Assessment of Energy Credits for the Enhancement of the Egyptian Green Pyramid Rating System

Shady H.E. Abdel Aleem, Ahmed F. Zobaa, and Hala M. Abdel Mageed

***Abstract*— Energy is one of the most important categories in the Green Building Rating Systems all over the world. Green Building is a building that meets the energy requirements of the present with low energy consumption and investment costs without infringing on the rights of forthcoming generations to find their own needs. Despite having more than a qualified rating system, it is clear that each system has different priorities and needs on the other. Accordingly, this paper proposes a methodology using the Analytic Hierarchy Process (AHP) for assessment of the energy credits through studying and comparing four of the common global rating systems, the British Building Research Establishment Environmental Assessment Method (BREEAM), the American Leadership in Energy and Environmental Design (LEED), the Australian Green Stars (GS), and the PEARL assessment system of the United Arab Emirates, in order to contribute to the enhancement of the Egyptian Green Pyramid Rating System (GPRS). The results show the mandatory and optional energy credits that should be considered with their proposed weights according to the present and future needs of green Egypt. The results are compared to data gathered through desk studies and results extracted from recent questionnaires.**

***Keywords*— Analytic Hierarchy Process, decision making, energy credits, energy rating systems, green energy.**

1. INTRODUCTION

Greenhouse gas emissions, an important topic within the green building domains, have been an area of discussion for years. Nowadays, global organizations are disbursing much attention on the impacts of the various emissions such as carbon dioxide (CO_2), carbon monoxide (CO) and other unsafe gases affect the surrounding and participate in climate change (Rozlan et al., 2011). Accordingly, several developments for maintaining a green and sustainable planet with the integration of three main goals, social, environmental and economic goals, have been practiced (Aly et al., 2012) and much attention has been focused on green building sectors. On the other hand, researchers are directed to the use of new alternatives to replace the fossil fuel by renewable energy sources, especially with the declining availability of fossil fuel resources and the considerable increase of global fuel price (Shahriar and Erkan, 2009; Wafik and Hanafy, 2015).

The success in this green trend depends on many criteria, and the only way to insure its success is to have an approach to evaluate them (Choongwan et al., 2014; Elgendy, 2010). Consequently, green building rating systems have been rapidly instituted and introduced in the civilized countries like Canada and United Kingdom. In 1990, the British Building Research Establishment Environmental Assessment Method (BREEAM) was introduced (BREEAM, 1990). It is one of the earliest introduced rating systems, and one of the world's most important environmental assessment methods and rating systems for buildings inside and outside United Kingdom. BREEAM uses the following weighting ranges to certify a building's rate, pass (25-39%), good (40-54%), very good (55-69%), and excellent (70% and above). It is obvious the simple measurability of the BREEAM system (BREEAM, 1990; U.K. Green Building Council, 2007). In 1998, the American Leadership in Energy and Environmental Design (LEED) is introduced (LEED, 2012; U.S. Green Building Council, 2012). Quickly, it became one of the most popular green building rating systems throughout the world (Yudelson, 2008). This is because LEED is mainly concerned with the main problem of energy use and gives lower importance to water whilst BREEAM does the opposite (Younan, 2011). Based on the number of credits achieved, a project is certified with one of the four levels: certified

(40–49 points), silver (50–59 points), gold (60–79 points), and platinum (80 points and above) (LEED, 2012). In 2003, the Australian Green Stars (GS) is presented. It uses a simple certification level of stars as a measure of sustainability of buildings, 4 Stars for low, 5 Stars for moderate, and 6 Stars for highly sustainable buildings (GBCA), 2002; Green Star, 2003). It is considered one of the easiest environmental green building rating systems that help in reducing the energy consumption and water uses. Despite it is a new rating system, it changes the way of thinking of the Australian construction markets. It is not strange that some countries, for example South Africa, depend on it because of its usability and applicability (Ammar, 2012)

In the Middle East region, specifically in the United Arab Emirates (UAE), there are two rating systems to assess green buildings, to be precise: UAE–LEED of Dubai and ESTIDAMA–PEARL Rating System of Abu-Dhabi. The ESTIDAMA–PEARL Rating System was established and introduced in 2010. It intends to focus on the sustainability of a given structure from design through construction to final operation (Estidama, 2010). Even the word ESTIDAMA in its name means sustainability in Arabic (Ammar, 2012). It depends on points addition to give a final rating in a range from 1 PEARL to 5 PEARL (best). It mainly depends on LEED with additional focus on their local water problems. Even though it is simpler to use and easier to be implemented than the LEED system; it focuses on finding quick solutions to minimize energy consumption rate rather than concentrating on maximizing the use of renewable energy sources. This is mainly because the economy of the oil-based nature of this region (Ammar, 2012; Elgendy, 2010; EmiratesGBC, 2006; Estidama, 2010; PEARL Rating System for Estidama, 2010). Going eastern in the Middle East; the first edition of Egypt's Green Pyramid Rating System (GPRS) was introduced on April 2011 for public review (Egypt-GBC, 2009; GPRS, 2011). Successive questionnaires with the aid of researchers, businessmen and expert opinions in the field demonstrates that the Egyptian Green Building Council has to develop and update the Egyptian GPRS that suites its environment and construction market through studying more global systems. Accordingly, this paper proposes a methodology using the Analytic Hierarchy Process (AHP) for assessment of the energy credits through studying and comparing four of the common global rating systems, thus developing and enhancing the Energy Category of the Egyptian GPRS. The results show all the energy credits that should be considered with their proposed weights according to the present and the future needs of greener Egypt. The results are compared to data collected through desk studies and the results of questionnaires taken from existing publications (Aly et al., 2012; Younan, 2011).

The well-known Analytic Hierarchy Process (AHP) is used as a decision-making tool for finding the optimal weights of the different energy credits because of its simplicity and well proven gains over years in engineering aspects. AHP depends on using a set of judgment matrices based on the relationships between the various credits and many other factors (Farghal et al., 2002; Loken et al., 2006; Saaty, 1980).

2. METHODS

2.1. Energy credits in the considered global rating systems

A comparison is carried out between the well established energy credits in the considered global rating systems. Based on (Green Star, 2003; LEED, 2012; PEARL Rating System for Estidama, 2010; U.K. Green Building Council, 2007) the following credits are included in the comparison.

Credit 1: Minimum energy performance. According to BREEAM, this credit aims to recognize and encourage buildings designed to minimize the energy demand, consumption and CO_2 emissions. Beside, LEED and GS were more specific in asking for establishing the minimum level of energy efficiency for the proposed building in order to achieve the same goal. On the other side, PEARL has a different vision in the creation of a decision support tool to assist the project team in making decisions about the alternatives of the building design to achieve the same target. This credit is mandatory for all of these rating systems.

Credit 2: Fundamental refrigerant management. According to LEED and PEARL, this credit aims to reduce ozone depletion. They classified it as a mandatory credit. It can be achieved by minimizing the use of chlorofluorocarbon-based refrigerants. On the other hand, it is optional in BREEAM system with a weight of 7.1%. In the GS system, it is not included, in contradiction with the location of Australia that is close to the ozone hole over the Antarctic. It should be noted that the highest rates of skin cancer are recorded in Australia because of this fact (Ozone Hole, 2014).

Credit 3: Peak energy demand reduction. This credit aims to minimize peak energy demand at peak usage time. In both USA and UK, despite the obvious focus on the demand-side management that aims to reduce peak demand on energy supply infrastructure or move the time of energy use to off-peak times, especially after the energy crisis in 1973, both BREEAM and LEED do not recognize this credit. On the other hand, the GS system considers this credit with a weight of 6.9%, whilst its highest weight is given as 9.1% in the PEARL rating system. It should be mentioned that this credit may have a special importance in the Egyptian system due to the considerable difference between the produced and utilized electric power that can reach 700 MW in a typical day which led to a partial blackout on September 2014 that affect around 20 million people.

Credit 4: Global warming impacts of refrigerants and fire suppression systems. This credit aims to improve selection of electrical and mechanical equipments according to their impact on the environment. It has a weight of 9.1% in PEARL and 5.7% in LEED. However, it is not included in the remaining systems under study.

Credit 5: Energy monitoring. It aims to broaden the use of metering facilities that allow the energy performance of the building to be recorded in order to be improved. Although PEARL has been derived directly from the LEED, PEARL has recognized this credit as a mandatory one because of its importance, whilst the LEED gives it a low weight of 8.6%, with respect to the other credits. Moreover, it is weighted by 7.1% in BREEAM and 6.95% in the GS. Since each measure may require a meter, the limiting consideration may be the additional costs related to the increased number of metering devices. Accordingly, the considered authorities in each country have to support the large end-users that will follow this requirement and simplify the calibration process of the devices.

Credit 6: Optimize energy performance. According to LEED and PEARL, this credit aims to achieve increasing levels of energy performance beyond the prerequisite standards and hence carbon emissions can be further reduced. According to the other systems, the aim of this credit is very close to that defined in Credit 1. It is obvious that LEED and PEARL were more specific by using the words of increasing levels of energy performance rather than the design encouragement used by the others. Moreover, this credit has different weightings in the considered global rating systems. It has a weight of 53.6% in BREEAM, 54.3% in LEED, 69% in GS and 34.1% in PEARL.

Credit 7: Energy-efficient equipment. It aims to ensure the optimum performance and maximum energy savings in the operation of building appliances. This credit is one of the common credits in any operating building or plant, whether it is green or not (Mohamed et al., 2014; Abdel Aleem et al., 2015). It has a weight of 7.1% in BREEAM and 6.8% in PEARL. However, it is not defined in both LEED and GS rating systems.

Credit 8: Fundamental commissioning of building energy systems. This credit aims to verify that the project's energy related systems are installed. It is a mandatory credit in the LEED system. Despite of its importance in comparison between the project's designed and installed energy systems, it is not mentioned in the other rating systems.

Credit 9: On-site renewable energy. Its aim is to encourage and recognize increasing levels of on-site renewable energy self-supply to reduce environmental and economic impacts associated with fossil fuel energy use (U.S. Green Building Council, 2012). Despite of the international trend to apply renewable energy technologies, nowadays, it is an optional credit in all the rating systems, and does not stated individually in the GS. The main reason is the correlation between the viability of applying these new technologies with the plant location or even the country location. However, regarding the fact that Egypt is one of the sunniest countries in the world and Egypt's seek for more economic and energy independence, this credit should have another situation in the energy categories of the Egyptian GPRS. Credit 9 has a weight of 17.9% in BREEAM, 20% in LEED, 0% in GS and 20.5% in PEARL.

Credit 10: Energy-efficient transportation systems**.** The aim of this credit is to promote projects that install energy efficient transportation systems. This credit is not included in LEED and GS. However, both, BREEAM and PEARL, have defined this credit with a weight of 7.1% and 6.8%, respectively.

It should be mentioned that the proposed analysis does not include the additional energy credits (that are not very common, but they exist in some of the rating systems) such as cool building strategies and lighting related credits.

2.2. Analytic Hierarchy Process

In 1980, Saaty, T.L. presented a new decision making procedure based on the interaction between the attributes to make a decision which is called Analytic Hierarchy Process (AHP), which is actually composed of a set of judgment matrices based on the relationships between the various attributes; the target is simply to make a decision in an organized manner and to create priorities that satisfying your goals. AHP ranks the decision elements and compares between each pair in each cluster (as a matrix) according to the available knowledge. This generates a weighting for each element within your level of the hierarchy (Saaty, 1980). This weighting vector is finally tested using a consistency test. Otherwise, the rank will not be consistent and the appropriate decision cannot be achieved until adjusting the elements in the matrices and their corresponding rank to be dependable (Farghal et al., 2002; Loken et al., 2006).

AHP assumes the 1 to 9 scaling method and their reciprocals to build the judging matrix. They are mainly nine fuzzy variables that can be represented as follows: 1, 2: represent the equal or weak importance, respectively. 3, 4: represent moderate or moderate plus importance, respectively. 5, 6: represent strong or strong plus importance, respectively. 7, 8: represent demonstrated or demonstrated plus importance, respectively. 9: represents that one criterion is extremely important than the other one. It is considered the highest possible order of pronouncement. On the other side, reciprocals represent the opposite comparison between each possible pair, *i*.e. if the weighting of alternative *A* with respect to alternative *B* equals 4; this implies that the weighting of alternative *B* with respect to alternative *A* equals 0.25 (Saaty, 1980).

Fig. 1 shows an analytic hierarchy process scheme of four levels. The target is always positioned at the top, with the main attributes on a level below, whilst the final alternatives are placed at the bottom level. The steps of a typical AHP procedure are arranged in five stages, as follows (Farghal et al., 2002; Loken et al., 2006; Saaty, 1980).

1. **Hierarchical model:** Define the attributes affecting the target which is choosing the most suitable weighting of energy credits in the Egyptian Green Pyramid Rating System.
2. **Judgment matrix (JM):** Originate the judgment matrix based on the relative importance of the different attributes, while complying with the priorities, needs and experts' recommendations.
3. **Mathematical analysis:** Calculate the maximum eigenvalue (λ_{max}) and the corresponding eigenvector of the judgment matrix.
4. **Consistency test:** In a typical AHP, the pairwise comparisons in a judgment matrix are considered to be satisfactorily consistent if the corresponding consistency ratio (C_R) is less than 10% (Saaty, 1980). However, calculation and checking the C_R value needs initial calculation of the Consistency Index (C_I) of the hierarchical model, as follows:

$$C_I = \frac{\lambda_{max} - n}{n - 1} \quad (1)$$

where n represents the dimension of the judgment matrix. Hence, the C_R is calculated by dividing the C_I value by a Random Consistency Ratio (RC_I), as shown in (2).

$$C_R = \frac{C_I}{RC_I} \quad (2)$$

The Random Consistency Ratio (RC_I) is determined according to the dimension of the judgment matrix. Recalling (Saaty, 1980), it can be approximated and given as follows:

$$RC_I = \frac{1.846n^2 - 5.538n + 3.692}{n^2 - 1.204n + 1.004} \quad (3)$$

5. **Results:** Collect the relative weights of decision elements to develop a final score for each option and

hence find the most suitable weighting of energy credits in the Egyptian Green Pyramid Rating System.

Fig. 1 An analytic hierarchy process scheme (Saaty, 1980)

2.3. Formulation of the proposed problem using AHP

AHP ranks the decision elements and compares between each pair in each cluster (as a matrix) according to the available knowledge. Regarding forming the judgment matrices for the considered rating systems, mandatory credits are scaled with the fuzzy variable 9 in order to represent that these criteria are extremely important than others. On the other hand, a scale with the fuzzy variable 1 is given to the equal or non-available energy credits. Other credits are scaled relative to their weights in the rating system. Consequentially, the four judgment matrices for the ten energy credits of the four considered rating systems can be structured as shown in the following scenarios.

Scenario 1 of the BREEAM rating system: In this Scenario, the judgment matrix is shown in Table 1. λ_{max} equals 10.115 and the corresponding eigenvector is [0.840 0.118 0.068 0.068 0.118 0.430 0.118 0.068 0.201 0.118]^T with an acceptable consistency ratio of 0.8587% (<10%). However, their weighted sum must equal 1, therefore, the values of the eigenvector are normalized by dividing by the row sum, hence, the new eigenvector representing weights of the energy credits of BREEAM will be given as [0.3917 0.0548 0.0316 0.0316 0.0548 0.2005 0.0548 0.0316 0.0938 0.0548]^T.

TABLE 1

THE JUDGMENT MATRIX FOR SCENARIO 1

Scenario 2 of the LEED rating system: In this Scenario, the judgment matrix is shown in Table 2. λ_{max} equals 10.289 and the corresponding eigenvector is [0.538 0.538 0.046 0.068 0.099 0.300 0.046 0.538

0.142 0.046]^T with an acceptable consistency ratio of 2.1518% (<10%). Recalling the previous procedure, the new eigenvector representing weights of the energy credits of LEED will be given as [0.2279 0.2279 0.0193 0.0288 0.0421 0.1273 0.0193 0.2279 0.0601 0.0193]^T.

TABLE 2

THE JUDGMENT MATRIX FOR SCENARIO 2

Scenario 3 of the GS rating system: In this Scenario, the judgment matrix is shown in Table 3. λ_{max} equals 10.079 and the corresponding eigenvector is [0.633 0.633 0.109 0.062 0.109 0.395 0.062 0.062 0.062 0.062]^T with an acceptable consistency ratio of 0.5879% (<10%). The new formulated eigenvector representing weights of the energy credits of GS will be given as [0.2890 0.2890 0.0498 0.0284 0.0498 0.1805 0.0284 0.0284 0.0284 0.0284]^T.

TABLE 3

THE JUDGMENT MATRIX FOR SCENARIO 3

Scenario 4 of the PEARL rating system: In this Scenario, the judgment matrix is shown in Table 4. λ_{max} equals 10.236 and the corresponding eigenvector is [0.542 0.542 0.099 0.099 0.542 0.247 0.068 0.044 0.163 0.068]^T with an acceptable consistency ratio of 1.7523% (<10%). The new formulated eigenvector representing weights of the energy credits of PEARL will be given as [0.2246 0.2246 0.0410 0.0410 0.2246 0.1025 0.0280 0.0181 0.0676 0.0280]^T.

TABLE 4

THE JUDGMENT MATRIX FOR SCENARIO 4

Four different attributes (criteria) are used for the assessment of the rating systems, They are arranged as follows:

1-Usability: It measures whether a rating system is practical and easy to be implemented by the users or not, while considering when the system was developed (maturity of the system in years). This is performed through calculation of the average number of certified projects of the system per year, as shown in (4). Table 5 demonstrates the findings of this criterion. Consequentially, the normalized vector representing weights of the rating systems, according to the usability criterion, is given as $[0.6821\ 0.3138\ 0.0034\ 0.0007]^T$.

$$\text{Usability}=\frac{\text{Total number of certified projects}}{\text{Maturity of the system in years}} \tag{4}$$

TABLE 5

CRITERIA 1: MATURITY AND USABILITY

2-Degree of similarity with the Egyptian viewpoint: It measures the degree of similarity of energy credits' weights of a rating system with those published in the first edition of Egypt's Green Pyramid Rating System (Egypt-GBC, 2009; GPRS, 2011). Fig. 2 demonstrates a chart for the energy credits' weights for the considered systems in addition to those of the Egyptian rating system. Consequentially, the sum of the average differences between a credit's weight (i=1, 2…10) in each rating system and the corresponding weight in GPRS is calculated. As a result, a similarity index can be defined as shown in (5). Hence, the normalized vector representing weights of the rating systems, according to the degree of similarity with the Egyptian viewpoint criterion, is given as $[0.035874\ 0.427782\ 0.032665\ 0.503679]^T$.

$$\text{Similarity Index}=\frac{100}{\sum_{i=1}^{10}\left|\left(\text{Credit's weight-Corresponding weight in GPRS}\right)_i\right|} \tag{5}$$

It must be mentioned that this index demonstrates a high degree of similarity (50.37%) between the GPRS and the PEARL rating systems. This degree may have two contradicting meanings. Firstly, it validates similar interests for the energy credits in the MENA (Middle East and North Africa) region. Secondly, it clarifies that the first Egyptian viewpoint for energy credits does not take into account the main difference in the potential of renewable energy resources between the two countries for achieving the required goals. In other words, Egypt's target is mainly dedicated to implement the energy credits through using of renewable resources (Solar, wind, and Biomass) beside the conventional energy resources, whilst that of UAE depends on achieving the same energy credits through minimizing energy consumption of their great potential of fossil fuels beside using the various renewable energy resources.

Fig. 2 Overview of the various energy credits' weights for the considered systems

3-Carbon Dioxide footprint: This criterion depends on quantizing the greenhouse gas emissions in the country of each global rating system through evaluating the CO_2 emissions (in metric tons per capita) that have developed from the burning of fossil fuels. It should be clear that the calculation of the total amount of CO_2 emissions in a country cannot be accurately determined, because of its wide and different causes (Wright et al., 2014). However, based on the data available in (Carbon Dioxide Information Analysis Center, 2014; IEA Statistics, 2014; World Bank Group, 2015), Fig. 3 demonstrates the CO_2 emissions for the considered systems' countries for a period ranging from year 2005 to the year 2010.

Fig. 3 Overview of the annual CO_2 emissions from the considered systems' countries in the specified period

As shown in Fig. 3, one can get the average values of the CO_2 emissions for the considered systems' countries in the specified period, inverting it (in order to guarantee that the country has a low average value of CO_2 emissions will be highly scored in the judgment matrix), and normalizing the output vector in order to follow the AHP requirements, hence, the output vector can be given as $[0.4390\ 0.1982\ 0.2066\ 0.1563]^T$.

4-Clean energy: This criterion measures percentage of use of clean energy with respect to total energy use, for the considered systems' countries. Clean energy includes renewable energy that does not produce considerable carbon dioxide emissions when generated and sustainable energy such as the nuclear one. According to (IEA Statistics, 2014; World Bank Group, 2015), Fig. 4 demonstrates the annual clean energy use (% of total energy use), for the considered systems' countries, for a period ranging from year 2005 to the year 2011. Hence, calculating their average values and normalizing the output vector, the output vector can be given as $[0.4203\ 0.5150\ 0.0647\ 0.0]^T$. It should be noticed that United Arab Emirates has no considerable clean energy use in this period range. Accordingly, PEARL has zero weight compared to other systems, as obvious in Fig. 4.

Fig. 4 Overview of annual clean energy use (% of total energy use) for the considered systems' countries in the specified period

After defining the four criteria that are used for the assessment of the rating systems (sub-criteria), hence, the last step is developing a hierarchy for them with respect to the main goal. In other words, importance of these criteria with respect to each other (the main judgment matrix) is given as shown in Table 6. λ_{max} equals 4.031 and the corresponding eigenvector is $[0.1661\ 0.8135\ 0.4826\ 0.2787]^T$ with an acceptable consistency ratio of 1.1475 % (<10%). Hence, the final normalized eigenvector is given as $[0.0954\ 0.4673\ 0.2772\ 0.1601]^T$. Accordingly, the complete four level hierarchical model of the proposed problem, which is choosing the most suitable weighting of the energy credits of the Egyptian Green Pyramid Rating System, is shown in Fig. 5.

TABLE 6

THE JUDGMENT MATRIX FOR THE MAIN CRITERIA

Fig. 5 Formulation of the proposed problem using AHP

3. RESULTS AND DISCUSSION

Based on the study of various energy credits in four global rating systems, AHP provides a logical framework to determine the relative weight for the energy sector of each system. Fig. 6 demonstrates the finding of these optimal weights compared to their corresponding weights on the basis of the similarity criterion. Regarding the LEED system, it is obvious the good agreement between both weights. On the other hand, the results indicate that much attention should be paid to the energy credits introduced in BREEAM at the expense of those of the PEARL rating system.

Fig. 6 Proposed weights for the considered rating systems

According to the previous weights of the rating systems, AHP reassesses the weighting of their energy credits. Hence, the optimal weights of the different energy credits under study, that are quoted from the AHP results, for the enhancement of GPRS, are listed in Table 7. Additionally, the proposed ranking of the credits, according to their importance in descending order, is provided.

TABLE 7

THE OPTIMAL WEIGHTS OF THE VARIOUS ENERGY CREDITS UNDER STUDY

Obviously, Fig. 7 demonstrates that the proposed weightings avoid shortcomings and attain most of the advantages of the other rating systems. A considerable difference is noted for energy monitoring: Credit 5, between the MENA rating systems (GPRS and PEARL) than the other systems. This indicates the common interest in broadening the use of the different metering facilities that allow measuring and hence controlling energy performance of a building, thus moving towards smarter grids. On the other hand, a considerable agreement is noted for fundamental commissioning of building energy systems: Credit 8, between the GPRS and the LEED rating systems, compared to its corresponding percentage in the other systems. Recalling that Egypt is a country of the third world, and variance of the degree of awareness of people, this agreement is very vital for the success of the GPRS, because of the importance of comparison between the project's designed and installed energy systems.

Fig. 7 The proposed weights of the various energy credits for the Egyptian Green Pyramid rating system

Aly et al., 2012, introduces results of a survey that had been carried to develop tailor-made based energy credits that could be considered as a guideline towards enhancing the energy category of the Egyptian GPRS. Its data were collected through desk studies and online questionnaires. Fig. 8 clarifies a comparison between the proposed weights that are quoted from the AHP results and those presented in (Aly et al., 2012), for the various energy credits of the GPRS. It should be clear that the weights of the energy credits presented in (Aly et al., 2012) are based on the various classifications of the survey's respondents, not the credits themselves. Therefore, only ranking of the credits according to their importance, will be discussed. Readers could refer to (Aly et al., 2012) for more details about the survey's respondents.

It is clear, from Fig. 8, that the general trend (ups and downs) of both weighting methods is similar. In both weighting methods, Credit 1 has the highest weight, while Credit 2 comes secondly. Consequentially, Credit 6 ranked third and Credit 8 ranked fourth. Besides, trivial differences are noted in the ranking of the rest energy credits.

Fig. 8 Comparison of the proposed weights of energy credits and those presented in (Aly et al., 2012)

Regarding the suggestion of mandatory energy credits for the enhanced GPRS, while taking into consideration the highly ranked credits of the proposed assessment method, it is obvious that Credit 1 that is ranked first, Credit 2 that is ranked second and Credit 8 that is ranked fourth, are the most suitable choice. The reason of exclusion of Credit 6, that was ranked third, from the mandatory credits, is its aim that is very close to that defined in Credit 1. In simple words, Credit 6 aims to achieve increasing levels of energy performance beyond the prerequisite levels of Credit 1. As a result, it is not logical to oblige customers to minimize and optimize their levels of energy performance at the same time. It should be mentioned that these results were extracted from an offline questionnaire carried by the authors. Fortunately, the suggested selection of the mandatory energy credits coincides with that of the LEED rating system. However, it disagrees, with both PEARL and the first launched GPRS, in their third mandatory credit. Since they have considered the energy monitoring: Credit 5, which is ranked fifth in the proposed weighting method, as the third mandatory credit. In that case, it must be mentioned that applying energy monitoring as a mandatory credit needs some proactive steps from the public sector in presenting facilities, providing incentives and tax exemption for customers and large end-users that will follow this requirement. From this point of view, it is important to verify that the project's energy related systems are primarily installed. Hence, monitoring the energy use of these devices.

The sustainable building design is a relatively new concept in Egypt. Although the Egyptian Green Building Council has been established by the Egyptian government in January 2009, it is still recognized by the World Green Building Council WGBC, as a Prospective GBC, the lowest membership level, which is one that has brought together a robust group of founding members, developed a strategic plan for how the GBC will be developed, and is registered as a legal entity. Hence, the involvement, contribution and integration of all stakeholders in the construction and industry (including government, community, buildings’ owners, contractors, consultants and designers) is the primary condition for ensuring that green building practices will be adopted in the very near future.

Based on the experience gained through preparation of this study, the following points should be taken into consideration for the successful implementation of the GPRS system:

- Developing new codes for energy efficiency in buildings and/or enhancing of old codes in order to comply with the green power requirements, taking into consideration identification of alternative paths, low-priced materials and new tools towards maximization of energy efficiency, while minimizing buildings' impacts on the human and the environment during buildings' lifecycles that begin with buildings' siting and end with buildings' removal.
- Sponsoring the dilemma of the sustainability concept which represents a larger and more comprehensive concept than a green architectural platform (Ammar, 2012). This can be done by educating, training and convincing engineers, builders, contractors and owners about the benefits of green construction to the individual, community and the nation (EGPC, 2009).
- Demonstrating requirements and targets of the various levels for green building certification according to the GPRS (Silver Pyramid, Golden Pyramid, and Green Pyramid), while highlighting that the highest level of certification is labeled "Green" in order to confirm that the ultimate goal and most valuable level is reaching the green level. Emphasizing the need for public awareness of the importance of the concept of green buildings, energy saving, and environmental conservation, as the main barrier is not the cost of constructing of these green buildings but low awareness of the problems of environment, energy and water.
- Promoting the concept of recycling, taking into account the main problems which characterize the Egyptian society, such as the high rate of domestic residues or the solid residues from building and demolition wastes.
- Developing logical and valuable incentive system that would encourage compliance and reward efficiency for all the builders sectors. Promoting construction programs that include different advantages, such as access to preferred and prime locations, tax breaks and postponements,

financial assistance, utility concessions, equipment support and finance, and employee support and assistance (EGPC, 2009).

- In Egypt, most of the organizations are creating projects with a limited share of own direct investments and a large proportion of loans. Classically, energy projects are geared by a 10 to 15% capital commitment and 85 to 90% bank loans. Thus, bank interest rates and financial conditions are critical for any project viability, Accordingly, supporting loans with low interest rates for green energy projects is required. It should be mentioned that the World Bank could finance a green public project with a 2 to 3 % interest rate long term loan.
- The most important point to be addressed for all the MENA region, from the authors' viewpoint, is the sustainability reporting. It is considered the real practice of measuring, disclosing, and being accountable to all stakeholders for organizational performance towards the goal of sustainable development. These guidelines are important for assessing performance of sustainability with respect to the codes, or demonstrating, analyzing, and expecting the past, present and future sustainability performance for the various organizations, and studying and comparing the sustainability performance within the Egyptian organizations with other global organizations (Sustainability reporting guidelines, 2011). This report should include clear performance indicators with appropriate importance or weights.

The economic development of Egypt depends on energy production. Nowadays, Egypt seeks for more economic and energy independence. A 20% renewable energy content in the overall electricity consumption portfolio has been set as an objective by 2020. This is both a sustainable objective and an independence progress. Consequentially, the GPRS is an important step for Egypt towards sustainability and energy efficiency. However, requirements for energy efficiency in new buildings should be set and updated regularly, insufficient finance for green energy projects should be surmounted, comprehensive policies that imply encouragement and enforcement systems of efficiency regulations for new buildings should be proposed, and finally, further research and development should be undertaken in order to surmount the different barriers, taking into account continuous comparison with other global rating systems, as presented in this work.

4. Conclusions and Policy Implications

This paper proposes a methodology using the Analytic Hierarchy Process (AHP) for assessment of the energy credits through studying and comparing four of the common global rating systems in order to contribute to the enhancement of the Egyptian Green Pyramid rating system.

Based on the study of various energy credits in four global rating systems, AHP provides a logical framework to determine the relative weight for the energy sector of each system. The outcomes indicate the similarity in the energy sector of the American Leadership in Energy and Environmental Design (LEED) rating system and the recommended energy sector of the Egyptian Green Pyramid rating system. On the other hand, the results argue that much attention should be paid to the energy credits introduced in the British Building Research Establishment Environmental Assessment Method (BREEAM) at the expense of those of the PEARL rating system. The results show the energy credits that should be considered with their proposed weights according to the present and future needs of green Egypt. Consequently, mandatory energy credits are suggested based on the results quoted from the proposed methodology. The results indicate that minimum energy performance, fundamental refrigerant management and fundamental commissioning of building energy systems should be considered as the mandatory energy credits.

Any green building rating system includes other categories beside the energy category, thus the study of these categories in various global rating systems, is a fundamental step towards approaching a proper local green building rating system that meets the requirements of the Egyptian society. Furthermore, it should be realized that moving towards green energy or sustainability should go together with developing a comprehensive energy policy for green applications. This policy must be built on a case-by-case basis to surmount the existing barriers. It should imply encouragement and enforcement systems of efficiency regulations for new buildings.

The AHP as a decision support tool, should be applied as an indication to what may be the most suitable weighting of the alternatives and not the main tool for deriving a final decision. Lastly, the proposed analysis is also applicable to any other category in the global rating systems.

ACKNOWLEDGMENTS

The authors gratefully acknowledge and thank the team of Newton Fund, Brunel University, the British Council in Egypt and the Science Technology Development Fund in Egypt for their support during the workshop regarding UK-Egypt enhanced research networks in renewable energy to support economic development. Additionally, the authors gratefully thank all the participants for their helpful comments that enhance this work.

REFERENCES

Abdel Aleem, S.H.E., Balci, M.E., Sakar, S., 2015. Effective utilization of cables and transformers using passive filters for non-linear loads. *International J. of Electrical Power and Energy Systems.*71,344-350. doi: http://dx.doi.org/10.1016/j.ijepes.2015.02.036

Aleh, C., Jessica, J., 2014. The concept of energy security: Beyond the four As. *Energy Policy* 75, 415–421. doi: http://dx.doi.org/10.1016/j.enpol.2014.09.005

Aly, A.A.S., Abou El-Zahab, E.E., Ibrahim, A.M., Elkady, M.A., 2012. Energy Credits investigation: In the development of an Egyptian Green Building Rating System. *In: International Conf. Engineering and Technology (ICET),* Cairo, Egypt, IEEE, Oct. 10-11, pp. 1–7.

Ammar, M.G., 2012. Evaluation of the Green Egyptian Pyramid. *Alexandria Eng. J.* 51, 293–304. doi: http://dx.doi.org/10.1016/j.aej.2012.09.002

Carbon Dioxide Information Analysis Center, 2014. Environmental Sciences Division, Oak Ridge National Laboratory, Tennessee, United States. Data from database: World Development Indicators. Available at < http://cdiac.ornl.gov >

Choongwan, K., Taehoon, H., Minhyun, L., Hyo, S.P., 2014. Development of a new energy efficiency rating system for existing residential buildings. *Energy Policy* 68, 218–231. doi: http://dx.doi.org/10.1016/j.enpol.2013.12.068

Egyptian Green Building Council (EGPC), 2009. Available at < www.egypt-gbc.org > (19.05.2015).

Elgendy, K., 2010. Comparing Estidama's Pearls Rating System to LEED and BREEAM. Carboun: Advocating Sustainable Cities in the Middle East. Available at < http://www.Carboun.com/sustainable-urbanism >

Emirates Green Building Council (EmiratesGBC), 2006. Available at < www.emiratesgbc.org > (24.05.2015).

Estidama, 2010. Available at < http://estidama.upc.gov.ae > (19.05.2015).

Farghal, S.A., Kandil, M.S., Elmitwally, A., 2002. Quantifying electric power quality via fuzzy modelling and analytic hierarchy processing. *IEE Proc. Gener. Transm. Distrid.* 149, 44–49.

Green Building Council of Australia (GBCA), 2002. Available at < http://www.gbca.org.au > (24.05.2015).

Green Pyramid Rating System (GPRS), 2011. The Egyptian Green Building Council, Housing and Building National Research Center.

Green Star, 2003. Available at < http://www.gbca.org.au/green-star/ > (25.05.2015).

International Energy Agency. IEA Statistics. OECD/IEA. Available at < http://www.iea.org/statistics/ > (25.05.2015).

Loken, E., Botterud, A., Holen, A.T., 2006. Decision Analysis and Uncertainties in Planning Local Energy Systems. *Int. Conf. on Probabilistic Methods Applied to Power* Systems, *PMAPS' 06*, Stockholm, IEEE, Jun. 11-15, pp. 1–8.

Mohamed, I.F., Abdel Aleem, S.H.E., Ibrahim, A.M., Zobaa, A.F., 2014. Optimal Sizing of C-type *Passive Filters under Non-sinusoidal Conditions. Energy Technology & Policy. 1, 35–44.* doi: http://dx.doi.org/10.1080/23317000.2014.969453

Papadopoulos, A.M., Giama, E., 2010. Rating systems for counting buildings' environmental performance. *Int. J. of Sustainable Energy* 28, 29–43. doi: http://dx.doi.org/10.1080/14786450802452423

Pearl Rating System for Estidama, 2010. Abu Dhabi Urban Planning Council, Abu Dhabi, UAE.

Rozlan, M.B.M., Zobaa, A.F., Abdel Aleem, S.H.E., 2011. The optimisation of stand-alone hybrid renewable energy systems using HOMER. *Int. Rev. Electr. Eng.* 6, 1802–1810.

Saaty, T.L., 1980. *The Analytic Hierarchy Process*, first ed. McGraw-Hill, New York.

Shahriar, S., Erkan, T., 2009. When will fossil fuel reserves be diminished?. *Energy Policy* 37, 181–189. doi: http://dx.doi.org/10.1016/j.enpol.2008.08.016

Sustainability reporting guidelines, 2011. Available at < https://www.globalreporting.org/resourcelibrary/G3.1-Guidelines-Incl-Technical-Protocol.pdf > (10.08.2015).

The American Leadership in Energy and Environmental Design (LEED). Available at < http://www.usgbc.org/leed > (25.05.2015).

The Building Research Establishment Environmental Assessment Method (BREEAM). Available at < http://www.breeam.org > (20.05.2015).

The Ozone Hole website. Available at < http://www.theozonehole.com/australianskincancer.htm > (19.05.2015).

The World Bank Group, IBRD. IDA, 2015. World Development Indicators. Available at <http://data.worldbank.org/indicator> (25.05.2015).

U.K. Green Building Council, 2007. Available at < http://www.ukgbc.org > (20.05.2015).

U.S. Green Building Council, 2012. Available at < http://www.usgbc.org > (20.05.2015).

Wafik, A., Hanafy, M., 2015. Feasibility assessment of diesel fuel production in Egypt using coal and biomass: Integrated novel methodology. *Energy*. doi: http://dx.doi.org/10.1016/j.energy.2015.03.068

World Green Building Council (WGBC), 2002. Available at < http://www.worldgbc.org/worldgbc > (10.08.2015).

Wright, L.A., Kemp, S., Williams, I., 2014. Carbon footprinting: Towards a universally accepted definition. *Carbon Management*. 2, 61-72. doi: http://dx.doi.org/10.4155/cmt.10.39

Younan, V.A., 2011. *Developing a green building rating system for Egypt*. M.Sc. dissertation. School of Sciences and Engineering, The American University in Cairo, Cairo, Egypt.

Yudelson, J., 2008. *Green building through integrated design*, first ed. McGraw-Hill, New York.

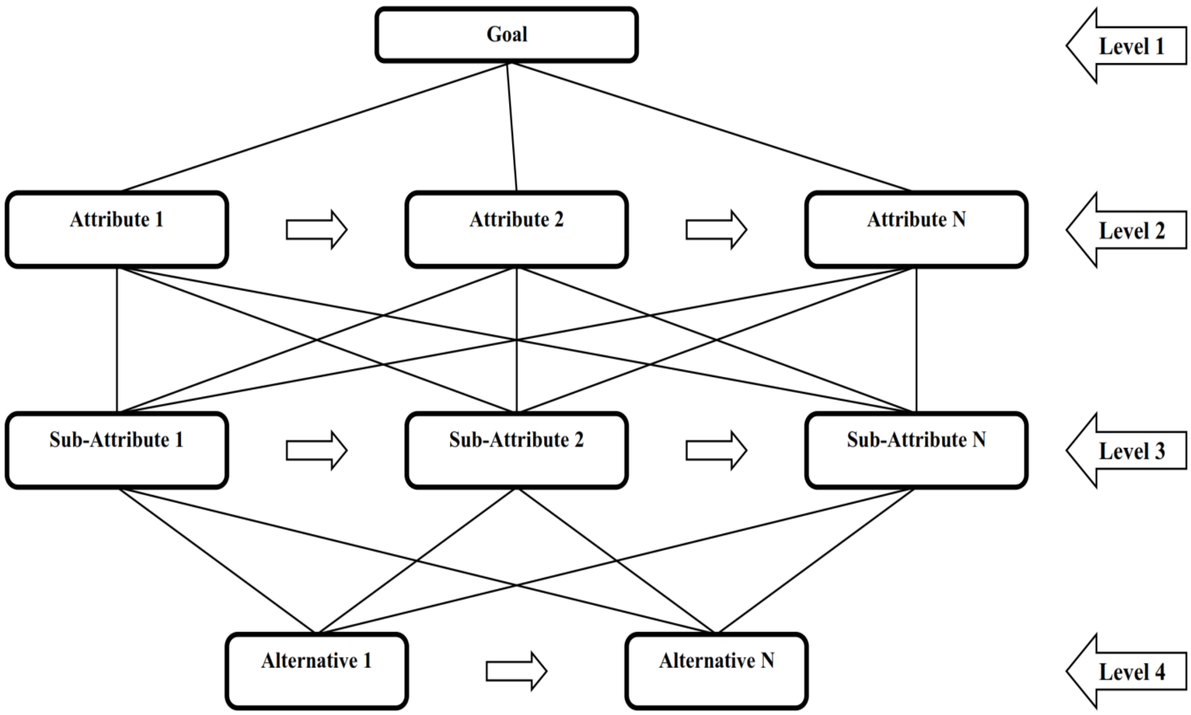
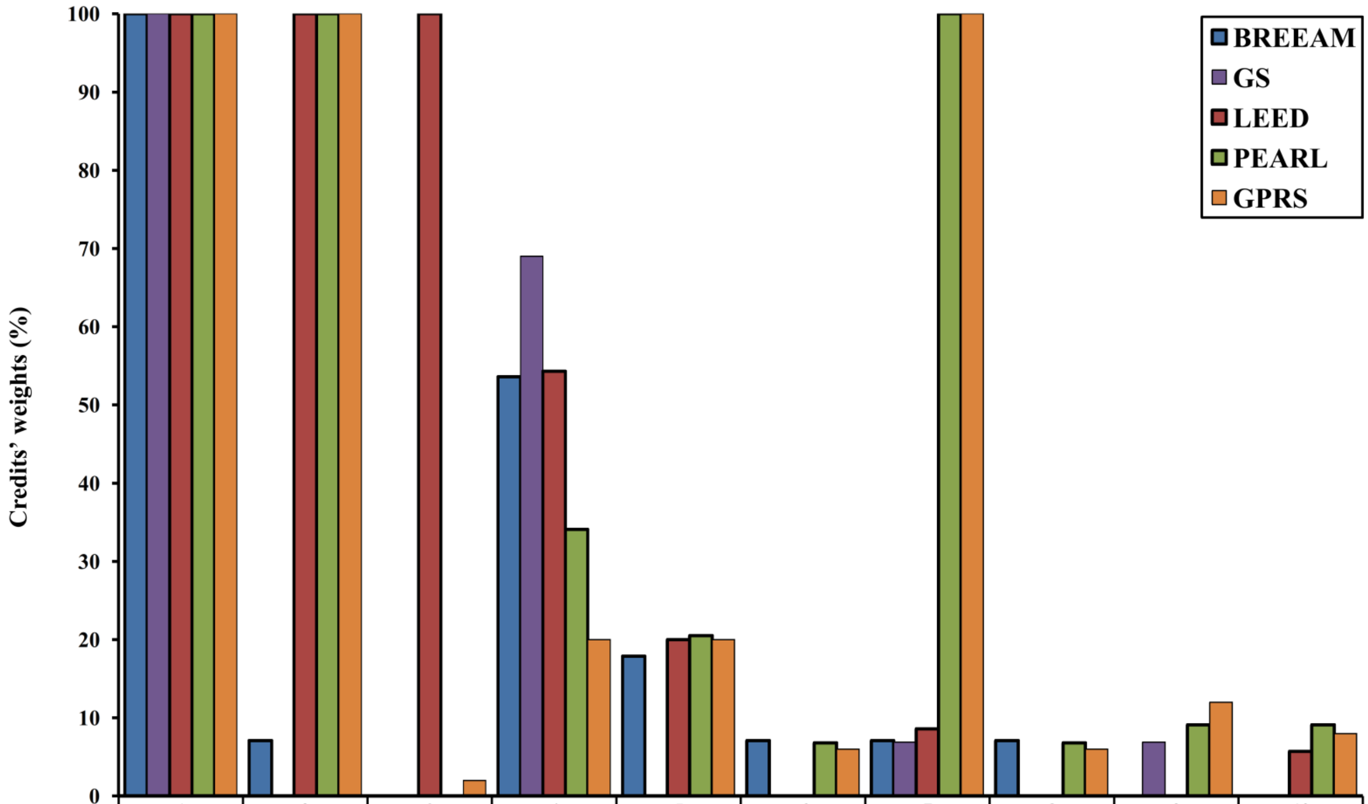


Fig. 1 An analytic hierarchy process scheme (Saaty, 1980)



	1	2	3	4	5	6	7	8	9	10
BREEAM	100	7.1	0	53.6	17.9	7.1	7.1	7.1	0	0
GS	100	0	0	69	0	0	6.9	0	6.9	0
LEED	100	100	100	54.3	20	0	8.6	0	0	5.7
PEARL	100	100	0	34.1	20.5	6.8	100	6.8	9.1	9.1
GPRS	100	100	2	20	20	6	100	6	12	8

Energy Credits

Fig. 2 Overview of the various energy credits' weights for the considered systems

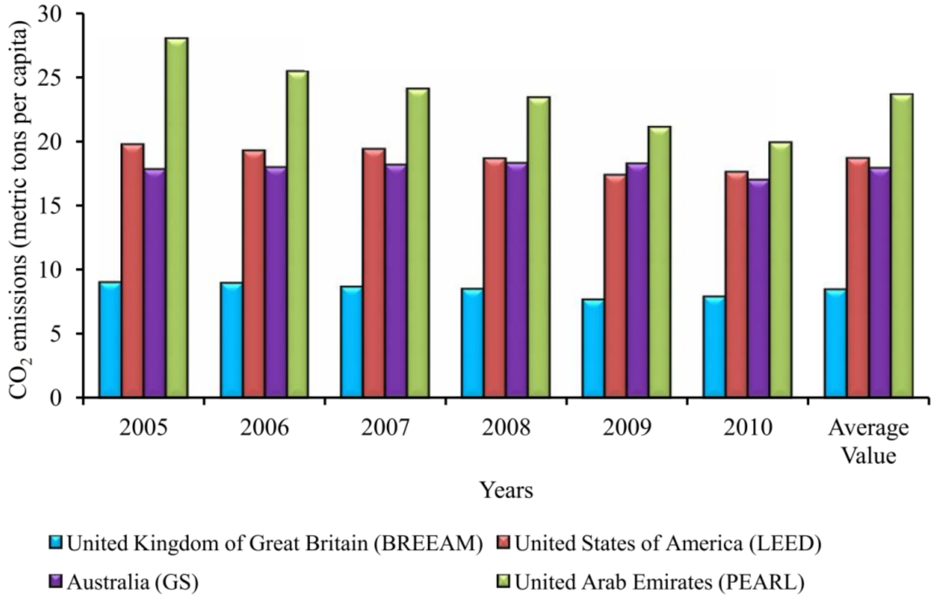


Fig. 3 Overview of the annual CO_2 emissions from the considered systems' countries in the specified period

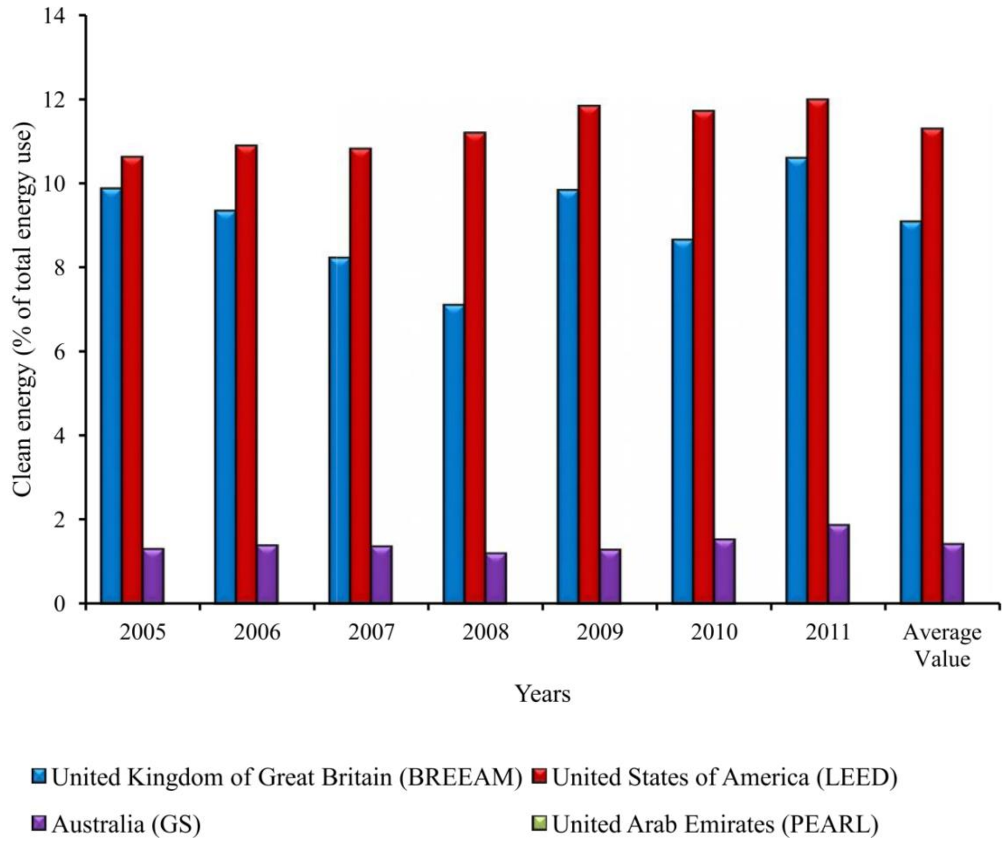


Fig. 4 Overview of annual clean energy use (% of total energy use) for the considered systems' countries in the specified period

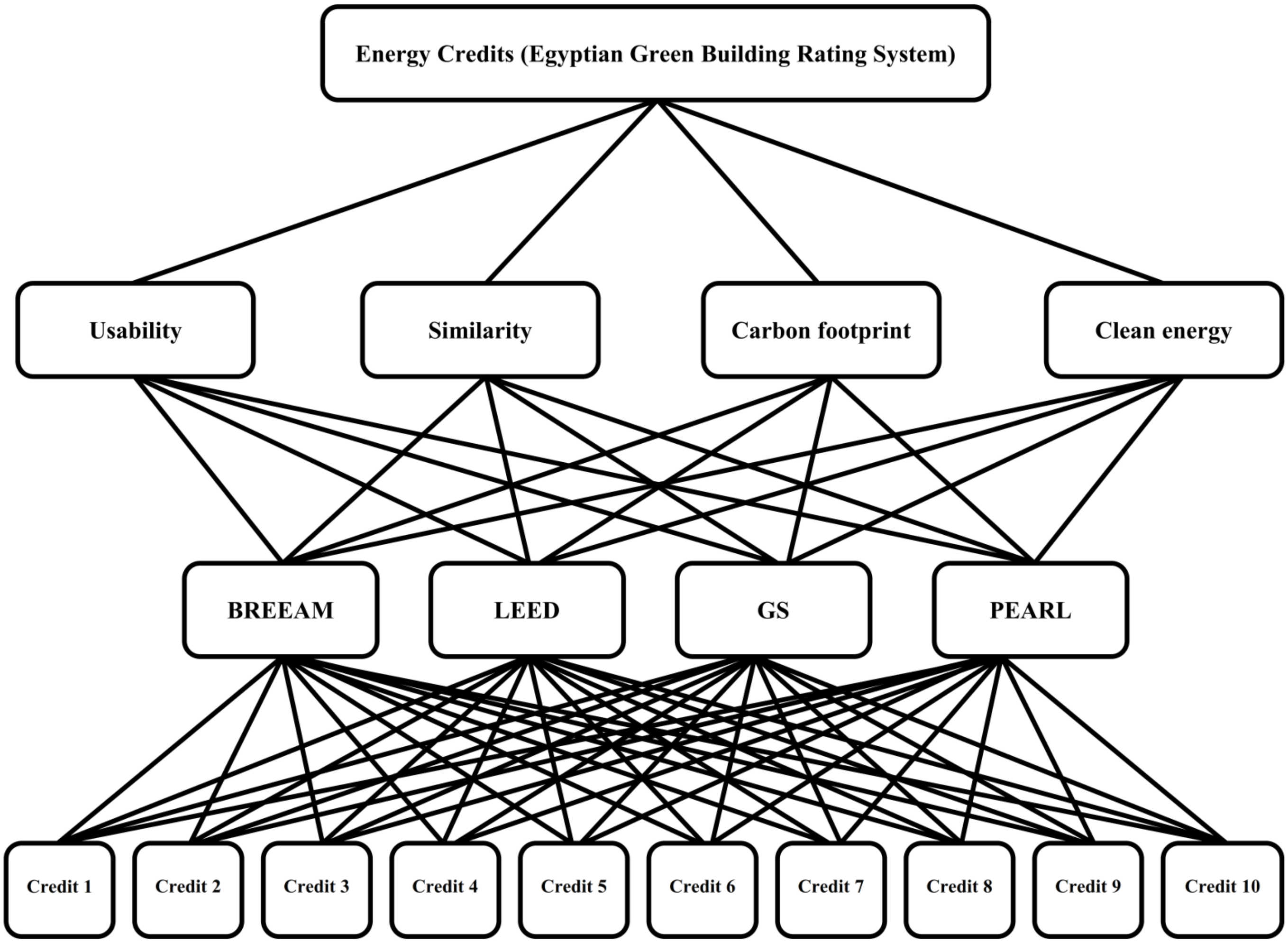


Fig. 5 Formulation of the proposed problem using AHP

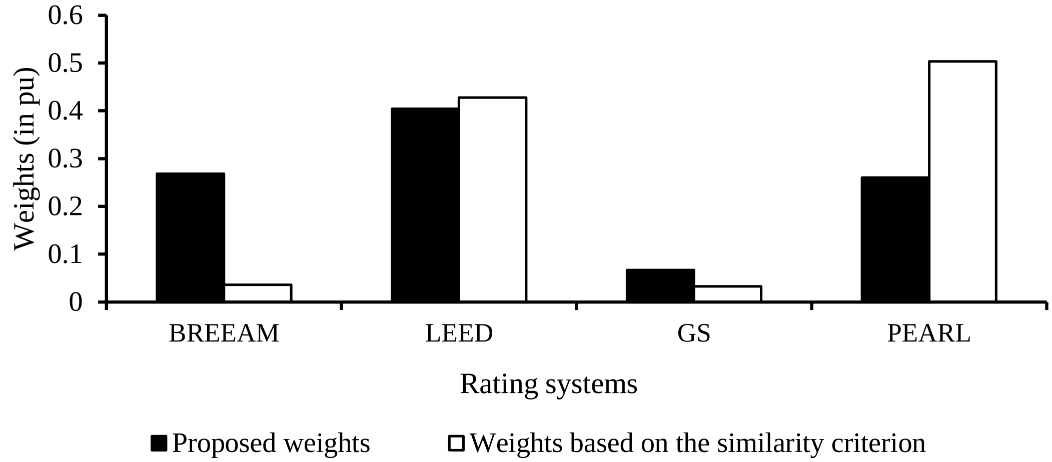


Fig. 6 Proposed weights for the considered rating systems

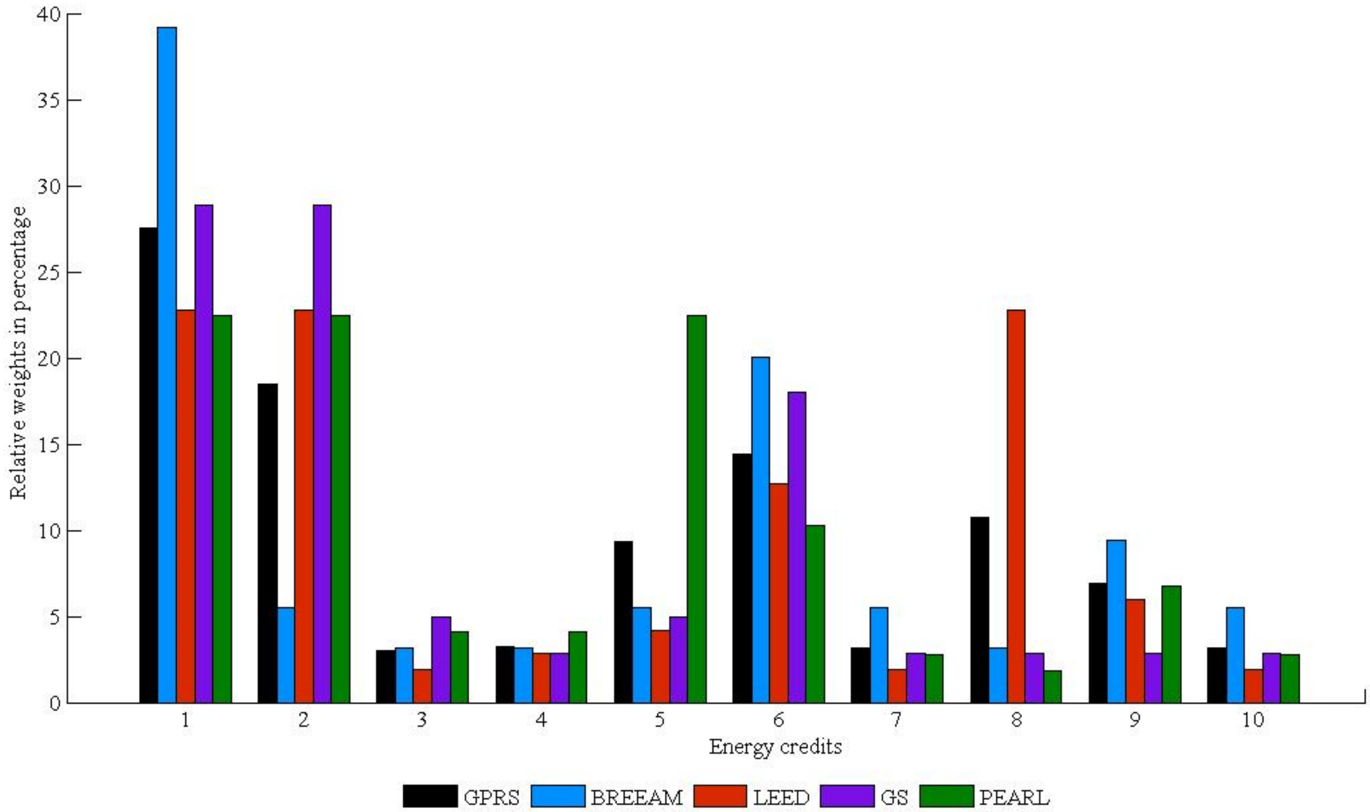


Fig. 7 The proposed weights of the various energy credits for the Egyptian Green Pyramid rating system

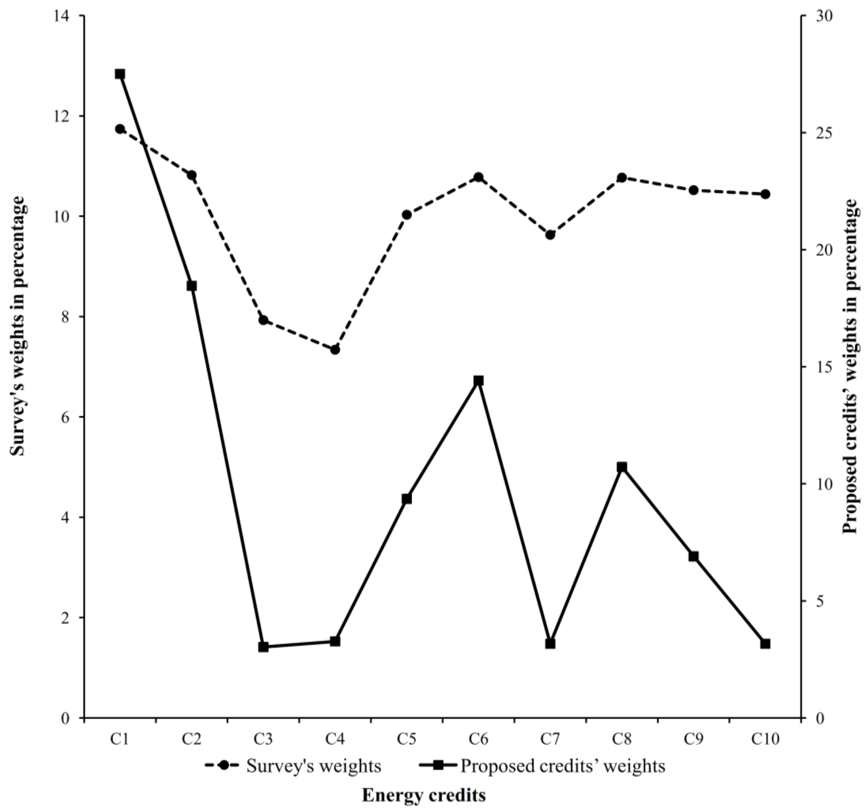


Fig. 8 Comparison of the proposed weights of energy credits and those presented in (Aly et al., 2012)

TABLE 1

THE JUDGMENT MATRIX FOR SCENARIO 1

Credits	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}
C_1	1.000	8.000	9.000	9.000	8.000	2.000	8.000	9.000	6.000	8.000
C_2	0.125	1.000	2.000	2.000	1.000	0.250	1.000	2.000	0.500	1.000
C_3	0.111	0.500	1.000	1.000	0.500	0.200	0.500	1.000	0.333	0.500
C_4	0.111	0.500	1.000	1.000	0.500	0.200	0.500	1.000	0.333	0.500
C_5	0.125	1.000	2.000	2.000	1.000	0.250	1.000	2.000	0.500	1.000
C_6	0.500	4.000	5.000	5.000	4.000	1.000	4.000	5.000	3.000	4.000
C_7	0.125	1.000	2.000	2.000	1.000	0.250	1.000	2.000	0.500	1.000
C_8	0.111	0.500	1.000	1.000	0.500	0.200	0.500	1.000	0.333	0.500
C_9	0.167	2.000	3.000	3.000	2.000	0.333	2.000	3.000	1.000	2.000
C_{10}	0.125	1.000	2.000	2.000	1.000	0.250	1.000	2.000	0.500	1.000