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Energy and atmosphere standards for sustainable design and construction in different countries

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ABSTRACT

The "energy and atmosphere" category of LEED accounts for 32% of the total points and heavily depends on U.S. standards such as ANSI/ASHRAE/IESNA. Difficulties arise when LEED is implemented in different countries, because of varying degrees of similarity of local standards to U.S. standards. In some countries, these standards may range from non-existent to locally developed instruments, while U.S. standards are preferred in some. The existing codes, standards, and regulations that are in effect in India, Abu Dhabi, and Turkey, and used in the relevant category of LEED are reviewed relative to their U.S. counterparts. It is found that in India, the ECBC combines local conditions with international standards; in Abu Dhabi, ESMA and ADQCC make sure the geographic conditions prevalent in that part of the world are reflected in the codes and regulations; in Turkey, the new BEP Code constitutes a significant step towards energy conservation. This study shows that the standards that are in effect in the subject countries have adapted U.S. and U.K. standards to local conditions and are in different stages of development. The variety in the quality, substance, and coverage of the standards make it difficult to implement green building certification systems in these countries.

1. Introduction

In order to achieve sustainable buildings, it is necessary to use design principles, construction materials and methods, and operational procedures that minimize negative environmental impacts throughout all the construction project phases of planning, designing, constructing, and operating [1–3]. For the effective management of these efforts, industrialized countries with consistent and well regulated industries have developed their own green building guidelines and certification systems in the last two decades based on established technical standards [4–7]. With the demand of international investors, as well as the demands of sophisticated buyers who are sensitive to sustainability issues, a growing portion of the construction industry in many countries has attempted to adopt the green building guidelines introduced by industrialized countries.

Green building certification systems rely on measurement efforts that involve metrics and processes that allow analysts to assess the level to which sustainability objectives are achieved within the scope defined by the owner and designer. Performance measurement requires the existence of well-defined requirements that address the specific issues of sustainability [8]. Standards play an important role in directing this effort. It should be noted however that standards do not function as solutions to problems, but as guidelines for practitioners to produce solutions to problems [9]. For successful application, standards need to be clear about goals, but comprehensive about scope, flexible for dealing with uncertainty, and supportive of continuous improvement [10]. Also, although government agencies play a critical role in setting up and promoting national standards [11], the success of standards is limited by their acceptance in the industry and by the extent to which they are implemented in practice [12].

Energy regulations and certification are two mechanisms that require quantifying a building's energy consumption and impact. Energy assessment tools are used to quantify energy consumption while energy certification promotes energy performance standards [13].

In LEED 2009 NC, the "energy and atmosphere" category includes three prerequisites (no points assigned) and six credits (a total of 35 points) that are listed in Table 1 with the standards that they use. Despite LEED's expanding global use, it should be noted

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Table 1
The "Energy and Atmosphere" category of LEED 2009 new construction.

Prerequisites and credits									Points	Referenced standards
Prerequisite 1—fundamental commissioning of building energy systems									–	None
Prerequisite 2—minimum energy performance									–	ANSI/ASHRAE/IESNA Standard 90.1-2007: Energy Standard for Buildings Except Low-Rise Residential ASHRAE Advanced Energy Design Guide for Small Office Buildings 2004 ASHRAE Advanced Energy Design Guide for Small Warehouses and Self Storage Buildings 2008 ASHRAE Advanced Energy Design Guide for K-12 School Buildings New Building Institute, Advanced Buildings Core Performance Guide Energy Star Program, Target Finder Rating Tool
Prerequisite 3—fundamental refrigerant management									–	U.S. EPA Clean Air Act, Title VI, Section 608, Complies with the Section 608 Refrigerant Recycling Rule
Credit 1—optimize energy performance									0–19	ANSI/ASHRAE/IESNA Standard 90.1-2007: Energy Standard for Buildings Except Low-Rise Residential, and Informative Appendix G, Performance Rating Method
Imp: New Bldg. (%)	Imp: Existing Bldg. (%)	Pt. (%)	Imp: New Bldg. (%)	Imp: Existing Bldg. (%)	Pt.	Imp: New Bldg. (%)	Imp: Existing Bldg. (%)	Pt.		ASHRAE Advanced Energy Design Guide for Small Office Buildings 2006
12	8	1	26	22	8	38	34	14		ASHRAE Advanced Energy Design Guide for Retail Buildings 2006
14	10	2	28	24	9	40	36	15		ASHRAE Advanced Energy Design Guide for Small Warehouses and Self Storage Buildings 2008
16	12	3	30	26	10	42	38	16		
18	14	4	32	28	11	44	40	17		ASHRAE Advanced Energy Design Guide for K-12 School Buildings
20	16	5	34	30	12	46	42	18		New Building Institute, Advanced Buildings Core Performance Guide
22	18	6	36	32	13	48	44	19		
24	20	7								
Credit 2—on-site renewable energy									0–7	ANSI/ASHRAE/IESNA Standard 90.1-2007: Energy Standard for Buildings Except Low-Rise Residential
Renewable energy (%)		Pt.	Renewable energy (%)		Pt.	Renewable energy (%)		Pt.		
1		1	7		4	11		6		
3		2	9		5	13		7		
5		3								
Credit 3—enhanced commissioning									2	None
Credit 4—enhanced refrigerant management									2	None
Credit 5—measurement and verification									3	International Performance Measurement and Verification Protocol, Volume III, EVO 30000.1-2006, Concepts and Options for Determining Energy Savings in New Construction
Credit 6—green power									2	Center for Resource Solutions, Green-e Product Certification Requirements
Total									35	

that the energy and atmosphere requirements have been prepared for the U.S. construction environment. LEED refers to U.S. energy codes and standards that do not exist in other countries, resulting in difficulties in the implementation of these credits in other countries even though it accounts for regional priorities.

The objective of this study is to review and discuss the status of local standards used in country-specific systems in India, Abu Dhabi, and Turkey relative to the "energy and atmosphere" category of LEED. Local standards may not exist, may be adopted from U.S. or other advanced countries' standards, or may have been developed based on the particular conditions of a country. A comparison of existing codes, standards, and regulations in India, Abu Dhabi, and Turkey is expected to question the applicability of sustainability principles in the said countries, and shed light on similar situations in other countries. The objective is to investigate the consequences of these different implementations in the hopes that the results will benefit sustainability efforts in these and other countries.

2. Standards used in green building certification

The green building certification systems used in countries interested in sustainability issues are often systems such as LEED and BREAM that have been developed in the U.S. and the U.K., respectively. There are some countries that have developed their own certification systems. There are also some countries where the guidelines in these systems are adaptations of certification systems used in advanced countries.

Regardless of the country where a green building certification system is used, assessments of sustainable practices during design (site selection, selection of materials, energy-efficient design, etc.), construction (project management, resource use, construction methods, etc.), and operation (energy use, water use, indoor environmental quality, etc.) need to be performed, which require adequate standards [14]. For example, as a prominent certification system, LEED heavily depends on codes, standards, and regulations that are in effect in the U.S., such as ANSI, ASHRAE, and IESNA. However, codes, standards, and regulations in some countries may or may not be similar to U.S. standards. Particularly in developing countries, codes, standards and regulations may range from non-existent to locally developed instruments, while U.S. standards are preferred in some.

The development of standards is a complex process. For example, the development process in Canada involves development of technical content by experts, development of technical details by participants, and reaching consensus between contributing parties. The process follows the steps of request, assignment of a committee, notice of intent, meetings, public review and editions, technical approval, procedural approval and final edition [15]. In the U.S., standards are introduced by professional organizations such as ANSI, ASTM, ACM, AISC, are used in the implementation of local building codes, are adopted as regulations after they are proven to be practical, and some become mandatory federal standards. For example, LEED is a de facto mandatory standard because the federal government requires that all its buildings be LEED certified [16]. In the European Union, proposals are introduced by interested parties to technical bodies, developed by experts, presented to the public for comments, reviewed and refined on the basis of these comments, submitted for voting, and published once approved [17]. Given the different local conditions, despite the complexity of the process, different standards are developed in different countries, some starting from scratch, but most adapting established standards such as ASHRAE's to accommodate local conditions.

The principles and priorities used in developing a standard have an important role in designers meeting the target of the standard. Standards directly specify the methods of measurement [18]. For example, in order to balance environmental and economic concerns, LEED promotes an energy cost budget, which converts energy use into energy cost for different kinds of fuels [19]. Since, LEED refers to ASHRAE Standard 90.1 Appendix G for sustaining energy efficiency, the standards in various countries refer to this ASHRAE standard or to a locally developed standard that may or may not have used energy cost budgeting [20].

Alternative solutions have been proposed in some countries to the relativity and noncomparability in issues such as energy use and related greenhouse gas emissions. One such solution is crediting performance instead of meeting general codes and standards. For example, in the European Union, member states provide energy performance certificates for high performance buildings based on a minimum standard defined by the EU Energy Performance of Building Directive [14]. Also, for accommodating local conditions, one of the subject countries of this paper (i.e., Turkey) has developed a national energy code based on EU's Energy Performance of Building Directive, ASHRAE standards, and standards independently created by the Turkish Standards Institute [7,21,22].

Relying on a variety of standards that are in effect in various countries may be a problem in implementing LEED in these counties. Indeed, difficulties have been encountered when LEED is implemented in different countries where different standards are in effect [7,22,23]. In the following sections, the existing codes, standards, and regulations about "energy and atmosphere" that are in effect in India, Abu Dhabi, and Turkey are reviewed and compared against U.S. standards.

2.1. Comparison of the standards used in LEED 2009 NC and LEED-India NC with respect to the "Energy and Atmosphere" category

India is among the first countries that have adapted LEED to local requirements and based on Indian construction needs [4,23,24]. While LEED 2009 NC [25] refers to the latest U.S. EPA codes and methods, and to the ANSI/ASHRAE/IESNA standards to sustain the levels required for certification (Table 1), LEED-India NC [26] has a shorter list of standards to be met, and refers to the previous versions of the U.S. standards (Table 2). At first sight, it looks like referring to fewer and older standards place LEED-India NC behind LEED 2009 NC. It should be noted however that LEED-India NC also refers to the Energy Conservation Building Code (ECBC) introduced in 2007 by the India Bureau of Energy Efficiency (BEE) [22,27,28]. India's Bureau of Energy Efficiency states that air conditioning and lighting are the top two drains for building energy use, and that with proper interventions, a progress of 20% for existing buildings and 40% for new buildings may be achieved [27]. This code was developed by domestic stakeholders as well as international professionals, some of whom are members of ASHRAE committees. Thus, the code meets U.S. standards but also considers India's local conditions. This is important in the adaptation of LEED 2009 NC to Indian conditions. LEED-India NC [26] introduces its own methods of calculation for some of the credits, which are brief in nature and easy to use. Some of these methods, such as the Green Power Credit require and thus encourage investment in renewable energy production.

One of the major differences between LEED 2009 NC and LEED-India NC is the sensitivity of the assignment of the points in energy credits in the items "Optimize Energy Performance" and "On-site Renewable Energy". Although both rating systems place equivalent emphasis on these credits, LEED 2009 NC sets increments in narrow intervals so that small changes in the values can be assessed, whereas LEED-India NC sets wider intervals and neglects the values in between. Similarly, the minimum thresholds for these two credits show significant difference. LEED 2009 NC requires higher performance in new buildings and more pronounced improvement in existing buildings. Considering the local conditions in India, the values set in LEED-India NC may be regarded as adequate, but these thresholds need improvement for meeting international recognition.

As a nation with high economic growth with a sustained increase in gross built-up area of 10% per annum in construction over the last decade [29], India faces major energy problems in terms of both quantity and equity. The growing energy consumption points to important impacts on the environment [30]. As a result, LEED-India NC emphasizes the Energy and Atmosphere category which has the highest point that can be earned by any category. Although the India Green Building Council (IGBC) acts as an independent non-profit organization and certifies buildings, the certification process refers to the Energy Conservation Building Code on many aspects. However, compliance with this code is still voluntary [31], which weakens the influence of the certification system in the industry.

A major barrier in the implementation of energy reduction measures in India is the large number of governmental entities (i.e., states), and the large number of climate zones. Many seats of authority and different implementations of codes reduce the universal acceptance of energy conservation practices. The existence of five different climate zones from cold to hot-dry [28] affects the energy consumption of buildings and the use of renewable energy. Without adequate guidelines, sustaining the code or implementing the rating system is nearly impossible. These two issues need proper attention in the certification system.

2.2. Comparison of the standards used in LEED 2009 NC and Abu Dhabi ESTIDAMA pearl building rating system with respect to the "Energy and Atmosphere" category

As seen in Table 2, the Abu Dhabi ESTIDAMA pearl building rating system [32], similar to LEED 2009 NC, refers to ANSI/ASHRAE/IESNA standards and the requirements of the Center for Resource Solutions. In addition to these, it refers to the ASTM standards. Abu Dhabi benefits from the consultancy of European companies and institutions, and thus the metering standards introduced by the Chartered Institute of Building Services Engineers (CIBSE), a British institution.

Abu Dhabi, located along the Persian Gulf and with its relatively high temperatures, has a hot/humid to hot/dry climate. In addition, the potable water is supplied by desalination [33]. The chronic water shortage puts heavy loads on the energy supply [29]. All these factors point to high rates of electric consumption both for air conditioning and desalination, thus CO_2 emissions. As a result of rapid development, annual CO_2 emissions have increased by 80% in Abu Dhabi between 1970 and 2004 [34]. Although the vernacular building design approaches are well adjusted to the local conditions, the new buildings of contemporary life bring loads to both the grid and the environment. On the other hand, Abu Dhabi is shifting from

Table 2
Standards Used in LEED-India NC, Abu Dhabi ESTIDAMA pearl building rating system: Design & Construction, Version 1.0, and Turkish National Green Building Certification - Homes with respect to the "Energy and Atmosphere" category.

LEED-India NC			Abu Dhabi ESTIDAMA Pearl Building Rating System: Design & Construction, Version 1.0			Turkish National Green Building Certification - Homes		
Energy and Atmosphere			Resourceful Energy			Energy Use		
EA Prerequisites and Credits	Pt	Referenced Standards	Requisites and Credits	Pt	Referenced Standards	Requisites and Credits	Pt	Proposed Standards
EA Prerequisite 1-Fundamental Building Systems Commissioning	–	N/A	–	–	–	Operational Setup	–	The Ministry of Environment and Urbanization, the Code for Building Energy Performance (BEP)
EA Prerequisite 2-Minimum Energy Performance	–	ASHRAE/IESNA Standard 90.1—2004 Sections 5.4, 6.4, 7.4, 8.4, 9.4 and 10.4 ASHRAE/IESNA Standard 90.1—2004 Sections 5.5, 6.5, 7.5, and 9.5	RE-R1—Minimum Energy Performance	–	ANSI/ASHRAE/IESNA Standard 90.1-2007: Energy Standard for Buildings Except Low-Rise Residential	–	–	The Ministry of Environment and Urbanization, the Code for Building Energy Performance
EA Prerequisite 3—CFC Reduction in HVAC&R Equipment	–	Regulated by LEED-India NC itself.	RE-R3—Ozone Impacts of Refrigerants & Fire Suppression Systems	–	N/A	–	–	The Ministry of Environment and Urbanization, the Code for Building Energy Performance Turkish Standard TS EN 378 "Standard for Refrigerating Systems and Heat pumps—Safety and Environmental Requirements" The European Commission Directive 97/23/EC

Table 2 (*Continued*)

LEED-India NC					Abu Dhabi ESTIDAMA Pearl Building Rating System: Design & Construction, Version 1.0						Turkish National Green Building Certification - Homes		
Energy and Atmosphere					Resourceful Energy						Energy Use		
EA Credit 1—Optimize Energy Performance	0–10	ASHRAE/IESNA Standard 90.1—2004 Appendix G ECBC (Energy Conservation Building Code) of the Bureau of Energy Efficiency, India ASHRAE Advanced Energy Design Guide for Small Office Buildings 2004 Advanced Buildings Benchmark Version 1.1 Basic Criteria and Prescriptive Measures			RE-1—Improved Energy Performance	0–15	ANSI/ASHRAE/IESNA Standard 90.1-2007: Energy Standard for Buildings Except Low-Rise Residential				Energy Efficiency	–	The Ministry of Environment and Urbanization, the Code for Building Energy Performance Turkish Standard TS 825—Thermal Insulation Requirements for Buildings”
		Savings for new Bldgs. (%)	Savings for Exist Bldgs. (%)	Pt. (%)			Percent reduction (%)	Pt (%)	Percent Reduction (%)	Pt			
		10.5	3.5	1			14.00	1	32.50	9			
		14.0	7.0	2			16.00	2	35.00	10			
		17.5	10.5	3			18.00	3	40.00	11			
		21.0	14.0	4			20.00	4	45.00	12			
		24.5	17.5	5			22.50	5	50.00	13			
		28.0	21.0	6			25.00	6	55.00	14			
		31.5	24.5	7			27.50	7	60.00	15			
							30.00	8					
EA Credit 2—Renewable Energy	0–3	N/A			RE-6—Renewable Energy	0–9	Center for Resource Solutions, Green-e Product Certification Requirements http://www.green-e.org/				Renewable Energy Use	–	The Ministry of Energy and Natural Resources, Law About the Change for the Use of Renewable Energy Resources in Electricity Production
		Renewable Energy Use	Pt.				Percent Required (%)	Pt	Percent Required (%)				
		EA Credit 2.1—2.5% Renewable Energy	1				1	1	10	5			
		EA Credit 2.1—5% Renewable Energy	2				3	2	13	6			
		EA Credit 2.1—7.5% Renewable Energy	3				5	3	16	7			
							7	4	20	8			
							Min. 20% Offsite Renewable Energy			1			

EA Credit 3—Additional Commissioning	1	N/A		–	–	–			Operational Setup	–	The Ministry of Science, Industry and Technology, “Law for the Protection of the Consumer”
EA Credit 4—Ozone Depletion	1	N/A	RE-7: Global Warming Impacts of Refrigerants & Fire Suppression Systems			Pt	–	–	The Ministry of Environment and Urbanization, the Code for Building Energy Performance Turkish Standard TS EN 378 “Standard for Refrigerating Systems and Heat pumps—Safety and Environmental Requirements” The European Commission Directive 97/23/EC		
			Refrigerant	1							
			Refrigerant leak detection	1							
			Refrigerant pump down	1							
			Fire suppression system	1							
EA Credit 5—Measurement and Verification	1	International Performance Measurement & Verification Protocol (IPMVP) Volume III: Concepts and Options for Determining Energy Savings in New Construction, April, 2003.		RE-R2—Energy Monitoring & Reporting	–	GIL 65: Metering Energy Use in New Non-Domestic Buildings CIBSE TM39 2009: Building Energy Metering			Energy Efficiency Verification	–	The Ministry of Environment and Urbanization, the Code for Building Energy Performance ANSI/ASHRAE/IESNA Standard 90.1-2007: Energy Standard for Buildings Except Low-Rise Residential

Table 2 (*Continued*)

LEED-India NC				Abu Dhabi ESTIDAMA Pearl Building Rating System: Design & Construction, Version 1.0						Turkish National Green Building Certification - Homes		
Energy and Atmosphere				Resourceful Energy						Energy Use		
EA Credit 6—Green Power	1	Regulated by LEED-India NC itself.		–	–	–				Green Energy	–	N/A
–		–		RE-2—Cool Building Startegies	6	ASTM E1980—01 Standard Practice for Calculating Solar Reflectance Index of Horizontal and Low-Sloped Opaque Surfaces ASTM E1918-06—Standard Test Method for Measuring Solar Reflectance of Horizontal and Low-Sloped Surfaces in the Field ASTM C1549-09—Standard Test Method for Determination of Solar Reflectance Near Ambient Temperature Using a Portable Solar Reflectometer ASTM E 408-71(2008)—Standard Test Methods for Total Normal Emittance of Surfaces Using Inspection-Meter Techniques ASTM C1371-04a, Standard Test Method for Determination of Emittance of Materials Near Room Temperature Using Portable Emissometers						
		RE-3—Energy Efficient Appliances	3			N/A				Energy Efficient Appliances	–	N/A
		RE-4—Vertical Trans-portation	3	SLL CIBSE Code for Lighting				Elevators	–	N/A		
		RE-5—Peak Load Reduction	0–4	N/A				–	–	–		
				Peak Load Compared to Design	Pt.	Peak Load Com-pared to Design	Pt.					
				80%	2	60%	4					
		–	–	–					Exterior lighting	–	N/A	
Total points	17			Total points	44					Total points	0	

being a city served by cars to a pedestrian-oriented city with adequate amounts of shaded areas, supported with urban furniture and green parks [33]. This is expected to reduce CO_2 emissions via personal transportation, as well as power loads on the grid via public transportation. The city is moving towards a sustainable status. The Abu Dhabi government has announced a sustainability policy in January 2009, which states that 7% of the power capacity should be obtained from renewable sources. According to this policy, an initiative has been created which leads the sustainable energy technologies in Abu Dhabi as well as the whole region [34]. With the PEARL rating system, the Abu Dhabi Urban Planning Council (UPC) [35] has aimed at a higher level of sustainability in terms of energy consumption, which can be achieved by complying with ASHRAE 90.1-2004 [36].

United Arab Emirates has established the Emirates Authority for Standardization and Metrology (ESMA) in 2001 [37]. Also the Abu Dhabi Quality and Conformity Council (ADQCC) has been founded in 2009 to satisfy the quality standard needs oriented to the local conditions [38]. However the number of standards introduced by ESMA and ADQCC is relatively small, thus there is scarcity in the standards needed for the application of a green building rating system. As a result, announced in 2010, the PEARL rating system relies on international standards, especially ANSI/ASHRAE/IESNA and ASTM (Table 2). Abu Dhabi also benefits from the consultancy of European companies and institutions, and thus the metering standards introduced by the Chartered Institute of Building Services Engineers (CIBSE), which is a British institute. However, lack of local energy standards suitable to local environmental and industrial conditions, weakens the likelihood of achieving the benefits claimed by the rating system. Local priorities such as reducing energy consumption by means of natural ventilation or reducing water usage have been neglected to a certain extent. Addressing these issues in the PEARL rating system rather than having compulsory rules in place dilutes the importance of these issues [33].

The energy-related category of ESTIDAMA PBRS refers to standards included in LEED 2009 NC. However, ESTIDAMA PBRS limits the number of standards that are referred to. For example, LEED 2009 NC refers to ASHRAE Advanced Energy Design Guide for Small Office Buildings 2004, for Small Warehouses and Self Storage Buildings 2008, for K-12 School Buildings for Minimum Energy Performance credit, and to the ASHRAE Advanced Energy Design Guide for Retail Buildings 2006 for optimizing energy performance credit, whereas ESTIDAMA PBRS refers to only ANSI/ASHRAE/IESNA Standard 90.1-2007: Energy Standard for Buildings Except Low-Rise Residential. Also, except for the Light Pollution Reduction credit, PBRS does not refer to any of the six international codes published in 2009 by the Department of Municipal Affairs for building, mechanical, energy conservation, fuel and gas, property maintenance, and private sewage disposal issues, even though these codes were introduced before the introduction of ESTIDAMA PBRS [39]. However, PBRS compensates for the lack of reference to U.S. standards and to their own international codes by referring to standards introduced by CIBSE. As an internationally recognized institution, CIBSE standards are competitors of U.S. standards. Metering building performance using CIBSE standards and acquiring consultancy services from CIBSE enhance the performance in these credits. Additionally, PBRS sets the threshold to a higher limit which promises higher performance (Table 2).

A major difference between LEED 2009 NC and ESTIDAMA PBRS is the four new credits introduced by PBRS, which are Cool Building Strategies, Energy Efficient Appliances, Vertical Transportation, and Peak Load Reduction. Thirty six percent of the total points are assigned to these credits which refer to ASTM and CIBSE standards. With these new credits, ESTIDAMA PBRS focuses on a major local priority, which is the temperature, as well as the main sources and time constraints of energy consumption.

2.3. Comparison of the standards used in LEED 2009 NC and Turkish National Green Building Certification—Homes with respect to the "Energy and Atmosphere" category

Since the Turkish National Green Building Certification - Homes is in the very early stages of preparation, methods and standards have not been introduced yet. However, the Code for Building Energy Performance (BEP) prepared by the Ministry of Environment and Urbanization sets an appropriate basis [40]. The code, the latest revision of which has been introduced in 2011, has been prepared using ASHRAE standards and European Commission directives, and sets a high and contemporary level for energy efficiency. The code is highly developed, quite sophisticated and generally meets most contemporary energy standards [7,21,22].

This study evaluates the credits proposed in the Turkish National Green Building Certification - Homes with regards to the above mentioned codes and the standards that are available and/or are in use in Turkey (Table 2). Some of the Turkish standards that are being used currently, such as TS EN 378 "Standard for Refrigerating Systems and Heat pumps – Safety and Environmental Requirements" [41] or TS 825 – Thermal Insulation Requirements for Buildings" may also be of value to the Turkish Green Building Certification System [41,42]. The law for the Protection of the Consumer, introduced by the Ministry of Science, Industry and Technology, may be used for the project owner's protection relative to energy issues. Finally, the Ministry of Energy and Natural Resources has introduced a law on the Use of Renewable Energy Resources in Electricity Production, which has great importance not only for energy policy, but also for building certification [7].

It is quite possible to earn points in the Turkish system from EA credits equivalent to LEED 2009 NC, except from EA Credits 2 and 6, which focus on renewable energy. Although there is a great potential about renewable energy sources in Turkey [43], the production of renewable energy is currently quite limited. In addition to that, LEED 2009 NC requires that the renewable energy source should be verified by a third party recognized by the Ministry of Energy and Natural Resources and the certification institution. However, an energy source verification entity does not exist in Turkey. As a result, the renewable energy sources' qualifications are unknown. The second option, buying Renewable Energy Certificates to prove that the energy bought from a party is renewable, is rarely applicable in Turkey because of the relatively low amount of renewable energy available on the market. In summary, because of the limited production of renewable energy, there are serious problems about the application of this credit in Turkey [7].

EA Credit 1 Optimize Energy Performance in LEED 2009 NC refers to the ASHRAE Advanced Energy Design Guide which sets climate zones for the U.S. and recommends separate actions for these zones, similar to the regional priorities category of LEED 2009 NC [25]. Although there is a wide range of climates in Turkey, from hot-dry to warm-humid, there is no standard that classifies these climates and that lists the proper actions. Thus Turkish standards and certification credits need to match climate zones [7].

The study of energy-efficient buildings has a long history in major universities in Turkey [44,45]. According to Karabulut et al. [46], fourteen Turkish universities have started Master's and PhD programs in renewable energy, especially in colleges of engineering, focusing on solar, wind, geothermal and hydraulic energy. As of 2011, 73% of the 42 colleges of architecture have core courses about the environment and sustainability. Additionally, 93% of the 30 master of architecture programs offer elective courses that deal with sustainability issues [47]. In addition, several local and national professional associations have organized yearly workshops, conferences, and symposia since 2005.

The main issue for the Turkish National Green Building Certification - Homes is that the standards and laws mentioned are quite general in nature and do not include implementation methods. Additionally, laws are mandatory, thus compliance with the law is expected, but does not satisfy the credit point assignments for certification. Establishing independent verification entities, encouraging educational institutions to teach and research sustainability-related issues, and recognizing the different conditions in different regions are critical for a viable certification system in Turkey.

Resolving these issues should greatly satisfy the expectations of not only local stakeholders, but also of international investors and building occupants.

3. Conclusion

Buildings are responsible for 50% of the energy consumption and CO_2 emissions in the world [48,49]. Driven by concerns about sustainability, buildings' energy performance must be evaluated at all stages from construction to demolition. However, evaluating building performance is a multi-dimensional endeavor including social, economic, environmental and technological aspects [50,51]. Thus, codes, standards, regulations, and guidelines are needed in this evaluation process. The following conclusions are reached about the subject countries based on the detailed comparison presented in Table 2:

- The Energy Conservation Building Code, which LEED-India-NC refers to frequently, combines local conditions with international standards. However, voluntary compliance weakens its influence.
- The PEARL rating system developed in Abu Dhabi makes use of codes and regulations mandated by the Emirates Authority for Standardization and Metrology (ESMA) and the Abu Dhabi Quality and Conformity Council (ADQCC); these agencies make sure that the geographic and weather conditions prevalent in that part of the world are reflected in the codes and regulations. The sustainability policy supported by the government is promising in terms of energy consumption and sustainable energy technologies.
- Although the Abu Dhabi Department of Municipal Affairs has introduced the International Energy Conservation Code, ESTIDAMA PBRS refers directly to it in only one single credit, LBo-10: Light Pollution Reduction. The eight bioclimate zones defined in the code have not been taken into consideration, except for that credit.
- Both India and Abu Dhabi have adapted LEED 2009 NC to local conditions, but ESTIDAMA PBRS has more extensive modifications and additions [23,24]. Although certification systems rely on several international standards, local conditions and priorities are generally considered to promote energy efficiency.
- Turkey, on the other hand, is a developing country with increasing demand for resources [52], and is at the start of the sustainability journey. Nevertheless, the recent Code for Building Energy Performance constitutes a significant step for energy conservation not only for certification but for the construction industry as a whole.

Different standards with different content in different countries create problems in measurement methods and consequently in the implementation of green building certification systems. Uniformity can be achieved if measurement methods are specified in internationally accepted universal standards. However, according to Trinius and Sjoström [9], one of the important problems of universal standards is the contradiction between stating too much detail that limits local applications in different countries, and setting little detail that forces users to look for additional guidelines. Adopting established standards that are developed for a specific country (e.g., for the U.S., or for the U.K.) will require extensive adaptation relative to climate, income level, building materials and techniques, building stocks, etc. [53,54]. Melo et al. [55] claim that many countries attempt to develop their own building energy efficiency standards based on the approach taken by ASHRAE Standard 90.1. For example, concerning climate implications, similar to ASHRAE Standard 90.1's eight climate zones, the Energy Conservation Building Code in India defines five climate zones [28]. In Turkey, four climate zones defined by the Turkish standard TS825 have been used in the Code for Building Energy Performance [42]. The Abu Dhabi International Energy Conservation Code proposes eight climate zones to regulate the minimum energy conservation requirements for new buildings [39,56]. The Chinese design standard for energy efficiency of public buildings, compliance to which is mandatory, serves as the national standard, much like the International Energy Conservation Code or ASHRAE Standard 90.1 in the U.S. The Chinese standard adopts five climate zones defined by the national standard GB 50176-93 [18]. In 2005, Brazil has proposed eight bioclimatic zones in its national standard NBR15520-Part 3 for evaluating the performance of buildings and their systems [57].

Although a unified approach and standard measurement scale provide the opportunity to compare energy performance across countries [53], introducing a set of internationally acceptable universal standards to be used all over the world is a very hard endeavor and the results are likely to be impractical. Since the content, jurisdiction, and implementation of standards inevitably vary from country to country, the language and measurement methods proposed in local standards should be simple and direct with well-defined performance indicators that fit well the local environment.

This study is expected to draw attention to the standards that are in effect in the subject countries relative to energy and atmosphere issues. The intent is not only to expose the standards-related problems in these countries, but also to function as guideline for other countries. This study contributes to the sustainability efforts of professionals in different countries. These professionals are expected to benefit from this study by deliberately creating new codes, standards and regulations, or adjusting the existing codes, standards and regulations to reflect the local conditions in their respective environments, and to facilitate the implementation of sustainability principles in their respective countries.

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