Approaches to Net Zero Carbon in Industry: ISO/PAS 50010

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ABSTRACT

A growing number of industrial companies are making net zero commitments for future years. Net Zero can be defined as "state in which a quantity of a commodity with one attribute is balanced by the same quantity of the commodity with a different attribute." The commodity can be greenhouse gas (GHG), energy, waste, water, etc.

But until 2023, there hasn't been an accepted standard for how to demonstrate achievement of net zero energy for an industrial organization. Current net zero standards focus on buildings, not industrial processes, and even then, do not distinguish clearly how a demonstration of net zero carbon (NZC) differs from one of net zero energy. "Carbon," as used in the net zero literature, means "greenhouse gas emissions measured in carbon equivalency."

A new ISO standard, ISO/PAS 50010 (ISO 2023), offers recommendations for organizations to follow and show that they are meeting their share of the global zero-carbon goal. "It distinguishes between several different scopes and boundaries for… different net zero goals and their targets, which are increasingly effective at reducing energy and GHG emissions, and correspondingly more difficult to achieve."

This paper describes how ISO 50010 builds on the foundational standard for Strategic Energy Management—ISO 50001—to offer guidance on several alternate choices for achieving net zero energy or carbon. It defines several levels of net zero with increasing scope and boundaries, and how one can use the Energy Management System standard ISO 50001 to demonstrate continual improvement toward increasing levels of achievement.

Introduction

Net zero energy (NZE) was first set forward as a goal by Architecture 2030 in 2005 as a tool for meeting globally accepted climate goals (*Architecture 2030* 2016). The NZE concept was that if a facility produced as much renewable energy as it consumed in a year, it would produce no net emissions. The concept was first applied to buildings: If all buildings did this, it could eliminate the building sector's approximately[1] 40 percent contribution to GHG emissions and would be a major steppingstone toward meeting global climate goals.

Even at the time, when we thought that the best target for global warming was 2 degrees Celsius, not the current 1.5 degrees Celsius, the perceived urgency of the climate crisis, coupled with analysis of the great opportunities for reducing emissions in buildings, led inexorably to a realization that we needed to reduce energy use in buildings to net zero by 2030. It was not long after that we saw net zero buildings as a step toward achieving net zero in all sectors by 2050.

[1] The fraction of greenhouse gases that the building sector is responsible for can be calculated in numerous different ways, as discussed in this paper. The calculation may be limited to the scope of direct emissions, or of the emissions associated with the electricity the building consumes, on net, or it may include emissions from construction and transportation. The calculation may be attributional, as most of the published data are, or consequential, as recommended by ISO 50010.

The International Energy Agency's analysis supports the goal of global net zero by 2050 in its ongoing energy policy assessments (IEA 2021). This goal also was adopted by the International Organization for Standardization (ISO) in 2022 in a document called IWA 42 (ISO 2022). Its purpose was to offer "guidance on what governance organizations and other organizations can do to effectively contribute to global efforts to limit warming to 1,5 °C by achieving net zero no later than 2050." Its purpose and scope include the goal "to maintain and promote the highest possible climate ambition."

IWA 42 offers guidance only at a high level. If an organization wants to develop a specific management plan to define a quantifiable goal or set of goals for a given timeline, it requires more detailed advice on how to define: 1) the scope and boundaries of the system that will embrace a zero energy or zero carbon outcome; 2) a timeline for meeting a Net Zero goal at a broader scope as the years pass; and 3) a method for estimating emissions that makes sense for the organization's activities and size.

It also needs an implementation plan to assure that it has sufficient staff and budget to meet the goals every year, and to identify and overcome observed deficiencies in the plan and its outcome that can be remedied by modifications to the implementation plan for the next year.

The development of ISO 50010

ISO started to address these issues when it approved the development of ISO PAS 50010 in 2016. The standard was intended to draw globally relevant but specific guidance on principles that were in standards already issued and under development by governments and NGOs around the world and to reconcile differences in goals and metrics as the scope and ambition of zero energy goals grew over time.

The concept of an international standard on net zero derives in part from the observation that many large organizations had adopted goals of "carbon neutrality," but there were (and are) no accepted standards for what that meant. Often, in practice, it merely meant the purchase of offsets to cancel out emissions from the organization's operations (Persefoni 2023). Many observers expressed doubts about the integrity of some of these offsets, and thus Net Zero is regarded as a more reliable metric of emissions performance (World Economic Forum 2022).

This conclusion was based in part on the existence of standards for what net zero meant. Thus, the value of having an international standard for net zero has become more evident.

ISO 50010 was issued in January 2023.

Two strong and consistent developments unfolded over those seven years (2016-2023), and these trends shaped the discussion of the experts who were drafting ISO 50010 for international review. First was the observation that renewable energy on the grid was developing at a fast pace in several regions, and consequently, the effect on utility-scale GHG emissions began to depend strongly on the time of day and year at which electricity was consumed. In such cleaner grids, the emissions reduction due to a kWh of reduced demand varied by a factor of 5 or more depending on the hour of the day and month of the year (as well as by region even within one country) (Kruis and Goldstein 2022).

In retrospect, this outcome is not surprising: if a grid distributes large amounts of solar energy, more demand for electric power in the middle of the day results in the need to construct or dispatch more zero-emission solar, whereas more demand for power when the sun goes down will cause greater dispatch of and eventually the need to construct more polluting generators.

In response, GHG reduction measures were identified that could reduce emissions but increase energy consumption, (e.g., thermal and battery storage).

The second trend was that net zero conferences and presentations, and ISO IWA 42, increasingly looked at not only GHG emissions from operations (already an expansion from Scope 1 energy to Scope 2 GHG emissions) but also at emissions embodied in the supply chain for the facility (Scope 3 emissions). Several potentially competing definitions of net zero were emerging, and the working group responsible for 50010 tried to address the traditional goal of international standards to harmonize standards worldwide.

This search for global consistency of standards made it clear that greater transparency was needed about what the scope and boundaries of the system that was planning on net zero accomplishment were. Without this clarity: 1) measures that would improve emissions performance would be measured as impeding it; and 2) achieving net zero performance with more ambitious definitions of scope and boundaries would not be seen as the improvement that it truly is. This gradual transition to broader scope and boundaries and thus more ambitious goals is already the global trend; over the past few years more and more countries found that the goal of net zero *energy* should be replaced by a goal of net zero *carbon*. One key reason is that energy accounts for 73% of GHG emissions (Our World in Data 2020). This means, on one hand, that accounting for the GHG consequences of energy use correctly is important, but on the other, that additional sources of GHG emissions need to be considered.

But it is one thing to call for net zero carbon in principle and another to employ metrics that truly lead to this outcome.

For example, the simplest way to calculate carbon emissions is to multiply annual energy consumption by an annual emissions factor. But this method does not work for net zero. If net energy is zero, emissions will be calculated as zero. Trivially so, since zero times ANY emissions factor remains zero. But a net zero *energy* facility is likely to continue to emit GHGs because the solar power it generates is produced in the daytime when the grid is cleanest while much of the consumption occurs after sunset when the grid is dirtiest.

Netting out these kWh does not result in netting out carbon emissions.

This problem of failing to account for time of use in the emissions metric persisted even as practitioners recognized that zero emissions is a more ambitious goal than zero energy. Thus, the working group responsible for ISO 50010 worked on the best way to identify this problem explicitly in the standard and suggest the solution.

Conferences on net zero increasingly identified even broader scopes for zero, as did ISO IWA 42. The most widely suggested way of doing so was to include Scope 3 embodied carbon emissions from the supply chain as well as direct emissions, and Scope 2 emissions from consumption of fuels and electricity on site. But there are a number of choices of what Scope 3 emissions to include in the calculation (in other words, where to limit the scope and boundaries of the analysis). Furthermore, the best set of choices to make is likely to depend on the details of the organization with the net zero goal(s) and its value chain. ISO 50010 was intended to address these issues.

This paper summarizes the recommendations of ISO 50010 and recounts the discussions and analysis that underlie its choices.

This section outlines the main recommendations in ISO 50010 and discusses how they were derived and agreed on.[2] This paper parallels the development and structure of the standard itself: this standard is unusual in that it makes recommendations in the main text and then

[2] ISO standards are set by consensus among ISO's member standards-setting organizations, so agreement of at least two thirds of the member countries is needed to publish an ISO standard. In the case of ISO 50010 the standard was approved by over 95% of participants.

discusses why these recommendations were made in Annex sections that are cross referenced to the quasi-normative text.

ISO 50010 is a guidance document in that it does not have hard or auditable requirements. Words such as “shall” or “must” are not used in a guidance document. But it does make actionable recommendations using words such as “should” and could be turned into a normative standard when it is reviewed in three years, if the recommendations turn out to be useful as requirements.

From the beginning of the ISO committee’s work, it was observed that despite local variation in the details, global standards for net zero had much more in common than they had differences. And even the differences were not conflicts—primarily they were differences in scope and boundaries (see discussion below). Thus, it would be possible to create a document that respected locally different requirements and that also reconciled differences in scope and boundaries by relating them to a common structure of increasing levels of ambition. (See subsection Defining Scopes and Boundaries below.)

Basis in an Energy Management System Standard

The standard initially recommends that net zero goals be pursued in the context of an Energy Management System (EnMS), and specifically that of ISO 50001. An EnMS is a type of system that encourages the staff of an organization to achieve continual improvement in performance—in this case energy performance. It does this by requiring quantitative measurements of energy performance, setting goals for their improvement, monitoring results to verify if the improvements are resulting in the desired outcomes, taking corrective action if needed, and adjusting the next year’s goals to reflect observed outcomes.

To achieve the best possible improvements, it requires a team to be responsible for administering the EnMS and that top management approve its plans every year and provide adequate resources of staff and money to carry them out. Implementing an EnMS will cause top management to consider their life cycle energy consumption. In the cycle, energy management is on average more than 80 % of the total cycle at the building or plant (see Figure 1). Of course, when energy management is improved as Net Zero goals are adopted into the EnMS, this percentage will decrease.

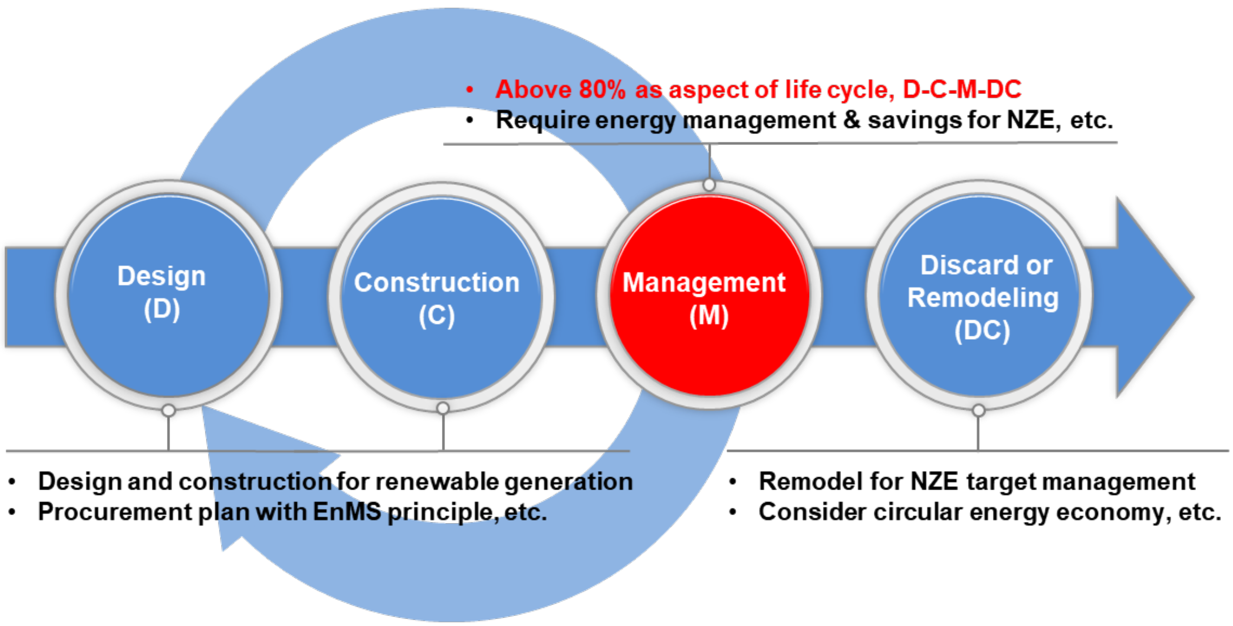

Figure 1: Total life cycle energy use of an organization.

Note: Figure 1 was revised from the original ISO 50010.

The organization's EnMS should provide a step-by-step plan for design, construction and management after setting NZE goals. ISO 50010 focuses on the activities of the NZE management through energy performance improvements based on ISO 50001, and then recommends the construction or acquisition of new renewable energy (see Figure 2).

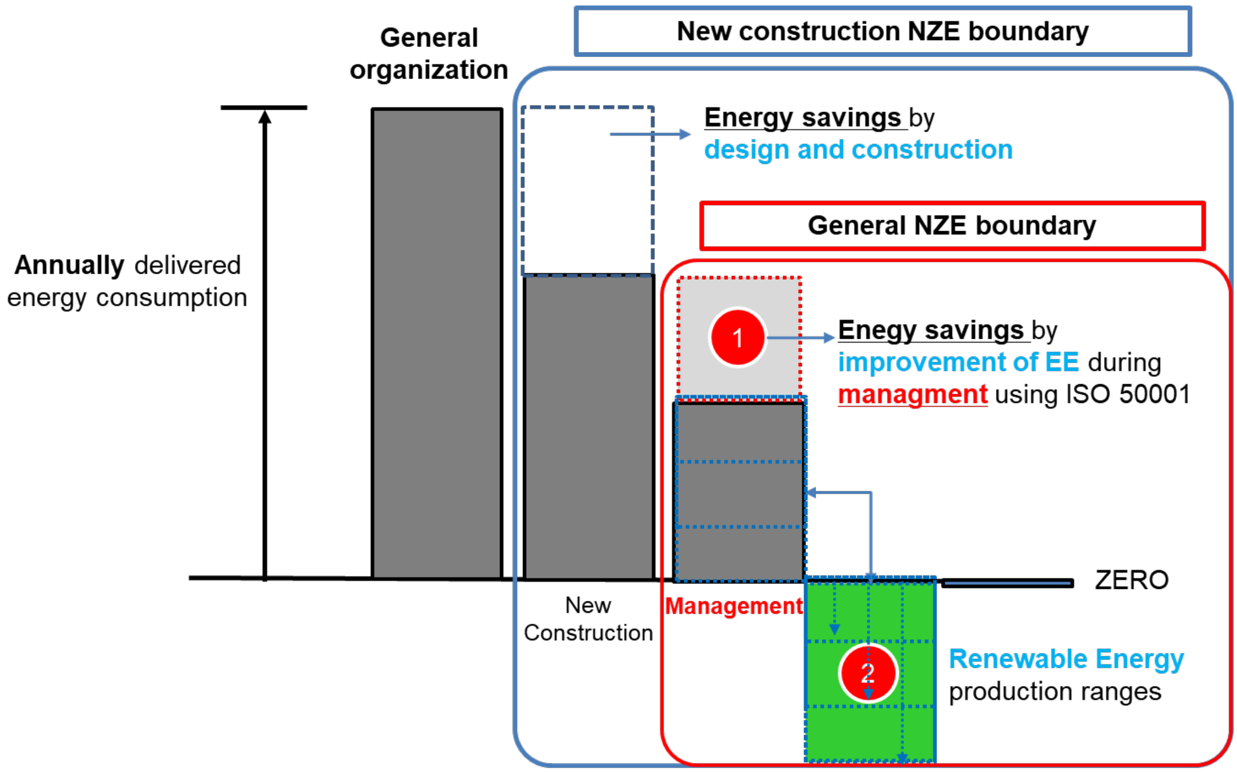

Figure 2: NZE principles with an EnMS on-site.

Note: Figure 2 was revised from the original ISO 50010 by changing from operation to management, etc. The keys are 1. Energy savings through the use of ISO 50001; 2 renewable energy production and production ranges which can be replaced with the energy consumption left for net zero energy.

An EnMS is a logical tool to employ in meeting net zero goals, because large changes in energy efficiency are found to be essential in meeting net zero goals, and these goals are met more easily and more completely using an EnMS, especially in industrial settings.

Thus, ISO 50010 recommends using ISO 50001 with suggested modifications (for example, 50001 does not account for clean renewable energy whereas net zero requires it) (ISO 2018). There is also a natural complementarity: ISO 50001 specifies a *process* for achieving energy performance goals but does not say what the goals should be. Previous net zero standards and guidelines were intended to specify a goal without saying how, as a process, an organization could best achieve them.

ISO 50010 goes beyond this by specifying the goal—in fact a set of goals for net zero with increasing breadth of scope and boundaries—while recommending an EnMS as an implementation mechanism. Thus, the standard defines 6 levels of net zero in generally increasing order of ambition/difficulty and recommends that the EnMS include a plan for progressing first to the lowest level[3] and over the years to improve continually to the highest feasible level.

[3] In some cases, even the lowest goal of net zero annual energy may be impractical. For such cases ISO 50010 recommends the use of performance indicators that are set at zero when the net zero goal chosen is achieved, so that a facility that is currently at a measured level of 100 can strive to reduce its energy or emissions to a lower level that is still above zero but is much lower than in the baseline years.

The recommendation to start with an EnMS, which focuses solely on improvements in energy performance, is explained in Section 4.3 of the Standard, which suggests a rank ordering for actions to progress toward any chosen level of zero:

1. First, develop and implement Energy Performance Improvement Actions. This suggestion is placed first because such actions usually have lower cost and ancillary benefits beyond energy and emissions savings.
2. Then, transfer the remaining energy consumption to less carbon-intensive or clean renewable energy.
3. Change the timing of energy consumption to reduce carbon emissions.

This rank ordering of recommended actions, along with the more rigorous treatment of off-site renewable energy, discussed next, address many of the concerns with carbon neutral goals.

Defining Appropriate Terms: Focus on Renewable Energy

The ISO committee found that net zero did not have a single accepted definition, nor was renewable energy commonly defined in a way that is relevant to setting greenhouse gas emission goals. For example, the ISO definition of renewable energy allowed for resources that renewed but were nevertheless polluting to be counted. Such renewable but not zero-carbon resources included some types of biomass. 50010 addressed this issue by defining *clean renewable energy* as very low in emissions (of greenhouse gases as well as health-related pollutants) and by recommending that renewables only count when they met locally required conditions that were at least as demanding as the ISO definition in the standard of clean renewable energy.

ISO 50010 noted that most existing net zero standards prohibited or discouraged or discounted renewable energy that was not produced on site and offered general recommendations on encouraging on-site renewables without being prescriptive. The need to include some provisions for off-site renewables is based on the recognition that many industrial facilities are not sited on enough land for on-site renewables to cover their energy consumption or GHG emissions, even assuming efficiency improvements.

But this need does not imply that off-site renewables should be treated the same as on-site. ISO 50010 recommends discouraging off-site renewables and explains the reasons for this preference in Annex B. A strong driver of this preference is the concept of additionality: Will the renewables really substitute for GHG-emitting resources, or would they have been built anyway even without the organization's commitment to a net zero goal? For improvements in energy performance and for the construction of renewables on site, the emissions savings clearly are additional. But as off-site renewables generally cost less than polluting energy sources, many of them are unlikely to be additional.

The standard suggests several factors be considered in how much to discourage specific off-site clean renewable energy resources:

- Whether to disallow the use of offsets or renewable energy credits unrelated to the operation of the facility.
- The distance of the generation from the facility site(s).
- The ability of the facility or organization to control the output and the generation.

- The degree of directness of the transmission facilities connecting renewables to the facility(ies).
- The ownership of the generation.
- The exclusivity that the facility has with respect to the use of the output of the renewable energy.
- The extent of connection of the generation to the grid on which the facility relies.
- The quality and duration of contracts for the energy between the owner or operator of the generation and the management of the facility.
- The ability to physically inspect the renewable generation facility to allow for an audit or review.

In its recommendations for how to count off-site renewables, ISO 50010 notes that the boundaries for consideration of renewable energy may be different—usually wider than—the boundaries for the EnMS. This possibility is illustrated in Figure 3 below.

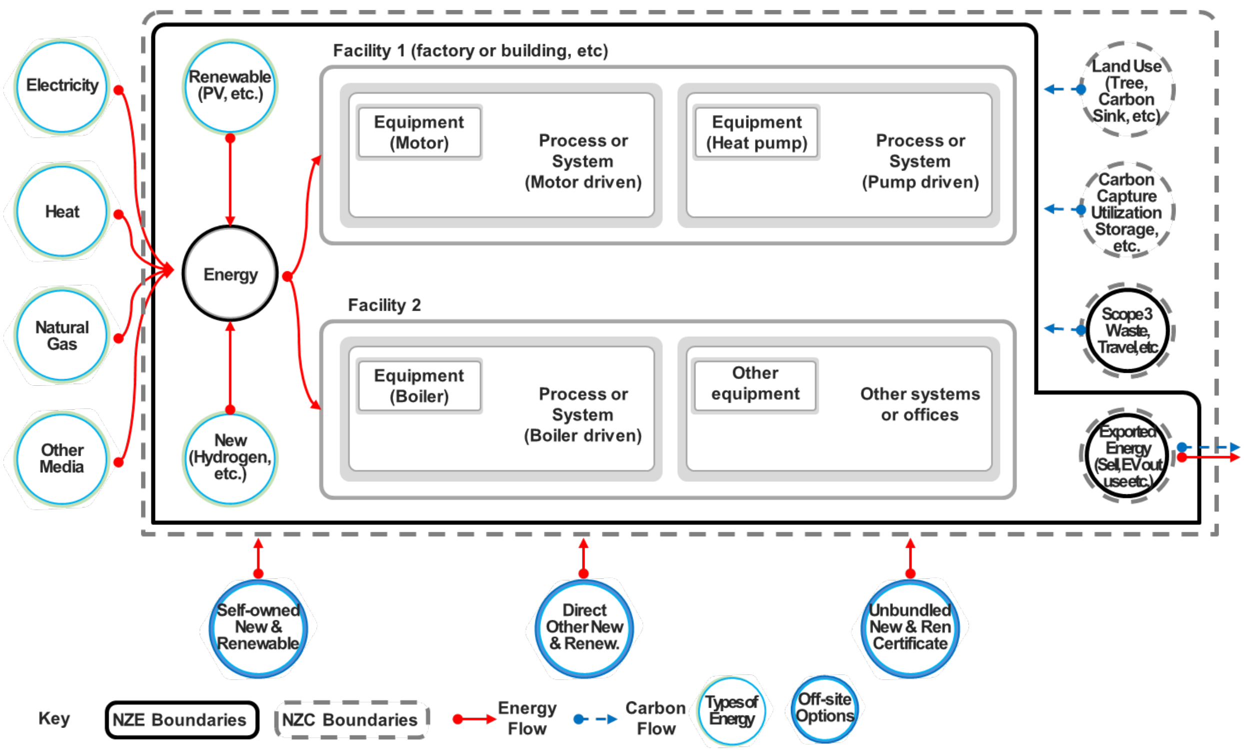

Figure 3: Example boundaries for NZE and NZC

Note: Figure 3 was revised from the original ISO 50010 by adding Scope 3 land use (trees, etc.), carbon capture utilization and storage, and Scope 3 are activities in the boundary of NZC.

The ISO committee's review of net zero literature online and in conferences and policy discussions showed that there were several important differences in how net zero was defined in terms of that type of emissions should be counted: Scopes 1 and 2 alone, or Scope 3 as well? If Scope 3 emissions were to be considered, which ones of them should be considered in scope and which out of scope?

For example, if a facility offered electric power to charge trucks used to transport its products to the customer, or to charge its staff's personal cars, should that power be counted or not? Questions such as these are answered by transparency about scope and boundaries of different levels of zero.

Defining Scopes and Boundaries: The energy planning process

The standard has two sections (Section 4.4 and Section 4.6) that direct the user to create well-defined scopes and boundaries that are consistent with common practices in different countries and allows the choices to be compared. It does this by "distinguish[ing] between several different scopes and boundaries for…different net-zero goals and their targets, which are increasingly effective at reducing GHG emissions, and correspondingly more difficult to achieve" (ISO 2023).

This distinction creates, in most cases, a clear hierarchy of levels of ambition, from net zero annual energy at the lowest level, to a full Scope 3 calculation from cradle to grave. The standard explicitly calls out the following progression of goals:

Goal 1: NZE based on annual energy.
Goal 2: NZE based on hourly source energy (Scope 2 energy).
Goal 3: NZC based on hourly carbon emissions.
Goal 4: Meeting Goal 3 and also achieving NZC for new facilities or additions as well as emissions associated with constructing the facilities; and Scope 3 emissions of suppliers to an industrial plant.
Goal 5: Meeting Goal 4 and also achieving reductions in Scope 3 emissions associated with transporting people (e.g., staff, customers or business partners; residents in a housing development) as well as supplies to the facility.
Goal 6: Meeting Goal 5 and including downstream emissions (e.g., product disposal and use).

A description of how this was planned (before additional enhancements in the Standard) is in Goldstein 2019.

Broad Operation and Maintenance (O&M) Guidance

While including the recommendation to consider time-of-use-based emission factors makes the achievement of net zero GHG) (appropriately) more difficult, it also opens up the option for an organization to schedule its consumption of electricity to align with the times when its grid is cleanest. This allows credit for operations and maintenance procedures that optimize the timing of electricity use, as well as for installing and managing thermal and electrical storage equipment.

50010's use of background policy discussion

Many of the quasi-normative sections make recommendations that may seem puzzling to the new user. For example, the recommendations on what qualifies as renewable energy that offsets purchased energy could seem arbitrary or unjustified when they are presented only as firm recommendations. Similarly, the recommendations to use long-run marginal energy to the grid in Scope 2 calculations rather than average (in other words, to calculate consequential emissions rather than attributional), and to ask for time-of-use-based emission source energy or GHG emissions factors are not normal practice. But they are more appropriate for net zero calculations because ***they meet the underlying goal of net zero standards: to reduce global emissions by taking new actions.*** Thus, the reasons to explain these choices are presented in some detail in Annex B of ISO 50010. Similarly, the process of continual improvement and its relationship to the hierarchy of net zero goals is explained in this Annex. Otherwise, the readers might ask: "If nothing is better than zero, how does one continually improve once one has met the goal?"

Global Context and Future Activities

Broad Societal Issues

ISO 50010 adds institutional weight to trends that are already strengthening in standards-writing organizations such as ASHRAE and RESNET (Fairey et al. 2022) and to state, national, and global activities that are happening at governments and at NGOs, such as the World Resources Institute Greenhouse Gas Protocol (WRI 2023).

ISO Activities

ISO 50010 was issued as a Publicly Available Specification (PAS). This format does not have the weight of an International Standard, and the scope of the document is as a non-normative document, but ISO rules allow it to be published more quickly. This was considered important to the standard's developers, as they perceived a narrow window of time to add weight to the IEA and ISO goals of NZE before 2050 and accelerated progress toward the zero goal by 2030, by providing a globally harmonized method for implementing these goals by an organization. A PAS only remains in print for three years, after which is needs to be reconsidered or withdrawn.

These choices were made for understood reasons: the document introduces a number of new ideas and recommendations, and there is little or no field experience in how they will work. So, a faster review makes sense, and all the more so if as the authors hope it is well used, such that the weaknesses and flaws become known and can be corrected.

Experience with complying with its recommendations can lead to continual improvement in the standard itself. This is how the continual improvement process of 50001 and well as 50010 is supposed to work.

The current ISO Technical Committee TC301 WG16 (Working Group on Net Zero Energy) submitted a New Work Item Proposal (NWIP) for NZE metrics and implementation in 2022. A new certification market should be created from the net zero energy sector, which accounts for an important reduction part of GHG emissions.

As the world continues to fall behind the milestones that would allow GHG emissions to be consistent with the Paris Agreement, the urgency of net zero increases: this perceived urgency is reflected in the IWA 42 guideline, and reinforced by the decision to accelerate the availability of 50010.

ISO 50010 can be applied and expanded for buildings, industry, for multiple organizations, and at the city, state/provincial, and country levels. In the case of RE100 (RE100 2022), net zero, or ESG-pledged (including a 24/7 carbon-free energy compact) companies/policymakers/investors, the organization can use the guidelines of ISO 50010 on the integration of ISO 50001 and renewable energy, an indicator of energy independence rate, and measurement and verification for NZE.

The problem of needing to accelerate GHG emissions reductions suggests that 50010 may have an important role to play in urging jurisdictions and companies into the most productive directions; creating ambitious goals of a reasonable choice of levels of net zero ambition and suggesting an EnMS as a management tool to help implement the goals on a planned schedule.

Conclusions

At a time when the number of countries and organizations declaring GHG reduction goals is rapidly increasing, there has been no clear tool to measure and verify net zero in a credible, globally harmonized fashion. ISO 50010 was intended to fill this gap in a way that is most consistent with the realization of global goals for zero GHG emissions before 2050.

The content of ISO 50010 was developed after reviewing existing national, regional, and NGO standards, which at present are mostly limited to the buildings sector. Currently, Net Zero Energy implementation for buildings often requires certifying the building based on national or regional standards and can be mandatory by law. (South Korea adopted zero energy building requirements leading toward net zero as a policy in 2014, effective in phases beginning in 2020 and then strengthened this mandate by law and regulation in 2021.)

The principles and indicators introduced in ISO 50010 can be the first step to improving NZE achievement. They address key weaknesses in organizational planning and in the acceptability of net zero claims by: 1) building on the success of ISO 50001's use of an EnMS as a tool for improving energy performance; 2) establishing a recommended priority order that places energy performance improvements first, on-site renewables second, off-site renewables third, and financial methods such as offsets or renewable energy credits last if they are to be credited at all; and 3) asking the user to specify one or several choices of scope and boundaries of the calculation that produce increasingly ambitious GHG reduction goals in future years with continual improvement allowing the organization to progress from one level to the other by plan.

The leading international organizations cited here all see increasing need for implementable guidance such as ISO 50001, ISO 50010 for net zero, and ESG activity at the organizational level. Throughout the world, it is time for a global guide applying ISO 50001 linked to renewable energy.

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