existing public and private office building stock

Countries	US (2003)	Austria (2008)	France (2009)	Germany (2009)	UK (2009)
Site EUI (Kwh/m2)	293	205	275	227	230

Source: CBECS 2003, Statistik Austria 2008, Odyssee 2009, Eurostat 2009

The table above shows that apart from France, Austria, Germany and the UK have a lower average site EUI among existing office buildings than in the US. This lower EUI prevails in these European countries despite the fact that Europe has a higher EUI in HVAC electricity end uses, which represents a high portion of all electricity end uses[58]. This could mean that in general European buildings lack efficiency in HVAC electricity end use consumption but make up for it when other fuels are used. As Europe generally uses less electricity as the US, this might also explain why existing office buildings in the European countries looked at seem to have on average a lower site EUI than American buildings. Another explanation for this could also be that the available data for the US is outdated since only 2003 data is available and that since then the EUI has lowered. A third and final explanation is that most EUI values cited in this study relates to western European countries rather than taking into account all European countries. One could expect eastern European to have relatively lower EUIs thus lowering the European average.

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[58] Data from the Joint Research Unit – European Commission

A look at both the Austria and US office building stocks allows us to assume based on the average EUI in both stocks that on average existing office buildings in Austria will perform better than existing office buildings in the US. This supports the argument that existing office buildings in Austria should get higher energy performance rankings on average if benchmarked against American buildings than if they were using a local benchmark.

10.3. Proposed compliance path

Although an alternative compliance path using a local benchmark is available for projects outside the US applying for EAC1, this thesis concludes that using the US benchmark is relatively beneficial to existing office buildings in Austria but also to existing office buildings in France, the UK and Germany.

The chosen strategy for existing office buildings in Austria is option 1 of LEED EAC1. This means entering the building energy consumption data into PM for a score. Such a score reflects the actual performance of the project building as compared with the performance of similar existing buildings in the US. Option 1 is recommended for existing office building projects in Austria. Nevertheless, this recommendation only extends to projects that fall under case 1 of EAC1.

10.4. Justification for choice of path

There are three main reasons for opting for this strategy.

First of all the USGBC provides no assurance that it will accept a CIR for the use of a local benchmark. Moreover, the USGBC has refused to be interviewed regarding this topic and has not answered queries sent by emails in the frame of this research pertaining to the use of a local benchmark.

Secondly, there is no publicly available local benchmark in Europe that meets the LEED standards for a local benchmark as stated in the reference guide. There are privately available benchmarks based on thorough surveys of the energy consumption of existing commercial buildings in many European countries, susceptible to meeting LEED standards; but these are not yet freely accessible to the members of the public.

Thirdly, this thesis assumes based on the average EUI that an average existing office building in Austria would be at an advantage if it were benchmarked against US existing commercial or office buildings.

11. Case Study: Reference Building

The following case study is of an existing office building in Austria currently undergoing LEED certification. This building will demonstrate how to apply the proposed compliance path and the potential of existing office buildings in Austria for achieving a high LEED rating in the EAC1.

11.1 Introducing the Building characteristics

The case study building is the Media Tower of Vienna, a modern existing office building right at the center of Vienna. The owner of the building is Generali Real Estate. The building complex basically consists of three interlinked blocks. Only two of those three blocks are being certified.

Table 23: Media Tower Wien: building description

Main Building Description	Media Tower Wien
Age	2000
Size	13700 m^2
Workers	821
N. of Computers	1725
Weekly Operating Hours	77

Source: CES (Clean Energy Solution), 2014

The building houses a number of companies and services among which a bank and a large Austrian publisher. The nature of the work undertaken in both those companies requires the use of many computers, servers and laptops thus explaining the high number of computers. Moreover, the publisher´s office, which makes up the largest area of the building, operates practically 7 days a week and 24 hours a day justifying the long weekly operating hours of the building.

Table 24: Media Tower Wien: Main business activities

Building spaces/businesses	Main part	Parking	Food service use	Restaurant	Bank	Meeting Hall
Area	12404 m2	2730 m2	60 m2	300 m2	656 m2	280 m2
Workers	767	NA	3	10	40	1
N. of Computers	1600	NA	5	10	100	10
Weekly Operating Hours	80	NA	60	20	40	30

Source: CES, 2014

11.2. Building owner´s motivation for pursuing LEED certification

Generali Real Estate’s motivation for certifying the building is to firstly improve the increase the market value of the building. 15 years after the building was erected, Generali has turned its attention towards renovation opportunities for Media Tower Wien. In so doing, Generali decided to pursue a Green Building Certification, namely LEED, with the objective of being the first LEED platinum certified existing building in Austria. Secondly the motivation is furthermore embellished by the architectural significance of the building.

The Building was built on a corner site in 1995 and was designed by Hans Hollein. The building complex is a collage of Vienna’s architecture at different points in modern times. The first block is made up of stone which represents the existing masonry buildings of the first half of the twentieth century (Phaidon Atlas, 2014). The second block is primarily built with metal to depict post–war slab building. The third block is a slightly inclined glass prism rising above the other blocks illustrating modern Vienna (Hans Hollein).

Media Tower Wien

The building was designed by Hans Hollein as the office headquarters for NEWS, Austria's major media group. The building also formed part of their marketing strategy (Phaidon Atlas, 2014).

11.3. Objective of the project and means

The objective of the project is to be the first LEED EBOM platinum certified building in Austria. The strategy adopted to reach this objective includes credits spread out over a number of categories. The challenge is to accommodate what the owner's desires for an environmentally friendly and energy efficient building with the tenant's desires for a comfortable environment.

11.4. Strategy for EAC1

The strategy followed for EAC1 is option 1. This means collecting actual consumption data and inputting it into PM.

A digital building management system (BMS) remotely controls and monitors the building's energy systems. This includes temperatures in tanks and pipes, thermal zone conditions, air and water flow rates, and electrical demands. This excludes lighting which is automatically controlled on a Digital Addressable Lighting Interface bus. In 2013, the total annual energy end use was 3175 MWh. In addition to this, 1215 MWh were purchased from the District Heating network for space heating in winter and to a limited extent Air Handling Units reheat coils.

Metering from the internal monitoring system was only reported on an annual basis.

Another measure of the energy consumption was reported by the utility: Wien Energy. This measure reported energy consumption on a monthly basis.

Once the energy consumption data gathered, it can be inputted into PM either as an excel spreadsheet of all sub level meter values on a monthly basis or the values can be inputted individually. For the purpose of this thesis, the inputted data was aggregated for district heating consumption and electricity consumption. The District heating consumption for 2012 and 2013 was 8484.47 GJ. The aggregate data for the electricity consumption for 2012 and 2013 based on utility data minus metered consumption from the building block not within the scope of project was 6098031 KWh.

11.5. Proposed energy saving measures for EAC1

There are currently four main suggested energy saving measures. These measures are no or low cost measures. The measures are related to the recommissioning of the Building Management System and the Air Handling Units as well as replacing the constant flow fans of both the Air Handling Units and the cooling towers by variable frequency fans.

The recommissioning of the BMS would pay careful attention to the BMS database in order to identify faulty or inefficient components, additional low cost saving opportunities, suggest changes to building management operations as well as BMS software tools. The objective would be to reorganize the data to firstly make energy efficiency savings opportunities more noticeable and secondly to make it more easily exportable to an external application for statistical analysis.

The recommissioning of the Air Handling Units would be specifically related to the enthalpy wheels. All Air Handling Units are equipped with enthalpy recovery. However, the enthalpy wheels in some units are not in operation due to a pressure imbalance from the air diffusers. A study will be undertaken to see whether the air balance in the diffusers can be corrected to allow for the enthalpy wheels to be reactivated.

As currently the Air Handling Unit fans only have the capacity to run at a constant flow, the idea would be replace them by variable frequency drive fans which would operate according to the flow of air, which does not always run at full capacity.

Finally another suggestion is retrofit the cooling towers with variable frequency drive fans.

11.6. Other engineering measures for other credits

Other measures have been suggested for other credit categories.

For Water efficiency, a retrofit was proposed to change urinals to non flushing urinals, thus allowing considerable savings in water consumption. Many water faucets in the lavatories have high volume flows. Therefore measures to limit the flow were suggested. As pressureless faucets are not easy to change a limiter was retrofitted. Energy saving measures for water closets were also suggested.

In the Material and Resources category, one key improvement relates to establishing a green procurement scheme for consumable goods. The measure, however, is challenging as it requires convincing the tenants.

In the Indoor Environmental Quality category, green cleaning measures require the agreement of the cleaning staff and the building management. For measures of thermal comfort, individual desk light controls are to be installed and differential pressure measurements for the smoking room requirements in the smoking prerequisite are to be undertaken.

12. Results

The results express the performance of the building in terms of the number of points achieved in the EAC1 of LEED EBOM v3. The score reflects the performance of the building before the implementation of any energy savings measures. In addition to this, hypothetical site EUI values representing the performance of the case study building will be determined. These hypothetical values assume that the building belongs to either the French, UK, German or US building stocks. This means that the hypothetical site EUI value of the case study building for France will be the performance of the case study building in Austria in terms of its site EUI, as computed by PM, multiplied by a coefficient which reflects the differences in the average site EUI of the existing office building stocks of France and Austria. In the end the hypothetical site EUI values for each building stock are equivalent in terms of the building's performance relative to the average energy performance of the respective building stock (as expressed by the average site EUI). In other words, the difference between the average site EUI of each existing office building stock is the same as the difference between the calculated hypothetical site EUI values of the case study building for each country. The same methodology is then applied comparing differences in source EUI based first on the US source-site energy conversion ratios and secondly on each country's respective source-site energy conversion ratios. Finally the thesis concludes with some recommendations for European decision makers and for future research on this topic.

12.1. Lmitations of the findings

The thesis explains the methodologies adopted by LEED EBOM in the EAC1. In so doing it describes the prerequisites for similar methodologies to be adopted in Europe. European benchmarking systems are furthermore warranted by an analysis of differences in the average EUI of the American and some European existing office building stocks which serves to support the argument for a European wide benchmarking system or a compilation of national benchmarking systems.

However due to limitations in the data, the PM regression analysis of its independent variables based on CBECS is de facto extended to any existing European office building. A statistical analysis of the energy performance of existing European office buildings would be needed to create Independent variables based on European normalization factors.

Moreover, this study does not look at other types of commercial buildings, especially those that are not eligible for Option 1 of EAC1.

In addition to this, the EUI differences between the existing office building stocks could only be compared as an average. EUIs at different levels of performance were not available for this study. In other words although a country might have a relatively high average EUI of its existing office building stock, the top 20% of existing office buildings might have unusually low EUIs, thus making the top 20% buildings competitive internationally in terms of energy efficiency. An average EUI cannot describe such a scenario. Moreover, the EUI value does not differentiate for any characteristics such as vintage, occupancy or climate.

Furthermore, only site energy is being compared. Although source energy can be extrapolated from site energy using source-site energy conversion ratios, the reason why these ratios differ from one country to another is unclear. The conversion ratio which varies the most among the countries studied is that for electricity. The factors influencing the source-site energy conversion ratios are many but it is unclear which factors have most influence. The study seems to point out to the fact that the calculation methods for determining the ratios are a political decision first and foremost. However, the study fails to explain why that is.

Finally, data used for this study to determine the energy consumption in US existing buildings is outdated. Data from the CBECS is from 2003 and represents the most recently available data of US existing commercial buildings. However, next year new data will be available including the energy consumption of existing commercial buildings built after 2003 up to 2014. This data has not yet been released and therefore could not be included in this study.

12.2. Provisional score of the case study building before the energy savings measures

The provisional case study building score is 83 which represents 12 points out of a possible 18. This score was achieved without any energy saving measures by just inputting the building's energy consumption data, the building characteristics and the business activities into PM. This score translates into a site EUI of 325Kwh/m2/y. This value is of course higher than the average site EUI of the existing building stocks of the US and Austria but this is due to the fact that this particular office building is affected by other factors which become normalized in PM. For instance, it is probably used more intensively than an average office building whether in the US or in Austria. A large part of this usage intensity is normalized through the building characteristics and business activities which were inputted into PM. This normalization means that even though it may seem that the case study building has a relatively high EUI, considering a number of factors such as the usage intensity and climate the building performs better than 83% of similar buildings from the CBECS 2003 data set. This finding is not surprising as the Media Tower was a high performance building when finally built in 2000.

12.3. Hypothetical score of the case study building when normalised for the average EUI of other building stocks

Average EUI differences are determined by a coefficient expressing the divergence of the average EUI of each building stock from a base value. The base value in this case is the average site EUI for existing office buildings in Austria. This base value is 205 Kwh/m2/y. Any divergence from this value is expressed by a coefficient as observed in the table below.

Table 25: Average site EUI of the existing public and private office building stock

Countries	US (2003)	Austria (2008)	France (2009)	Germany (2009)	UK (2009)
Site EUI (Kwh/m2/y)	293	205	275	227	230
Coefficients	1.43	1	1.34	1.11	1.12

Source: CBECS 2003, Statistik Austria 2008, Odyssee 2009, Eurostat 2009

If we take the site EUI from the case study building and multiply it by the coefficients for each respective country, the value obtained is the hypothetical site EUI of an existing office building, with a similar ranking in terms of its performance with regards to the average site EUI of the national existing office building stock.

Table 26: Energy Performance of the case study building normalized for differences in national building stock performance (based on the difference in average EUI between building stocks)

Countries	US	Austria	France	Germany	UK
Coefficients	1.43	1	1.34	1.11	1.12
Case study hypothetical EUI (Kwh/m2/y)	465	325	436	361	364
PM score	56	83	62	77	76
LEED score	0 (no certification)	12	0 (no certification)	6	5

Source: CBECS 2003, Statistik Austria 2008, Odyssee 2009, Eurostat 2009

By benchmarking the case study building in PM, one notices that although the building only registers an EUI value of 325 Kwh/m2/y and although the average US site energy existing office building EUI is 293 Kwh/m2/y, the case study building is said to perform better than 83% of similar buildings in the US. As mentioned before, this is due to building characteristic and business activity factors which become normalized. In order to give us an idea of how well the case study building would perform if benchmarked against similar building in Austria, we use the coefficient of different in average EUI between the US and Austria which is 1.43 and we multiply it by the EUI of the case study building. This gives an EUI of 465 Kwh/m2/y, which is about 59% more than the average existing office building EUI in the US. Similarly the EUI of the case study building is 59% greater than the average existing office building in Austria. Taking the normalizable factors into consideration such as the intensity of usage and climate, the building in the US with a hypothetical EUI of 465 Kwh/m2/y performs better than 56% of similar existing office buildings in the US.

Based on the average EUI in each existing office building stock and based on the differences in these averages expressed by coefficients, one would expect the case study building, once normalized for its additional factors, to perform better than 56% of similar existing office buildings in Austria. Based on this assumption, which has of course substantial limitations in its statistical accuracy, one could conclude that the case study building which is slightly above average in Austria performs better than 83% of similar existing office building in the US, thus granting it a substantial advantage when being benchmarked against US buildings.

The assumption is of course limited as it is only based on an average value of the EUI in the existing office building stocks of the US, Germany, the UK, France and Austria. One would probably expect that at higher levels of performance the differences in EUI would be relatively smaller, which in turn would lead to smaller differences in performance.

Another way energy performance of a building can be assessed among the different building stocks is through a comparison of source EUI. The source EUI requires a source site energy conversion factor which varies from country to country. The table below represents the source EUI of the case study building when normalized for difference in average energy performance of the different building stocks.

In this case, the source-site energy conversion ratio used for converting the District Heating part is the case study building is the ratio used for the US (1.2) as no data could be found regarding DH source-site conversion ratios for the other countries. The source-source conversion ratio used for converting the electricity part is specific to the country.

Table 27: Source EUI of the case study building normalized for differences in average building performance between the different building stocks

Countries	US	Austria	France	Germany	UK
Site EUI (Kwh/m2/y)	465	325	436	361	364
Source EUI (Kwh/m2/y) with US source-site ratios	1207	844	1131	937	944

Source: CBECS 2003, Statistik Austria 2008, Odyssee 2009, Eurostat 2009

The same methodology applied to table 27 is applied to table 28.

Table 28: Source EUI of the case study building for each country's source-site conversion ratios

Countries	US	Austria	France	Germany	UK
Source EUI (Kwh/m2/y) with country respective source-site conversion ratios	844	933	714	719	766

Source: CBECS 2003, Statistik Austria 2008, Odyssee 2009, Eurostat 2009

This table shows that if the case study building had to use Austrian source-site energy conversion ratios it would not perform as well as if it used US source-site energy conversion ratios.

Table 29: Energy Performance of the case study building for each country's source-site conversion ratios and normalized for differences in average EUI between the different building stocks

Countries	US	Austria	France	Germany	UK
Source EUI (Kwh/m2/y)	1207	933	956	797	856
PM score	56	77	78	86	82
LEED score	0 (no certification)	6	7	13	11

Source: CBECS 2003, Statistik Austria 2008, Odyssee 2009, Eurostat 2009

These tables show that if the buildings could use their country respective source-site energy conversion ratio, the energy performance would be different. If the building was uses the Austria source-site ratio it will perform than if it used the US ratio. Conversely, if the building used French, German or UK source-site ratios, it would perform better. In most cases the use of the national source-site ratios is beneficial for buildings in Europe. However, this is not the case for Austria and a further reason for encouraging buildings in Austria to opt for the US benchmark rather than a local benchmark.

13. Conclusion

This thesis first provided a historical overview of the development of energy performance assessment standards which accelerated after the oil crises of the 70s and marked a turning point for energy efficiency research and policies. Such efforts first focussed on new constructions before gradually leading to the emergence of Green Building certifications. The development of energy standards and energy performance assessment tools in Europe reflected the needs of more inward looking markets when compared with the US.

This aspect was further reflected in the types of assessment methods used in European Green Building certifications when compared with the US. Europe priviledges absolute standards whereas the US priviledges relative standards.

The following analysis of both Portfolio Manager and CBECS, which form the basis of the energy performance assessment component of LEED EBOM, explains in detail how this relative standard is applied.

It is then deduced from this analysis but only after carefully examining the different compliance paths offered in EAC1, that in order to determine the best strategy to follow for existing office buildings in Austria wishing to achieve the maximum number of points under EAC1, a comparison of the energy performance of the building stocks of Austria and the US must be made.

Such a comparison, although limited to a comparison of the average EUI of both existing office building stocks due to the lack of data, is undertaken in section 10. The assumption which followed on from this comparison was that, on average, existing office buildings in Austria perform better than similar existing US office buildings.

This assumption forms the basis for the strategy proposed in section 10. The strategy involves existing office buildings in Austria being benchmarked against similar US existing office buildings in order to achieve a scorer than if they were to be benchmarked locally.

Finally, the case study serves to validate the chosen strategy. The average EUI in the existing office building stock comparison is extended to France, Germany and the UK. The assumption based on this comparison is also extended to include source energy based both on US source-site energy conversion ratios as well as the source-site energy conversions of each respective building stock.

The results show that prospective existing office buildings from France, Germany and the UK are better off being benchmarked against American buildings. Nevertheless, the results indicate that the score would be even higher if project buildings in France, the UK and Germany were allowed to use their own source-site energy conversion ratios. Interestingly in that scenario, buildings in Austria would perform worse.

The case study demonstrates based on differences in average site EUI and source EUI in the respective building stocks of Austria and the US, that on average an existing office building in Austria would manage a higher score if using the US benchmark rather than using a local benchmark. The case study furthermore demonstrates that it is advantageous for existing office buildings in Austria to be benchmarked against similar American buildings using US source-site energy conversion ratios rather than Austrian ones.

Due to firstly limitations in the scope of research, secondly present limitations to the data to be overcome by generation of newer data and thirdly constant data revisions, it is worthwhile to offer a few guidelines for future research on the same topic.

The first guideline would be to repeat the basic comparison made in this study with data from CBECS 2014 and looking at the new LEED EBOM v4. Data for CBECS

2014 should be available by the second half of 2015. LEED EBOM v4 is presently on the market.

Another guideline would be to focus the research on one comparative statistical analysis of CBECS with another European survey. The study would be insightful in terms of providing a detailed picture of both building stocks and indentifying differences in the types of factors affecting performance in both surveys as well as the degree to which these factors would be affect performance. In addition, a comparison of the energy performance of the building stock at different levels of performance would enable to us to know with more certainty and precision whether the use of a local benchmark is warranted or not. This work could be beneficial to both project owners and decision makers, whether from the USGBC or from Europe. This study would only be possible if data from one of the European surveys would be made available for the purpose of research. This might be foreseeable either working in collaboration with a third party who would interested in the study and would be ready to finance the access to the data or in collaboration with the Building Performance Institute of Europe (BPIE) who might also be interested in such a study.

A final research suggestion would be to investigate strategies for developing a European wide benchmarking system. For this, close collaboration with the BPIE would be needed.

A direct conclusion from this study is that existing office building projects in Austria ought to make use of the US benchmark or option 1 of EAC1. The study concludes that in Austria it is advantageous to do so. This conlusion, based on the assumption of this thesis, extends to all existing office buildings in France, Germany and the UK.

Based on the underlying assumption of this thesis, which presents some limitations[59], the existing office buildings stock of France, Germany, the UK and Austria perform better on average than the existing office building stock of the US.

Therefore, this thesis recommends that the Member States of the EU develop a European benchmarking system to compete with the system used by LEED. This would involve either nationwide surveys of the energy consumption of existing commercial buildings or a European wide survey.

Nationwide surveys are already present in some countries in Europe. In fact, all countries studied in this thesis, have developed nationwide surveys. However, these surveys are not yet freely available to the public. The reason for this is that voluntary Green Building labels are not yet very popular in Europe. Moreover most European countries have centralized regulations and markets with large public actors competing in them, which do not tend to encourage the development of voluntary Green Building labels. As a result, the Green Building labels of France and Germany use absolute standards and although the UK label uses a relative standard, the standard is simulated to an average or simulated to a building code. In the US, instead of having a minimum energy efficiency threshold which must be reached by all, LEED rewards the best performers as relative to the other performers. If granted the recognition and legitimacy for fulfilling the global moral principle of protecting the environment, LEED becomes a pure product of the market. This is to a large to extent the reason why LEED has grown in popularity so quickly. It is not only recognized by the markets as having acquired a sufficient level of legitimacy but it also adapted its assessment structure to the market.

Building nationwide surveys and allowing access to the public would encourage first and foremost the creation of national benchmarking systems and secondly might also encourage the creation of a European wide survey. Such data gathering would

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[59] Limitations are explained in Chapter 12.1

be beneficial to creating competitive European labels, domestically and internationally.

There are currently two main incentives for European projects, wishing to get certified by a Green Building label, for opting for LEED rather than a French, UK, German or Austrian label. First of all, LEED is more popular than the other labels and therefore tends to certify projects wishing to attract international recognition. Secondly, as this study has illustrated, the existing office buildings of the European countries looked at tend, to be more energy efficient on average than similar US buildings and therefore tend to fairly easily achieve a high score in the energy performance credit.

As European projects have a strong incentive to apply for LEED certification rather than a European label, policy makers whether at the European level or at the national level ought to make use of the energy efficiency advantage of European existing commercial buildings, as illustrated by the relatively low EUI of the existing office building stocks of France, Germany the UK and Austria, by creating nationwide or European wide voluntary benchmarking systems. Such systems, by virtue of their higher energy efficiency standards and larger domestic market, could compete with LEED internationally.

According to Arcipowska from the BPIE, who is in charge of creating a Europan wide database for building performance, Europe is leaning towards a system of benchmarking at the national rather than at the European level. This might, however, be the first step towards a European wide benchmarking system.

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15. Index of tables

16. Annexes

16.1. Annex 1

List of Energy and Atmosphere credits	Acronym	Number of points
Energy efficiency best management practices - planning, documentation and opportunity assessment	EAp1	Required
Minimum energy efficiency performance	EAp2	Required
Fundamental refrigerant management	EAp3	Required
Optimize energy efficiency performance	EAc1	Up to 18 points
Existing building commissioning - investigation and analysis	EAc2.1	Up to 2 points
Existing building commissioning - implementation	EAc2.2	Up to 2 points
Existing building commissioning - ongoing commissioning	EAc2.3	Up to 2 points
Performance measurement - building automation system	EAc3.1	1 point
Performance measurement - system-level metering	EAc3.2	Up to 2 points
On-site and off-site renewable energy	EAc4	Up to 6 points
Enhanced refrigerant management	EAc5	1 point
Emissions reduction reporting	EAc6	1 point

16.2. Annex 2

EAC1 Credit Description

Optimize Energy Efficiency Performance

	EBOM
Credit	EA Credit 1
Points	1-18 points

Intent

To achieve increasing levels of operating energy performance relative to typical buildings of similar type to reduce environmental and economic impacts associated with excessive energy use.

Requirements

Case 1. Projects eligible for Energy Star rating

For buildings eligible to receive an energy performance rating using the EPA's ENERGY STAR's Portfolio Manager tool, achieve an energy performance rating of at least 71. If the building is eligible for an energy performance rating using Portfolio Manager, Option 1 must be used.

The minimum energy cost savings percentage for each ENERGY STAR threshold is as follows:

EPA ENERGY STAR Energy Performance Rating	Points
71	1
73	2
74	3
75	4
76	5
77	6
78	7
79	8
80	9
81	10
82	11
83	12
85	13
87	14
89	15
91	16
93	17

95	18

Achieve energy efficiency performance better than the minimum requirements listed above; points are awarded according to the table below.

Have energy meters that measure all energy use throughout the performance period of buildings to be certified. Each building's energy performance must be based on actual metered energy consumption for the LEED project. A full 12 months of continuous measured energy data is required.

Calibrate meters within the manufacturer's recommended interval if the building owner, management organization or tenant owns the meter. Meters owned by third parties (e.g., utilities or governments) are exempt.

Case 2. Projects not eligible for Energy Star rating

For buildings with a primary space type not eligible to receive an energy performance rating using Portfolio Manager, comply with 1 of the following:

Option 1

Demonstrate energy efficiency performance that is better than 71% of similar buildings (71st percentile or better) by benchmarking against national source energy data provided in the Portfolio Manager tool as an alternative to energy performance ratings. Projects outside the U.S. may use a local benchmark based on source energy from their country's national or regional energy agency. Follow the detailed instructions in the LEED Reference Guide for Green Building Operations & Maintenance, 2009 Edition.

OR

Option 2

For buildings not suited for Case 2, Option 1, demonstrate energy efficiency performance by determining an alternative rating score using the Portfolio Manager tool to report the building's energy use data from the performance period. Follow the detailed instructions in the LEED Reference Guide for Green Building Operations & Maintenance, 2009 Edition.

Option 2a. Streamlined baseline (EAp2 only – 0 points)

This option is only available through EAp2. Enter energy use data during the performance period for at least 1 year into Portfolio Manager to determine the "weather-normalized source energy intensity". Use this value in the offline calculator to determine the percent reduction from the streamlined baseline.

Option 2b. Energy baseline including historical data (up to 9 points)

Enter at least 3 consecutive years of historical energy use data into Portfolio Manager in addition to the current year's data to determine the "weather-normalized *source energy intensity" for each year. Use these values in the offline calculator to determine a baseline using the historical energy use data of the project building.*

Option 2c. Energy baseline including historical data plus comparable buildings (up to 18 points)

In addition to the historical data used in Option 2b, provide energy use data for at least 3 other buildings with similar uses over at least a 2-year period to determine the "average energy performance of a similar building" in Portfolio Manager. Enter this data into the offline calculator.

AND

Achieve energy efficiency performance better than the minimum requirements listed above; points are awarded according to the table below.

Have energy meters that measure all energy use throughout the performance period of all buildings to be certified. Each building's energy performance must be based on actual metered energy consumption for both the LEED project and all comparable buildings used for the benchmark. A full 12 months of continuous measured energy data is required.

Calibrate meters within the manufacturer's recommended interval if the building owner, management organization or tenant owns the meter. Meters owned by third parties (e.g., utilities or governments) are exempt.

Use the Portfolio Manager tool available on the ENERGY STAR website to benchmark the project even if it is not eligible for an EPA rating: http://www.energystar.gov/benchmark.

Percentile level above the national median (for buildings not eligible for ENERGY STAR energy performance rating)	Points
21	1
23	2
24	3
25	4
26	5
27	6
28	7
29	8
30	9

31	10
32	11
33	12
35	13
37	14
39	15
41	16
43	17
45	18