Net Energy Index:

A New Way To Measure Energy Efficient Buildings

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Abstract

Energy efficiency indexes are useful for providing tangible measurements of energy efficiency in buildings. Buildings use approximately 70% of all electricity in the USA. Using that energy efficiently has two primary benefits: limiting greenhouse gas emissions and reducing grid strain. Utilizing local renewable energy sources contributes to the same benefits. Currently, there is no index that considers renewable energy sources when measuring energy efficiency. Therefore, this paper proposes the Net Energy Index, which compares the net power usage of a building to the floor area of the building in order to determine energy efficiency. If renewable energy supplies power to a building, this index is not only useful and justified, but it is also practical through advances in energy meters.

Net Energy Index:

A New Way To Measure Energy Efficiency

Introduction

Energy efficiency is a pressing topic that is considered one key to a sustainable future. This paper will begin by presenting why energy efficiency in buildings is such an important issue, then continue by exploring several ways that are typically the focus of improving efficiency. Next, the current methods of measuring energy efficiency, known as energy efficiency indexes, will be discussed. The two indexes that are described will provide a strong enough background for the following section: the proposition of a new index, titled the Net Energy Index. A new index needs to be considered because it takes a wider approach and considers the direct impact of renewable energy sources. Renewable sources not only reduce greenhouse gases, but they also reduce grid strain. Next, two case studies to support the proposition will be reviewed. This paper will consider a current building that has already been indexed and will show how this building would rate with varying amounts of renewable energy generation. It will also demonstrate how the index could be applied to a typical home in the USA. Finally, the paper will conclude by reviewing the data presented considering the new index.

Energy Efficiency in Buildings: Why is it Important?

In the modern age, designing a building considers many factors that need to be kept in balance. Energy efficiency is one of those factors that is growing in weight of consideration; this is particularly true in highly populated areas. This high population density strains the energy grid because of high demands in such concentrated areas [1]. While more power plants can be built to offset the high demand with more supply, there are many negative side effects of power plants [2]. This paper focuses on the greenhouse gas emissions and grid strain because these may be the most critical, as explained in more detail below, and they most nearly relate to the scope of the paper. However, other effects include almost 2000 deaths per year, radioactive emissions, and large amounts of land requirement [2]. With this in mind, efficiency in buildings is a more sustainable and cost-effective approach. The need to increase efficiency is not unique to overpopulated areas, rather, it is important across the whole building industry. The European Union has found it so important, that as a part of their 20-20-20 energy policy, they have committed to a 20% increase in energy efficiency between 2009 and 2020 [3]. While final results have not yet been released, if the EU stayed on pace with what was released in 2017, then this number could be achieved by the end of 2020 [4].

This is not merely important in Europe, but around the world. Reports in most countries prove that while 40% of all energy is used in buildings [5], nearly 70% of all electricity in the USA is used in buildings [6]. This means that focusing on the electricity usage of buildings by developing energy efficiency indexes is a reasonable approach to have a large impact. Therefore, the scope of this paper, focusing on energy efficiency as primarily the use of electricity in buildings and how efficiently it is utilized, is reasonable. The United Nations has listed seventeen broad scope objectives titled Sustainable Development Goals that are a universal call to ensure a safe and sustainable world [7]. While each may not be a specific or measurable goal, four of these are directly centered around improving energy efficiency. Goal number seven states the desire to “ensure the affordable, reliable, sustainable, and modern energy for all” [7]. Clearly this is not possible without improved efficiency. The eleventh goal focuses on sustainable cities and communities where the hope is to design cities and human settlements to be “inclusive, safe, resilient, and sustainable” [7]. Sustainable and resilient cities are only plausible through energy being carefully used. Goal twelve is titled “responsible consumption and production” which plans to ensure “sustainable consumption and production patterns” [7]. Finally, the thirteenth objective connects to climate action. The hope is to “take urgent action to combat climate change and its impacts” [7]. A key step to fighting climate change involves more responsible use of energy because of its impact on greenhouse gases. The UN goes deeper by outlining how the climate is changing and the primary cause behind this is the power sector and its carbon emissions [7].

Arguably the most important reason to focus on energy efficiency is the need to provide enough power to serve the growing market without increasing greenhouse gas (GHG) emissions [3]. Producing energy is one of the main causes of releasing GHG into the environment, with electricity contributing nearly 30% of the GHG emissions in 2017 [8]. Efficiency is important, then, because if the same amount of energy that is currently providing enough power for the world can be used to provide enough power for a larger market, then GHG emissions will, at worst, remain the same. Ideally, efficiency would improve at a rate that reduces GHG emissions in the future. The reality is that for several years the energy consumption increase from year to year in the building industry is rising as depicted in Fig. 1, leading to more GHG [9].

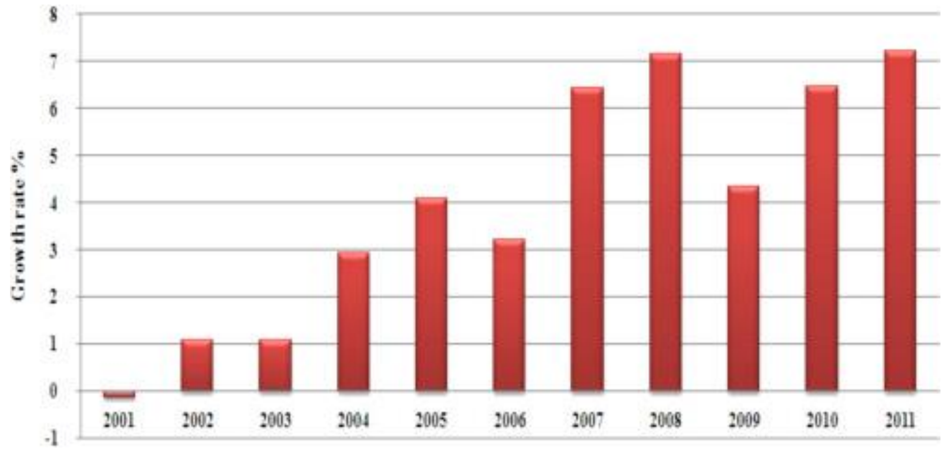

Fig. 1. Percentage Increase of Energy Consumption in the US [9].

Greenhouse gases are gases that trap heat in the atmosphere [8]. The GHG are closely linked to climate change and could be detrimental should they become too highly concentrated in the atmosphere. While many may argue the reality or seriousness of climate change, there is no doubt that these gases are harmful to the environment [8]. The four main GHG in order of prominence are carbon dioxide, methane, nitrous oxide, and fluorinated gases [8]. Production of electricity is the second highest contributor to carbon dioxide, which is by far the most abundant GHG in the atmosphere, as seen in Fig. 2 [8].

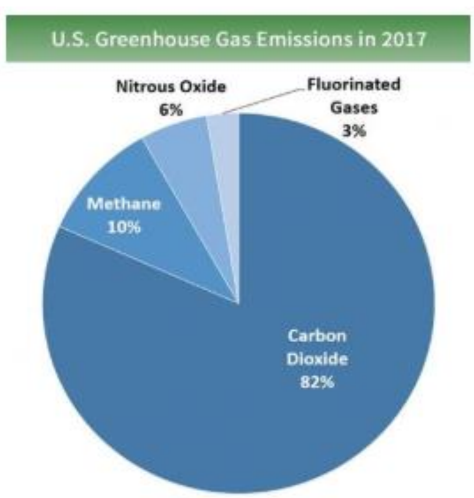

Fig. 2. Breakdown of GHG Emissions [8].

It is important to understand the reality of energy production and its ties to GHG and therefore to the atmosphere. The second goal as a part of the 20-20-20 plan in the EU is to have at least a 20% reduction of GHG by 2020, when comparing to 1990 levels [3]. As an update, in 2015 and 2016 this number was surpassed, achieving more than 20% less greenhouse gases; assuming this trend continues, the EU reached this goal with ease [8]. Governments understand the effects of GHG emissions which is why plans of action, such as those by the UN or the EU, are encouraging efficiency.

It is clear that governments have properly understood the importance of energy efficiency and its role in a sustainable future, but is it just as important for typical homeowners, universities, or commercial builders? The answer is simple: yes, and there are several reasons to justify that answer. First, energy efficiency is an easy way to save money on utilities for the typical consumer [10]. On the commercial scale, this socio-economic boost helps promote sustainable development that is an important factor when considering how competitive a company is [11]. Second, the reality that global energy demand is expected to increase by 50% by 2050, should lead people to action, and if no personal responsibility is taken, the governments will be unable to ensure sustainability [11]. There is major concern over the potential environmental impact that will occur with the continued increase of energy usage. The possibility of limiting energy usage and thus climate change via efficiency is a monumental plan that needs to be considered when measuring the importance of efficiency [11]. Should this not be considered, governments may have to issue energy conservation policies that basically limit energy usage such as a maximum wattage each house is permitted to use, designated hours without electricity, etc. [12]. It has been demonstrated that energy efficiency impacts energy costs, economic growth, employment opportunities, and social equity objectives [11]. Therefore, efficiency can boost the economy, improve social development, aid environmental sustainability, and promote personal health and well-being [11]. This reality may have an even bigger impact on the economic growth of the company that is taking steps toward efficiency as medical care of employees may be reduced due to healthier living conditions.

Energy Efficiency in Buildings: How is it Accomplished?

A common problem relating to the importance of energy efficiency, as noted above, is that many are uninformed on how it can practically be accomplished. Recent research suggests that 20-30% of building energy consumption can be eliminated through the use of optimized efficiency techniques such as better energy management and operation, even without changing hardware or structures already in place [13]. There are several ways to increase a building's energy efficiency, and it is of growing importance that the general public is aware [11]. On the industrial and building design level, there are an abundance of ways to make the building more efficient. In the commercial sector, about 32% of the energy goes into powering a building's heating, ventilation and air-conditioning (HVAC) system, plus 25% powers the lighting, while the next highest category is 12% for computers and other electronics [14]. Therefore, it is rather obvious that HVAC and lighting are two areas that could drastically affect the total energy use, and thus the energy efficiency. It is important to focus on efficiency in the design phase because properly utilizing natural light and ventilation can make a large impact on the use of artificial lights and HVAC. Taking advantage of natural light allows a lessened use of artificial lights, whether this be less artificial light sources or that the lights are simply used less often [14]. Either way, this leads to less power being used without sacrificing the convenience of light.

Natural ventilation allows for improved methods of cooling and heating. In warmer environments, the building may be designed in a way that helps a natural breeze flow through the office, keeping temperatures cooler. In colder environments, the focus may be on preventing heat loss by limiting ceiling height and utilizing effective insulation. In any circumstance, the building should be designed to allow it to be most efficiently heated and cooled and maintain its balance regardless of the outside temperatures. Again, this allows for less energy being needed to maintain the comfortability that is expected.

While the design phase may be the easiest way to ensure the highest efficiency, existing buildings can still improve energy efficiency in a variety of ways. The simplest way for a typical homeowner to increase efficiency is to buy newer appliances and light sources that are more energy efficient [10]. Another method would be eliminating outside drafts from entering the building, improving insulation, and installing double-glazed windows, all to minimize heat loss [11]. Similar methods may be used for companies that may not be building brand new workspaces or purchasing state of the art facilities. The economic benefits alone could be enough to convince a company, but there are other standard practices that encourage businesses to invest in efficiency. For example, efficiency can be increased by taking advantage of technological opportunities and by implementing standard upgrading of office technology [11]. Improving efficiency may be an important part of reducing risk levels or ensuring regulations are properly followed [11].

Conventional Methods of Measuring Building Energy Efficiency

There are several methods in use to measure energy efficiency. One index involves measuring efficiency with regards to climate, another based on meteorological data, another in reference to the area of the building, and still another in comparison to other buildings [14]. Each method may have its advantages or disadvantages, but there are several in existence because of the need to put energy efficiency into a quantifiable and measurable statistic. As the understanding of the general public grows and as it becomes more apparent just how important and practical energy efficiency is, people will want to be able to measure how efficient their building is. An index not only provides a grade, but also allows a measurable comparison between buildings. It provides a comprehensible output to both technical and non-technical parties, who may be making decisions regarding how seriously their company will approach energy efficiency. Therefore, it has become critical to develop, analyze, and maintain indexes that inform stakeholders and homeowners throughout the design and life cycle phases regarding the building’s efficiency [11].

While there is not necessarily a universally used index, there are a few that are most popular. The scope of this paper focuses on two of those indexes; these include comparing the energy consumption to the area of the building and comparing the energy use to other similar buildings. These two will shed insight relating to the purpose of this paper. Researchers seem to prefer to categorize the buildings and only compare energy efficiency between similarly classified buildings. This prevents unfair comparisons that do not consider variables such as normal hours of operation, number of occupants, purpose of building, etc. [14]. An energy efficiency index can be defined as the output of the performance, service, energy, or end products divided by the input of energy [15]. The question often lies in what is considered the input and what is considered the output [15]. An energy efficiency index provides a metric for energy intensity. It is typically set as energy output, *o*, over the energy input, *i*, resulting in the index being $\eta = o/i$ [11].

Building Energy Index

The first commonly used index is the basic comparison of energy usage to building area. The Building Energy Index (BEI) measures the ratio between annual energy consumption and the net floor area in square meters, as shown in Equation (1) [16]. The output has units of kWh/year/m^2 [5]. This equation is basic, yet it gives a powerful comparison and measurement between buildings. A study conducted in 2011 found that the average building in Malaysia measured between 200 and 250 kWh/year/m^2 [5]. The given benchmark is buildings with less than 100 are considered low energy buildings and those that score less than 50 are titled zero energy buildings [5]. In [17], several other buildings are analyzed, and the BEI is applied to demonstrate where average buildings fall on this scale. This is the goal for current and future buildings.

$$\mathrm{BEI}\left(\frac{\frac{\mathrm{kWh}}{\mathrm{year}}}{\mathrm{m}^2}\right) = \frac{\sum \text{Annual Energy Consumption (kWh/year)}}{\sum \text{Net Floor Area (m}^2\text{)}} \tag{1}$$

Energy Efficiency Index of a Building

Another common method to define the energy efficiency of a building is to compare the actual building to a reference building [15]. This is useful for comparing how the building being studied compares to a typical building that has a similar purpose and area. This method can be used to compare energy consumption (*C*), or CO_2 emissions (*E*). The formula can be seen in Equation (2) [15]. The lower the output of the formula, the better. It is important to compare buildings of similar purpose and size as this may change the energy consumption drastically. For example, a 1600 m^2 office will use significantly less energy than a three-story office where each floor is 5000 m^2. As far as purpose, it is only logical that somewhere such as a hospital, which powers machinery continuously, may use far more power than a typical home, which may be empty for at least 8 hours on any given day. Additionally, the reference building may not always be one building, it may be the average of several or all buildings of that type [15]. Utilizing an average will help provide more accurate results for comparing the actual building to similar ones in the area, while comparing to only one other building may be simpler and helpful for providing a general idea of how the actual building rates. With that being said, this metric can be applied in more detail depending on how in-depth the comparison needs to be between the actual building and the reference building. Suggested values for a grading system of the equation output are listed in Table I. The score must be greater than or equal to the minimum and less than the maximum when assigning a grade [15].

TABLE I
GRADING SCALE FOR THE EEIB

Grade	EEIB Score Minimum	EEIB Score Maximum
A	0	0.4
B	0.4	0.65
C	0.65	1
D	1	1.3
E	1.3	1.6
F	1.6	2
G	2	N/A

$$\mathrm{EEI_B} = \frac{\mathrm{C_{AB}(kWh)}}{\mathrm{C_{RB}(kWh)}}, \mathrm{EEI_B^*} = \frac{\mathrm{E_{AB}(kgCO_2)}}{\mathrm{E_{RB}(kgCO_2)}} \quad (2)$$

Comparing the Two Existing Indexes

There are several advantages and disadvantages between the two indexes described. The advantages of the BEI involve its ease of usability and comparison. The required inputs involve only numbers that are typically available to the owner of the building, namely the power consumption and the area of the building. Its output is in practical units that are easily understood, interpreted, and communicated. It also provides benchmark goals and can be applied to many buildings to develop an average rating for buildings in a certain area. The disadvantages primarily revolve around the lack of depth to the metric. Its output is merely a number and does not provide immediate feedback as to where the efficiency ranks in comparison to the regional average. There are current categories given to help understand how the building rates, but while having a rating of 75 may be great in one region, it may be the average in a different region. For the second method, the main disadvantage is that the statistics for reference buildings may not be easily found or accessible. However, one major advantage to this index is how easily adaptable it is between measuring power consumption or CO_2 emissions, allowing the interpreter to choose which he values more. Another advantage includes the reality that it involves comparison to other real-world buildings as references, so the EEIB will always have the same value from year to year. If it continually has a value of 1, that will always be above average, regardless of how other buildings are trending, it may simply be harder to maintain that rating if other buildings are trending well. This also means the outputs need to be updated periodically, showing that if the actual building maintains the same energy consumption from year to year it may trend downwards when using this index. For the other method, having a BEI rating of 50 may be excellent in one year, but in five years, that may be a mediocre value. This reality encourages ongoing improvements to energy efficiency [15].

Proposed Energy Efficiency Index: Net Energy Index

While these two indexes are useful, they may be slightly outdated because they do not consider the beneficial usage of renewable energy resources. As renewable energy becomes even more prevalent, and other technology continually improves, a new index is necessary to reflect this. This paper is proposing the Net Energy Index (NEI) which takes a wider view of efficiency by considering the energy source, and therefore, the GHG emissions as well as the building's impact on the grid. While the index may seem basic, it is fully justified, and its implications will be explained in detail. The NEI of a building can be found by subtracting the total power generated by the local renewable sources (P_r) from the total power consumption of the building (P_T), then dividing that by the area of the building (A). This formula is represented by Equation (3). For the scope of this paper, local renewable energy sources include any renewable sources directly connected to the building of interest or offsite renewable sources that are owned or leased by the same company as the building. This formula replicates the simplicity of the BEI but adds another dimension to the measurement. The BEI was used as the base for the NEI because its advantages seem to outweigh its disadvantages. The simple usage and applications of the index designate a grade of energy efficiency to the building with ease. If a comparison of an actual building to other reference buildings is necessary, such as in the EEIB, it may be just as simple to apply the NEI to several other buildings and compare the outputs to the building in question. This is even possible for buildings of different sizes, allowing buildings with a similar function to be compared, regardless of area.

$$\text{NEI} = \frac{P_T - P_r}{A} \tag{3}$$

Subtracting the local renewable energy from the total consumed energy in the building is justified for two main reasons. First, this renewable energy is not contributing to GHG emissions; therefore, less emissions will be present for the same amount of power. While GHG emissions may not be the immediate, primary concern of an individual, it is the one of the most important factors to the general public as a whole. Therefore, utilizing this index not only encourages efficiency, but it also encourages cleaner sources of energy, which contributes to a similar goal. While the population is trending in the right direction of releasing less emissions each year, the production of electricity still releases large amounts of GHG emissions [8]. Using renewable sources can only help reduce GHG emissions even more [12]. This proves that renewable energy sources are valuable enough to be considered when measuring energy efficiency. The second reason to justify the NEI comes from the reality that while the building may be using a certain amount of power, its impact on the grid is reduced by the utilization of local renewable energy sources. Therefore, the building will consume less energy from the grid's perspective than the amount of energy the building is actually using. This is important because it will reduce the strain placed on the grid, an issue that is particularly present in densely populated areas. This also means that power plants that produce GHG emissions, and have so many other negative side effects, will not have to produce the extra power that is being covered by the local renewable source. The two reasons that justify the NEI also happen to be the two main reasons detailed in the beginning of this paper for why energy efficiency in buildings is important: limiting GHG emissions and reducing the grid strain, particularly in high population densities.

Developing a grading system may be the most difficult part of the new index. There could be two lines of thought regarding the grading system. The first considers that it is more likely for a building to have a lower score now that the index only considers net energy rather than total consumed energy. With this thought process, it seems logical to have a stricter grading scale. On the other hand, though, using a similar grading scale as the BEI is reasonable because it is measuring the emissions-based energy, so there is no need to change the scale. With all things considered, adding a new level to the scale could help encourage even better use of electricity. This combination of the two thought processes seems to be the most reasonable. This new level is made more realistic because of the changes in the index allowing lower (better) scores to be more achievable. Therefore, it appears best to use similar numbers as the BEI but grade them slightly differently. Buildings with an output of less than 100 kWh/year/m^2 should be considered low energy buildings, while those with less than 50 kWh/year/m^2 should be titled green energy buildings, while those with less than 25 kWh/year/m^2 should be named zero energy buildings. These numbers are justified based on the amount of energy being drawn from the grid, but the new category is added because it is reasonable to expect the possibility of more high performing buildings with the additional considerations of the NEI.

Table II outlines several ways that energy efficiency can be combined with local renewable resources to limit the net energy use of a building [6]. Option zero primarily focuses on efficiency before renewable energy is even considered, while options one and two list renewable resources that can be combined with the building on site, then options three and four outline potential off site resources for the company to invest in for a sustainable future. While each has its benefits and the categories can be combined, one category should be selected or prioritized based on the context of the actual building for best results [6].

TABLE II
ENERGY EFFICIENCY AND RENEWABLE ENERGY OPTIONS

Type	Option Number	ZEB Supply-Side Options	Examples
Efficiency	0	Reduce Site Energy through low-energy building technologies	Daylighting, high-efficiency HVAC equipment, natural ventilation, evaporative cooling, etc.
On-site Supply Options	1	Use renewable energy sources available within the building's footprint	PV, solar hot water, and wind located on the building
	2	Use renewable energy sources available at the site	PV, Solar hot water, low-impact hydro, and wind located on site but not on the building
Off-Site Supply Options	3	Use renewable energy sources available off site to generate electricity on site	Biomass, wood pellets, ethanol, biodiesel, etc.
	4	Purchase off-site renewable energy sources	Utility based wind or PV, emissions credits, hydroelectric, etc.

Impact of Renewable Energy Generation on Building Energy Efficiency

This paper is proposing a new energy efficiency index that considers renewable energy sources. Because of how often efficiency and renewable energy are discussed together, many may find themselves in support without properly thinking through the proposed index. It needs to be noted that renewable energy sources have no impact on how efficiently the energy in a building is being used, it is merely a different supply [12]. Therefore, one may argue that proposing a new index for measuring energy efficiency and considering renewable energy in that index is basically an oxymoron. It is modifying one thing based on a completely irrelevant idea. This has been carefully considered, however, and the proposed index is justified because of its intention to measure GHG as well as how the power consumption affects the grid. This index truly measures the total amount of energy that is contributing to GHG emissions. When looking to long-term sustainability, improving and utilizing renewable energy resources may actually be more beneficial when compared to energy efficiency and considering the goal of limiting GHG emissions [12]. The NEI, then, properly reflects the positive impacts of this truth. The third goal of the 20-20-20 plan in the EU is to have 20% of the total power being produced by renewable energy sources [3]. This is yet another evidence for the connection between renewable energy and the goal of reduced GHG emissions. Both [18] and [19] discuss more applications of renewable energy usage to help with a building's energy efficiency. The issue is that no current index would reflect the beneficial changes that have been made by incorporating renewable energy sources with an already efficient building.

Net Power Measurement

If the index is reasonable, justified, and beneficial, then the next step is ensuring that it can be practically implemented. Having accurate measurements of power consumption and renewable energy production are key to having a useful index. This means that the energy system in the building needs two-way communication with the grid. This technology had its beginnings as early as 2006 when smart meters began to roll out to homes [20]. Over the years, this technology has developed to the point that major power companies, such as Exelon, are making smart metering a standard practice [21]. Smart metering began as a way to measure real time use of utilities and allow off site reading of the data on the meter [20]. This technology has grown and now also includes net metering [22]. Net metering is the most widespread method for properly considering buildings that utilize solar panel energy [22], and therefore local renewable energy. It helps ensure the owners are charged properly for the net energy drawn from the grid, rather than total energy consumed. It considers both the energy being consumed as well as contributed to the grid [22]. Net metering may also be titled bi-directional metering, which may help provide a better understanding of how the technology works [23]. Essentially, the meter counts up when energy is being consumed and begins subtracting the energy that is being produced and sent back into the grid from the local renewable energy sources [23]. Improvements in this system are leadin to coordinating a smart home controller with the smart meter, allowing the controller to maximize efficiency by powering down smart devices when not in use or when the grid is being strained [23]. In other words, the technology that is enabling the proper measurement of power consumption and energy generation, may also be a major key for improved energy efficiency via appliance control and reduced grid strain [23].

Case Study

To help see how this index is properly utilized, it is beneficial to review two case studies. The first contains information gathered from a government office building in Putrajaya, Malaysia [5]. The BEI has already been applied to this building in [5]. Therefore, there is a detailed breakdown of the energy use per month as well as the size of the building. The second case is that of the typical home in the United States of America. Chosen for similar reasons, the government has released data regarding average house size and electricity consumption per home. As the information is considered, more information will be added to each case to demonstrate how the Net Energy Index reflects changes that the Building Energy Index does not should renewable energy sources be added to the building.

The trend of renewable energy throughout the different months is demonstrated in Fig. 3 [24]. While the actual output varies greatly by system and capacity, the trend can safely be assumed as consistent. It is clear that the output is fairly consistent throughout the year, but March through June seems to rate the best while July through September seem to consistently rate lower. The trend passes the logic test as typically the months with less sun are also windier, and vice versa, which leads to a fairly consistent output should the system be balanced. It also

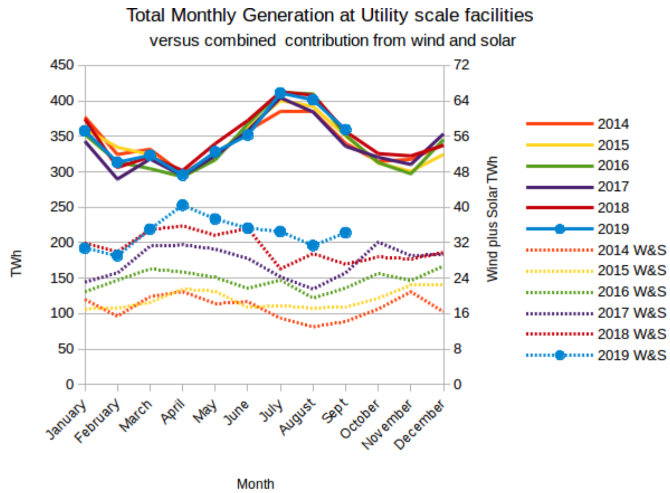

Fig. 3. How renewable energy production varies throughout the year [24].

must be considered that renewable energy potential varies greatly by region, therefore, averages are being utilized. This assumes that averages may be reasonably achieved via some combination of resources. If the building were to follow the typical trend in the USA and focus more on solar energy, whose output is traced in Fig. 4 [25, 26], then the summer months would have slightly higher power generation.

Fig. 4. Solar Panel Output Trend [25].

These charts can be combined to safely assume that April through July will be the months with the greatest impact on the NEI. This is used when considering the how the NEI would rate a building in Malaysia. The Power Consumed column of Table III shows the electricity consumption of the 74,585 m^2 office building [5]. Should the BEI or NEI be applied, they would both output a score of roughly 132 kWh/year/m^2. This building has very high energy consumption, and therefore, it does not rate very well on the indexes. However, this score could be impacted if the building stakeholders chose to invest in local renewable energy sources. If the stakeholders of the building were to invest in enough local renewable sources to offset only 10% of their total power consumption, the new score on the NEI would be 118 kWh/year/m^2, while the BEI remains at 132 kWh/year/m^2. If this investment was to reach 20% of the total power consumption, the NEI would output 105 kWh/year/m^2. If 25% of the buildings total power were to be offset by renewable energy generation, then the NEI score would be 99 kWh/year/m^2, low enough to fall into the low energy building category. Keep in mind that at this point, the BEI would continue to rate the building at 132 kWh/year/m^2.

Assuming that the summer months can offset 30% of the electricity consumed that month and breaking down the other months based on the trends presented, it is very possible to achieve the low energy building title, as demonstrated in Table III. The Power Generated column is the amount of energy that the renewable energy resources would have to produce to reach the percent offset of the power consumed, as displayed in the % Offset column. The final two columns demonstrate how the outputs of the BEI and the NEI change with the introduction of renewable energy generation.

TABLE III
DEMONSTRATION OF BEI AND NEI DEPENDING ON NET POWER

[kWh] unless noted	Power Consumed	Power Generated	% offset [%]	BEI Score	NEI Score
Jan.	867482	-182171	21	12	9
Feb.	754936	-158537	21	10	8
Mar.	836328	-200719	24	11	9
Apr.	805045	-225413	28	11	8
May	818482	-253729	31	11	8
June	825301	-247590	30	11	8
July	824019	-206005	25	11	8
Aug.	826358	-231380	28	11	8
Sept.	811674	-186685	23	11	8
Oct.	852456	-170491	20	11	9
Nov.	791612	-150406	19	11	9
Dec.	806447	-153225	19	11	9
Total	9820140	-2366351	24	131.7	99.9

Another useful demonstration of the NEI is applying it to a typical home in the USA. Renewable energy resources are becoming more popular and many are investing in rooftop solar panels. While most only consider how it affects their energy bill, the benefits of reducing carbon emissions and grid strain should be considered. Assume an average home is 232.25 m^2 [27] and uses 10972 kWh/year [28]. Now this already scores a 47 on the NEI and BEI, which is logical because of the reality that offices typically use more power than homes due to number of occupants and purpose. The purpose of the building has a great impact on its energy usage [29]. Therefore, the average American home rates as a low energy building on the NEI and a zero-energy building on the BEI. However, calling this a zero-energy building implies that improvements do not need to be made. If the homeowner were to invest in rooftop solar panels that covered 50% of the consumed power, the building could easily rate as a zero-energy building, scoring a 24 on the NEI. While 50% of a high-power consuming building, like the office in Malaysia, may not be reasonable, this is completely reasonable for an average home in America. This would work out to be about 5500 kWh/year, which breaks down to about 15 solar panels (adapted from [30]). This investment causes the home to be upgraded into the most efficient category of the NEI and should definitely be considered.

Conclusion

Energy efficiency is an important topic that rightfully deserves discussion and action. There are many reasons that efficiency, specifically with regards to electricity consumed in the building sector, should become more standard in everyday life. Two of the biggest reasons for that include the reality that greenhouse gas (GHG) emissions being produced from traditional power generation pose a serious threat on the sustainability of the planet, and the electricity grid is already strained in densely populated areas and will continue to be more strained as a growing population means more electricity consumption unless efficiency improves. There are several practical steps to help a building become more efficient. The biggest impact can be made during the design phase of the building to maximize the use of natural light and ventilation, but several changes can be made post construction such as increasing insulation or using more energy efficient appliances.

While improving energy efficiency is great, it is helpful to have a way of measuring just how efficient a specific building is. There are several indexes that do just that. The most popular is titled the building efficiency index (BEI) and measures the total power consumption divided by the area of the building in square meters. If the output is below 100 kWh/year/m^2, the building is considered a low energy building, while anything below 50 kWh/year/m^2 is considered a zero-energy building. The second index considered is the energy efficiency index of the building (EEIB). This index provides a direct comparison of the energy consumption of a given building to a reference building. If the output of this index is one or smaller, than the given building is more efficient than the reference building. While both indexes have their advantages, the BEI is simpler to apply and interpret. Both of these indexes fall short of the current level of technology available. Neither index considers the impact of local renewable energy sources when rating the buildings.

The Net Energy Index (NEI) corrects this problem by dividing the net energy consumed by the area of the building. This index is similar to the BEI, but it only considers net energy, which in this case would be the total power generated by local renewable sources subtracted from the total power consumed. This index properly reflects how renewable energy makes a positive impact on energy consumption. While utilizing renewable energy does not directly improve energy efficiency, it does impact how the energy is generated. Because renewable energy resources help reduce both GHG emissions and grid strain by producing clean energy that is local to the consumer, it has essentially the same outcome as energy efficiency. Net energy can be properly measured via bi-directional smart meters. These meters, as the technology continues to improve, are beginning to not only measure energy usage, but also increase efficiency through a smarter use of appliance control. Therefore, they play a major factor in the practicality of the NEI.

To prove how the NEI works, especially when compared to the BEI, two different cases were considered. The first involves a large government office building in Malaysia that uses a massive amount of power. The NEI demonstrated that by investing in renewable energy resources that produce 25% of the building's total energy usage, the building would be upgraded into the low energy building category in the NEI. The second case involved the typical home in the United States of America. A typical home scores about 47 kWh/year/m^2 on the NEI, placing it in the green energy building category, but by investing in a 5 kW rooftop solar panel system, this score could be reduced to 24 which would place it in the zero energy building category.

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