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# The Use of Energy Values in the Environmental Assessment of Buildings

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## Abstract

For a long time, money was the basic value to express any product, work, or consumption. The environment is a system of interactions and several components that are related to each other and can't be separated. The environmental balance is the best way to describe the right environmental relations that exist by default if no human disturbance, and should be achieved. To determine environmental balance achievement using monetary terms, the environment components become commodities, and nothing indicate their whole role they were created for, besides their impact and relations to the other environmental components, for example; the waste cost value is zero in spite of its negative impact on the environment. The research encourages the use of energy values to express the environmental components and achievements towards sustainability, as it relates the inputs and the outputs into certain cycles, and can express the environmental balance through the law of energy conservation. Sustainability, then, can be expressed as a zero energy result. Building environmental assessment methods had emerged to help buildings being sustainable, but researches whom studied developing these methods quickly turned to study the way of minimizing the cost of their achievement, rather than their environmental benefits over the time, considering that many important assessment credits depend mainly on the achieved economic savings. The aim of the research is to encourage the use of energy values in the building environmental assessment methods instead of monetary values. Thus, this research paper focuses on the differences between money and energy as values of expressing the building environmental efficiency. A comparative analysis was used to do so.

## Keywords

Sustainable Development, Environmental Equilibrium, Energy Conservation,
Environmental Assessment Methods of Buildings, Exergy

## 1. Introduction

Money represents the common form and way of dealing among countries and people. It can expresses the value of a product, work, or consumption. It also reflects the economic level of countries and people, affects their financial capabilities, transactions, and relations. So, it has got an important worth even it depends on variables such as human preferences over the time, and currency values among countries. Buildings are products that can be expressed in a cost manner, and they can be divided according to their economic levels too.

The environmental assessment methods of buildings emerged across the world to determine the environmental principles and standards for buildings. They are used in issuing assessment certificates to confirm the building commitment to the environment according to specific classifications. The most well-known and widespread method is "Leadership in Energy and Environmental Design" (LEED), produced by the US Green Building Council (USGBC) in the United States of America, and was applied in 2000. [1, 2] Many researches focused on the relation between achieving LEED ratings and the cost spent for that. The U.S. General Services Administration (GSA) started these researches in 2002 (Matthiessen and Morris 2002). [3] Davis Langdon (DL), a global construction consulting company had also funded number of researches to examine the cost of LEED from multiple perspectives (Kat, 2003). [4] Other growing number of studies addressed the cost and benefits of building green and commissioning green buildings (Chad Mapp et al, 2011). [5] These different researches concluded that many construction projects can achieve sustainable design and different levels of LEED certification within their budget or by an increase of cost from less than 1% to 8.1% (2.5% to 7% in 2002 GSA study, 1% to 6% in the 2003 DL study, 1.4%–8.1% in the GSA 2004 study, 0% to 3% in the DL 2007 study, 2% to 30% in a 2010 study), others indicated that they can achieve sustainable design by a decrease of cost by 0.4%–4.4% (in the 2004 GSA study). [3],[4, 5] Thus, they concluded that there is no significant difference in average costs for green buildings as compared to non-green buildings for several building types. Figure 1 shows the concluded incremental percentage capital cost of meeting LEED according to some researches.

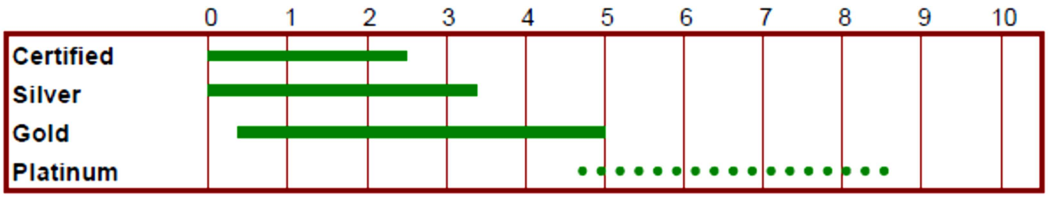



***Figure 1.** Typical incremental percentage capital cost of meeting LEED according to some researches. [6].*

Taking a close look to the concept of these studies, we can notice that they were made by the use of ‘‘no cost’’ or ‘‘low cost’’ credit opportunities. Geof Syphers and Darren Bouton, 2003 discussed some green building measures that may be achieved with no change in cost (e.g., recycled content structural steel), in comparison to some green building features involve a change in practice that effectively moves costs from one budget to another. [6] The credits in LEED checklist can be classified based on their costs to minimize the cost for a building’s LEED certification. From classification results, credits are sorted into a group with low difficulty with no cost (Costless-Easy), a group with high difficulty with no cost (Costless-Hard), a group with low difficulty and a cost (Cost-Easy), and a group with high difficulty and costs (Cost-Hard). The difficulty of achieving a credit even depends on building characteristics and location. Therefore, the difficulty was determined based on these factors. The overall items can be represented with the four groups in Table 1. [7]

***Table 1.** Classification of LEED V4 credits by cost and difficulty. [7].*

| Costless-Easy | Costless-Hard | Cost-Easy | Cost-Hard |
|---|---|---|---|
| SSc1 | SSc3 | SSp1 | SSc6.1 |
| SSc2 | SSc7.1 | SSc4.2 | SSc6.2 |
| SSc4.1 | SSc8 | SSc5.1 | WEc2 |
| SSc4.3 | EAc4 | SSc5.2 | EAp1 |
| SSc4.4 | MRc1.1 | SSc7.2 | EAp2 |
| EAp3 | MRc1.2 | WEp1 | EAc1 |
| MRp1 | MRc3 | WEc1 | EAc2 |
| MRc2 | IEQc2 | WEc3 | EAc3 |
| MRc4 | IEQc3.1 | EAc6 | EAc5 |
| MRc5 | IEQc8.1 | MRc7 | MRc6 |
| IEQp1 | IEQ8.2 | IEQc3.2 | IEQc1 |
| IEQp2 | | IEQc4.1 | IEQc4.3 |
| IEQp7.1 | | IEQc4.2 | IEQ4.4 |
| IEQc7.2 | | IEQc6.1 | IEQc5 |
| | | | IEQc6.2 |

The question appears is whether the achievement of LEED by focusing on the Costless-Easy credits group was the aim that the environmental assessment created to, and whether the lower cost building is the more environmentally effective one. What could frighten that the way of focusing on the resulted cost may mislead the environmental assessment from its main goal. Especially when noticing that the initial building cost doesn’t represent what could be returned through its lifecycle, besides, the cost cannot express properly the benefits and returns from green buildings. The following parts is searching the ability of encouraging the researchers and decision makers to express environmental building efficiency in terms of energy value rather than money misleading value.

## 2. Sustainability and the Environmental Assessment Methods of Buildings

Sustainable development appeared in the seventies of the twentieth century, in a period in which there was a debate on the relationship between the environment and the development.[1] Some see that they contradict, they stress on the limits that the protection of the environment makes on the economic growth, and vice versa, as the economic growth negatively affects the environment. While others emphasize the concept that environment and development are only two sides of a single coin. Over time, the evidence supporting this relationship gradually increased until there is consensus that there are integrative and exchange relationships that link the environmental and development issues. As development cannot continue on a degraded environmental resource base, and the environment cannot be protected when development neglects the cost of environmental damage. [8, 10]

Sustainable construction principles refer to minimizing the environmental negative impacts. The interest in sustainable

1 Since the beginning of the seventies, a series of theories and ideas have been launched on the environment and development relations. These ideas have become the basis for extensive discussion in many regional and international forums and conferences such as the 1997 Phoenicia Symposium on Environment and Development, the 1972 United Nations Conference on the Human Environment held in Stockholm, 1974 development strategies symposium held in Mexico, and 1992 on the environment Earth Summit in Rio de Janeiro. Where these forums introduced new expressions and ideas such as alternative modes of development, ecological development, Sustainable development and others. [8]

construction is growing over the past two decades. Green building certification systems are being frequently used as a mean of rating sustainable buildings. There are several systems developed in different countries. Some countries use their own systems, while some others prefer to adopt them. [9, 10] The “Building Research Establishment Environmental Assessment Method” (BREEAM) was the first, which released from the Building Research Establishment (BRE) in the United Kingdom in 1990, then many others appeared. LEED certification system was the next, which appeared in the U.S. BREEAM and LEED are the two most widely recognized environmental assessment methodologies used globally in the construction industry today. [6] The systems aims to use resources efficiently by using less energy and water, reducing greenhouse gas emissions, and focusing on materials to reduce the effects of their harmful components. [9]

## 3. Credibility of Cost for the Environmental Assessment Methods of Buildings

Across the U.S., green building professionals are lowering their estimate of the cost of achieving a LEED rating. As previously discussed, number of studies found that it is possible to achieve different LEED rating levels with little to no additional cost. [6] The cost usually contains non-environmental factors, such as training costs. LEED projects tend to have a large fraction of an organization’s green building program start-up and training costs ascribed to them. For example, the cost of developing a waste management plan, finding a list of acceptable low-VOC finishes, or establishing appropriate contract documents is far less for second and third LEED projects. A clear illustration of this cost trend is the experience of the City of Seattle. [12] Fortunately, as more design teams and consultants gain experience, their fees for LEED documentation are decreasing. Thus, the cost of these projects were not related to their environmental efficiency achievement. [12]

A Cost Study of Steven Winter Associates, 2004, showed that there is no correlation between the point value of a LEED credit and its cost. The cost of some credits varies significantly based on the building type and building program. Some credit costs vary based on region specific or project-specific issues. The following Figure shows the range of estimated construction cost impacts for the Certified and Silver rated scenarios falls below the 5% estimating accuracy that would normally be expected of early conceptual estimates. In addition, the construction cost impacts for all of the rated scenarios, including Gold, fall below the 10% design contingency that is carried in most GSA project budgets at the concept phase. These numbers imply that in some scenarios (depending on the design solution, market conditions, and other contingency factors), a LEED rating could potentially be achieved within a standard GSA project budget (without a green building budget allowance). By including a dedicated green building allowance, the potential for GSA buildings to achieve higher LEED rating levels - with the attended benefits - is substantially greater, as shown in Figure 2. [13]

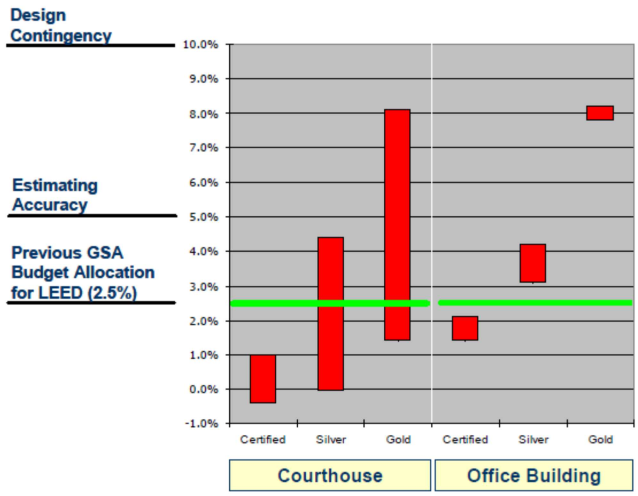



***Figure 2.*** *LEED Construction Cost Impacts vs. Estimating Accuracy and Design Contingency (GSA 2002 and 2004 reports). [13].*

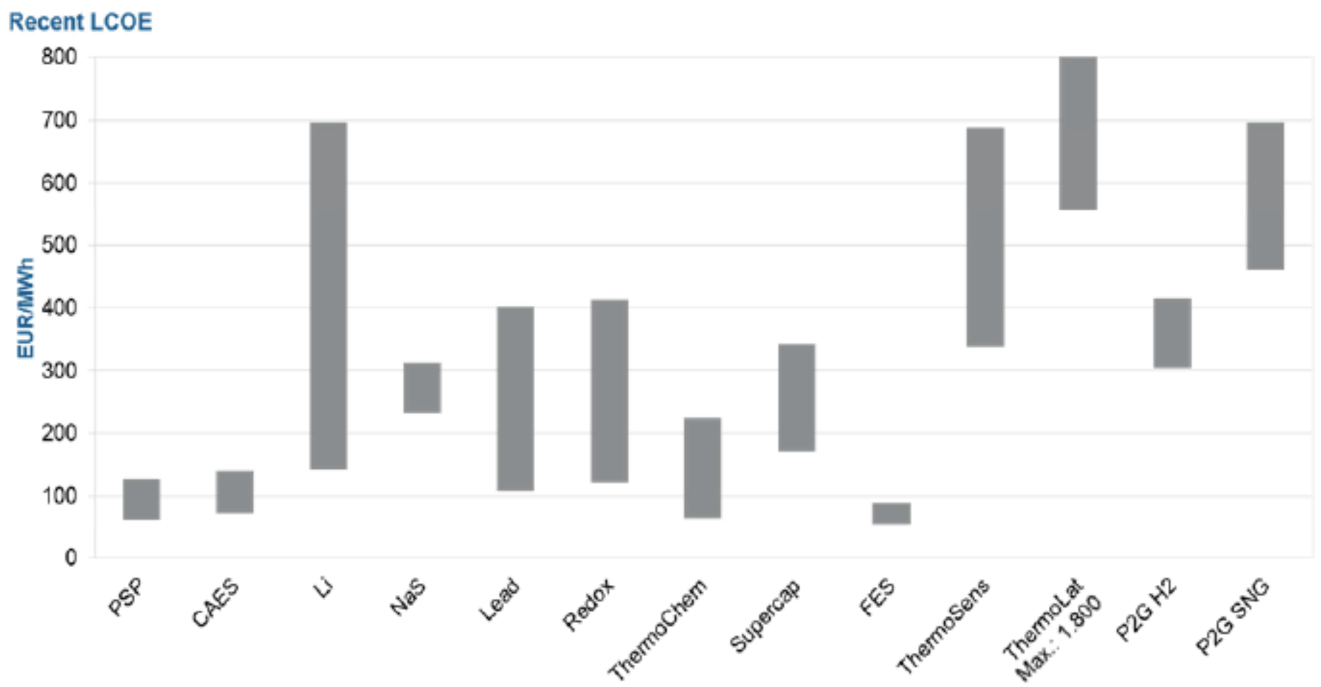
Northbridge Environmental Management Consultants, 2003, found that obtaining LEED certification adds from 4 to 11% to a project’s construction costs, but the research emphasized that if we only focus on costs, it is easy to lose sight of the fact that many of the investments made to earn points under the LEED system or to green a building pay for themselves over time. It believed in the importance to balance the discussion of costs with an understanding of the benefits. [14] Alpin Limited, 2017, illustrated that with the creation of green buildings, examining Capex costs only makes sense when the return on investment (ROI) is also taken into consideration. Investors, however, might still want to know about up-front costs for reasons of planning their initial investment, long term benefits notwithstanding. According to various sources compiled by the World GBC in 2013, estimated that green building costs are often higher than the actual reported costs. With the note that the first critical stages in environmental design and engineering, such as orientation, layout, and the use of passive conditioning systems, may not have an impact on the initial cost. They do add, however, high performance materials, components and systems that increase first cost, but have measurable life cycle benefit. In other words, non-green building, or even lower certified green building, can come at the price of missing out on long term economic, ecologic and societal benefits. The much saving potential a LEED project will have often depends on which LEED credits development team decides to pursue. Decisions on the level of certification and how to pursue these goals are therefore important and must be made on a case-by-case basis. The decision for green design in general, however, should not doubted, as societal and ecological benefits are guaranteed and financial payback can be expected on most development projects. [15]

Alpin Limited, 2017, clarified that some Green benefits can be readily monetized; others are almost impossible to quantify in economic terms. Some accrue to those who foot the bill;

others inure to broader segments of society. Furthermore, because of differing perspectives, what may be seen as a benefit by one party (e.g., ratepayers paying for fewer kWh) may be seen as harmful by another (e.g., a utility absent decoupling, or a generator). Other benefits have been regarded as “externalities” – external to power system considerations – and typically not considered, despite clear evidence of the magnitude of these benefits to society. There is also a need for clear quantification of the expected and potential magnitude of costs to the utility system as new air, water, solid waste, reliability, and other regulations are promulgated. Studies suggest, however, that the non-energy benefits of efficiency measures can be quite large, often equal to or greater than the energy benefits. If so, then excluding them from regulatory consideration enhances the potential for suboptimal economic, social, and environmental outcomes. [15]

Jim Lazar et al, 2013, seeks to comprehensively identify, characterize, and provide guidance regarding the quantification of the benefits provided by energy efficiency investments that save electricity. The research focuses on the benefits of electric energy efficiency, but many of the same concepts are equally applicable, like the demand response (DR), renewable energy (RE), and water conservation measures. [16] “Avoided cost” means the incremental costs to an electric utility of electric energy or capacity or both which, but for the purchase from the Qualifying Facility QF, such utility would generate itself or purchase from another source. [17]

The relation between the renewable energy and its cost is considered one of clear examples of the separation between the environmental value of the product and its monetary value. The World Energy Council for sustainable energy in its report, 2013, intended to analyse what the cost base of an array of energy storage technologies really means. A key conclusion is that a narrow focus on liveliest cost alone can be misleading. Throughout the cost modelling process, the same issues repeatedly emerged, namely the importance of defining the business model under consideration and how the storage plant was being operated. Although the report focused on cost, it led to a number of insights on the value of storage from which certain recommendations can be made. The most important of these recommendation was to focus less on an investment cost approach for storage technology assessment, where only technologies with the lowest liveliest cost of storage (LCOS) are rewarded. Cheapest is not always best, or possible. To examine storage through holistic case studies within a specific context, rather than place faith in generic cost estimations. To accelerate the development of flexible markets, working with transmission and distribution system operators and regulators to help quantify and realise the true potential value of increasing system flexibility. To establish policy support and an enabling regulatory framework to facilitate further commercial deployment of storage technologies. To consider storage as a key component when planning for grid expansion or extension. Thus, storage liveliest cost estimations are arbitrary, since the application case can vary widely. [10, 11, 18] Figure 3 shows the wide differences between the 2015 to 2030 renewables storage LCOS costs.



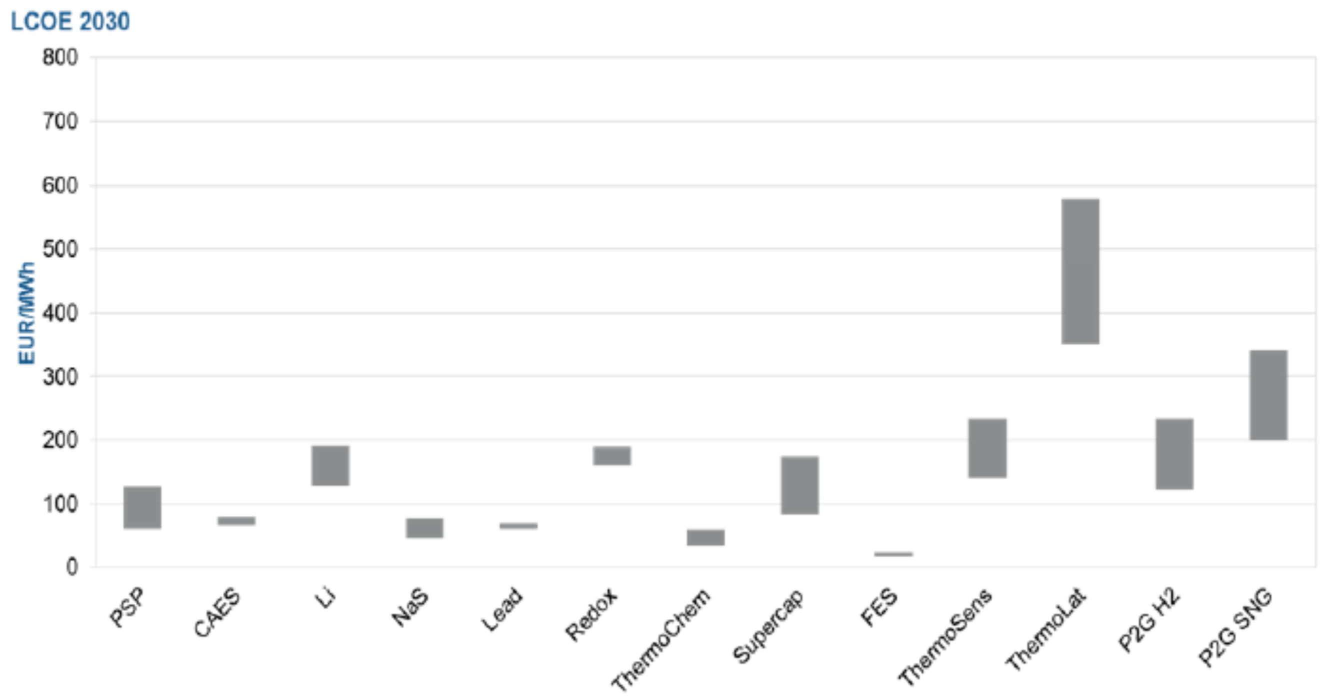



***Figure 3.*** *The renewables storage LCOS costs for the 2015 study period (above), and then the possible LCOS costs in 2030 (below) showing the wide differences of the same product cost over the time. [18].*

No policy of re-orientating the production–consumption system can become successful on a larger scale unless the market is trustworthy. As has happened until now, the different ecological costs are underestimated with regard to other economic costs and therefore do not "tell" that the environment is the actual bottleneck that has to be dealt with. The issue of attributing proper costs to natural resources is a widely discussed argument, we can observe that the issue has evolved from the "The Polluter Pays" principle, through the studies of new financial tools, to the projects of reforms embracing the entire fiscal system (eco-tax reform), which are supposed to shift the focus from income and work, as it is today, to resource consumption and waste. [19]

Essam E. Khalil, 2009, concluded from his research that it is important to incorporate an energy performance directive as a Standard, such a goal will aid energy savings in large buildings and set regulations to energy efficient designs that are based on Standard calculation methods. It is recommended to develop standardized tools for the calculation of the energy performance of buildings, and define comparable energy related key values (kWh/m$^2$, kWh per person, kWh per apartment, kWh per produced unit etc.), and to develop a common procedure for an energy performance certificate. [8]

## 4. Environmental Balance from the Monetary and Energy Side of Views

Environmental systems consist of number of interactions that are in a continuous flow to achieve equilibrium, they consist of number of connected and interrelated components that cannot act separately, and cannot be separated without affecting the other components. Therefore, the environmental systems cannot be evaluated or any of their components by monetary terms that usually isolate them from their functions, and evaluate them out of their cycles. Such an evaluation looks to the environmental components as commodities far away from the role in which they were created for. [8, 10, 16]

Environment systems include natural and built environments. The built environments consist of all the buildings and constructions that the man construct. After and during their construction, they are overlapped by the different surrounding natural relations, and become one of the direct and indirect effects on the natural environment balance. The environmental status for any building is to take and give energy and resources within the environment equilibrium, without any negative effects, while their optimum status is to enrich the natural equilibrium cycles. However, the building cost reflects mainly its physical mass, thus, it cannot express the relation between the building and the other environment components over its lifecycle. [8, 10]

Some main differences between the monetary and energy side of views regarding the environmental balance can be discussed as follows:

First: Energy conservation law states that "In a closed system, the total energy of the system is conserved", which means that energy can neither be created nor destroyed; rather, it can only be transformed from one form to another. Thus, the Environment as a number of various closed systems can be expressed using that law. The different energy transformation forms can reflect all the environment relations. Sustained energy represents the continuity of life and reflects the environmental equilibrium. Sustainability is represented as "zero energy" when achieving the equilibrium of the different environmental levels. [8, 18]

Second: In the monetary side of view, resources are environmental components that human perceive and can assess their utility, and can prepare them to be a part of economic exploitation to satisfy a specific human need. So, as long as human capabilities and needs are constantly changing over time, the resources are not static, but they are continually changed in their basis according to human needs and knowledge over the time. Then, resources basis may expand sometimes to include new resources that was discovered as a result of the improving knowledge and changing human demands. Thus, resources sometimes were discovered from environmental components that have not been used or monetary valued before, such as bauxite and uranium. On the other hand, energy values can display the various environmental components worth regardless their commercial uses, this value is according to the component's effect on the environmental equilibrium relations when decreased, increased or changed in characteristics. Therefore, the value does not change according to human needs as for the cost, it is always related to the environment need and balance. [10, 18, 19, 21]

Third: Energy values are not affected by time pass. Their equations are constant and continuous over the time. On the other hand, the cost of any product, has to be constantly updated over the time. The monetary updating may be done according to various several calculations that defer over the time, places and reasons, and then, it is too hard to conclude the previous monetary value from a subsequent value and vice versa. [11, 21, 22, 23]

Forth: A zero Energy result represents continuity and reflects the existence of various resources within their environmental limits of equilibrium. The environmental equilibrium is the form that all the universe was created according to, within limits that should not been exceeded. So, by studying the balanced proportions of the used resources in different locations that leads to zero energy; can help deciding using them or not. Renewal of resources can easily lead to zero energy if used, while economy may overlooks the scarcity of a resource or its ability of renewing before its use. Thus, recourses classification into stocks (non-renewable) and flows (renewable) [1] is very important in the energy calculations. [8, 10, 16]

Fifth: Environmental negative impacts can be identified by a lost or unused energy. The European Organization for Economic Cooperation and Development OECD defines pollution as the direct or indirect addition of substances or energy to the environment by human, causing harmful effects that can endanger human health or affect biological resources or ecosystems. These pollutants are, in fact, particles or energy that have not been used for their optimum and maximum use. [10, 24] Thus, sustainability means no pollution, as long as there is no energy loss. Which means that, any loss from the inputs to the final product leads to the presence of pollutants, which may appear in different forms, such as solid, liquid or gaseous pollutants, noise, radiation, heat, vibrations or other types of pollution. On the other hand, monetary value cannot express the damages caused by a product, it only represents the value of its final quantity. [21, 22]

Sixth: Energy values are not affected by human factors, they are only subjected to the universe laws that the environment cycles follows. On the other hand, monetary values are interfered by many human factors, they can control, raise, or reduce the cost of products for no environmental reason. The human non-physical factors include political, economic, social, aesthetic factors and others. Some of the main economic factors influencing the monetary values are marketing policies, profits, taxes, customs or subsidies that certainly give a false final value of the product, and can be too much far from its actual one. [21, 22, 23]

Virtually, monetary values of any product are parallel to their energy values until the human factors interfere them in a way in which certainly do not have the same effect on the energy consumption and environmental relations. So, without the effect of the human factors, the set of least-cost solutions to most if not all environmental regulations indicate energy efficiency. By including energy efficiency, one lowers the cost associated with environmental compliance, while also promoting sound use of energy efficiency as a resource. Environmental compliance requirements are mandated in such statutes as the Clean Air Act, the Clean Water Act, and the Resource Conservation and Recovery Act. They impose both immediate and future compliance costs on regulated generators in the form of: Capital costs and fixed Operations and Maintenance O&M costs for pollution control and monitoring equipment; Variable O&M costs associated with pollution control equipment and other compliance activities; allowance costs where a "cap-and-trade" program exists; permit fees; emission fees; and other fees. These costs are

1 Stocks Resources are resources that have limits of quantity that can ultimately be used, and can be divided into consumable by use or recyclable. The consumable resources, such as petroleum, gas, and coal should be used according to their optimal use rate. While the recyclable resources such as metals, if the recycling ratio reached 100%; their total quantity will maintain constant over the time. Many technologies allowed recycling some resources several times without significant loss of quality. [8, 16]

Renewable resources are divided into resources with no critical zone such as air, and with critical zone such as forests, animals and soil. For critical zone resources, to be regenerated indefinitely, their utilization rate should be equal to or less than their regeneration rate, but if their utilization rate was higher than the normal regeneration rate; then they will become like any non-renewable resource with certain stocks. For example, the soil, if misused, can be degraded and exposed to the risk of desertification. Non-critical zone resources are continuously renewable regardless the human activity, although some may be temporarily degraded in quality or quantity due to misuse. For example, the river flow can be reduced due to increased water or air pumping in a certain place, or can be polluted, but after controlling the causative within its natural limits, the river returns to its normal level of flow and quality. [8, 16, 22] currently included in some utility prices, and more will be included over time.

It is important, when forecasting long-run market prices, to recognize that pollution control costs will increasingly be internalized (reflected in energy prices), that new environmental regulations are likely and should be anticipated, and that health and other damage costs of actual emissions should decline. It is important to count these very real costs once (but not twice), in estimating the value of energy efficiency. Increased end-use efficiency reduces the need to generate electricity and can thus reduce air emissions, water discharges, and solid waste from regulated generators producing energy on the grid. Avoiding those emissions may reduce environmental compliance costs for generators. [10, 16, 20]

Environmental regulatory requirements and compliance costs can also vary based on a generator's rated capacity, location, fuels, age, and other factors. For example, a generator's costs for allowances under an emissions trading program would vary significantly with the amount of electricity it produces, while permit fees or financing costs may not vary at all with output. A variety of methods and tools for estimating the emissions reductions attributable to energy efficiency efforts have been developed, and they range from very simple to very complex. Capital Costs and Fixed O&M Costs Generators may need to install expensive pollution control technologies to comply with environmental regulations. Pollution control equipment may be installed at the same time a generating unit is built or be retrofitted to an existing source. Monitoring equipment for some pollutants may also be required. There are both fixed and variable costs of operating and maintaining pollution control and monitoring equipment. National Pollutant Discharge Elimination System (NPDES) (water) permits contain fee schedules that vary based on the amount of permitted discharge. Table 2 shows a sample of this fees. [10, 16, 20]

***Table 2.*** *A sampling of Fees for air Pollutant Emission (2013). [16].*

| State | Source or Pollutant | Fee per Ton Emitted |
|---|---|---|
| Arkansas | All air pollutants | $22.07 |
| Colorado | Criteria pollutants | $22.90 |
| | Other pollutants | $152.90 |
| Georgia | Coal-fired electric generators | $35.84 |
| | All other facilities | $34.00 |
| New Hampshire | All air pollutants | $205.27 |

## 5. Advantages of Using Energy Values to Evaluate Buildings Efficiency

Using energy as an environmental evaluating value for buildings gives them some more advantages to the previous general ones, which makes for the energy calculations special role in the architectural field. These advantages are as follows:

First: The building lifetime can be considered long in comparison of many other products, thus, buildings should not be evaluated according to their temporary status, and their efficiency must be expressed over their lifetime. Energy calculations take into consideration the building continuity during its lifetime phases, which are construction, operation and demolition. These phases cannot be separated, and should be enclosed in a cycle or overlapped and integrated to other environmental cycles to be sustained. On the other hand, monetary values fail to express the buildings environmental efficiency over its lifetime, they mainly represent the used materials costs, the construction, operations and transportation costs, besides the added profit. Reducing the building cost can be done by reducing materials or using cheap ones, while from the energy side of view the building materials should be studied over all the building lifecycle, as the more expensive one may lower the building need for air conditioning during its operation phase, or could be reused after the end of the building lifetime. [8, 10, 11, 24]

Second: Energy calculations help deciding the best used energy alternatives for buildings, as these calculations express the renewably of the energy sources over the time. On the other hand, energy cost doesn't express its natural limitations, and may be affected by human laws that don't match its natural laws, such as giving subsidies on petroleum products. [16, 23]

Third: Energy buildings calculations contain the energy that could be restored. Restored energy in buildings represent wide range of examples, such as heat recovered from wasted heated water, and the wasted heated or cooled air. While the only way to restore the building cost can be through the reused or recycled building materials. [11, 18, 23]

From all the previous, the following table, Table 3, summarizes the advantages of using energy values to evaluate environmental buildings efficiency versus the monetary values.

***Table 3.*** *Advantages of using energy values to evaluate environmental buildings efficiency versus the monetary values.*

| Monetary value | Energy value |
|---|---|
| Depends on its temporary use, such as the commercial use. | Equal to their natural significance regardless their commercial use. |
| Considered a highly variable value over the time, which needs to be updated constantly. | Constant over time. |
| Cannot define the scarcity of a material or a resource, or their renewability. | Zero energy represents the existence of the materials and resources within their environmental equilibrium limits, which express sustainability. |
| It is not possible to identify the negative impact of any component on the | The negative impact of any product on the environment can be identified |

| Monetary value | Energy value |
|---|---|
| environment, and may completely ignore the environmental impact. | with the presence of lost or unexploited energy. |
| Affected by different positivist factors, such as political, economic, social and aesthetic factors, by raising or decreasing its value without any physical reason. | Not affected by the positivist factors, and stays constant over place and time. |
| Fails to express the building over its lifetime, and usually expresses the initial cost with addition of profit. | Helps to express the continuity of the building, its components, and resources during its various life phases. |
| Excludes the type of used energy, and its renewability. | Helps to consider the type of used energy, and its renewability. |
| Cannot be recovered unless buying some building components to be reused for example. | Can be recovered through the reused, recycled components, and returned energy loss. |

## 6. Ways to Use Energy Values When Assess Buildings Environmentally

First: Using energy calculations

Buildings lifecycles start from the construction phase passing through the operation phase, the demolition phase, then may continue through the construction phase of the same building, other buildings, or other environmental components. Main energy consumption elements in the three main phases of the buildings are equipment and labor. The well-known relationship of energy "energy = power × time" may be the basis of energy calculations. The proper ratio between the equipment and the labor through all the building phases and sub-phases could be decided according to the previous energy calculation, which means multiplying their powers[2] in the time they spent to do any work related to the building.

Factors that influence energy consumption in buildings may be chosen from their wide alternatives according to the previous energy calculations concept. Their influence are due to their effect on determining the labor and equipment used. These factors are the building materials, implementation methods, building systems, time management, designed form, waste management, and used energy. To reduce the energy results; we may choose the most suitable factors' alternatives according to their characteristics which affect the energy consumption in the different buildings phases. The way assessing these factors according to the energy consumption elements (equipment and labor) may be discussed in another research paper.

Thus, to calculate Energy value for any operation through the building lifecycle, we should first determine the equipment and labor (type and number) used to perform it, then calculate the total sum of the power multiplied by the time they needed to perform that operation. That concept can be applied for all different building operations, such as air conditioning, transporting, manufacturing…etc. we can also decide the preferred labor and equipment types, and proportion according to their spent power and time. To calculate the whole energy value over a building lifecycle; we calculate the sum of the resulted energy values of all operations through the building lifecycle phases. The energy value results will have a positive sign if start from origins, but if they were recovered from previous operation, then they will get a negative sign. The proportion amount of reused equipment components, labor training, building materials, and resources will reduce the energy value related to them when divided by these proportions. The waste of building materials, energy, or resources, will be added values with positive signs, and will be calculated by multiplying the waste ratios by the energy results of all the previous operations before being wasted. The used reused and recycled materials, building parts, and resources will have energy values with negative signs, and calculated with their proportions. The concept of these calculations may be discussed in another research paper. [10, 11]

Second: Using Exergy calculations

Another suggested way to determine the energy values of buildings is the use of Exergy calculations, as some researchers have suggested that the impact of energy resource utilization on the environment is best addressed by considering Exergy. The Exergy of a quantity of energy or a substance is a measure of its usefulness or potential to cause change, and it appears to be an effective measure of the potential of a substance to impact the environment. The term Exergy also relates to Ideal Work, and Exergy Losses relate to Lost Work. These are some definitions showing the relation between Exergy and Sustainability:

1. "Exergy is the amount of work obtainable when some matter is brought to a state of thermodynamic equilibrium with the common components of its surrounding nature by means of reversible processes".
2. "Exergy of a system at a certain thermodynamic state is the maximum amount of work that can be obtained when the system moves from that particular state to a state of equilibrium with the surroundings". [25]
3. "Exergy can be considered the confluence of energy, environment and sustainable development". [26]
4. "Exergy is an indication of Energy Quality. Different energy forms have different quality (or different amounts of Exergy) in the sense that they have different capabilities to generate work". [25]

Exergy analysis makes visible where quality of energy is lost. This loss of energy quality cannot be made visible in energy analysis, while it is this energy quality that we need

2 Energy produced from a human body depends on the amount of work. Several ways have been found to calculate the worker's energy, the labor power could be studied by comparing an equipment power that could do the same work in the known time spent by him. The labor power may also be determined according to the metabolic rate for different works, which defers according to the different body or working conditions, gender, age, and weight. Metabolism reflects the energy generated inside the body by oxidation to perform its functions, and there are many tables to express that energy during different situations. Labor power can also be decided using the body latent heat calculations used in the cooling loads calculations. [19]

to carry out the things we want to do. So, by identifying the places where quality of energy is lost; Exergy analysis clearly pinpoints where improvements should be made. In Exergy analysis both mass and energy flows can be taken into account by means of their Exergy values, thus without the need of classification factors. Order destruction and chaos creation, resource degradation, and waste Exergy emissions are some relationships between Exergy and three forms of environmental impact. All three forms of environmental impact decrease with increasing 'process Exergy efficiency'. For sustainable development the destruction of the Exergy reservoirs of natural resources has to be minimized to a level at which there is no damage to the environment and at which the supply of Exergy to further generations is secured. Other methods that have been developed to take into account (some of the) ecosystem goods and services are the Ecologically Based LCA method (Eco-LCA), Ecological Cumulative Exergy Consumption (ECEC), and Eco-exergy. [26]

Third: Using energy equivalent environmental indicators

Another second way to include energy values in the environmental assessment of buildings is by finding an equivalent environmental indicators to represent the result of used energy instead of non-equivalent used indicators, such as the LEED metric ($), which is an effective marketing tool but arguably not the most relevant metric for environmental impact assessment. For the energy and atmosphere assessment field in the environmental building assessment methods there are number of indicators that may be used and related to the direct energy use, such as the amount of $CO_2$ resulted from the building for cooling or heating. In BREAM, the energy efficiency credits are given according to the amount of $CO_2$, so it is more expressive than the way used in LEED, which depends on the energy cost saving percentage. EA1 in LEED is roughly equivalent to Ene 1 in BREEAM. However, for EA1; buildings achieve their points when demonstrate improvement on energy cost against a normalized building baseline. While for Ene 1; buildings achieve their points according to a target carbon amount. This is also the case for EA2 in LEED which looks at renewable energy and is roughly equivalent to Ene 5 in BREEAM. [1, 2, 9, 27]

Similarly, some indicators can be represented by the environmental effects and reflect the energy use or loss. All environmental effects are regrouped according to their impact on human health, the environment, and the exhaustion of resources. Some common impacts are depletion of energy resources, depletion of raw materials, global warming, Ozone layer depletion, acidification, eutrophication, smog, toxic substances, and polluted waste. Substances that cause more than one effect are listed in different classes. Characterisation, as a stage, has been defined, but is still under development. Its objective is to bundle all the impacts into one environmental impact class. To aggregate the contributions of input and output towards a certain impact, it is not enough just to sum up their units of measurement (kg, l, MJ etc.). Some substances have more intense effects than others and require that greater or smaller influences are calculated before the overall sum. Practically, the contribution of all extractions and emissions towards a certain environmental effect is calculated, multiplying one by one with a certain equivalence factor that shows their relative contribution. [18, 19]

## 7. Conclusion

The Environmental Assessment methods of buildings had emerged around the world to ensure their sustainability, such as LEED. The assessment goals were put to achieve the environmental balance conservation; such as using resources efficiently, reducing greenhouse gas emissions, and reducing the effects of the building materials harmful components. Widely, these methods were studied, reviewed, and criticized according to their effect on the building cost. Generally, these methods contain number of important assessing items that depend mainly on the obtained reduction of cost. When considering the goals of the Assessment methods in which they were appeared for; monetary values are not the values to express the assessment achievement or results properly, and it gives false image of the resulted achievements. We can easily drive many disadvantages when discussing the environment aspects and effects using the monetary values, they simply drive the Environmental Assessment Methods away from their main goals. On the other hand, there are more effective ways to represent sustainability, such as the use of energy values.

Energy values can express the environmental balance through the zero energy concept, express continuity, renewability, and negative impacts on the environment. Energy values are also constant across place and over the time, especially because of the no effect of the positivist factors. It helps explaining the environmental balance as inputs and outputs within environmental closed cycles using the energy conservation law, so using that law, sustainability is zero energy result, and balance represent the existence of the materials and resources within their environmental equilibrium limits. Energy values can also represents the natural significance of the different components during the buildings life phases, whether negative or positive, as the negative impact appears as unexploited energy. Energy values consider the source of resources, instead of only their final results, such as renewable energy, and they consider also the returned resources, instead of only their raw inputs, such as the reused and recycled buildings components. In contrast, monetary values cannot do any of the previous, besides being highly affected by the positivist factors which don't comply with environmental reasons. Beside the use of energy conservation law in the assessment, there are some other suggested ways to conclude the buildings sustainable worth according to their energy values, such as the use of Exergy calculations, which measure the usefulness or potential to cause change, and measure the potential of a substance to impact the environment. Energy values can also be represented using equivalent environmental indicators to assess items like EA1 and EA2 in LEED, such as the use of the $CO_2$ indicator instead of the energy cost indicator used in these items.

## 8. Recommendations

Develop the energy calculations to be used to represent the building sustainable worth. Besides, encouraging the different Governmental organizations and ministries to deal with the buildings according to their energy values results rather than their monetary values, taking into consideration covering the whole lifecycle of the building, what can be returned, and its impact on the environment.

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