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Applicability of LEED's energy and atmosphere category in three developing countries

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ABSTRACT

The construction industry consumes a significant amount of energy. Heavy consumption of energy results in sustainability problems. Sustainable building projects need to manage their energy consumption in all the phases of construction, including production and transportation of materials and equipment, performance of construction activities, and operation and maintenance. Leadership in Energy and Environmental Design (LEED) is one of the most extensively used green building certification systems around the world. In this system, the "energy and atmosphere" category accounts for 32% of the points that a building can receive. Some countries apply LEED and some have modified it by taking into account regional conditions. Existing inspection agencies, standards, adversities encountered in usage, education, technical know-how, experience, and renewable energy supply are reviewed with respect to "energy and atmosphere" in India, Abu Dhabi, and Turkey, and are compared against the situation in the U.S. The study finds that India has slightly modified the U.S. system, Abu Dhabi has developed its own certification system, and Turkey appears to be in the early stages of developing a certification system. The findings indicate that the differences between countries stem from the differences in the standards, laws, and regulations that are in place in the respective countries. While mostly U.S. standards are used in India, proprietary standards have been created in Abu Dhabi to accommodate the local conditions, and Turkey is struggling to find the middle way. The study is expected to function as a guideline for other developing countries in the process of setting up their certification systems.

1. Introduction

"The green building" concept was developed in the 1970s to design and construct sustainable buildings [1,2]. Since construction activities can be the source of adverse impacts on the environment, energy efficiency should be one of the most important factors that should be incorporated into the design and construction processes for sustainability, as several researchers claim that energy efficient design can reverse the impacts of global warming [3]. Overall, researchers agree that the driving objective of energy-efficient design is to minimize or eliminate the negative impacts on the environment, natural resources and nonrenewable energy sources.

Energy consumption is the most significant environmental impact of buildings over their life cycle. Buildings consume 30–40% of all primary energy worldwide [4]. They are the single source of carbon emissions, which account for 50% of total emissions [5]. Energy use in buildings comprises the energy used in the production and transportation of construction materials, and the energy used for the building's construction, operation, and demolition [6]. According to Rowings and Walker [7], the distribution of energy use was 28.5%, 36.8%, and 34.7% in the pre-construction, construction and post-construction phases of an embankment project, respectively. Hong et al. [8] found that during the construction phase, material manufacturing consumes almost 95% of the energy while the remaining 5% was consumed in the transportation of materials and on-site construction activities. Guggemos and Horvath [9] calculated that the structural frame accounted for 42% of the energy consumption in the on-site construction activities.

The steady increase in the energy consumption of buildings has already exceeded the energy consumption levels by the industrial and transportation sectors [10]. Indeed, according to the

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International Energy Agency [11], the construction industry consumes 47% of the energy produced, whereas its closest competitor, the industrial sector uses only 28%. Therefore, the improvement of energy efficiency in buildings has become essential to ensure an adequate energy supply in the future [12]. Although legislative measures driven by sustainability policies play a leading role, voluntary standards and building rating systems have been introduced by non-governmental entities [13]. These rating systems focus on energy use, indoor environment and general environmental effects in order to evaluate the impact of these issues on the global environment and on human health [14]. Many countries put out a considerable amount of effort to develop their own standards, many of which are based on the approach of ASHRAE Standard 90.1-Energy Standard for Buildings Except Low-Rise Residential Buildings [15]. However, achieving the desired level of savings depends on the approach used for measuring energy use and/or cost in the standards [16].

LEED is generally based on practices, codes, and regulations that are currently in effect in the U.S. Different energy regulations and certification systems are used in different countries to control energy efficiency and consumption in building construction and operation. Although many certification systems such as BREEAM, CASBEE, SBTOOL, and GREENSTAR have been developed in different countries for rating buildings, LEED was developed by the U.S. Green Building Council (USGBC) and has established strong credibility among experts [17,18]. LEED is developed by USGBC to assess the environmental impact of projects, and adopts the energy cost budget approach by assessing different kinds of fuels and energy sources, converting them to cost, and taking these costs into account [19]. However, since it is based on the cost of energy instead of its consumption [15], LEED's energy evaluation approach proves to be inadequate for comparing consumption in different regions or countries. LEED 2009 NC [20] for New Construction and Major Renovations offers alternative compliance paths for projects outside the U.S. It is in use in 135 countries [21]. Still, the limitations and possible contributions can vary from country to country. Since LEED 2009 NC refers to U.S. codes, regulations and standards, users face difficulties when they are applied in countries other than the U.S., which limits the success of LEED in these counties [18,22]. Attempts are underway to establish new systems in India [23], Abu Dhabi [24], Canada, Brazil, Turkey [25] and other countries. In LEED 2009 NC [20], 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 their intents. It is possible to earn a maximum of 35 points associated with the six credits listed under the "energy and atmosphere" (EA) category, which constitutes 32% of the maximum total points (110 points) that one can score in LEED evaluations.

LEED's credibility and popularity as a certification system encourages professionals in other countries to use LEED too. However, limited success is achieved in non-US environments. Since building production and usage require a considerable amount of energy, sustainability efforts should focus on design and construction processes as well as operational performance in all countries. The objective of this study is to review and discuss the "energy and atmosphere" category of LEED relative to its adaptation and contribution to a possible country-specific system in India, Abu Dhabi, and Turkey. India and Abu Dhabi have already used and adopted LEED as a guideline for the development of regional green certificate systems. Turkey has guidelines and codes that regulate the use of energy, but although different parties are working on developing certification systems, there is no local certification system in place yet. Because of this lack of a certification system, green buildings in Turkey are mostly constructed based on LEED and BREEAM requirements [26]. The objective is to investigate the situation in these countries in the hopes that the results will benefit other developing countries.

Table 1
The "energy and atmosphere" category of LEED 2009 new construction.

EA prerequisites and credits	Points	Intent
Prerequisite 1 – Fundamental Commissioning of Building Energy Systems	–	Verify that the project's energy-related systems are installed and calibrated to perform according to owner's project requirements; basis of design and construction documents
Prerequisite 2 – Minimum Energy Performance	–	Establish the minimum level of energy efficiency for the proposed building and systems to reduce environmental and economic impacts associated with excessive energy use
Prerequisite 3 – Fundamental Refrigerant Management	–	Reduce stratospheric ozone depletion
Credit 1 – Optimize Energy Performance	0–19	Achieve increasing levels of energy performance beyond the prerequisite standard to reduce environmental and economic impacts associated with excessive energy use
Credit 2 – On-site Renewable Energy	0–7	Encourage and recognize increasing levels of on-site renewable energy self-supply to reduce environmental and economic impacts associated with fossil fuel energy use
Credit 3 – Enhanced Commissioning	2	Begin the commissioning process early in the design process and execute additional activities after systems performance verification is completed
Credit 4 – Enhanced Refrigerant Management	2	Reduce ozone depletion and support early compliance with the Montreal Protocol (UNEP, 2000) while minimizing direct contributions to climate change
Credit 5 – Measurement and Verification	3	Provide for the ongoing accountability of building energy consumption over time
Credit 6 – Green Power	2	Encourage the development and use of grid-source, renewable energy technologies on a net zero pollution basis
Total	35	

2. Energy consumption in different countries

Energy consumption in different countries depends on the existing conditions with respect to regional construction processes, policies, regulations and codes. For example, more than 76 million residential buildings and 5 million commercial buildings in the U.S. account for 37% of all energy used, 68% of all electricity, and 40% of raw materials used in the U.S., generating 36% of the CO_2 emissions [27], while the International Energy Agency (IEA) predicts that non-OECD countries account for 93% of the increase in global energy demand between 2007 and 2030, mostly driven by China and India [28].

According to the Economist's 2004 Q4 Technology Report, research studies show that sustainable building practices can considerably reduce the built environment's role in energy consumption. A survey of 99 green buildings in the U.S. showed that green buildings use an average of 30% less energy than conventional buildings [29]. However, there are some other studies indicating that energy reduction is not always possible in green buildings although the principles of sustainable construction are followed. For example, Newsham et al. [30] analyzed the energy consumption data of 100 LEED-certified commercial and institutional buildings supplied by the New Buildings Institute and the U.S. Green Building Council. They found that although these buildings used 18–39% less energy per floor area, 28–35% of them used more energy than their conventional counterparts. Also, Menassa et al. [31] compared the energy data of eleven LEED certified U.S. Navy buildings with other U.S. Navy and Marine Corps non-certified buildings of comparable size, usage and location. They found that four of the green buildings had overused electricity when compared to non-LEED counterparts.

The adverse impacts of excessive energy consumption forced many countries to make efforts to reduce energy consumption and CO_2 emissions. According to Directive 2010/31/EU of the European Parliament and Council, buildings in the European Union are responsible for 40% of energy consumption [32]. Since the sector is still expanding, it is required to reduce energy consumption and to acquire energy from renewable sources. Therefore, a binding legislation named "climate and energy package" was proposed by the European Commission, which was agreed by the European Parliament and Council in 2008 and became law in 2009. This package set an integrated approach to climate and energy policy known as 20-20-20 targets. These are reductions in EU greenhouse gas emissions of at least 20% below 1990 levels, using renewable resources for 20% of EU energy consumption, and 20% reduction in primary energy use with energy efficiency improvement technology by 2020 [32].

Greenhouse gas emission reduction in South Korea is currently promoted by the government with the Green-School Project. The aim of the project is to create energy-saving solutions when renovating deteriorated school buildings. In order to reduce CO_2 emissions, several energy-saving techniques are implemented and an optimal scenario is created by performing life cycle cost analysis for each scenario. The results show that replacing the existing lighting with light-emitting diode (LED) lighting is the most effective scenario [33].

In India, the Ministry of Power [34] is responsible for electric energy development and according to the Ministry of Power's General Electricity Authority, as of April 2012, the total installed capacity is 201,503 MW in the country, which heavily depends on thermal facilities (133,363 MW) that account for 66% of all electric energy generation. 85% of these thermal facilities are coal-based power stations generating 113,782 MW [34]. According to UNEP (2007) [4], the energy-related CO_2 emissions in India were 591 and 961 million tons in 1990 and 2000, respectively. Several strategies are addressed to promote sustainable power generation and protect the environment. For example, it is recommended that the 90 million tons of fly ash generated annually by coal-based power stations be used in the manufacture of cement, brick, pavement materials, floor tiles, wall panels, road construction, and landfills [34]. The Ministry of New and Renewable Energy [35] aims to develop and deploy new and renewable energy for supplementing the energy requirements of the country. Renewable energy sources account for approximately 12% of all power generation in the country.

Abu Dhabi is the largest emirate of UAE and its capital. It lies on dry desert. It has the highest per capita rates of CO_2 emission in the world and the second highest water consumption per capita [36]. Electricity consumption in Abu Dhabi was 5616 MW in 2008 and is expected to reach 26,878 MW in 2030. The residential sector is the largest consumer of electricity followed by the commercial and institutional sectors [37]. The major sources of air pollution are industrial operations in oil and gas production, electricity generation, and desalination of water [36]. Abu Dhabi has started to look into ways to create a clean energy sector and is committed to generate at least 7% of all power from renewable energy sources by 2020.

In Turkey, energy production was dominated in 2005 by coal (47%) and renewable energy resources such as hydraulic, biomass, wind, solar and geothermal (39%), followed by petroleum (10%), and natural gas (4%) [38]. Being a country that relies heavily on external energy resources, only 27.5% of the demand for energy was met by domestic production in 2005. In other words, Turkey's total energy imports correspond to 72.5% of the total energy supply. The energy-related CO_2 emissions were reported as 138 and 206 million tons in 1990 and 2000, respectively [4]. There are some efforts to implement sustainable approaches to reduce energy consumption and CO_2 emissions. For example, because 20% of the consumed electricity is used for lighting purposes, the Ministry of Energy and Natural Resources established a policy on "Transition to Efficient Public Lighting" [39] to minimize the consumption of electricity in public institutions. According to this report, public institutions would act as an example to society regarding energy efficiency. Transitioning to energy-saving lighting systems in 20% of government buildings corresponds to a yearly energy saving of 5.6 billion kWh, which is equal to the yearly production of the Afsin-Elbistan thermal power plant or the Keban hydroelectric power plant. The benefits of this implementation were better public lighting performance by 23%, reduction of electricity capacity by 102 MW, return of purchasing cost in 101 days, and improvement in the yearly budget by approximately $23 million.

3. Certification in India, Abu Dhabi, and Turkey

LEED-India NC [40] has three prerequisites and six credits in the "energy and atmosphere" category, same as LEED 2009 NC. One can observe only slight differences between LEED-India NC and LEED 2009 NC in Credits 1 and 2 (i.e., the percentage of cost savings, and the percentage of improvement in the use of renewable energy) based on regional characteristics. In LEED-India NC, twelve out of seventeen points may be earned from Credits 1 and 2. Currently, there are 2209 registered and 362 LEED-India certified buildings in India [27].

The Resourceful Energy category of ESTIDAMA Pearl accounts for approximately 25% of the total points necessary for these prerequisites and seven categories. In addition to the Resourceful Energy category's focus on reducing energy use, the RE-1 Improved Energy Performance credit focuses on energy efficiency for major improvements and the RE-6 Renewable Energy credit focuses on reducing energy consumption from the grid via producing energy.

Due to its prestigious positioning both in domestic and international environments, LEED is the preferred system for certification in Turkey. Studies to develop a country-specific rating system are under way. As of June 2014, seventy buildings have received LEED certificates in Turkey, while 180 buildings are in the registration stage of the process [41]. For five of the green buildings that were LEED certified, the average earned points from the energy and atmosphere category is approximately 20% of the total points. Currently, some energy regulations and building codes set by the Turkish Government are in effect.

LEED 2009 NC emphasizes the "energy and atmosphere" category assigning approximately 32% of the total points that can be earned. However, LEED-India NC and ESTIDAMA PBRS assign approximately 25% of the total points to energy and atmosphere. The energy and atmosphere category has the highest percentage of points in all three rating systems. LEED-India NC's second priority lies in "indoor environmental quality" with 25% of the total points,

Table 2
General comparison of energy-related certification systems of LEED 2009 NC, LEED India, ESTIDAMA PBRS, and Turkish National Green Building Certification – Homes.

	USA	India	Abu Dhabi	Turkey
(1) Inspection agency	Although USGBC points to commissioning and consulting agencies for the design, commissioning and monitoring of the performance of the building with regards to the Energy and Atmosphere category, the final approval belongs to USGBC.	LEED-India heavily relies on Energy Conservation Building Codes (ECBC). Since ECBC has been introduced by Bureau of Energy Efficiency (BEE) in 2007 [44], the requirements and standards for sustainability are set by BEE.	Supported by CIBSE certified engineers, Abu Dhabi Urban Planning Council (UPC) performs inspection services [45].	Since Turkish National Green Building Certification – Homes is not announced officially, TGBC is expected to be the inspection agency. However, the Code for Building Energy Performance introduces a good basis for a certification, compliance with which will be inspected by the Ministry of Environment and Urbanization
(2) Standards	Extensive standards are in effect in the U.S. such as ANSI, ASHRAE, IESNA, NIST, ASTM [41]. These standards are well established and are in constant use by designers and constructors. LEED 2009 NC often refers to these standards, making it easier for practitioners to know what is expected of them.	LEED-India NC doesn't refer to any local standards. There is an urgent need for standards adequate for local conditions of India for an efficient application LEED-India NC.	Although Emirates Authority for Standardization and Metrology (ESMA) has been established by the United Arab Emirates in 2001 [46], Abu Dhabi Quality and Conformity Council have been founded in 2009 [47]. Thus there is scarcity in the standards needed for the application of a green building rating system. As a result of lack of standards needed for the implementation of a rating system, Abu Dhabi Urban Planning Council refers to ASTM and ANSI/ASHRAE/IESNA standards, as well as CIBSE standards.	The Code for Building Energy Performance, which has been developed based on EU and ASHRAE standards, measures and regulates the energy performance of buildings in Turkey. In addition, the Turkish Standards Institute's TS standards are used for meeting local conditions [18,48]. Application of the code has become mandatory in 2011.
(3) Adversities about usage	One of the major critics about LEED 2009 NC is the minimum limit of the monitoring process, which is one year. Since the performance of the systems and/or materials may vary in years, being LEED certified keeps the building exempt from further monitoring.	Although ECBC has been introduced in 2007, compliance is still voluntary [49]. Since LEED-India heavily relies on ECBC, tackling with the Energy and Atmosphere category during the certification process becomes tricky.	Since ESTIDAMA PRS heavily relies on ASTM and ANSI/ASHRAE/IESNA standards, as well as CIBSE standards, matching local conditions and the requirements of these standarts introduce difficulties.	Since Turkish National Green Building Certification - Homes is not announced officially, the adversities are not identified yet. If it relies on the Code for Building Energy Performance -as expected-, compliance and inspection will be relatively easy since compliance with the code is mandatory.
(4) Education	As a result of long history in sustainability movement, environmental conscience has influenced every level of education in the states. Energy efficiency is an important input in all engineering programs in the universities both in undergraduate and graduate level. In addition,	The availability of faculty, courses and curriculum on energy and environment in architectural schools is inadequate in India [49]. Architects and engineers lack competencies for the application of sustainable practices [49,50]. Raising the level of project management through proper education will likely affect the practice positively [49]. The main sources for green building guidelines are, in order of importance, workshops/seminars, education, periodical/magazines, and courses [50].	UPC has initiated "UniverCity" platform for education of young generation about ESTIDAMA PRS. Through this initiative, UPC has started collaboration with ALHOSN University and American University of Sharjah [45]. Besides, in close cooperation with Massachusetts Institute of Technology, Masdar Institute in Masdar City, which will be providing graduate level education in sustainability and future energy, has been established [36].	Universities are showing interest to sustainability in general. The number of courses related to energy and environment are increasing gradually. Additionally, the number of researches and classes in both undergraduate and graduate levels is increasing [51]. Although the level of interest among academics, researchers and students at university level is steadily increasing, the topic of renewable energy is still a specific topic and the number of people studying about it is limited [52]. The number of professionals trained for consulting and commissioning services needed is still limited.

Table 2 (*Continued*)

	USA	India	Abu Dhabi	Turkey
(5) Technical know-how	As of December 2011, there are 153,761 LEED professionals in USA [53]. Additionally, because of long history of sustainability movement, agencies introducing consultancy services have environmental concerns.	Majority of the professionals i.e. architects, engineers do not have in-depth knowledge to incorporate ECBC in their designs [49]. Additionally, governmental agencies lack enforcement for construction documents and site inspections [44].	UPC provides trainings and exams for professionals to become Pearl Qualified Professionals (PQP). PQPs serve as consultants for Pearl accreditation process, and documents for licensing should be submitted by PQPs. As of December 2012, there are 32 national and international companies that accommodate PQPs [24].	The Ministry of Environment and Urbanization has authorized the Chamber of Architects and the Chamber of Mechanical Engineers to introduce certification programs for professionals. These professionals will provide consulting and commisioning services for projects to meet the Code for Building Energy Performance requirements.
(6) Experience	Since LEED refers heavily to ANSI/ASHRAE/IESNA Standards, which are U.S. Standards and have been used for years, the level of experience for implementation of these standards, and thus the certification system is considerably high.	Since compliance to ECBC is voluntary, the demand to comply with ECBC in the industry has not reached the level to require professionals to be trained. In addition, professional practice is lacking guidelines for the implementation of ECBC, and sustainability in general [49].	As of December 2012, 29 national and international companies accomodate Independent Commissioning Agents (ICA), certified by UPC [24]. However, training for ICAs and PQPs have started in May 2012. Thus, the experience accumulated by these professionals are limited. Additionally, a number of entities introducing consulting and commissioning services are foreign based, which limit their hold on local weather conditions.	Although certification for professionals focusing on implementing and inspecting compliance with the Code for Building Energy Performance is relatively new, because of high energy prices, renewable energy is has been in emergence recently. This demand has been directing the architects and engineers to trainings and studies.
(7) Renewable Energy Supply	Renewable energy production is compansated with tariff support since 1978. Additionally tax advantages, grants and loans are present. Renewable energy supply in 2030 is aimed to 20% [54].	Starting with the Electricity Act in 2003, Indian Government has started supporting renewable energy. With the National Electricity Policy in 2005, electricity production from non-conventional resources has been promoted and supported with the Tariff Policy introduced in 2006. Indian Electricity Grid Code, which has been introduced in 2010, regulates operation, connection and commercial activities for renewable energy sources like wind and solar generation plants. Further services have been delegated to Central Electricity Regulatory Commission (CERC) and Science and Engineering Research Council of each state. As of June 2010, renewable energy supply in India is 10% of the total capacity [55]. Renewable energy goal for 2020 is 15% for electricity and 20% for primary energy [54].	Abu Dhabi has set a target 7% for renewable energy in 2020 [54]. To reach that target, the first solar power plant, Shams 1 has been opened and the second solar power plant, Nour 1, which has the same capacity with Shams 1, is still under construction. The wind farm located on Sir Bani Yas Island, which is 250 km southwest of Abu Dhabi, is also under construction [54].	According to the Turkish Wind Energy Association's report, there are 41 wind farms in Turkey. These wind farms are located generally on the west and northwest part of Turkey, i.e., in Izmir, Canakkale, Balikesir, Manisa and Aydin in response to the high energy demand caused by extensive industrialization in these regions [56]. Various research studies have been conducted about renewable energy resources in Turkey, one of which is the MILRES Project. The project aims to develop a wind turbine for energy production resulting in a saving of $15 billion in a 20 year span [57]. In addition to wind energy, there is a great potential for geothermal energy, and solar energy in Turkey]. Improvements about wind energy have shown considerable progress. However, the other energy sources need the government's attention and support [18]. The renewable energy target set for 2020 is 25% [54].

because this category is of special importance in the crowded and high-density residential and office buildings particularly in the warmer southern states of the Indian subcontinent; whereas ESTIDAMA PBRS's second priority lies in "precious water" with 24% of the total points, because potable water in Abu Dhabi is quite scarce and is supplied mostly by desalination. The Abu Dhabi Urban Planning Council places emphasis on water, whereas IGBC places emphasis on indoor environmental quality, yet USGBC considers both water and indoor air-related issues to be of lesser importance when compared with "energy and atmosphere". In this study, only the "energy and atmosphere" category of LEED is reviewed with respect to its adaptation to developing countries.

A general comparison of energy-related certification systems in these countries is presented in Table 2 under the criteria of (1) inspection agency, (2) standards, (3) adversities about usage, (4) education, (5) technical know-how, (6) experience, and (7) renewable energy supply. The long-term success of a certification system depends heavily on these seven criteria because these criteria affect the development, adoption, implementation, and updating of certification systems. For example, the inspection agency points to the authority that directs the application; standards indicate the existence established rules and regulations or dependence on other countries' specifications; adversities about usage lists the barriers that limit application; education, technical know-how, and experience point to the current reserve of professionals and their level of qualification; and finally renewable energy supply indicates the continuity of technological advances and industrial developments in support of sustainability principles.

Table 2 indicates that there are marked differences between sustainability efforts in the U.S. and developing countries. For example, the level of maturity in the sustainability efforts in India is higher than what has been achieved in Turkey; the degrees of experience and the levels of renewable energy sources vary significantly from country to country; and education-related challenges and the availability of technical know-how are quite diverse in each of the countries studied. However, if one looks at the core of the problems, one can observe that the differences stem from the differences in the standards, laws, and regulations that are in place in the respective countries. While India is using mostly the U.S. standards, Abu Dhabi tries to create its own, and Turkey is struggling to find the middle way. A detailed comparison of the sustainability efforts with respect to the energy and atmosphere-related issues in these countries is presented in the following section where conclusions are drawn based on this comparison.

4. Conclusion

According to the Organization for Economic Cooperation and Development [42], developing countries are expected to consume over 70% more energy in 2030 compared to 2004, and improving energy efficiency is the most environmentally friendly way to reduce the demand for new investments in energy supply. The World Bank working paper No. 204 states that the built-in energy loads, such as heating, cooling and lighting systems, should be addressed during design and construction processes [43]. At this point, green building certification systems are useful as they include energy efficiency issues into these processes. Additionally, LEED 2009 NC suggests improving the energy loads of new buildings compared to the design by EA Credit 1.

This research examines the different stages of development in the energy and atmosphere category of sustainability and green building certification in four countries, the most mature of which is the U.S. and the least mature is Turkey. Out of the two countries in between, India has basically copied and slightly modified the U.S. system, whereas Abu Dhabi has developed its own certification system. With this sampling, this study covers the whole spectrum from least mature country to most mature country in achieving energy and atmosphere goals.

After presenting the intents of the credits in the "Energy and Atmosphere" category of LEED 2009 NC in Table 1, and after performing a general comparison of energy-related certification systems of LEED India, ESTIDAMA PBRS, and Turkish National Green Building Certification – Homes [24] against LEED 2009 NC in Table 2, the following conclusions were reached:

- ESTIDAMA PBRS and the Turkish National Green Building Certification – Homes, with its expected referral to the Code for Building Energy Performance, state the methods of implementation relative to energy and atmosphere requirements. There is need for similar guidelines in the implementation of the Energy Conservation Building Code in India.
- PQP and ICA training and certification in Abu Dhabi, and training programs provided by Chambers of Architects and Mechanical Engineers in Turkey produce professionals needed for consultancy and commissioning, whereas the number of training programs and the number of energy consultants are limited in India. Organizing more seminars and courses to train professionals for consultancy and commissioning is necessary in India in addition to promoting the certification system industry wide.
- To meet the long-term needs of design and construction professionals, Abu Dhabi has initiated specific education programs in cooperation with national and foreign universities. Turkey, on the other hand, prefers embedding environmental courses to the existing programs and improving the education system as a whole. India, however, needs to concentrate more on education in order to raise the level of the engineering capabilities needed for sustainability.
- India accounts for 10% of the increase in energy consumption expected between 2004 and 2030 in the world [58]. The certification system active in India proves to be effective, especially with its characteristics representing the tough and variable local conditions in the region. The Energy Conservation Building Code, which LEED-India-NC refers to frequently, combines local conditions with international standards. However, voluntary compliance weakens its influence. Turkey, on the other hand, introducing the Code for Building Energy Performance has made a significant step for energy conservation not only for certification but also for the construction industry as a whole.
- The history of certification systems in the subject countries reflects their attention to renewable energy. India has started investing in renewable energy in 2003, with the Electricity Act, and as of June 2010, the renewable energy supply is 10% of the total capacity [55]. Abu Dhabi finished constructing the first solar power plant in 2013. After completing the construction of another solar power plant and a wind farm, renewable energy production is planned to be 7% of the total capacity in 2020. Although, based on its geographic location, Turkey is in a good position for producing renewable energy, Turkey has limited investment in these ventures. Nevertheless, the target is set to 25% for 2020 with the new hydro-electrical plants under construction, in addition to the 41 active power plants [54].
- The PEARL Rating System developed in Abu Dhabi can be a good example for countries sharing similar geographic and weather conditions. The sustainability policy supported by the government is promising in terms of energy consumption and sustainable energy technologies. Although the certification system relies on several international standards, local applications and priorities should be considered more to promote energy efficiency.

This study is expected to draw attention to energy and atmosphere issues in the subject countries as well as other developing countries. The intent is not only to address the issues in these countries, but also to function as a guideline for countries developing their certification systems. However, one should not forget that local conditions differ from country to country, and that an approach that appears to be most appropriate in a country can be quite impractical in another. Therefore, researching the developments only in India, Abu Dhabi and Turkey does not allow the creation of universal recommendations that are applicable in all developing countries. This limitation can be mitigated by researching the situation in additional countries in future research.

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References

[1] C.W.K. Yu, J.T. Kim, Building environmental assessment schemes for rating of IAQ in sustainable buildings, Indoor and Built Environment 20 (1) (2011) 5–15.
[2] A. Haapio, P. Viitaniemi, A critical review of building environmental assessment tools, Environmental Impact Assessment Review 28 (2008) 469–482.
[3] L.B. Robichaud, V.S. Anantatmula, Greening project management practices for sustainable construction, Journal of Management in Engineering 27 (1) (2011) 48–57.
[4] UNEP, United Nations Environment Program, Buildings and Climate Change, Status, Challenges and Opportunities, 2007, Retrieved from: http://www.unep.ch/etb/ (accessed 01.03.12).
[5] M. Mir, Energy efficient architecture and building systems to address global warming, Leadership in Engineering 8 (2008) 113–123.
[6] A. Sabapathy, S.K.V. Ragavan, M. Vijendra, A.G. Nataraja, Energy efficiency benchmarks and the performance of LEED rated buildings for information technology facilities in Bangalore, India, Energy and Buildings 42 (2010) 2206–2212.
[7] J.E. Rowings Jr., R.O. Walker Jr., Construction energy use, Journal of Construction Engineering and Management 110 (4) (1984) 447–458.
[8] T. Hong, M. Ji, C. Jang, H. Park, Assessment model for energy consumption and greenhouse gas emissions during building construction, Journal of Management in Engineering 30 (2) (2014) 226–235.
[9] A.A. Guggemos, A. Horvath, Decision-support tool for assessing the environmental effects of constructing commercial buildings, Journal of Architectural Engineering 12 (4) (2006) 187–195.
[10] L. Perez-Lombard, J. Ortiz, C. Pout, A review on buildings energy consumption information, Energy and Buildings 40 (2008) 394–398.
[11] IEA, International Energy Agency, Energy Balances of Non-OECD Countries, 2007.
[12] A.B.R. Gonzalez, J.J.V. Diaz, A.J. Caamano, M.R. Wilby, Towards a universal energy efficiency index for buildings, Energy and Buildings 40 (2011) 980–987.
[13] Y. Schwartz, R. Raslan, Variations in results of building energy simulation tools, and their impact on BREEAM and LEED ratings: a case study, Energy and Buildings 62 (2013) 350–359.
[14] M.J. Kim, M.W. Oh, J.T. Kim, A method for evaluating the performance of green buildings with a focus on user experience, Energy and Buildings 66 (2013) 203–210.
[15] A.P. Melo, M.J. Sorgato, R. Lamberts, Building energy performance assessment: comparison between ASHRAE standard 90.1 and Brazilian regulation, Energy and Buildings 70 (2014) 372–383.
[16] T. Hong, A close look at the China design standard for energy efficiency of public buildings, Energy and Buildings 41 (2009) 426–435.
[17] S.J. Beauregard, S. Berkland, S. Hoque, Ever green: a post-occupancy building performance analysis of LEED certified homes in New England, Journal of Green Building 6 (4) (2011) 138–145.
[18] R. Komurlu, D. Arditi, A.P. Gurgun, Assessment of LEED requirements for energy and atmosphere in Turkey, in: 10th Int. Congress on Advances in Civil Engineering, October 17–19, Ankara, Turkey, 2012.
[19] W.L. Lee, Benchmarking energy use of building environmental assessment schemes, Energy and Buildings 45 (2012) 326–334.
[20] LEED 2009 NC, LEED Ref. Guide for Green Bldg. Design and Const., For the Design, Const. & Major Renov. of Commercial & Institutional Bldgs. Including Core & Shell, K-12 School Projects, USGBC, USA, 2009.
[21] USGBC, U.S. Green Building Council, About USGBC, 2014, Retrieved from: http://www.usgbc.org/about (accessed 10.06.14).
[22] R. Komurlu, A.P. Gurgun, D. Arditi, Assessment of indoor environmental quality for LEED certification in developing countries, in: S. Yazdani, A. Singh (Eds.), ISEC-07, 7th Int. Structural Engineering and Construction Conf., New Development in Structural Eng. and Const., vol. II, 2013, ISBN 978-981-07-5354-2, pp. 1691–1696.
[23] IGBC, Indian Green Bldg. Council, 2012, Retrieved from: http://www.igbc.in/site/igbc/index.jsp (accessed 01.03.12).
[24] ESTIDAMA The Pearl Rating System (PBRS) for ESTIDAMA, Building Rating System, Design and Construction, Version 1.0, Abu Dhabi Urban Planning Council, Abu Dhabi, 2012, April, Retrieved from: http://estidama.org/pearl-rating-system-v10.aspx?lang=en-US
[25] CEDBIK, The Turkish Green Building Council, Retrieved from: http://cedbik.org/icerikdetay.asp?ID=319&IcerikID=321 (accessed 01.03.12).
[26] O. Ekincioglu, A.P. Gurgun, Y. Engin, M. Tarhan, Approaches for sustainable cement production – a case study from Turkey, Energy and Buildings 66 (2013) 136–142.
[27] USGBC, U.S. Green Building Council, Building momentum: national trends and prospects for high-performance green buildings, in: Prepared for the U.S. Senate Committee on Environment and Public Works, Washington, DC, 2003, Retrieved from http://ec.europa.eu/energy/efficiency/buildings/buildings_en.htm
[28] IEA, International Energy Agency, World Energy Outlook, 2009, Retrieved from http://www.iea.org/speech/2009/Tanaka/WEO2009_Press_Conference.pdf (accessed 01.03.12).
[29] The Economist, Q4 Technology Report, 2004, Retrieved from: http://www.economist.com/node/3422965 (accessed 01.03.12).
[30] G.R. Newsham, S. Mancini, B.J. Birt, Do LEED-certified buildings save energy? Yes, but. . ., Energy and Buildings 41 (8) (2009) 897–905.
[31] C. Menassa, S. Mangasarian, M. El Asmar, C.C. Kirar, Energy consumption evaluation of Unites States Navy LEED certified buildings, Journal of Performance of Constructed Facilities 26 (1) (2012) 46–53.
[32] European Parliament and Council, Directive 2010/31/EU on The Energy Performance of The Buildings, 2010.
[33] T. Hong, H. Kim, T. Kwak, Energy-saving techniques for reducing CO_2 emissions in elementary schools, Journal of Management in Engineering 28 (2012) 39–50.
[34] Ministry of Power, 2012. Retrieved from: http://www.powermin.nic.in/JSP_SERVLETS/internal.jsp (accessed 01.03.12).
[35] Ministry of New and Renewable Energy, 2012. Retrieved from: http://www.mnre.gov.in/mission-and-vision-2/mission-and-vision/ (accessed 01.03.12).
[36] T. Mezher, D. Goldsmih, N. Choucri, Renewable energy in Abu Dhabi: opportunities and challenges, Journal of Energy Engineering ASCE 137 (4) (2011) 169–176.
[37] EAAD, Abu Dhabi Environment Agency, State of The Environment. Retrieved from: http://www.soe.ae/ (accessed 01.03.12).
[38] MENR, The Ministry of Energy and Natural Resources, General Directorate of Energy Affairs, Workgroup Report on Greenhouse Gas Reduction in Energy Sector, 2006, Retrieved from: http://www.enerji.gov.tr/yayinlar_raporlar_EN/Enerji_Grubu_Raporu_EN.pdf
[39] MENR, The Ministry of Energy and Natural Resources, Transition to Efficient Public Lighting, 2009, Retrieved from http://www.enerji.gov.tr/yayinlar_raporlar_EN/KVAG_Raporu_EN.pdf
[40] N.C. LEED-India, Green Building Rating System, Abridged Reference Guide for New Construction and Major Renovations (LEED-India NC), Version 1.0, January, The Indian Green Building Council (IGBC), India, 2007.
[41] USGBC, U.S. Green Building Council, LEED Projects and Case Studies Directory, Certified Project Directory, 2012, Retrieved from http://www.usgbc.org/projects
[42] OECD, OECD Contribution to the United Nations Commission on Sustainable Development 15 – Energy for Sustainable Development, 2007, Retrieved from: http://www.oecd.org/greengrowth/38509686.pdf
[43] F. Liu, A.S. Meyer, J.F. Hogan, Mainstreaming building energy efficiency cods in developing countries - global experiences and lessons from early adopters. World Bank working paper no. 204, 2010, Retrieved from https://openknowledge.worldbank.org/handle/10986/5915
[44] M. Evans, B. Shui, S. Somasundaram, Country Report on Building Energy Codes in India, US Department of Energy, Pacific Northwest National Laboratory, Retrieved from:, 2009, April http://www.pnl.gov/main/publications/external/technical_reports/PNNL-17925.pdf (accessed 01.03.12).
[45] UPC, Abu Dhabi Urban Planning Council. Retrieved from, http://www.upc.gov.ae/univercity-program.aspx?lang=en-US (accessed 05.02.13).
[46] ISO, International Standards Organization. Retrieved from: http://www.iso.org/iso/home/about/iso_members/iso_member_body.htm?member_id=1704 (accessed 05.02.13).
[47] ADQCC, Abu Dhabi Quality and Conformity Council. Retrieved from, http://www.qcc.abudhabi.ae/English/AboutUs/Pages/Our%20Journey.aspx (accessed 05.02.13).
[48] MEU, The Ministry of Environment and Urbanization, What is the Energy Identity Card in Buildings, 2014 (in Turkish). Retrieved from http://www.csb.gov.tr/db/samsun/webmenu/webmenu4379.pdf (accessed 10.06.14).
[49] S. Kumar, R. Kapoor, R. Rawal, S. Seth, A. Walia, Developing an energy conservation building code implementation strategy in India, in: ACEEE Summer Study on Energy Efficiency in Buildings, 2010, pp. 8-209–8-224, Retrieved from http://www.aceee.org/files/proceedings/2010/data/papers/2174.pdf
[50] V. Potbhare, M. Sayal, S. Korkmaz, Adaption of green building guidelines in developing countries based on U.S. and India experience, Journal of Green Building 4 (2) (2009) 158–174.
[51] S. Korkmaz, D. Erten, M. Syal, V. Potbhare, A review of green building movement timelines in developed and developing countries to build and international adoption framework, in: Fifth Int. Conf. on Cons. in the 21st Century (CITC-V) Collaboration & Integration in Eng. Management & Tech., May 20–22, Istanbul, Turkey, 2009.
[52] A. Karabulut, E. Gedik, A. Kecebas, M.A. Alkan, An investigation on renewable energy education at the university level in Turkey, Renewable Energy 36 (4) (2011) 1293–1297.
[53] GBCI, Green Building Certification Institute. Retrieved from www.gbci.org (accessed 03.12.11).
[54] T. Mezher, G. Dawelbait, Z. Abbas, Renewable energy policy options for Abu Dhabi: drivers and barriers, Energy Policy 42 (2012) 325–328.

[55] S.K. Soonee, M. Garg, S. Prakash, Renewable energy certificate mechanism in India, in: 16th National Power Systems Conference, December 15–17, 2010, Retrieved from: https://www.recregistryindia.nic.in/pdf/REC_india.pdf
[56] TWEA, Turkish Wind Energy Association, Wind Power Plants under Operation in Turkey Report, 2011, Retrieved from http://www.ruzgarenerjisibirligi.org.tr/index.php?option=com_docman&Itemid=69&limitstart=5
[57] S.N. Engin, TUBITAK Marmara Research Center energy systems department wind energy study regions and project MILRES, in: Izmir Wind Symposium and Exhibition, December 23–24, 2011, Istanbul, Turkey, 2011.
[58] UNEP, The Ozon Secretariat United Nations Environment Program, The Montreal Protocol on Substances That Deplete The Ozon Layer, 2000, Retrieved from http://www.unep.org/ozone/pdf/Montreal-Protocol2000.pdf