



Article The Unsustainable Direction of Green Building Codes: A Critical Look at the Future of Green Architecture

Isaac Guedi Capeluto 💿

Climate and Energy Lab in Architecture, Faculty of Architecture and Town Planning, Technion-Israel Institute of Technology, Haifa 3200003, Israel; arrguedi@technion.ac.il

Abstract: Buildings are a major contributor to global energy consumption and energy-related carbon dioxide emissions. In light of the climate crisis, changes in the way we design, construct and use buildings are needed to reduce their environmental impact. Green Building Codes (GBCs) and rating systems have been developed around the world as a basis for green building practices. However, several studies raised doubts about the actual performance of certified buildings. Moreover, they use a per unit area approach to assess the use of resources rather than per capita, penalizing small buildings or those with high occupancy, ignoring the concepts of equity and shared common effort which are central to sustainable design. In this paper we propose adjustments to GBCs to encourage new ways of designing and evaluating green buildings. We introduce the Occupancy Correction Factor (OCF) which prioritizes smaller and more densely occupied buildings reducing land use, total operational energy consumption and embodied energy. Results show changes in their energy ratings of one to three levels both up and down, compared to their original ratings. In addition, we propose the prioritization of high-efficiency Low-Energy and Nearly Zero-Energy buildings over Net Zero Energy buildings, encouraging innovative urban design to enhance solar access and electricity production potential on-site or nearby.

Keywords: Green Building Codes; green architecture; sustainable design; energy use; well-being; Zero Energy buildings; occupancy; per capita resource consumption

1. Introduction

The building sector accounts for about 35-40% of the global final energy use and of the energy-related carbon dioxide (CO₂) emissions [1]. Therefore, buildings can play a significant role in reducing the impact they have on the environment, and thereby help reduce the effects of climate change. Designing energy efficient green buildings that are compliant with sustainable design standards and Green Building Codes (GBCs) could be an important step in tackling those challenges.

Following the growing public interest and concerns about environmental issues, the requirement to reduce pollution and energy consumption, and the transition to the use of alternative energy sources, a wide range of methods for rating buildings, and standards for green construction have been developed in recent years around the world [2,3]. These methods reflect a system of values and priorities set by a society in order to analyze and evaluate the influence of planned or existing projects on the environment.

One of the major contributions of the introduction and dissemination of building rating systems, such as the American LEED [4,5], the British BREEAM [6] and others, is their holistic approach raising awareness of designers and general public regarding the importance of environmental issues as a whole. In Israel, a green building standard SI5281 and a rating system of buildings according to their energy consumption SI5282 were also developed in recent years [7–9], to provide practical tools for designers, aimed at achieving high-quality architectural solutions on the one hand, and on the other hand, to make it easy for consumers to identify and understand the product quality, encouraging demand for, and application of green construction.



Citation: Capeluto, I.G. The Unsustainable Direction of Green Building Codes: A Critical Look at the Future of Green Architecture. *Buildings* **2022**, *12*, 773. https:// doi.org/10.3390/buildings12060773

Academic Editor: Audrius Banaitis

Received: 27 April 2022 Accepted: 4 June 2022 Published: 6 June 2022

Publisher's Note: MDPI stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.



Copyright: © 2022 by the author. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https:// creativecommons.org/licenses/by/ 4.0/). Despite the environmental concerns mentioned above and the development of these methods, global electricity consumption continues to grow even faster than renewables in recent years [10]. Figure 1 shows the increase of electricity consumption per capita in the case of Israel.



Figure 1. Israel's electric power consumption per capita (2000–2020). Data source: IEA Energy Atlas International Energy Agency.

Following this trend, terms such as green building, green architecture, climatic design and sustainable architecture have become widely used in architecture. However, they are not always used with a similar or uniform meaning which makes it difficult to understand and assess their real environmental contribution and impact [11,12] Along with projects that implement principles of green design and construction from the schematic–conceptual design phases, there are architectural projects which define themselves as "green", in which the proposed green solutions focus on the advanced design stages or even after construction, by adding different types of mechanical systems to the building. Moreover, the use of these terms do not always reflect the implementation of the knowledge and principles of climate-conscious design or green techniques in buildings, but is often deployed as a means of public relations to promote the project and the image of the developer involved in its development [13].

It is not clear as well whether the adoption of these GBCs has led to an improvement in the performance of the buildings that are certified as green compared to non-certified buildings, regarding their energy consumption or the user's satisfaction. The difference between certification systems, metrics applied, as well as the different parameters compared, may explain the varied findings in the studies intended to verify this claim. Because of their different approaches, it is difficult to determine which system can respond best to sustainability requirements. To achieve a more balanced approach to the sustainability requirements of different GBCs, some studies proposed and integrated a model of multi certification [11].

2. Literature Review

One of the main goals of the Green Building Codes is to provide a mechanism to promote energy efficiency in new and existing buildings by adhering to prerequisites and credits that address this subject, in addition improving the thermal comfort, human health and satisfaction of their occupants.

However, there are also a number of limitations to these methods, as pointed out by Shaviv [14]. They use a simple 'point hunting' approach which encourages the choice of the cheap and easy-to-achieve points. Credits related to improving the energy efficiency of the building are usually expensive compared to the alternatives and therefore there is often at least a partial attempt to avoid them. In addition, there are no incentives for bioclimatic, passive and low-energy building designs, and energy-saving considerations are left late in the design process, leading mainly to mechanical system-based design. Moreover, passive solar energy is not considered as renewable energy: a passive solar heated building did not receive any extra credit for renewable energy on-site. As a result, passive solar design and the use of passive solar energy is not encouraged. The successful implementation of green building strategies, including passive design, requires a continuous dialogue between the various green building stakeholders involved in the process [15].

2.1. Energy Use and Performance

Several studies in the literature have found different results regarding the energy use and performance of green certified buildings. Some have found advantages in green certified buildings [16,17], while some raise doubts about the actual energy savings and found little correlation with the certification level of green buildings [18–20].

In 2008, the New Buildings Institute (NBI) conducted a study [17], commissioned by the US Green Building Council (USGBC), which compared measured Energy Use Intensity (EUI) of 121 LEED New Construction (NC) certified buildings with data from the national building stock. EUI is expressed as the energy per unit area per year, and allows comparison of the energy use of buildings of different sizes. In the analysis, 21 buildings with unusually high energy loads, such as laboratories and data centers, were excluded, while only the remaining 100 buildings (medium energy) were analyzed. According to the study, the median EUI of LEED buildings was 25–32% lower than the mean EUI of the Commercial Buildings Energy Consumption Survey (CBECS) buildings for the year 2003. Criticism of the study refers to the fact that it compared the median EUI of the LEED buildings with the mean EUI of all US commercial buildings, and little attention was paid to the differences that related to climate zone, building size or age [21].

In a re-analysis of the data conducted in 2009 [18], it was found that, on average, the LEED buildings used 18–39% less energy per floor area than their conventional counterparts. However, 28–35% of the LEED buildings used more energy. Moreover, the measured energy performance of the buildings had little correlation with the certification level or the number of energy credits achieved by the building at design time.

In addition, the conclusions of such analyses may differ substantially if considering the site or source energy [21]. Site energy is the energy consumed by the building as shown in the utility bills, and therefore it is easier for designers and consumers to evaluate and understand. However, site energy does not account for the energy consumed off-site in generating and delivering electric energy to the building. For this reason, this value does not reliably present the real impact of the building on the environment associated with its operation. Source energy, on the other hand, includes all transmission, delivery and production losses and is therefore a more comprehensive unit for comparing different buildings to each other. Performing this calculation requires knowledge of the primary energy conversion factors that can be difficult to determine.

2.2. User's Satisfaction

Regarding the user's satisfaction about environmental quality, the results of different studies in the literature are also varied. Some studies have found that satisfaction about the environmental quality was higher in green certified buildings than in non-certified buildings [22]. Other scholars found that there was no significant influence of green certification on occupants' satisfaction with the indoor environmental quality [23].

Grzegorzewska and Kirschke [12] investigated human factors in certification systems through the analysis of several certified office buildings in Poland. They note that, while LEED and BREEAM focus on the building and its servicing, the most recent WELL building standard [24] focuses on its users, prioritizing user safety and health, following a reevaluation of the weight of several factors due to the recent pandemic. They point to a need to revise the standards to address these issues.

2.3. Energy Performance Gap

An additional drawback of building certifications regarding energy consumption is that they are based on computer simulations of energy use before construction, rather than on actual usage. In many cases, the actual energy consumption data of the buildings that have been certified are biased and not easy to obtain (voluntary submission), which further limits analysis and evaluation of their real performance. Furthermore, energy consumption is strongly affected by final design, and how people use the building in real life [25]. Several studies have shown that there is a gap between theoretical projections based on assumptions and reality, and often buildings use more energy than projected. This is known as the energy performance gap [17,26,27].

3. Research Questions and Objectives

Regardless of the advantages and limitations of the GBCs outlined above, it is essential to question whether it is reasonable or acceptable that, under the auspices of these green standards, buildings are designed in direct conflict with the basic principles of climate-conscious design and well-being.

The design of the building envelope significantly influences its energy performance [28–30]. Architects often ignore this aspect, passing on the responsibility of its performance very late in the design process to mechanical and building envelope engineers [31]. Opposite approaches on the design of the building envelope and its consequences exemplify two extremes of this debate: Can a fully glazed building that relies mainly on mechanical systems be considered green despite not being energy efficient, as in the case of the LEED Platinum Bank of America Building [32]? Or should all-glass skyscrapers be banned [33], as discussed following the New York Green Deal Initiative [34]? On the other side, can a residence hall with windowless bedrooms be considered green, despite the risk of being uncomfortable for residents, as in the case of the UCSB Munger Residence Hall (aimed for at least a LEED Gold certification) [35]? An affirmative answer to these two extreme situations, for green certification at the highest levels, indicates that something fundamental with the values of these systems needs to change.

In the first case, it can be argued that a glass-box building provides lots of natural light and views, factors that are very important in high-quality design. However, useful daylight can be obtained with smaller openings, according to the orientation and climate [36]. All-glass buildings can suffer from overheating and glare [37], so interior shading devices must be necessary, obstructing the views and affecting daylighting. In the second example above, despite the claims for floor-efficiency, the disconnection with the outside and the lack of natural light and ventilation could be detrimental to human health, not to mention avoiding the possibility of natural ventilation in a pandemic situation, such as the one experienced in recent years.

A number of questions arise regarding the results of the application of these Green Building Codes: Do they guarantee the promotion of the values for which they were formulated and promoted? Do they represent a growing awareness of environmental issues and a real change in architectural practice? Are they promoting architectural design for a sustainable future?

The argument in this article is twofold: for architects who offer such solutions, and for Green Building Codes that encourage them [38]. In this paper, we will address some fundamental aspects that are currently missing in current standards and we will propose ideas to encourage their incorporation to promote sustainable design, considering both use

of resources and renewable energy supply. In addition, we will develop and demonstrate a method for implementing a correction factor for weighting building size and occupancy. The effect of this correction on the rating and how it can drive changes in design will be assessed based on the Energy Rating system for residential buildings in Israel.

In the next sections we will review the definition of sustainable design emphasizing the topics of building size and low energy architecture, and propose the implementation of the correction, based on a per capita approach.

4. Sustainable Design: Revisiting the Definition

The concept of sustainable development was defined in the report "Our Common Future" by the World Commission on Environment and Development [39] as: "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." In this view, equity is a central concept to pursue this Common Interest, so there must be a shared common effort to achieve that goal. Thus, sustainable design should minimize negative impacts on the environment and contribute to improving well-being through fair and collaborative efforts.

They add: "The concept of sustainable development does imply limits-not absolute limits but limitations imposed by the present state of technology and social organization on environmental resources and by the ability of the biosphere to absorb the effects of human activities".

4.1. Small Is Beautiful and Sustainable

Minimizing resource consumption and construction waste in the construction industry is vital for sustainable design, reducing the potentially harmful effects on the environment. The production of building materials and components requires raw materials, energy and emits greenhouse gases. The design, construction, renovation and demolition of buildings must give priority to reducing the amount of material resources employed and waste produced. Increasing the floor area of offices or residential spaces in buildings causes an increase in the use of resources and land use, reduces the reserves of open and green areas and results in increased energy consumption. Studies found that downsizing could bring significant energy savings, and address a range of other economic and social benefits, such as lower bills, rent, maintenance costs and also potential lifestyle improvements [40]. It can also contribute in mitigating the housing crisis in cities. Consequently, we should expect Green Building Codes and standards to encourage the reduction of built-up areas of buildings and to give a higher ranking to re-used and resource-efficient buildings [38]. In fact, in the current situation, there is no incentive to reduce built-up areas at all.

Since 1975 American homes have almost doubled in size, although the average size of families has shrunk over the same period [41]. Figure 2 shows the relation between the average gross apartment area in Israel for the period 2000–2015, and the average number of persons per household from 2001–2020. While the average gross apartment area grew in that period from 155 to about 190 sqm., the average number of persons per household decreased from 3.37 to 3.25.

Previous studies have found that conventional residential energy research has often failed to untangle the complexities of household energy use [42] and highlighted the role of households and their housing choices in shaping residential energy consumption patterns. In addition, current methods overlook the role of human social behavior [25], underestimating the complexities of the role of resident households in energy use. This is often due to a lack of freely accessible data, including information on both actual consumption and occupant habits.

In order to determine the energy rating or improvement ratio of the designed building, a comparison with a reference building is usually made, as in LEED and BREEAM, which is adapted geometrically to the building "as designed" (a fact that also discourages the search for efficient building forms). That is, the larger the designed building, and the bigger its external envelope area, the greater the reference value. In the case of the Israeli standard SI5282 for the energy rating of buildings, the geometry of the reference building is pre-defined and constant, for example a 10 m. by 10 m. unit for apartments in residential buildings. Regarding its orientation, in LEED and SI5282 the reference value expresses the average of the four main directions, and sometimes, such as in BREEAM, this value remains as designed [3]. These standards handle the issue of size by dividing the total energy consumption of the building by its area.



Figure 2. The evolution of average gross apartment area (2000–2015) and average persons per household (2001–2020). Data source: Israel Central Bureau of Statistics.

As a result, the size of the designed building is not reflected in its rating. This metric known as Energy Use Intensity, is commonly used to rank and assess the building's energy performance [43]. EUI disfavors small buildings, which generally have a higher exterior envelope area to floor area ratio and higher fixed heat loads per square meter than larger buildings.

Furthermore, by normalizing energy consumption by building area EUI allows buildings of different sizes to be compared unequally. In this way, it is possible that an apartment of 70 sqm. has a higher EUI than a neighboring one of 140 sqm., despite having a much lower total energy consumption, less embodied energy and use of materials and other resources. Even more puzzling, this situation will remain even in the case where four people live in the first apartment, and in the second, only a couple. In this way, EUI and consequently GBCs provide an incentive for the design of large buildings, which have unused areas, a low occupancy and consume a lot of resources. This is contrary to the concepts of equity and shared common effort, which are core to sustainable design, as discussed above.

To correct this distortion, energy use per resident in residential buildings [42], or energy use per worker in commercial buildings, should be included in the green certification considerations, as demonstrated in Sections 5 and 6. A per-capita approach is recommended to evaluate the use of additional natural resources as well. Progress in this area can contribute to more fundamental changes in the way buildings are designed, built and used, which are needed to reduce their environmental impact.

4.2. Low Energy Architecture and Nearly Zero-Energy before (Net) Zero Energy Buildings

Small and low buildings located in low density areas may have a high potential for solar access and on-site electricity production using PV systems integrated in their envelope or in near surrounding open areas. However, the integration of solar systems for energy generation from renewable sources in dense cities, where energy use is very intensive, is complex and presents new challenges to building and urban design [44,45]. Mutual shadowing between buildings may be an obstacle to install photovoltaic arrays on the building envelope and open spaces around them, compromising the feasibility of the Zero Energy Building (ZEB) equation [46].

In a Net Zero Energy building or complex, its annual source energy consumption is considerably reduced by energy-efficiency measures, and is less than or equal to the renewable energy generation on the site [47]. Buildings that occupy entire lots located in dense urban areas, or with high process loads, may not be able to balance energy use with on-site renewable energy, and then allowed to use Renewable Energy Certificates (RECs). Renewable Energy Certificates are a market-based instrument which allows owners to make claims about using renewable electricity. It is claimed that the purchase of RECs by companies, institutions, or individuals may support the renewable energy market. This article is not intended to discuss this point, or the unsustainable implications of promoting renewable energy generated anywhere by mega solar facilities, which can damage the biodiversity of sensible regions and lead to the loss of traditional farming jobs, as is occurring in some regions in Spain [48]. However, RECs have nothing to do with building design and construction, which are the focus of this paper.

The United States Department of Energy's (DOE) Renewable Energy Certificate-Zero Energy Building (REC-ZEB) definition, allows building owners buying off-site renewable electricity utilizing RECs to help balance the annual used energy. Some Green Building Codes and standards then recognize the possibility of achieving green credits for buildings by buying RECs. Although the mechanism has positive goals, it is unacceptable that it grants green credits to buildings. RECs credits should be granted to the owners of the RECs to obtain fiscal or other benefits, not to buildings. GBCs should encourage excellence and innovation in architectural design for a sustainable future; by giving green building credits to cheaper RECs instead, they are prioritizing other factors and creating misinformation, lack of trust in them and inequity.

If we consider two buildings, say two neighboring office buildings, A and B, with similar energy use, identical building form and urban situation, if the owners of building A can buy RECs, it can obtain green credits, eventually be called zero and claim that the building is greener than its neighbor. An energy-conscious re-design of building B can drastically reduce energy use and even help to enhance solar access and potential for electricity production, even if the conditions do not allow for balance to be reached. Despite having a greater environmental contribution, building B will not obtain that qualification.

According to the EU definition [49] Nearly Zero-Energy Buildings have a very high energy performance, that should be covered to a very significant extent by the energy from renewable sources produced on-site or nearby. To achieve this, it is important to implement a solar-oriented design on the urban level as much as on the building scale, to reduce energy consumption and maximize on-site energy production. The possibility to improve energy performance and increase on-site renewable energy, to achieve Nearly Zero-Energy Buildings and Complexes, can be affected significantly by architectural design: massing, the building's orientation, openings, shading devices, etc. Accordingly, Low-Energy Architecture and Nearly Zero-Energy buildings are important and proper goals to be promoted by GBCs [50].

In each country, and for each standard, it will be necessary to adjust the weight of the different topics mentioned in this paper, in order to achieve an appropriate balance. In order to show how these themes can be incorporated into GBCs, in the next sections we will demonstrate an analysis of the influence of the incorporation of occupancy in residential buildings as a leading value for their Energy Rating, through a revision of this topic in the Israeli standard SI5282.

5. Methodological Change Proposal for Energy Rating of Buildings in Israel

5.1. Energy Rating of Buildings in Israel

In the performance approach of SI5282, the energy consumption per unit area of the proposed design is compared to that of a theoretical reference unit, which determines the energy budget. The rating of the building is determined according to the ratio of energy savings in relation to the reference, from level F (worst) to level A+ (best) [51]. A dynamic energy hourly simulation model is used to implement this method. The improvement percentage (IP) for each unit is calculated according to Equation (1):

$$IP = 100 \times \frac{EC_{ref} - EC_{des}}{EC_{ref}}$$
(1)

where:

IP = Improvement percentage (%) of energy consumption per floor area;

ECref = Reference unit energy consumption (kWh/m² year);

ECdes = Designed unit energy consumption (kWh/m² year).

For residential buildings, Table 1 shows the required improvement percentages for each level (rating of unit) in accordance to the climate zone where the project is located. Depending on the level obtained, a grade value ($GradeValue_u$) is assigned to each evaluated unit (apartment, office, etc.) for the calculation of the rating of the whole building.

Table 1. U	Unit energy	efficiency	rating	(residentia)	l units)) with GradeValue _u .	
------------	-------------	------------	--------	--------------	----------	----------------------------------	--

		Energy Efficiency Improvement Percentage by Climatic Zone (%)					
Rating of Unit	Grade Value	Climate Zone A	Climate Zone B	Climate Zone C	Climate Zone D		
A+	5	≥35	≥35	≥ 40	≥ 29		
А	4	≥ 30	≥ 30	≥ 34	≥ 26		
В	3	≥25	≥ 25	≥ 27	≥23		
С	2	≥ 20	≥ 20	≥ 20	≥ 20		
D	1	≥ 10	≥ 10	≥ 10	≥ 10		
Е	0	<10	<10	<10	<10		
F	-1	<0	<0	<0	<0		

It can be noted that the above IP value is based on calculations per unit area (m^2) , so that the total area of the unit, and therefore its total energy consumption, are not reflected in the results. There is also no reference to the degree of occupancy of the unit.

The rating of the whole building is calculated according to Equation (2):

$$Bld_{rate} = \frac{\sum_{u=1}^{m} Area_u \times GradeValue_u}{\sum_{u=1}^{m} Area_u}$$
(2)

where:

Bld_{rate} = Energy rating of the building;

 $GradeValue_u$ = Energy rating of unit (apartment/office) from Table 1;

Area_u = Area of unit (m²);

u =Unit;

m = Number of units.

We propose to implement an "Occupancy Correction Factor" (OCF) to rectify the IP obtained from Equation (1) for each unit, and consequently the energy rating of the whole building, as shown in the next section.

5.2. Defining Occupancy Correction Factor

In SI5282, energy use calculations for rating apartments are based on the theoretical assumption of one person per 25 m². Since the reference unit has an area of 100 m² it assumes an occupancy of four persons. Constant and non-constant heat loads per unit area are set for apartments up to 150 m², a decrease for larger apartments.

In order to weigh the size and occupancy of the apartment in its rating, the Potential Occupancy (PO), according to the area of the unit, can be determined following Equation (3):

$$PO = Area_{\mu} / APP \tag{3}$$

where:

APP = Area per person = 25 m^2 . The OCF can therefore be determined according to Equation (4):

$$OCF = Actual Occupancy/PO$$
 (4)

where:

Actual Occupancy expresses the number of occupants in the unit in practice.

Table 2 shows the OCF calculated for apartments of variable sizes and different occupancy rates. Occupancies of less than one person per 25 m² result in OCF values smaller than one reducing the original IP and consequently lowering the rating obtained for the residential unit. For higher occupancies, the OCF is above one, improving the rating obtained. In order to obtain an acceptable rating of large and low-occupancy housing units, further efforts will be needed to improve the IP by improving their design and implementing additional energy-saving measures. It should be noted that the APP value is theoretical and in this work is based on the assumptions of SI5282 for residential buildings. A change of this value may lead to different ratings, and therefore it should be adjusted according to local needs and practices and for different building types.

Table 2. Occupancy Correction Factor (OCF) for various apartment areas and occupancy rates.

Apartment Area (m ²)	PO (Persons)	Actual Occupancy (Persons)					
		2	3	4	5	6	
70	2.8	0.71	1.07	1.43	1.79	2.14	
100	4	0.50	0.75	1.00	1.25	1.50	
125	5	0.40	0.60	0.80	1.00	1.20	
150	6	0.33	0.50	0.67	0.83	1.00	
200	8	0.25	0.38	0.50	0.63	0.75	
300	12	0.17	0.25	0.33	0.42	0.50	

6. Results

Figure 3 presents the proposed OCF for different units' areas and number of persons in relation to the existing situation in SI5282 (indicated by an horizontal dotted line). As stated above, the standard in the current situation has no effect on the rating obtained for the size of the apartment and the number of residents (OCF = 1). In contrast, this picture also shows situations in which the resulting rating decreases (below line SI5282), and those in which the rating improves as a result of an increase in the ratio of the number of residents to the area of the apartment.

The results of the application of the proposed correction factor for an apartment are presented in Table 3. In this example located in the Climate Zone A (coastal plan), a 100 m² apartment (bold in Table 3) was analyzed before (four persons) and after (varying occupancy and area) the implementation of the OCF. As can be seen in the present situation, assuming an IP in the range of 25–30%, the obtained rating according to SI5282 is B for all of the alternatives. After the application of OCF for 100 m², the option with four residents remains in the same rating, as expected. However, when considering a total of five persons in an apartment with the same area, its rating improves to A or even A+, in accordance with its IP. If the 100 m² apartment is designed for a couple, its rating drops to level D. Since in Israel a rating of C is a pre-requisite for submission to the SI5281 green standard, in this case it will be necessary to rethink and improve the design. With a reduction of its area to 70 m², and an occupancy of two persons, its rating can achieve a C. We can see as well that increasing the area to 125 and 150 m^2 , with an occupancy of five persons, means that a rating of B and C, respectively, will be obtained. Additional design improvements to further reduce the energy consumption may help in achieving a higher rating.



Figure 3. The Occupancy Correction Factor (OCF) as function of Floor Area and number of persons per household. The dotted line indicates SI5282.

Table 3. Results of the application of OCF in rating apartments with different areas and occupancy rates, in Climate zone A.

Apartment Area (m ²)	Occupancy (Persons)	Rating Old	IP_SI5282 (%)	OCF	IP_Corrected (%)	Rating New
70	2	В	25-30	0.71	17.75-21.3	D-C
100	2	В	25-30	0.50	12.5–15	D
100	4	В	25-30	1.00	25-30	В
100	5	В	25-30	1.25	31.25-37.5	A–A+
125	5	В	25-30	1	25-30	В
150	5	В	25–30	0.83	20.75-24.9	С

7. Discussion and Conclusions

In light of accumulated experience in recent years, this paper asked fundamental questions about the influence of Green Building Codes on architectural practice. There is no doubt that they have helped to promote environmental discourse in education and architectural practice and raised awareness among the general public. There is also no doubt that, beyond the debate over the performance of green certified buildings in relation to other buildings, there are concerns about the possible certification of buildings which contradict basic principles of climate-conscious design and well-being. Moreover, they ignore the concepts of equity and shared common effort in minimizing resource consumption, which are central to sustainable design. This does not imply that there are no good examples of green buildings, just as there are examples of good architecture.

Corrections are needed in GBCs to encourage essential changes in the way we design construct and use buildings to reduce their environmental impact. This does not mean that we should lower our comfort standards, but rather redefine them. It is imperative to adapt our lifestyle to the challenges of sustainable development, without abandoning the joy in architecture. This means moving forward from Bjarke Ingels' hedonistic sustainability approach to a more responsible, sustainable hedonism. In this paper we discussed ways in which architectural design can contribute to this effort, acting on how buildings can become greener and more efficient on the demand side, and producers of local renewable energy on the supply side. On the demand side, it is important to promote conservation of natural resources: incentive projects that reduce land use, decrease total operational energy consumption and reduce embodied energy in the built environment, by encouraging the decrease of built-up areas per person. On the supply side, it is preferable to stimulate local generation: encourage innovative architectural and urban design to increase the potential of on-site or nearby renewable energy in small and medium-size installations, to achieve Nearly Zero-Energy Buildings and Complexes. Passive solar and low-energy design should be rewarded, and source energy must be considered for certification.

Previous studies have analyzed several shortcomings relating to different factors included in GBCs or their results, and sometimes even suggested ways to overcome each problem individually. However, there is a lack of critical examination of the general approach and assumptions of these standards, and they are generally analyzed point by point, rather than as design tools that can, and ideally must, encourage sustainable design.

This work demonstrated the implementation of a correction factor for rating buildings, weighting their size and occupancy. This correction produced changes in their energy ratings of up to three levels both up and down compared to their original ratings, which can stimulate improvements and changes in design. It should be noted that it has a number of limitations: the proposed Occupancy Correction Factor requires further research to adapt to different building types and be used in other places, according to local practices. Besides, it may be necessary to develop additional correction factors to consider additional subjects, such as a crowding factor to ensure the well-being of the occupants, and obtain a balanced design solution. To implement this approach, the difficulty in obtaining updated data regarding the number of residents or workers in a building also requires further research.

Architectural practice must adapt to changes in household sizes, the changing needs of people and families and respond to transformations posed by co-living, telecommuting and more. GBCs should encourage the retrofit and reuse of existing buildings, and designs that allow increasing occupancy rates in buildings, which need to be used for many hours during the majority of the year. There should also be incentives for post-occupancy monitoring, and the publication of actual energy consumption data.

It may seem that by implementing these principles, the number of green certified and ZEB buildings, as they are known today, will decrease, and it is estimated that they probably will decrease at first. These changes will, however, hopefully result in a change in architectural practice, and a growth in the medium term of a new type of building that are not only called green, but actually help to minimize their impact on the environment.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The data used in this study are publicly available at the sources cited in the text.

Conflicts of Interest: The authors declare no conflict of interest.

References

- 1. U.N. Environment Programme. *Global Status Report for Buildings and Construction: Towards a Zero Emission, Efficient and Resilient Buildings and Construction Sector;* United Nations Environment Programme: Nairobi, Kenya, 2021.
- 2. Shaviv, E.; Yezioro, A.; Capeluto, I.G. Energy Code for Office Buildings in Israel. Renew. Energy 2008, 33, 99–104. [CrossRef]
- 3. Schwartz, Y.; Raslan, R. Variations in Results of Building Energy Simulation Tools, and Their Impact on BREEAM and LEED Ratings: A Case Study. *Energy Build.* 2013, 62, 350–359. [CrossRef]
- 4. USGBC. LEED for New Construction and Major Renovation, Version 2.2; USGBC: Washington, DC, USA, 2006; ISBN 978-1-932444-11-7.
- 5. USGBC. *LEED Reference Guide For Green Building Design and Construction*, 2009th ed.; USGBC: Washington, DC, USA, 2009.

- 6. BREEAM. Sustainability Assessment Method. 2016. Available online: https://bregroup.com/products/breeam/ (accessed on 25 April 2022).
- 7. *SI 5281;* Buildings with Reduced Environmental Impact ("Green Buildings"). The Standards Institution of Israel: Tel Aviv, Israel, 2005.
- 8. SI 5281; Sustainable Buildings. The Standards Institution of Israel: Tel Aviv, Israel, 2011.
- 9. SI 5282; Energy Rating of Buildings. The Standards Institution of Israel: Tel Aviv, Israel, 2011.
- 10. Global Electricity Demand Is Growing Faster than Renewables, Driving Strong Increase in Generation from Fossil Fuels. Available online: https://www.iea.org/news/global-electricity-demand-is-growing-faster-than-renewables-driving-strong-increase-in-generation-from-fossil-fuels (accessed on 8 April 2022).
- 11. Assefa, S.; Lee, H.-Y.; Shiue, F.-J. Sustainability Performance of Green Building Rating Systems (GBRSs) in an Integration Model. *Buildings* **2022**, *12*, 208. [CrossRef]
- 12. Grzegorzewska, M.; Kirschke, P. The Impact of Certification Systems for Architectural Solutions in Green Office Buildings in the Perspective of Occupant Well-Being. *Buildings* **2021**, *11*, 659. [CrossRef]
- 13. Alves, I.M. Green Spin Everywhere: How Greenwashing Reveals the Limits of the CSR Paradigm. J. Glob. Chang. Gov. 2009, 2, 1–26.
- Shaviv, E. Applications of Simulation and Cad Tools in the Israeli "Green Building" Standard for Achieving Low Energy Architecture. In Proceedings of the Building Simulation 2011: 12th Conference of International Building Performance Simulation Association, Sydney, Australia, 14–16 November 2011.
- 15. Sahid; Sumiyati, Y.; Purisari, R. The Direction of Developing Green Building Criteria in Indonesia. *J. Phys. Conf. Ser.* **2021**, 1811, 012090. [CrossRef]
- 16. Fowler, K.M.; Rauch, E.M.; Henderson, J.W.; Kora, A.R. *Re-Assessing Green Building Performance: A Post Occupancy Evaluation of 22 GSA Buildings*; Pacific Northwest National Laboratory (PNNL): Richland, WA, USA, 2010.
- 17. Turner, C.; Frankel, M. *Energy Performance of LEED for New Construction Buildings*; Final Report; New Buildings Institute (NBI): Portland, OR, USA, 2008.
- Newsham, G.R.; Mancini, S.; Birt, B.J. Do LEED-Certified Buildings Save Energy? Yes, But ... Energy Build. 2009, 41, 897–905.
 [CrossRef]
- 19. Scofield, J.H. Efficacy of LEED-Certification in Reducing Energy Consumption and Greenhouse Gas Emission for Large New York City Office Buildings. *Energy Build*. **2013**, *67*, 517–524. [CrossRef]
- 20. Amiri, A.; Ottelin, J.; Sorvari, J. Are LEED-Certified Buildings Energy-Efficient in Practice? Sustainability 2019, 11, 1672. [CrossRef]
- 21. Scofield, J.H. Do LEED-Certified Buildings Save Energy? Not Really ... Energy Build. 2009, 41, 1386–1390. [CrossRef]
- 22. Liu, Y.; Wang, Z.; Lin, B.; Hong, J.; Zhu, Y. Occupant Satisfaction in Three-Star-Certified Office Buildings Based on Comparative Study Using LEED and BREEAM. *Build. Environ.* **2018**, *132*, 1–10. [CrossRef]
- Altomonte, S.; Schiavon, S. Occupant Satisfaction in LEED and Non-LEED Certified Buildings. Build. Environ. 2013, 68, 66–76.
 [CrossRef]
- 24. International WELL Building Institute (IWBI). WELL Standard. Available online: https://v2.wellcertified.com/en/wellv2 /overview (accessed on 21 April 2022).
- 25. Lutzenhiser, L. Social and Behavioral Aspects of Energy Use. Annu. Rev. Energy Environ. 1993, 18, 247–289. [CrossRef]
- Norford, L.K.; Socolow, R.H.; Hsieh, E.S.; Spadaro, G.V. Two-to-One Discrepancy between Measured and Predicted Performance of a 'Low-Energy' Office Building: Insights from a Reconciliation Based on the DOE-2 Model. *Energy Build.* 1994, 21, 121–131. [CrossRef]
- 27. De Wilde, P. The Gap between Predicted and Measured Energy Performance of Buildings: A Framework for Investigation. *Autom. Constr.* **2014**, *41*, 40–49. [CrossRef]
- 28. Lin, Y.-H.; Lin, M.-D.; Tsai, K.-T.; Deng, M.-J.; Ishii, H. Multi-Objective Optimization Design of Green Building Envelopes and Air Conditioning Systems for Energy Conservation and CO2 Emission Reduction. *Sustain. Cities Soc.* **2021**, *64*, 102555. [CrossRef]
- 29. Sozer, H. Improving Energy Efficiency through the Design of the Building Envelope. *Build. Environ.* **2010**, 45, 2581–2593. [CrossRef]
- 30. Capeluto, I.G.; Ochoa, C.E. Simulation-Based Method to Determine Climatic Energy Strategies of an Adaptable Building Retrofit Façade System. *Energy* **2014**, *76*, 375–384. [CrossRef]
- 31. Capeluto, G.; Ochoa, C. Intelligent Envelopes for High Performance Buildings: Design and Strategy; Springer: Cham, Switzerland, 2017; ISBN 978-3-319-39254-7.
- 32. Roudman, S. Bank of America's Toxic Tower. The New Republic, 29 July 2013.
- 33. Sturgis, S.; Bezzel, E. Should All-Glass Skyscrapers Be Banned? *CTBUH J.* 2020. Issue I. Available online: https://global.ctbuh. org/resources/papers/download/4243-should-all-glass-skyscrapers-be-banned.pdf (accessed on 25 April 2022).
- 34. Action on Global Warming: NYC's Green New Deal. Available online: http://www1.nyc.gov/office-of-the-mayor/news/209-19 /action-global-warming-nyc-s-green-new-deal (accessed on 25 April 2022).
- 35. UC Santa Barbara Munger Hall Q&A. Available online: https://www.news.ucsb.edu/2021/020455/munger-hall-qa (accessed on 7 April 2022).
- 36. Ringel, G.; Capeluto, I.G. An Energetic Profile for Greener Buildings. Sustain. Cities Soc. 2020, 61, 102171. [CrossRef]

- Ulpiani, G.; Benedettelli, M.; di Perna, C.; Naticchia, B. Overheating Phenomena Induced by Fully-Glazed Facades: Investigation of a Sick Building in Italy and Assessment of the Benefits Achieved via Model Predictive Control of the AC System. *Sol. Energy* 2017, 157, 830–852. [CrossRef]
- Koo, C.; Hong, T.; Lee, M.; Park, H.S. Development of a New Energy Efficiency Rating System for Existing Residential Buildings. Energy Policy 2014, 68, 218–231. [CrossRef]
- 39. World Commission on Environment and Development Our Common Future; Oxford University Press: Oxford, UK; New York, NY, USA, 1987; ISBN 978-0-19-282080-8.
- Huebner, G.M.; Shipworth, D. All about Size?—The Potential of Downsizing in Reducing Energy Demand. *Appl. Energy* 2017, 186, 226–233. [CrossRef]
- 41. US Census Bureau. Available online: https://www.census.gov/en.html (accessed on 7 April 2022).
- 42. Estiri, H. A Structural Equation Model of Energy Consumption in the United States: Untangling the Complexity of per-Capita Residential Energy Use. *Energy Res. Soc. Sci.* **2015**, *6*, 109–120. [CrossRef]
- Fairey, P.; Goldstein, D.B. Metrics for Energy Efficient Buildings: How Do We Measure Efficiency? In Proceedings of the ACEEE Summer Study on Energy Efficiency in Buildings, Pacific Grove, CA, USA, 21–26 August 2016.
- Wall, M. Towards Zero-Energy Buildings and Neighbourhoods—A Combination of Energy-Efficiency and Local Renewable Energy Production. *Indoor Built Environ.* 2017, 26, 1313–1318. [CrossRef]
- Chen, H.-H.; Dietrich, U. Land-Use Planning for Zero-Energy-Buildings: Comparison of Four High-Density Cities WIT Transactions on Ecology and the Environment; WIT Press: Seville, Spain, 2017; pp. 491–502.
- Kolodiy, O.; Capeluto, G. Towards Zero-Energy Residential Complexes in High-Density Conditions. *Indoor Built Environ.* 2021, 30, 1751–1765. [CrossRef]
- 47. U.S. DOE. A Common Definition for Zero Energy Buildings; U.S. DOE: Washington, DC, USA, 2015.
- Govan, F. Residents Vow to Stop Mega Solar Park That Will Ruin Environment and Spoil Views in Most Desirable Corner of Southern Spain. Olive Press Spain News, 15 June 2021.
- European Commission. Nearly Zero-Energy Buildings. Available online: https://energy.ec.europa.eu/topics/energy-efficiency/ energy-efficient-buildings/nearly-zero-energy-buildings_en (accessed on 7 April 2022).
- Capeluto, I.G. Buildings' Morphology, Solar Rights and Zero Energy in High Density Urban Areas. In Sustainable Energy Development and Innovation: Selected Papers from the World Renewable Energy Congress (WREC) 2020; Innovative Renewable Energy; Sayigh, A., Ed.; Springer: Cham, Switzerland, 2022; pp. 351–356, ISBN 978-3-030-76221-6.
- Yezioro, A.; Capeluto, I.G. Energy Rating of Buildings to Promote Energy-Conscious Design in Israel. *Buildings* 2021, 11, 59. [CrossRef]