Something IS better than Zero: Integrating Continual Improvement and Zero Energy Goals

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ABSTRACT

Zero Net Energy (ZNE) has proven an attractive goal in the building sector and is beginning to be promoted as a realistic goal for industry. Zero is an easily understood target that motivates better energy efficiency and more effective operational and maintenance-based behavior. It also motivates the use of solar photovoltaics. Strategic Energy Management (SEM) has as a central goal continual improvement in energy performance. But the primary standard for SEM—ISO 50001—defines energy performance as limited to reducing energy consumption, not as also considering clean energy production. This paper explores how the two concepts—Zero Net Energy and SEM—and their differing approaches to clean energy production and to improving performance over time can be combined to help society meet ambitious climate pollution reduction commitments.

Introduction to the Zero Net Energy (ZNE) Concept

If the goal of energy efficiency is to reduce energy consumption while providing the same level of energy services, then it would appear that "nothing is better than zero" (energy consumption) (Higgins 2011). This is one of the attractions of the goal of Zero Net Energy, a concept that has attracted rapidly increasing attention and implementation around the world since the early 2010s.

One of the reasons for this success is that Zero Net Energy is an emotionally salient concept. Unlike efficiency, which is invisible and could mean anything from a nearly negligible improvement in one part of a facility to a 90 percent reduction in total energy use, Zero Net Energy relies on highly visible solar (or wind) generation equipment in addition to comprehensive energy efficiency actions and suggests the total elimination of nonrenewable energy use.

The situation is not so simple, however. Common definitions of Zero Net Energy (USDOE 2015; New Buildings Institute 2015; Seryak 2011)[1] settle on some key attributes that Zero Net Energy facilities must meet:

- Annual energy consumption lower than annual production of renewable energy
- Compliance preferably based on metered results, not just projections or simulations
- Consideration of effects beyond the boundaries of the facility site—thus a requirement to retire Renewable Energy Credits from production on-site, a rejection or de-rating of renewable energy generated off-site and not connected by a physical wire to the site, and, typically, the use of source energy to measure energy consumption for fuels other than electricity

[1] These are not the only such definitions, but they are widely cited ones. Many of the definitions are only summarized in non-published documents not yet available to the public, or not translated into English.

These attributes do not address all the issues regarding what constitutes a Zero Net Energy facility. Several other critical questions are left unresolved in the definitions of ZNE, including:

- Zero Net Energy consumption does not mean zero net energy bills nor Zero Net Emissions of greenhouse gases, or of other pollutants. What would it take to achieve such goals?
- Should consideration of energy be limited to operational energy, and or should it consider the embodied energy (or emissions) to construct the facility, and to transport goods or people to and from it? (Goldstein 2012).
- In a world where most facilities may achieve Zero Net Energy goals by the year 2030 or so, how can facility managers help to integrate the renewable energy production into our electric grids?

Another key issue is how the concept of *continual improvement in energy performance*, the cornerstone concept of Strategic Energy Management (SEM), helps achieve the goals of organizations that build or operate Zero Net energy facilities.

It is not completely straightforward to answer the question, “If nothing is better than zero, how can you continually improve?” This paper proposes a pathway to such an answer.

Zero Net Energy *buildings* are proliferating around the world. In North America, the number of identified building projects has been increasing at a rate of 80% annually. Industrial sector Zero Net Energy projects documented on the Internet exist as well, but research on how many there are and how well they work is lacking. The concept is attractive for *industrial plants* because although their energy use intensity may be much higher than that of a building, they also tend to be located in places where land is not a constraint, such that large solar arrays or even the use of wind generators is feasible.

This paper attempts to address some of these questions by: 1) proposing four increasingly ambitious levels of Zero, and 2) using the principle of continual improvement to link the achievement of them to an organization’s energy plan. (An energy plan is a requirement for SEM, as reflected in ISO Standard 50001) (ISO 2011, 2018). As energy performance continually improves, these criteria for Zero can become part of the energy plan’s future targets.

How to Count Renewable Energy in Measuring Zero

It is easy to trivialize the otherwise ambitious goal of Zero Net Energy: an organization just commits to purchasing 100% renewable energy. The action might be to purchase Renewable Energy Credits (RECs) in an amount equal to the quantity of energy used in each year. Deciding to buy 100% renewables would require no work to improve energy performance—it would mean merely writing a check. This is not the intent of Zero Net Energy policies, as reflected in all the various published definitions worldwide.

To avoid this trivialization, and to direct organizations with ZNE goals to develop energy plans that meet the intent of ZNE, two steps are needed. The first, which is in widespread use, is that ZNE policies always prefer, and often require, that the renewable energy be generated on-site, or near to the site, or with some direct physical connection to the site. The second, which is just beginning, is to recognize through the definitions of Zero that variable-output renewable energy does not reduce societal use of non-renewables on a one-for-one basis, and that the energy analysis must take account of the systemwide effects of renewable energy production both on-site and offsite on the grid.

Where should the renewables be sited?

The reasons for preferring on-site renewables include:

- Zero Net Energy policies are intended to encourage better-performing facilities—ones that combine advanced levels of energy efficiency, and as will be discussed later, Demand Response and other methods to harmonize energy consumption patterns over the year with the availability of renewable energy on-site and on the grid. There are other more direct methods of encouraging more renewables than Zero Net Energy policies, and these ought to be harmonized with Zero Net Energy policies.
- In practice, for buildings (where we have much more data on achieved performance) virtually all Zero Net Energy facilities employ state-of-the-art levels of efficiency combined with modest amounts of solar photovoltaic (PV) generation. (The first objective is realized in the data but we want this result to continue with new facilities).
- Renewable Energy Credits may or may not be truly additional—they may not at the end of the day increase the fraction of renewable energy on the grid by much. In all cases, they are unresponsive to the need for additional generation in a given hour. This issue will be discussed below.

A preference for on-site renewables raises several issues, most of which have been addressed by policies, but not always in the same way.

One issue is: where do we draw the boundaries for "the site" geographically and contractually? Does it refer to one industrial plant? Or to a site that includes several different plants, which may not be contiguous to each other? What about an industrial park with plants owned by diverse organizations? What about a solar or wind farm that is located 1 kilometer away from a plant, but that has a transmission line to convey the electricity? What if we allow the generation to be arbitrarily distant from the plant, as long as it is directly connected by transmission wires? What types of contracts ensure additional renewable generating capacity on the grid? What level of control does the facility have over the renewable generators?

The concept of Zero Net Energy as an integrated system of efficiency and renewable energy works best when its exemplars can be seen as demonstrations of environmental responsibility. Putting the solar a long distance away and having it owned and/or operated by someone else reduces the salience of the demonstration. Thus, standards for claiming Zero Net Energy prefer restrictive geographic limits. Different jurisdictions decide the issue somewhat independently in different circumstances, such as new building construction in California and in South Korea, as do organizations attempting to influence markets, such as the U.S. Department of Energy (USDOE) and the New Buildings Institute, the European Union, and the World Green Buildings Council. All have developed criteria to keep renewables on-site or at least near the site, and to discount or prohibit offsite generation and the use of RECs.

Accounting for the Variability of Renewables

If we are only building one Zero Net Energy facility on a grid that is mostly fed by polluting resources, time of the year doesn't matter much. But *if most facilities are Zero Net Energy*, then the generation (likely mostly solar) will all be at about the same times, which will overlap heavily with the performance of the grids (both gas and electric). Energy generation during the morning hours, when solar generation is strong and demand is light, may not displace much (or any) emissions, while energy consumption after the sun sets in the late afternoon or early evening is likely to rely on the dirtiest generation. Figures 1 and 2 illustrate this problem.

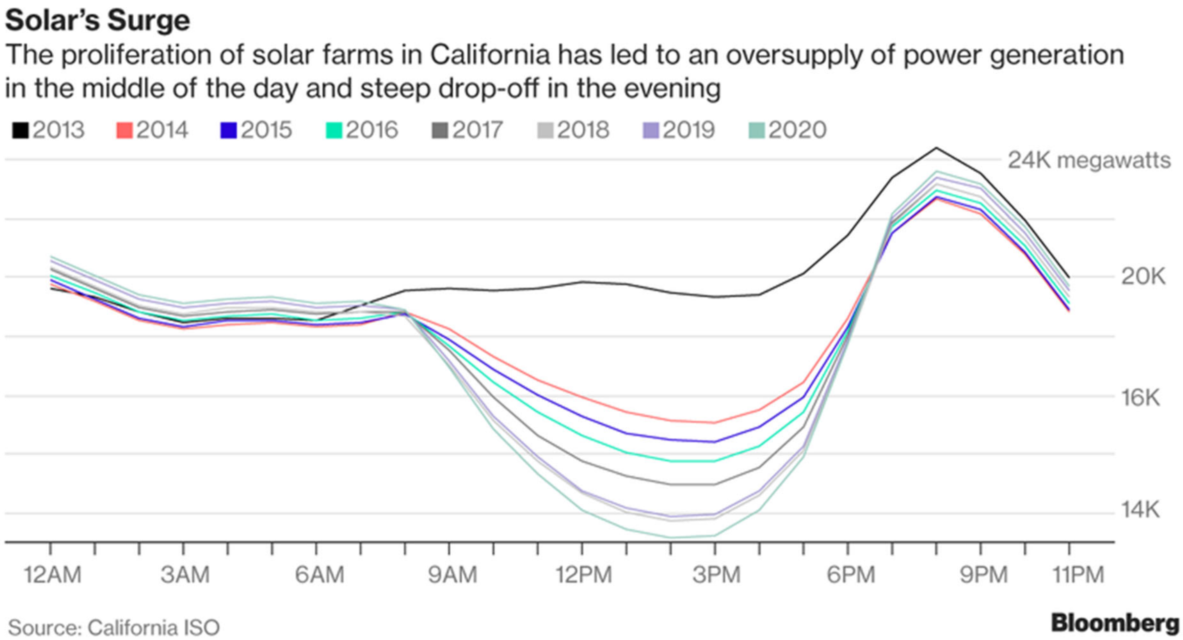

Figure 1: Power demand as a function of time of day, Spring. *Source*: California ISO via Bloomberg

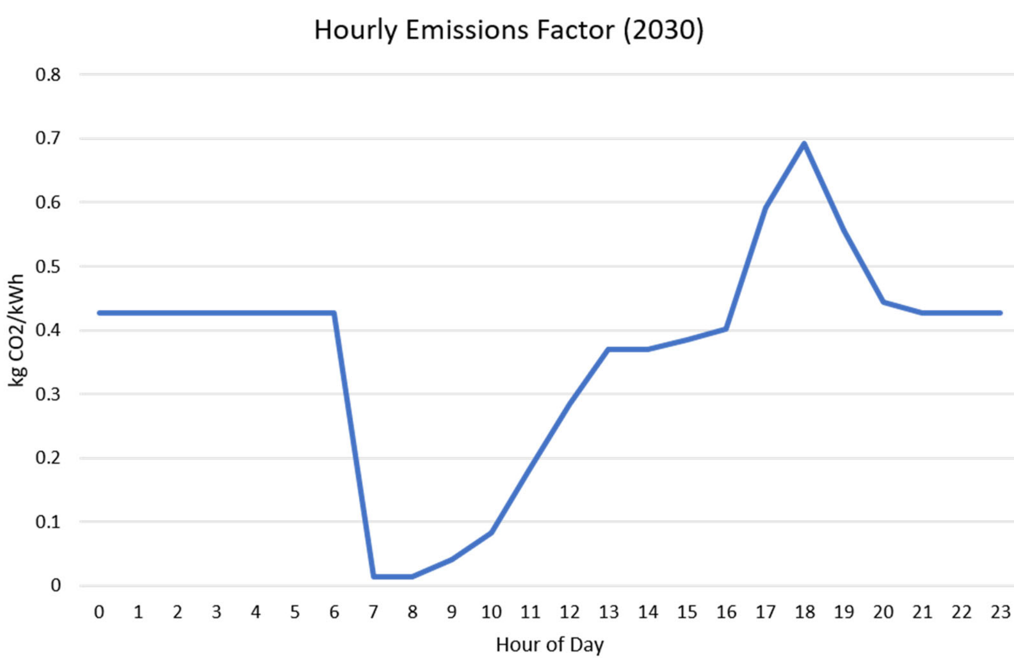

Figure 2: California GHG Emissions Factors 2018. *Source:* CPUC Avoided Cost Model 2018: http://www.cpuc.ca.gov/General.aspx?id=5267

The variations in the Figures account only for the dispatch order of already-existing power plants. If we consider the construction of new power plants, the difference between different hours of the day is even larger. The definitions of Zero Net Energy do not yet address these issues explicitly, so this paper will suggest how to do so. The first step would be to develop and implement *the types of methodologies used to produce Figure 2*. Accounting for the societal value of energy consumption will require multiplying net energy use for a facility in each hour of the year by a factor that accounts for societal energy consumption (or pollution emissions). After this is done, *ZNE can be defined in terms of time-weighted source energy or emissions.*

Integrating ZNE and Strategic Energy Management (SEM)

Energy plans developed for the purpose of SEM must include future-year targets that an organization commits to meeting. These future-year targets allow for a thorough integration of ZNE and SEM as goals are set for energy performance improvements. We have just seen that ZNE on a societal basis is more challenging of a goal than ZNE on average over the year, because the renewable energy generation is highest when the source energy and emissions intensity of the grid is relatively low. This paper discusses two additional layers of achievement and argues that we want to look at the trends over long periods of time, proceeding to ever-more-ambitious definitions of Zero on a planned path.

How to Count Energy Impacts in Measuring Zero

While there has been growing interest in the concept of Zero Net Energy, the energy consumption at a facility has little inherent interest to people. Instead, energy is usually a proxy for two things that people DO care about: emissions and costs. And even those who might be concerned about energy itself—policy-makers in government who have legal assignments of responsibility for reducing energy consumption, for example—care more about overall societal energy use than about how much is consumed on net in a given facility.

This sort of question can be addresses by Life Cycle Analysis (Goldstein 2015). This method defines energy use or emissions in terms of three categories of increasing scope:

- Scope 1 considers direct energy use or emissions from inside the facility boundary. It is commonly referred to as site energy. It seldom correlates well with either emissions or costs.
- Scope 2 includes the energy input to the facilities that produce the energy that is eventually delivered—for example, the gas burned by the electricity provider, or the gas used to power the compressors that deliver the gas to the facility, or its associated emissions. This is also known as source energy, and definitions of Zero Net Energy usually prefer this metric.
- Scope 3 includes the energy or emissions used to construct the facility and to produce the raw materials, water, and manufactured inputs to an industrial plant. It also includes transportation energy to get supplies and staff to the plant. Scope 3 often goes several organizations up the supply chain.

Zero Net Energy is usually defined to include Scope 2 energy, but some have argued that it ought to include Scope 3. This expansion of the mission to Scope 3 greatly increases the difficulty of meeting the goal, as the direct energy use or emissions of a typical efficient building (the comparable calculation is unavailable for a typical industrial plant) are only about 35%-40% of Scope 3 energy or emissions (Goldstein 2012).

How do we reconcile the goals of continual improvement in energy performance (defined by ISO 50001 to not include renewable generation) with the goal of ZNE? This paper proposes to do so by encouraging *a progression over the years* from the lowest level of ZNE to higher and more societally relevant levels. It begins by updating the calculation of Scope 2 energy consumption.

This paper proposes two different definitions of Scope 2 energy use and emissions. In the past, Scope 2 has been calculated by estimating a (one) source multiplier for each fuel type, which is applied to the metered energy use crossing the site boundary. For the last 50 years, these multipliers have been on the order of 1.1 for direct combustion of fuels and 3 for electricity. They have tended to be about equal regardless of whether the metric was denominated in energy units, in cost units, or in emissions units, and usually do not vary much from region to region throughout the world.

But this historic type of calculation is no longer valid for many regions, and if we are to prevent the climate catastrophe predicted in the recent report of the Intergovernmental Panel on Climate Change (IPCC 2018) it will soon have to change everywhere.

In the past, on the margin nearly everywhere and on the average in most regions since at least the early 1970s, electricity cost about three times as much at the site boundary, used about three times as much source or Scope 2 energy, and emitted about three times as much (sometimes more if the marginal fuel was coal). But in the last decade, policies such as state-mandated renewables portfolio standards have meant that the marginal electricity source is 30% to 50% or 60% renewables, and the decline of coal has meant that the marginal source is or is becoming gas combusted at high efficiency plants.

Efficient gas plants now (or in the near future) fill in at times when renewable power is insufficient to meet load.

Therefore, source multipliers now should not be single numbers but rather *files of such numbers* that differ for each hour of the year, as illustrated in Figure 2. These hourly numbers are quite similar for source energy and for emissions, since the marginal generation fuel is generally gas and the marginal efficiency and emissions rates of the plants are not that different. Cost-based metrics produce different outcomes because natural gas costs in North America are substantially lower than electric costs.

This change has not been reflected in a change in calculational methods for Zero Net Energy outside of California. To do so would require collecting the data on marginal emissions or source energy factors which has only been done in a very few places, and even then, incompletely. For example, Figure 2 was derived from a relatively expensive grid simulation model for only one grid—California—and is oversimplified in that it looks at change in dispatch order of existing generating capacity and ignores new capacity. Enhancing the fidelity of "Scope 2" energy and emissions is a significant change with big consequences for the meaning of Zero, and one that requires new analytic effort.

Expanding the calculation methodology for Scope 2 changes the meaning of the word "Net" in Zero Net Energy or Emissions: there is no longer any undifferentiated netting of positive and negative contributions to the grid as if a kWh at 7 pm on a Spring day is the same as a kWh at 3 am in Summer. Instead, a consistent metric of value becomes, effectively, a Joule of Scope 2 energy or a gram of emissions.

This change makes two differences for organizations with goals for Zero Net Energy facilities. On one hand it will likely make the target of Zero harder to achieve, especially if the facility has heavy energy demands in the late afternoon or evening. On the other hand, it allows the facility operator to take credit for energy saved at the powerplants through schedule changes even when the total annual energy consumption is unchanged. An example might be a single-shift production facility that changes its shift from 9-5 and moves it to 6:30-2:30, or that schedules a piece of equipment that only operates 3 hours a day to work from 7-10 am.

Valuing different times of day and year opens up many unexplored opportunities to improve energy performance in the industrial sector. These options include: a) using automatic controls that respond to typical grid conditions; or b) using controls that respond to real-time conditions such as real-time electricity prices obtained using Internet connection; or c) controls activated in real time directly by utilities or grid operators within constraints or limits specified by the facility's managers.

Note that utility rates often vary with time of use and/or charge for maximum power demands, so there can be some harmonization of optimizing for energy cost reduction and optimizing for minimum Scope 2 energy or emissions, at least for electricity.

Introduction to "Strategic Energy Management" in the Context of Zero Net Energy

Strategic Energy Management (SEM) is a relatively new concept in industrial energy efficiency policy in most countries. It was developed as an international standard over the period of about 2000-2011, culminating in the issuance of the International Organizations for Standardization's Standard 50001 in 2011 (ISO 2011).

Some of the roots of this concept date back to the 1970s, when Japan responded to the energy crisis of the 1970s by requiring industrial enterprises above a given size to hire an energy manager and report back annually to the government on the progress their organization had made in saving energy. After two decades, the energy intensity of Japanese industry had declined dramatically to a level lower than that of almost any other country (NAS 2010).

SEM programs are based on an Energy Management System (EnMS) that directs change in an organization's culture (CEE 2014). The EnMS requires top management to provide sufficient resources and staff to continually improve the organization's energy performance over the years. Since the performance indicators used to measure and track compliance with the organization's energy performance improvement goals are often based on whole-facility energy consumption, the EnMS credits major process changes, equipment performance improvements, improvement in operations and maintenance (O&M), and conservation behaviors.

The experience with SEM has been that organizations that undertake the method have been able to maintain near-constant rates of annual energy performance improvement for the length of their participation (Therkelsen et al. 2015). These rates can be quite high—in some cases 4 percent to 6 percent annually over periods of time as long as 40 years.

Consequently, a plant that is intended to be net zero on an annual basis initially, and also to implement SEM, will usually see energy consumption go down while renewable energy production stays about constant. These trends, which are the goal of SEM, will cause the plant to produce ***increasingly more energy*** than it consumes, on an annual basis. This can be true even if expected product production levels (e.g., tons of concrete produced per month) increase, at least as long as the rate of improvement of energy performance exceeds the rate of increase in energy caused by more production. This approach is conceptually similar to an earlier paper's suggestion that renewable production be sized to meet ambitious goals for increased efficiency at a given level of production (Seryak 2011).

A Ladder to More Ambitious Visions of Zero

The common definition of Zero Net Energy, which looks at annual total energy production compared to consumption, is the easiest to attain of all the goals. Yet it is still a tiny niche achievement even for buildings, where it has been promoted actively for almost a decade, and is minimally used in industry at present. Thus, suggesting a more difficult level of initial achievement in place of the current definition seems self-defeating.

Instead, we can define more ambitious levels of Zero that facilities can *plan to achieve in future years* through continual improvement of energy performance due to SEM, even while maintaining the same level of renewable energy production over the years. This progression will be illustrated in Figures 3-6 below.

The first level of Zero corresponds to the definition used by USDOE and others for buildings. The only differences are: 1) for buildings, it is relatively easy to estimate future energy use based on the physics of the structure and the engineering of its climate conditioning system. For many industrial facilities it may be less reliable to estimate energy use before a plant is built, so sizing the renewable energy system to meet the goal of Zero may involve some trial and error. For existing plants, getting to Zero is simpler because the energy baseline that is found in implementing SEM will allow good predictions of future energy consumption under any reasonable scenario of future production levels; and 2) for some industrial plants, purchased fuels may be used for feedstock, and the production process may create waste heat that can be put to good use, so consistent methodologies for accounting for this will be needed.

In any case, the claim of Zero Net Energy would seem to require some reliance on normalized measured data because of the possible variability of energy consumption and production as a result of changes in relevant variables such as product production levels and weather, as well as static factors.

Thus for a plant built in Year 1, we should have good data on whether the Zero Net Energy goal was achieved by Year 3 or so. If not, monitoring should establish ways of homing in on the goal. Beyond Year 3, a facility whose management has implemented SEM can anticipate a goal of continual improvement and thus gradual reductions in energy consumption.

The second level of Zero is more ambitious: Zero Net Emissions: the savings in net Scope 2 energy consumption due to renewable energy, summed over each hour, are smaller than the simple, unweighted annual sum. This occurs because (usually) everyone else is also generating renewable energy at the same time. Thus reduced consumption of energy at some hours *avoids on-grid renewable generation rather than polluting fuels* (see Figure 2).

To see what it would take to start with the easier goal and then progress to the second level, consider an illustrative example. Suppose that a plant has an energy consumption level of 100 units/year. This energy use is offset by 100 units of PV production; hence, it achieves (level 1 of) Zero Net Energy. But the emissions savings is substantially less—assume 60 units of carbon reduction, so that the net carbon emissions level is 40 units/year.[2]

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[2] These assumptions are arbitrary and for illustrative purposes only. They are based eyeballing Figure 2 because further attempts at precision would be misleading; Figure 2 is based on incorrectly restrictive assumptions and applies to only one grid in the world.

Assume a 3% annual reduction in energy consumption in a scenario where the timing of the consumption doesn't change. Note that this 3% might be the result of a higher annual improvement rate in its energy indicators (which account for other variables) being reduced by these variables otherwise leading to greater energy consumption. The results of this example case are displayed in Figure 3. In this example, carbon emissions will achieve the second, more ambitious goal of Zero Net Emissions in Year 25.

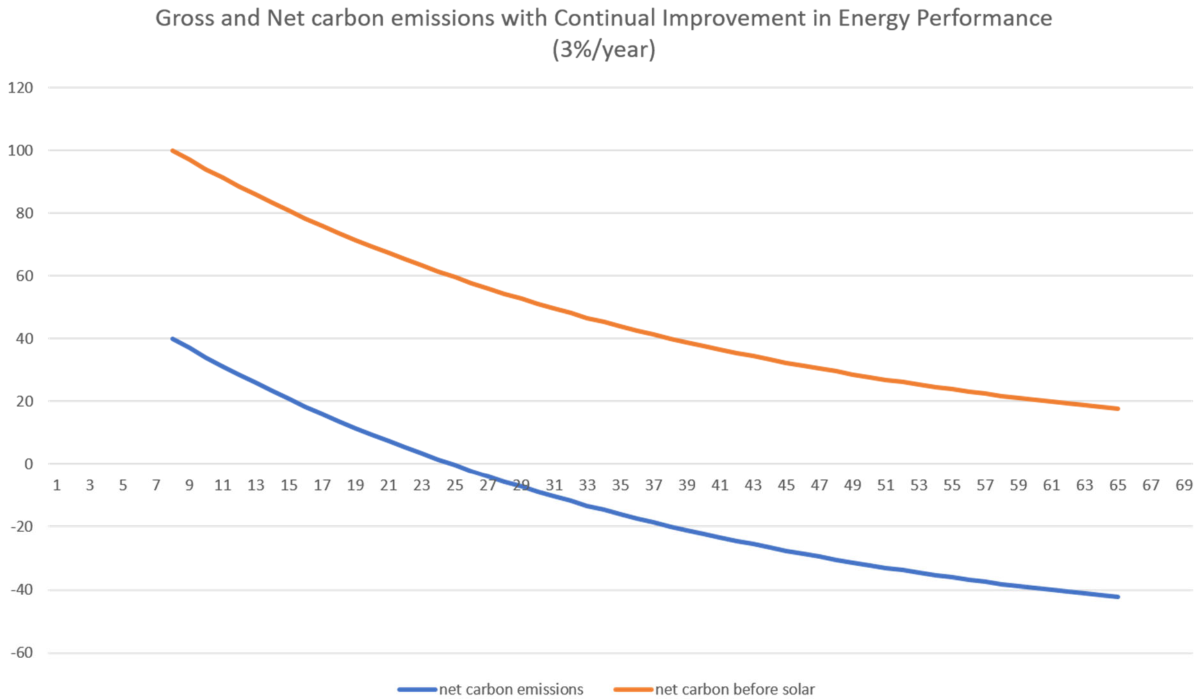

Figure 3: Carbon emissions over time – 3%/year decline rate of energy consumption.

One could also look at faster rates of improvement. Figure 4 illustrates what happens when the decline rate of energy consumption is 5% annually. In this case, we hit the Zero goal in Year 18.

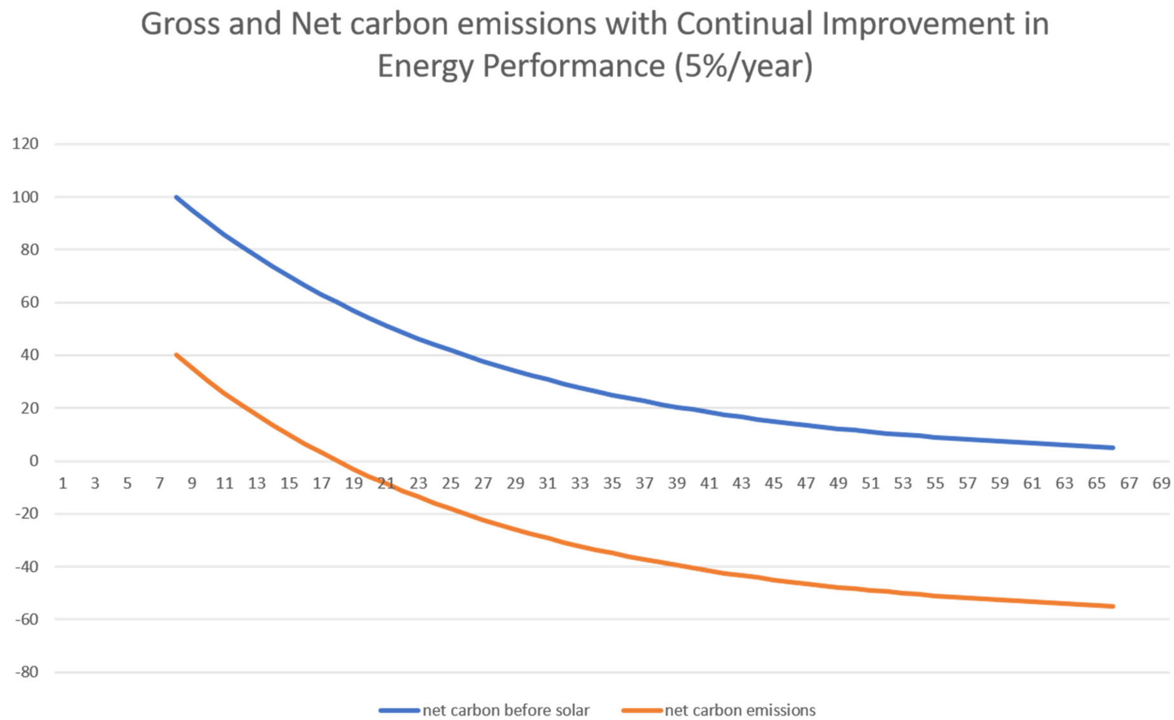

Figure 4: Carbon emissions over time – 5%/year decline rate of energy consumption.

The third level of zero includes Scope 3 emissions. As we shall see, this goal may be MUCH more difficult. The author is not aware of generic analysis of the Scope 3 emissions of constructing an industrial plant, and suspects that a generic analysis would not be meaningful in any event due to plant-to-plant variation, so the next Figures are based on analysis of a generic building (Goldstein 2012) because it is all we know how to do. In this case, construction energy for an efficient building on the level of the consumption of currently documented Zero Net Energy buildings is about 5000 units, or about 50 years of operational energy consumption. Figure 5 illustrates the *cumulative emissions* from a building with enough PV to achieve Zero Net Energy in Year 3 that starts out efficient and improves at a 3% annual rate.

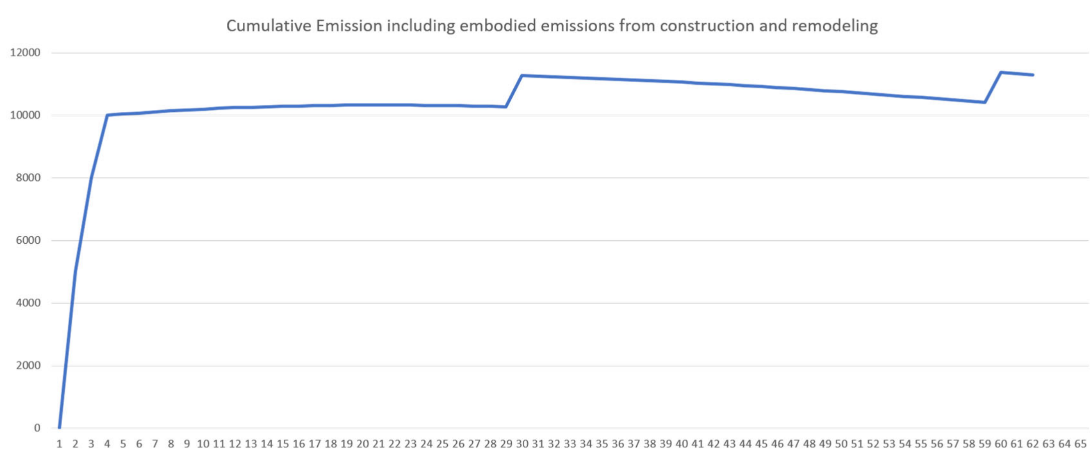

Figure 5: Cumulative carbon emissions.

The results show how difficult this goal is: assuming small remodeling costs in emissions terms every 50 years, we really can't zero out construction emissions no matter how long we take. Clearly raising the percentage improvement won't make enough difference (orange line in Figure 6).

Therefore, we try adding more renewable generation, and show parametric results of doubling solar and using 10 times more solar in Figure 6:

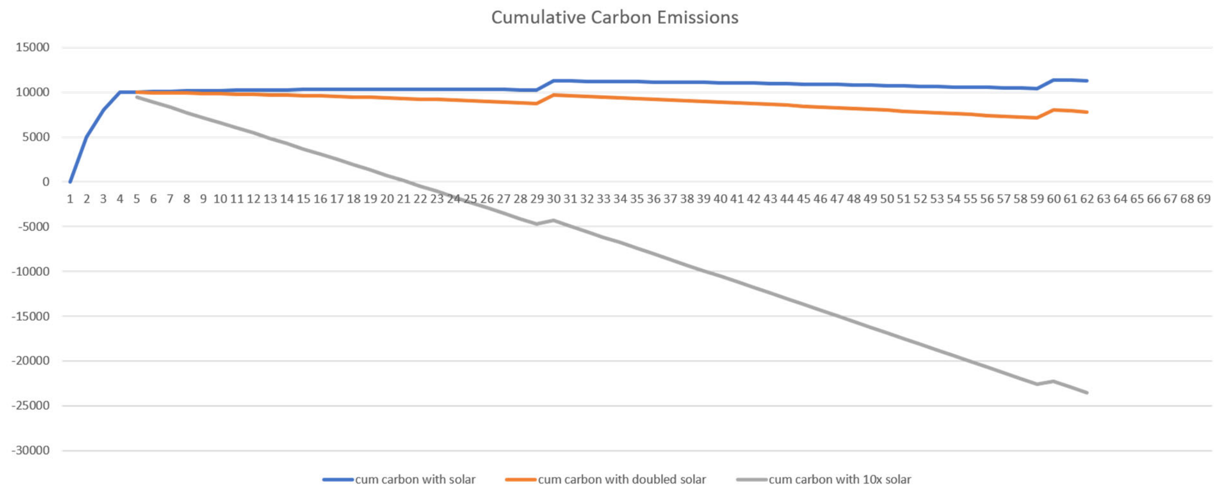

Figure 6: It takes a lot more solar.

We can see from this schematic analysis that as much as 10 times the amount of solar is needed to zero out the construction energy of a building: the gray line shows the cumulative carbon emissions from increasing solar 10 times compared to that needed for the lowest ZNE goal. Results will vary for industrial plants depending on the ratio of their construction and renovation energy and emissions to their annual operating energy. Note that the Scope 3 impacts of the PV (both to install and to maintain it) must be considered (which they are not in the Figure).

The results presented here are likely to be a worst-case scenario for zeroing out Scope 3 emissions because the results are based on business-as-usual construction techniques that do not have the minimization of construction energy as a goal. Indeed, the task of doing so today would be difficult because the data on the energy or emissions intensities of construction materials, as delivered to a specific site from a specific supplier, are not available to designers. We can anticipate that as designers of industrial plants and buildings start to target Zero Net Energy goals, the market or the government will make such input data more available, and designers will use it to cut construction energy compared to current practice.

The fourth level of zero includes zeroing out transportation energy requirements as well. Very little work has been done on the amount of transportation energy use associated with specific industrial plants. For buildings, personal transportation is important, accounting for more than half as much energy as the building uses itself. For most industrial facilities, the ratio is likely much lower. But freight transportation can be significant: how much energy and emissions are associated with getting component parts and supplies to the plant? We know that freight transportation is more than 7% of economy-wide carbon emissions in the U.S., but there is a dearth of information on how this is associated with a particular plant or industry. If organizations begin to consider zeroing out all carbon emissions, we will start to learn how difficult this fourth level is for different organizations.

This analysis assumes that the relevant variables and static factors that affect a plant allow it to reduce its energy consumption on a recurring basis every year, or most years. This is a reasonable assumption on its face, because overall industrial energy use in the U.S. has been declining even while overall production is increasing. For plants where this is not the case—for example, for plants where output is predictably increasing faster than its operators can expect energy performance improvements, maintaining ZNE status (at any level) could require that more renewables be added during planned future years.

What about a goal of Zero Net Energy bills? Utility rates are based on the costs of extending and maintaining services, and a substantial fraction of the costs consist of fixed investments such as transmission and distribution, rather than variable costs such as fuel. For a Zero Net Energy facility, these costs may be either higher or lower than they are in the do-nothing case. But they certainly will not be zero. Someone still must pay for grid backup: long-term storage on-site that is able to provide reliable service over the course of a year rather than a day is not likely to be economically viable. Therefore, electricity service will continue to be reliant on a grid, and the costs of the grid must still be paid by customers, including ZNE facilities.

Conclusions

Zero Net Energy is a policy goal for facilities owners that is attracting increasing interest around the world. While Zero sounds like a simple target, various stakeholders have suggested a range of definitions with varying levels of difficulty.

This paper has suggested a way that these levels can be reconciled and harmonized, by proposing a ladder of increasingly demanding levels beginning with the international consensus on a definition—that annual production of renewable energy on-site, or under specified conditions and/or limits, off-site, equal or exceed annual energy consumption, measured using simplified Scope 2 criteria that do not depend on time of day/year.

Continual improvement, with its requirement of a multi-year energy policy and an energy plan with quantitative goals—the cornerstone of Strategic Energy Management—allows most facilities to progress from this established Zero Net Energy goal to more demanding and societally valuable goals, such as Zero Net Emissions, and eventually in many cases to achieving Zero Net Emissions including all Scope 3 emissions.

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