

C O M M E N T

THWARTING CLIMATE CHANGE, BRICK BY BRICK

by Bill Caplan

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SUMMARY

While climate policy typically focuses on future decarbonization 10 to 20 years out, temperatures continue to rise. Greenhouse gases emitted upfront from the materials fabrication, construction, and renovation of our physical environment—embodied emissions—accelerate the rate of global warming now. They increase atmospheric carbon before our buildings and infrastructure are even used. While these emissions are often ignored or deemed too perplexing to resolve, this Article, excerpted from *Thwart Climate Change Now: Reducing Embodied Carbon Brick by Brick* (ELI Press 2021), addresses the need to reduce them immediately.

Humanity's failure to confront the built environment's carbon emissions is not for lack of trying. During the last 20 years, scientists, engineers, architects, and designers have focused their attention on sustainable design as a means of energy *conservation*, and thereby the reduction of greenhouse gas (GHG) emissions to thwart the progression of climate change. More than 200,000 professionals have been trained and qualified by the U.S. Green Building Council for Leadership in Energy and Environmental Design (LEED®), and over 1.5 million residential units and 100,000 commercial and government projects have been registered or certified worldwide. The U.K. BREEAM® has registered or certified 2.5+ million buildings in 70 countries. Yet even with such training and certification oversight, more than 40%¹ of energy-related global carbon emissions still originate from the materials, construction, and operation of buildings.

Though well intended, many of these sustainable design efforts were inappropriate, or misapplied applications of go-to antidotes under the broad umbrellas of “sustainability” and “green.” Many resulted from oversights, unobserved footnote, or fine print qualifiers to the data and statistical conclusions. Many failed to focus on the most pressing need—to reduce carbon emissions now, not gradually over the next 10 to 15 years. Why, because the

cumulative gains derived from operating efficiencies and zero-carbon energy over the next decade might be too insufficient to be effective soon enough. Yes, incremental efficiency gains in energy use are absolutely necessary, and incremental gains in the implementation of low-carbon and zero-carbon energy sources are essential. And yes, we must continue to safeguard our air, water, food chain, and environmental quality. Nonetheless, we must focus our attention and resources to the *immediate* reduction of GHG emissions in order to buy time for cumulative operating gains and a dominance of zero-carbon energy to take hold.

The thrust of this Article, and my book, is to target the engine that drives this failure, “embodied” emissions—the carbon footprint attributable to the design of our built environment and the physical nature of our dwellings and infrastructure—their layout schema and materials. With all the exposure, training, and certification, the formulation of these catalytic elements is still taken for granted, is still a matter-of-fact; yet their very composition generates much of our environmental poison, determining what is emitted *before* a new structure is occupied. Think of embodied emissions as a mushroom cloud of GHGs released during fabrication and construction, forever reflecting back the earth's heat. Accordingly, the efficiencies achievable through physical design are paramount.

Building materials alone contribute 28% of all *building*-related carbon dioxide (CO₂) emissions. Just a single component of the embodied carbon, yet they generate 11% of

1. INTERNATIONAL ENERGY AGENCY (IEA), GLOBAL STATUS REPORT FOR BUILDINGS AND CONSTRUCTION: TOWARDS A ZERO-EMISSIONS, EFFICIENT, AND RESILIENT BUILDINGS AND CONSTRUCTION SECTOR 2018 (2018) [hereinafter GLOBAL STATUS REPORT 2018].

the world's total energy-related emissions.² The release of carbon emissions occurs on so many fronts, it is difficult to stay abreast of the numerous contributors to establish meaningful priorities. Some seem obvious, but others are subtle. Had we confronted our reliance on fossil fuels a decade or two earlier, the rate of warming would have been more manageable. Efforts to reduce operating carbon would have been less burdensome, and reducing embodied carbon would have been easier and more effective.

Unfortunately, that window of opportunity has closed. By hanging our hopes on the gradual decarbonization of the global energy supply from 2030 through 2050, we will have subjugated the future to wishful thinking. We are up against a need for *immediate* action to target the low hanging fruit that seeds coincident emissions, the physical nature of our built environment: the buildings, their systems, appliances, and infrastructure; the spectrum of materials they cause to be manufactured. Policy and design control this, yet policymakers and designers ignore the inherent carbon, as though the carbon footprints were imaginary, or future efficiencies justify design irrespective of embodied emissions. It is futile to evaluate a structure, an appliance or even the equipment to harvest zero-carbon energy without noting the emissions from its fabrication, maintenance, removal, and replacement. These are the key vectors of concurrent atmospheric carbon; they have a large and lasting impact on global warming. Carbon-free energy may be the only viable ticket to a long-term sustainable future, but we must forestall the acceleration of carbon-induced warming until it is available in sufficient quantities worldwide.

Multiple means already exist to preclude emission increases and enable their ultimate reduction. In that regard, using less operating energy; switching to low-carbon and no-carbon fuel sources; smarter material selection, material re-use, and material repurposing; and renovating are all important. *All should be employed.* Nonetheless, some means offer more efficacy and timeliness than others. At this stage in the progression of global warming, the thrust to reduce emissions must not be misaligned with other concurrent issues of global concern. Pollution of our air, water, and food supply, each existential in its own right urgently threatens sustainability, yet resolution of each problem area requires its own laser focus. Some elements will benefit from the solutions of others, but combining them within a broad category such as a “green” or “sustainable” solution threatens to draw attention from one storm cloud to another, deflecting action from carbon emissions, the specific target that must be speedily addressed. Bundling the quest to minimize carbon emissions under a broad green umbrella, a broad moniker for sustainability, or an economic program, renders the probability of achieving a *timely* success minimal. Time is of the essence.

Whether tall or small, designing a building to be environmentally sound is synonymous with built-in operating efficiencies and energy conservation. Operating efficien-

cies and energy conservation dictate the level of a building's recurring energy consumption and thereby its annual emissions throughout its useful life. The tactical use of natural light, shade, insulation, sealed interfaces, the sun and the earth's warmth, and solar energy are typical means. Yet how often are the carbon gases emitted while processing and fabricating building materials the standard for their selection, let alone the transportation emissions or those from a building's construction and eventual demise? How often do we consider the manufacturing footprint of the appliances and conditioning systems? In other words, how often does a developer or designer contend *seriously* with a building's “embodied” emissions—its “carbon footprint”? Depending on the design and construction methodology, embodied emissions worth decades or more of a building's operating emissions can be avoided. Not only are they predetermined, a good part are emitted years prior during raw material processing, well before the construction begins.

I. Reading Beyond the Headlines; Probing the Text

Understanding what claims and statistics mean is a formative obstacle to effective carbon-conscious design, such as interpreting the headlines, the pronouncements, and targets in terms meaningful to those capable of effecting change. Most articles on this subject are either misleading or beyond relatable comprehension. As such, we lack a coherent basis from which to apply the tenets of appropriate design, or to evaluate alternate materials for an intelligent design decision. The manufacturers, suppliers, and industry associations that sell or promote the products dispense most of the technical information from which an evaluation can be made. Impartial reports with in-depth energy consumption and emissions data are difficult to parse. Restricted to a few use sectors with misleading titles they provide broad characterizations with numerous qualifications and exclusions. Expedient solutions rely on *comprehensible facts* that do not require reading above, below, and between the lines. *The first stage of deciphering the problem is to “parse the claims”—fallacious conclusions can be disconcerting.*

Tracking progress on carbon emissions is akin to monitoring the stock market on an hourly basis; a zigzag of ups and downs with an ever-changing array of explanations and recommendations. It is not a sound basis for intelligent action without careful study. The underlying data from which most summations originate stems from just two sources: the International Energy Agency (IEA) for global statistics and the Energy Information Administration (EIA) for U.S. statistics. GHG emissions are estimates derived from energy production and consumption sales statistics. This is fairly sound but there are caveats. Owing to the complex presentation of this material it is not broadly understood nor easily analyzed. Consequently, storylines frequently ignore the subtleties and qualifications that would reveal their true meaning. Many news articles and trade publications draw talking points directly from an IEA's or EIA report's preface

2. *Id.*

or executive summary without examining the detailed presentation of the underlying data, without evaluating “cause and effect.” Cherry-picked statistics, unintentional or otherwise, can easily distort reality and lead readers to erroneous conclusions, for example touting significant reductions from buildings and construction in the United States while emissions increase to dangerous levels worldwide.

A well-meaning message from the American Institute of Architects (AIA) Committee on the Environment, in which it emailed a congratulatory pat-on-the-back to more than 10,000 architects, designers, builders, developers, and academics, exemplifies the problem.

It began:

Dec. 13, 2018:

Happy Holidays!
THIS IS BIG

Amid all the sobering stories and projections about climate change in the news lately, we have some upbeat news to share. Our hard work is having a BIG impact.

Today, U.S. building sector CO₂ emissions are 20.2% below 2005 levels.

According to data from the U.S. Energy Information Administration, energy efficiency and power sector decarbonization have reduced U.S. building sector CO₂ emissions by 20.2% below 2005 levels, despite adding approximately 30 billion square feet to our building stock during the last 12 years.

And, global building sector CO₂ emissions appear to have leveled off in the past few years.

That’s the good news.

Of course, that’s only the beginning. There is still much, much more to do. . . .³

Without careful scrutiny: “Our hard work is having a BIG impact” might provide a false sense of accomplishment. Although the assertion that 2017 U.S. building sector emissions were 20% below those in 2005, *despite nearly 30 billion square feet of new construction*, was true, the hard work of the architecture and construction industries had little to do with those reductions, which were from power sector decarbonization and energy-use efficiencies—the declining use of coal and light bulb innovations that led the way by intent. They also had little to do with the diminished energy demand resulting from mild weather and poor economic conditions that were beyond our control. The 20% reduction *did not result* from building design nor construction improvements as might have been construed.

Fortunately, emissions declined *in spite of* the design and construction methodologies employed during the ensuing 12 years. There was upbeat news behind the numbers, but

it was not appropriately emphasized. The increased utilization of compact fluorescent lighting followed by the introduction of light-emitting diodes (LEDs) provided a notable reduction in the energy used for illumination, and thereby a reduction in carbon emissions—perhaps the most significant contribution to lowering operating emission since 2000. With the replacement of incandescent lamps far from complete worldwide, the opportunity for continued reductions from LED lighting is very real. Replacing coal-fired energy with natural gas, wind, and solar was good news as well, although methane released during natural gas production is still problematic. These strategies significantly impacted carbon emissions; most importantly they were immediate and will continue to grow.

But one should not confuse those gains with the lack of verifiable progress made elsewhere in design and construction. For those who read further in that holiday greeting, ominous warnings appeared which were far from the holiday cheer: “[I]f buildings and infrastructure are designed and built to current standards, we will lock-in *emissions that will be with us for the foreseeable future.*” And quoting U.N. Secretary General António Guterres: “[W]e are still not doing enough, nor moving fast enough, to prevent irreversible and catastrophic climate disruption.”⁴ Those statements are also true. Nevertheless, the message ended on a positive note: “Let’s welcome in the New Year with some good news, and a resolution to increase our momentum!” *Momentum?* “Our hard work is having a BIG impact” may sound comforting in troubled times, but it nurtures a fantasy about the nature of our achievements, one that is misleading and potentially counterproductive.

II. The Data Is Available; Why Is It Confusing?

The primary source for energy production and consumption data in the United States is the EIA, with statistics from as far back as 1949. Established in 1977 in response to the oil market disruptions of 1973, global warming was not an issue and energy-related emissions were not a concern. Though emissions became a topic in the following decade with a growing interest in sustainability, the EIA’s principle purpose was to maintain efficient energy markets and data analyses for policymaking, which continues to this day. Emissions tracking was added to their charter in 1992. Given its origins, EIA reports are structured to provide analyses of energy generation and consumption, *not to scrutinize building construction and operating emissions.* As such, with data specifically categorized to track energy production and distribution, it is difficult to parse the emissions that are ascribable specifically to buildings and construction—those embodied and from operations.

Energy consumption data is categorized by broad “end-use” sectors: Residential, Commercial, Industrial, and

3. Posted to the AIA Committee on the Environment Digest on Dec. 13, 2018, by Edward Mazria FAIA sourced from the Architecture 2030 E-NEWS (Emphasis in original.).

4. Brady Dennis & Chris Mooney, “We Are in Trouble.” *Global Carbon Emissions Reached a Record High in 2018*, WASH. POST, Dec. 5, 2018, <https://www.washingtonpost.com/energy-environment/2018/12/05/we-are-trouble-global-carbon-emissions-reached-new-record-high/>.

Transportation. That's it—just four, plus a single “supply” sector, Power, to track the electricity generated and sold to those sectors. The end-use sectors purchase electricity from the Power Sector, but they purchase fossil fuels and biofuels for space heating, industrial heat processing, and transportation directly from the suppliers. Some users harvest their own solar or geothermal energy as well. Energy sources include fossil fuels, nuclear, and the renewables—hydroelectric, geothermal, wind, solar, and biomass.

Although these tabulations are seemingly straightforward, the extent of the energy consumption attributable to the building sector as a whole is not inherently obvious, and the ensuing carbon emissions are even less clear. When the EIA refers to Buildings, it refers to the composite operation of the Residential and Commercial sectors. Unfortunately, this presents only part of the built environment's picture. This characterization ignores the operating energy of industrial buildings as well as the energy embodied in *all* buildings. Therefore it ignores the resulting embodied emissions—their carbon footprint past, present, or future. The emissions tabulated for the building sector are computed solely from the energy “consumed” in daily operations. Some of the carbon footprint can be found in the Industrial Sector's output, though it is extremely difficult to allocate or parse. This might surprise those who base their headlines on EIA Building Sector statistics.

Most *embodied* emissions reside in industrial sector manufacturing along with its operating emissions. This covers a broad range of carbon emissions from raw materials and fossil fuel extraction to powering production equipment. The list spans the entire economy from consumer products to agriculture, forestry, fishing and everything relating to the physical aspect of buildings and infrastructure, i.e., heavy equipment, construction materials, appliances, and furnishing. It even includes some, but not all, emissions due to material transportation. Every material component's carbon footprint involves transportation: moving material from mines to processors to manufacturers to suppliers and to construction sites, locally or halfway around the globe. Some of these emissions are included in the Industrial Sector and some are embedded in the fourth use sector, Transportation, which comprises all vehicles whose primary purpose is to transport people and/or goods. It does not include equipment or vehicles like cranes, bulldozers, tractors, and forklifts used in construction; those emissions are tallied in the Industrial Sector, but not necessarily attributed to buildings. Nevertheless, whether a byproduct of industrial production, transportation, or construction vehicles, these emissions result from a building's design and construction; their tally should not be obscured by sector categorization. We need to know what they are to understand the true impact of our buildings and construction on climate change.

As global warming knows no borders, however, the EIA's U.S. statistics are only part of the picture. Global statistics provide the overall portrait of GHG emissions and perhaps our fate. Those statistics are provided by the IEA, which also emerged from oil supply security concerns

in 1973. The IEA did not track GHG emissions until the late 1990s; their *World Energy Outlook* focused on carbon emissions every two years as of 1998. IEA sector characterizations are similar to the EIA but not the same. This in itself creates confusion when discussing building sector emissions. The IEA categorize building information with nomenclature such as Buildings, Buildings Sector, and the Buildings and Construction sector. Whether referring to EIA or IEA data, the problem lies not in the nomenclatures themselves but in how they are defined, what they include or exclude, and principally *how they are perceived*. Unfortunately, EIA and IEA summaries for building sector energy consumption and emissions are often perceived as their *total* contribution, yet the embodied components are either absent or lost in the weeds. Sector differentiations in IEA global statistical presentations are much better than the EIA's, and many of their reports focus specifically on the buildings sector; but they too miss the mark when it comes to “carbon footprint.” As a result, absent careful study, media portrayals provide misleading storylines that are easily misunderstood. Conclusions derivable from one agency's building sector reports may not reflect those from the other; especially when seeking cause and effect among the multiple facets of building design, construction, and operation. Unfortunately, “cause and effect” are prerequisite to finding a solution.

III. Missing Biomass and the Selective Lens

Another note of caution concerns the basis for “emission” calculations, which are *derived from energy consumption* data. CO₂ emissions are calculated by a mathematical conversion predicated on the carbon content of an *estimated* mix of energy sources: from oil, coal, natural gas, nuclear, biomass, hydro, wind, and solar. Moreover, the primary data is footnoted with qualifying assumptions visible only to those who read fine print and glossaries. For example, emissions from the use of biomass energy are excluded from residential, commercial, industrial, and transportation sector tabulations and the power sector as well. This conforms to the International Panel on Climate Change's (IPCC's) 2006 *Guidelines for National Greenhouse Gas Inventories*. Mention of these footnoted qualifications is generally absent from the abstracts and summaries often quoted. Those so inclined can include biomass emissions by doing the math, the data can be found at the end of the EIA *Monthly Energy Review's* “Environment” section, which tabulates U.S. biomass consumption and emissions separately.⁵

Although biomass emissions are considered to be air pollutants, biomass energy is not considered a significant source of carbon emissions in many circles because it is

5. GLOBAL STATUS REPORT 2018, *supra* note 1. According to the IPCC's 2006 GUIDELINES FOR NATIONAL GREENHOUSE GAS INVENTORIES, carbon released through biomass combustion is excluded from reported energy-related emissions. To reflect the potential net emissions, the international convention for greenhouse gas inventories reports biomass emissions in the category agriculture, forestry, and other land use, usually based on estimates of net changes in carbon stocks over time.

not generated from “fossil fuels.” Plant-based biomass is considered nearly carbon-neutral because, until it is used for fuel, it sequesters the carbon extracted from the atmosphere during photosynthesis. Unfortunately, being nearly carbon-neutral also comes with many qualifiers. GHGs are released during planting. Tilling the earth exposes soil to the air, releasing the earth’s sequestered carbon. Fertilizer production, the use of farm equipment, transportation fuel, and the emissions embodied in farm equipment and buildings are all carbon intensive as well. It is true that carbon sequestered in trees or perennial plants can remain locked in their root mass for extended periods, nonetheless, deforestation for fuel has a significantly negative impact by eliminating an important source of natural sequestration.

Processing biofuels consumes energy and emits GHGs whether ethanol, wood pellets, charcoal, or other plant or animal byproducts. Growing agricultural crops one year but returning their carbon to the atmosphere in the next immediately negates the benefit. Deforestation for fuel is even worse in that regard, emitting CO₂ to the atmosphere daily while depleting a depository of long-term sequestration—one that will take decades to replace even if replanted. Unfortunately, the characterization of biomass fuels as “carbon neutral” helps justify government subsidies that incentivize increasing production, rather than encouraging more appropriate zero-carbon renewables. In 2019, 217 million metric tons of carbon emissions spewed forth from the consumption of biofuels by residential, commercial, and industrial sectors in the United States. This added 7% more CO₂ emissions from energy consumption than were indicated from these three end-use sectors. Even more concerning, biomass energy constitutes nearly 45% of all primary “renewable” energy consumption in the United States; nearly double hydroelectric, double wind, 5 times solar, and 24 times geothermal consumption.⁶ In 2011, the residential sector consumed nearly three-quarters⁷ of the world’s biomass fuel owing to its use by developing countries. It would be significantly more sustainable to use agricultural land to grow crops to feed people and livestock rather than to produce biofuel, and to replace biomass fuel with *zero-carbon* solar, wind, hydroelectric, and geothermal sources. Yet relying on the “true” zero-carbon renewables—solar, wind, and hydro—remains a distant goal.

Sadly, while *end-use* statistics provide an incomplete picture of carbon emissions, their repetition in published studies renders them credible. Conclusions generally cite the same source material, papers, and summaries. Waters are muddied further by deductions derived from differing time frames that refer to an assortment of base years (2000, 2005, 2010, 2016, and 2017) with forecasts to 2030, 2040, 2050, and 2060, or the end of the century. Comparisons are difficult at best but more often useless. Industrial production might be included, biomass fuels not, onsite transportation sometimes and the like. The

results may apply to a particular statistic over an arbitrary time period filtered by an array of definitions; summarized in abstracts, executive summaries, prefaces, forewords, and press releases. News reports and journal articles are often contradictory or impossible to decipher, making it hard to validate trends, and worse yet, “cause and effect.”

Ultimately, the media and trade associations often provide spin from statistics that suit, unknowingly biasing conclusions, while manufacturers and developers might bias their promotional material by intent. Too often the *upfront* consequences of embodied emissions are missing, as well as their *impact on the global warming timeline*. This is difficult enough to parse in scholarly searches, but for those who write the news, who influence design, procurement, and policy decisions, factual verification is a complex puzzle not likely to be solved. The complete picture is not apparent. Embodied emissions are buried in industrial, transportation, and biomass fuels; and the 40% of energy-related CO₂ emitted by building and construction likely exceeds 50. Thus, a forum exists that proffers misleading conclusions, clouding the path to appropriate solutions. This need not be so. Data is available for analysis by those who scrutinize the charts.

Given the education and certification of design professionals, the abundance of emissions data available, and the present focus on sustainable design, we *have* the means to extract important revelations to improve our buildings and their methodology of construction. After all, with 11% of energy-related emissions attributable to material choice alone, more than one-quarter of the 40% total, we already know where to start. But in order to determine a pecking order for the actions, we must clarify which components require tackling up front. Our focus on sustainability is not misplaced, just misapplied, failing to heed the cause and effect timeline. The first step is to parse the claims, the second is to face “what we are up against.” We are able to make sense of this picture. One measure of this challenge is expressed by the “emissions gap,” the difference between the Paris Agreement signatory pledges and the emissions levels allowed by the 2 degrees Celsius (°C) and 1.5°C scenarios as they relate to “current” emission levels. The U.N. Environment Programme (UNEP) refers to this as the “commitment gap”: “[T]he commitments countries are making to reduce their emissions and the impact these commitments are likely to have on overall emissions reduction.”⁸

IV. 2019 to 2020

“Even if the nations of the world live up to their current commitments, that will likely result in global warming of around 3°C by the end of the century.”⁹ This stern warning was contained in the foreword to UNEP’s *Emissions Gap*

6. EIA, MONTHLY ENERGY REVIEW (Mar. 2020).

7. See IEA, ENERGY EFFICIENCY INDICATORS: FUNDAMENTALS ON STATISTICS (2014) and UNITED NATIONS, UNITED NATIONS INTERNATIONAL RECOMMENDATIONS ON ENERGY STATISTICS (2013).

8. U.N. Environment Programme, *10 Things to Know About the Emissions Gap 2019*, Nov. 26, 2019, at <https://www.unep.org/news-and-stories/story/10-things-know-about-emissions-gap-2019>.

9. See Joyce Msuya, *Foreword* to UNEP, EMISSIONS GAP REPORT 2018 (Nov. 2018).

Report 2018. Not as a pronouncement of doom, rather it issued a call for immediate action, continuing with “yes, it is still possible to bridge the emissions gap to keep global warming below 2°C Closing the emissions gap means upping our ambition.” But only one year later, the 2019 report foreword was more dire:

Each year for the last decade, the UN Environment Programme’s Emissions Gap Report has compared where greenhouse gas emissions are headed, against where they should be to avoid the worst impacts of climate change. Each year, the report has found that the world is not doing enough. Emissions have only risen, hitting a new high of 55.3 gigatonnes of CO₂ equivalent in 2018. The UNEP Emissions Gap Report 2019 finds that even if all unconditional Nationally Determined Contributions (NDCs) under the Paris Agreement are implemented, we are still on course for a 3.2°C temperature rise.

Our collective failure to act strongly and early means that we must now implement deep and urgent cuts.¹⁰

Sadly, the *Emissions Gap Report 2020* foreword contains the same refrain for the third year running: “Overall, we are heading for a world that is 3.2°C warmer by the end of this century.”

The 2019 and 2020 gap reports reaffirmed that *cumulative* emissions from 2018 through the end of the century must be contained within 1,200 billion metric tons to achieve the Paris Agreement’s most liberal goal, the *Below 2.0°C* scenario. With total emission including land use exceeding 55 billion metric tons per year, they be must curtailed to a maximum near 40 billion metric tons *annually* by 2030.¹¹ Furthermore, the energy supply must be “decarbonized by 2060 with 98% of all generation from low-carbon sources.”¹² Simply put, by 2030 we must drive this annual 15 billion metric ton emissions gap to zero, and ultimately, “carbon neutrality” will be essential to maintain global warming below 2.0°C through 2100, removing as much carbon from the atmosphere as we emit.

Nevertheless, decarbonizing our energy by 2060 is a long way off; our first challenge is to close the emissions gap by 2030. And that serves only a 66% probability of capping the globe’s temperature rise near 2.0°C. More favorable odds of 80 percent¹³ requires trimming another 820 billion metric tons *cumulatively* through the end of the century. *This is the long-term challenge*. In the short term, which we can impact now, we must reduce global emissions by at least 2.7% *each year* from 2019 through 2030 to maintain that 66% chance of keeping the increase below 2.0°C.¹⁴ That means eliminating 1.5 billion metric tons in 2020, and a little less each year to 1.1 billion metric tons in 2030.

Overall, the breakdown of the 55.3 gigatonnes (Gt) of GHGs emitted in 2018¹⁵ indicates the “causes” we have to mitigate, 2019 should be similar.

- 14.8 Gt: Energy-related emissions from buildings and construction
- 14.2 Gt: CO₂eq from methane, nitrous oxide (N₂O), fluorinated gases¹⁶
- 11.6 Gt: Other energy-related industrial emissions
- 8.6 Gt: Energy-related transportation emissions
- 3.5 Gt: Land use change emissions
- 2.6 Gt: Other

At 14.8 Gt, energy-related emissions from buildings and construction constituted 27% of *all* emissions—of the 55.3 Gt total, not just those stemming from energy. Consequently, their 27% burden-share of the 15 Gt emissions gap equates to 4 Gt. Therefore, to achieve the *Below 2.0°C* scenario’s minimum goal, emissions from buildings and construction must be reduced by 2.7% annually, eliminating 0.3 to 0.4 billion metric tons per year from each prior year through 2030.

The second largest contributor, CO₂eq GHG “equivalents” coming from methane, N₂O, and fluorinated gases, are usually absent from built environment discussions which focus on energy-related emissions. But at 14.2 Gt, they are a significant part of the total picture. Methane alone was responsible for 9.7 billion metric tons in 2018. 3.2 billion were attributed to the production of coal, natural gas, and oil. Fortunately, most of that will be eliminated in the long term through decarbonization of the energy supply. Nevertheless, 0.3 billion metric tons of methane will remain as long as we continue to use biomass fuels. Enteric fermentation from animal digestion and the decay of waste in landfills, wastewater and from agricultural manure management generated 2.6 billion metric tons of methane CO₂ equivalents. N₂O attributable to agricultural fertilizers, accounted for 2.6 billion metric tons of CO₂eq, and fluorinated gases, which are frequently substituted for ozone-depleting gases, are responsible for 1.7 billion metric tons.¹⁷

As energy-related emissions in general produced 68% percent of the total, all of the IPCC scenarios rely on decarbonization of our energy supply in the long term. That includes tackling the 14.8 Gt from buildings and construction. Nonetheless, as we are already behind in

10. Inger Anderson, *Foreword* to UNEP, EMISSIONS GAP REPORT 2019 (Nov. 2019).

11. UNEP, EMISSIONS GAP REPORT 2019 (Nov. 2019) [hereinafter EMISSIONS GAP REPORT 2019]; UNEP, EMISSIONS GAP REPORT 2020 (Nov. 2020).

12. IEA, ENERGY TECHNOLOGY PERSPECTIVES (2017).

13. *Id.*

14. EMISSIONS GAP REPORT 2019, *supra* note 10.

15. *Id.*

16. J.G.J. OLIVIER ET AL., TRENDS IN GLOBAL CO₂ AND TOTAL GREENHOUSE GAS EMISSIONS SUMMARY OF THE 2019 REPORT (PBL Netherlands Environmental Assessment Agency, The Hague 2019).

17. The preceding statistics were computed from analyses and data supplied by the IEA & UNEP, GLOBAL STATUS REPORT FOR BUILDINGS AND CONSTRUCTION: TOWARDS A ZERO-EMISSIONS, EFFICIENT, AND RESILIENT BUILDINGS AND CONSTRUCTION SECTOR 2019 (2019); IEA & UNEP, GLOBAL STATUS REPORT FOR BUILDINGS AND CONSTRUCTION: TOWARDS A ZERO-EMISSIONS, EFFICIENT, AND RESILIENT BUILDINGS AND CONSTRUCTION SECTOR 2020 (2020); TRENDS IN GLOBAL CO₂, *supra* note 15; Global Methane Initiative, *Global Methane Emissions and Mitigation Opportunities*, <https://www.globalmethane.org/documents/gmi-mitigation-factsheet.pdf>; and U.S. ENVIRONMENTAL PROTECTION AGENCY, GLOBAL ANTHROPOGENIC NON-CO₂ GREENHOUSE GASES: 1990- 2030 (revised Dec. 2012).

the quest for decarbonization, significant reductions must be achieved in the short term from thoughtful building design and material choice. It is too late and too risky to rely solely on the “potential” of operating efficiencies and decarbonization, that they will be accomplished soon enough on a broad enough scale. In 2019, building sector operating emissions increased to a new high once again,¹⁸ and total global emissions climbed to their highest level yet, 59.1 Gt.¹⁹

V. The Zero-Carbon Lens Versus the Built Environment’s DNA

Zero-carbon energy is the ultimate solution for the building, construction, and manufacturing sectors. It will virtually eliminate “operating” carbon emissions and reduce the embodied carbon of future buildings, including their environmental conditioning systems and appliances. End-stage embodied carbon in preexisting buildings will be minimized as well: the embodied carbon attributable to maintenance, deconstruction and the processing of materials for reuse or disposal. Most importantly, the energy-related emissions embodied in future materials diminish when manufactured with zero-carbon energy; only emissions from the chemical byproducts of materials processing will remain, such as from processing cement and steel.

Multiple technologies are already in use to provide zero-carbon energy worldwide, harvesting and generating emissions-free energy; harvesting the sun’s energy with photovoltaic solar cells to output electricity, or with solar collectors or mirrors that heat fluids to create hot water or steam for electric generation. We harvest wind and water flow to mechanically power electricity generation. Nuclear energy rounds out the top four, while other means such as tapping the earth’s geothermal heat, water current, and deep lake temperature differentials may gain traction as well. All are free of carbon emissions with the notable exception of *emissions embodied in their generating equipment, operating facilities and transmission infrastructure*. They all have embodied carbon, none of which is minimal and cannot be ignored. According to the IEA *Renewables Information Overview 2019*, “zero-carbon” energy sources produced nine percent of the world’s total primary energy supply (TPES). In the long term, as this 9% share grows to 90% of the world’s energy supply, the carbon embodied in future equipment, facilities, and infrastructure—manufactured, transported, and constructed with carbon-free energy—will become minimal too. Reaching this goal is a matter of financial investment, equipment availability, technological advances in energy storage, and the installation of sufficient storage and transmission infrastructure. And all of this requires time and “political will.”

But once again we must choose our words carefully. The current focus is on increasing the use of “renewables.” As with emissions statistics generally, renewables reports also can mislead or be difficult to decipher as

they commonly refer to annual *growth*, rather than their total share of the energy supply. One must not misconstrue the percentage of “new” or “increased” capacity or generation, for the “total” capacity or generation actually installed. One must be careful not to understand “electricity” generation as our *entire* energy supply, nor to believe *all* “renewable” energy is “zero-carbon.” The *Perspective on the Global Renewable Energy Transition*²⁰ reported that “[r]enewables accounted for 64 percent of new net electricity generation capacity in 2018,” a staggeringly large number. But this refers to “new” capacity, not total generation. Renewables were estimated to reach 27% of total *electricity* generation worldwide by the end of 2019. This is a good accomplishment. According to the report, however, “[e]lectricity accounts for only around 17% of worldwide energy demand, so there is an urgent need to decarbonize heating, cooling and transport as well,” as renewables “provide only 10% of the energy used for heating and cooling, and just over 3% of energy use for transport. Shares of renewables in these latter sectors are growing so slowly that renewable energy consumption is barely keeping up with global growth in energy demand.” The *Renewables 2020 Global Status Report* concluded that “[d]espite the growing deployment of renewable energy around the world, the share of renewables in total final energy consumption (TFEC) has seen only a moderate increase.”²¹

As of 2018, renewables accounted for roughly 13.5% of the world’s primary energy supply and 12.3% of the U.S. primary energy supply.²² This figure includes biomass fuels, which represented two-thirds of the global energy coming from renewables, and approximately 40% of the renewable energy in the United States.²³ Biomass emissions in the United States exceeded 300 million metric tons of CO₂ in 2020 for the 11th consecutive year, and were close to 7% of all U.S.²⁴ emissions from energy consumption, three-quarters from the residential, commercial, industrial, and electric power sectors. And biofuels represented 91% of the renewables consumed by road transportation worldwide in 2017.²⁵ Biomass fuels are not carbon-free, though a significant improvement over fossil fuels, biomass emissions are far from negligible. Biofuels are helping to make this transition, but they too must be eliminated in the long term.

Given that eliminating high-carbon fuels and generating more zero-carbon energy are already top priorities on the world agenda, and that we are making gains, why can’t we wait for energy decarbonization to cap global warming? While it is true that decarbonization will facilitate a large decrease in carbon emissions in some countries over the next decade, this will not happen on a global basis. Within

18. GLOBAL STATUS REPORT 2020, *supra* note 16.

19. *Id.*

20. REN21 SECRETARIAT, PERSPECTIVES ON THE GLOBAL RENEWABLE ENERGY TRANSITION, TAKEAWAYS FROM THE REN21 RENEWABLES 2019 GLOBAL STATUS REPORT (2019) (ISBN 978-3-9818911-7-1).

21. *Id.*

22. IEA, RENEWABLES INFORMATION: OVERVIEW (2020); EIA, MONTHLY ENERGY REVIEW (Jan. 2021) [hereinafter MONTHLY ENERGY REVIEW 2021].

23. IEA, RENEWABLES INFORMATION: OVERVIEW (2019) & MONTHLY ENERGY REVIEW 2021, *supra* note 21.

24. United States biomass emissions sourced from EIA, MONTHLY ENERGY REVIEW, tbl. 11.7 (Apr. 2021).

25. REN21 SECRETARIAT, RENEWABLES 2020 GLOBAL STATUS REPORT (2020).

the time frame currently required to close the emissions gap, decarbonization of the world's energy supply alone will not be widespread enough to cap the increasing rate of emissions, nor effective enough to slow the current rate of global warming. On the scale of the decarbonization required, this first step toward achieving "carbon neutrality" remains distant. Some believe such implementation might reach critical mass near 2050, while others believe it will be later. In all cases it will take a lot longer than a single decade to be completely resolved.

Sadly, after three years of stabilization through 2016, with global emissions reaching record highs in 2017 and 2018, the portion due to energy-related emissions also reached record highs. Even if all of the commitments submitted by the signatories to the Paris Agreement were implemented by 2020, energy-related CO₂ emissions would still require a significant annual reduction by 2030, which must be maintained through the rest of the century. Seventy-eight percent of all emissions are produced by the G20 Group members²⁶ and there is no sign they will decline any time soon. Gap reports for 2018 and 2019 indicate that absent a rapid increase in action within the next few years, these emission levels *will not* reach their peak and stabilize by 2030 as desired. The "scale and pace of current mitigation action remains insufficient" and "current policies of G20 Members collectively fall short of achieving the unconditional [nationally determined contribution] commitments to the Paris Agreement."²⁷ As such, there is risk of long-term lock-in due to inertia, as well as a dependency on long-lived "capital stocks" and "committed emissions resulting from existing infrastructures."²⁸ This is the handwriting on the wall.

We will continue to see improvements in the reduction of operating carbon emissions by municipalities around the world having access to low-carbon or carbon-free energy—especially wherever coal is eliminated in favor of natural gas, or more favorably by solar, wind, hydro, geothermal, or nuclear power. Nonetheless, whatever the rate, such implementation is unlikely to advance sufficiently to halt the progression of global warming within the next 10 to 15 years, let alone reverse it. Although each new announcement of a coal plant closed, a wind farm brought online, or a requirement for new homes to include solar panels provokes a sigh of relief, we must re-focus our lens to capture the global perspective. Global warming knows no boundaries. It is easy to become complacent, fooled by early gains associated with a specific nation or community whether it be the United States, China, the European Union, or otherwise, but the United States and most other countries are a far cry from the handful of those making major gains. It is easy to misjudge progress, fooled by those touting double or triple growth of a carbon-free source based on minimal prior use. Success or low emissions in

one region, or conversion to low-carbon or zero-carbon fuel, does not necessarily indicate such gains for the entire global community.

We can no longer take solace from reports of individual strides forward nor can we wait for zero-carbon energy to become the world's predominant supply. Nor can we wait for global commercialization of technology to scrub CO₂ from the atmosphere. The urgency demands immediate reductions. Reducing operating energy expenditures, increasing the use of renewables, purchasing carbon credits, and the like are important steps in the overall scheme, but they do not justify the needless release of GHGs traceable to inefficient building design and construction, or unnecessary carbon embodied in the infrastructure we erect. These problems are more prevalent than one might expect, encompassing even the most rudimentary forms of construction. Constructing a simple 320-square-foot cinder-block shelter (30m²) with a corrugated-metal roof²⁹ emits nearly 25 metric tons of emissions, just from manufacturing the cinder-block, mortar, and corrugated metal. Ten such structures would require 10 years of growth from 6,000 newly planted trees to absorb and sequester their embodied emissions.³⁰

Slowing the buildup of atmospheric carbon in the coming decade is our most pressing problem. Tackling the immediate impact of embodied emissions, the near one-third of the built environment's 40% share, is an expeditious path to an impactful solution. Forethought and sound design can minimize a carbon footprint by dint of careful material selection and structural methodology. At the same time, designing an energy-efficient facade with a site-responsive orientation can reduce operating emissions as well. A building's physical design and construction establishes the demand for heating, cooling, mechanical ventilation, and artificial lighting, all of which engender operating emissions. Thoughtful design can reduce the need, thereby minimizing energy consumption and the associated carbon emissions. The less mechanical conditioning required, the less capacity required, the smaller the system procured, and the lower the embodied carbon. And as some structural systems yield lower carbon footprints than others, the same is true for cladding materials as well.

The time spent devoted to low-carbon design is our best means for reducing embodied carbon, our best means to create *building efficiencies inherent to the design*. Design is doubly impactful; it determines both embodied and operating emissions for better or worse. Thus we can chip away at the carbon gap building by building. Millions upon millions of buildings are constructed each year and old ones renovated or reconfigured.

The operating carbon emitted today during the production of cement, steel, aluminum, plastics, glass, and the like will be included in future construction's carbon

26. Argentina, Australia, Brazil, Canada, China, France, Germany, India, Indonesia, Italy, Japan, Mexico, Russia, Saudi Arabia, South Africa, South Korea, Turkey, the United Kingdom, the United States, and the European Union.

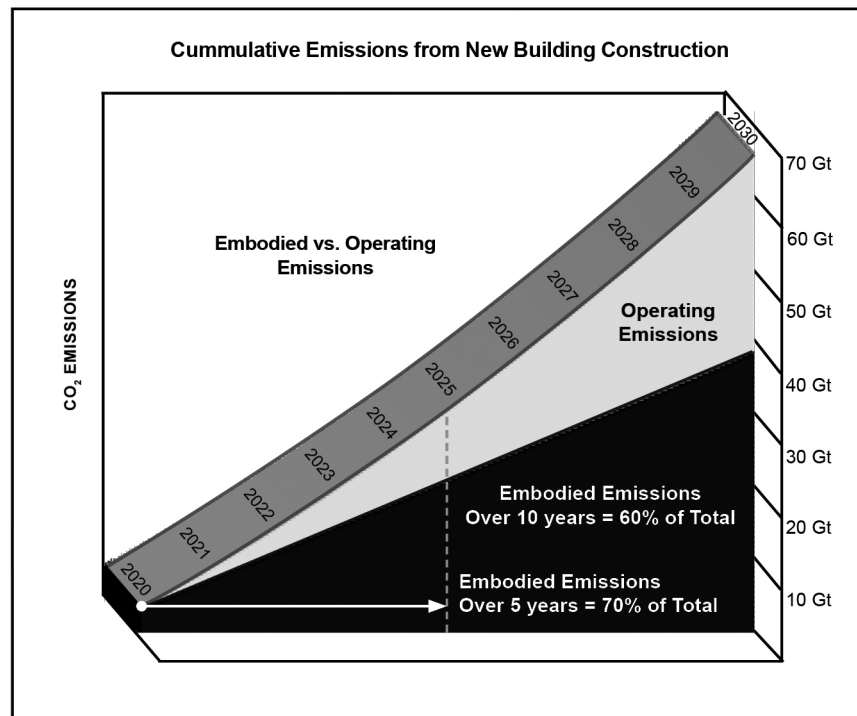
27. GLOBAL STATUS REPORT 2018, *supra* note 1; EMISSIONS GAP REPORT 2019, *supra* note 10.

28. UNEP, EMISSIONS GAP REPORT 2018, *supra* note 8, 3.5.3.

29. 16 x 20 feet with 10-foot walls and a corrugated metal peaked-roof (30m², 5 x 6m with 3m walls).

30. Calculated from "[r]educing 1 MMT of CO₂ emissions is equivalent to: 26,000,000 tree seedlings grown for 10 years," California Air Resources Board, www.arb.ca.gov, AB 32.

Accumulation of Embodied Emissions Versus Operating Emissions 2020-2030



Source: Graph generated from *IEA Global Status Report 2020* Building and Construction sector data for 2019 Emissions, prorated for 77 billion m² of new construction (*Perspectives for the Clean Energy Transition: The Critical Role of Buildings*, International Energy Agency (IEA), April 2019), with a Building sector emissions rate for a global building stock of 235 billion m² (*IEA Global Status Report 2017*).

footprint. When these materials are purchased, delivered, and used in construction, they will be tallied as embodied carbon, part of a long trail of emissions related to the material's composition and manufacturing commencing with the extraction and processing of its raw materials. This is an emissions trail tied to material choice. The notion of a single structure's embodied carbon does not adequately acknowledge the environmental damage already incurred through the supply chain prior to its materials delivery, prior to a product's manufacture or a building's construction. This emissions chain is triggered regularly, renewed by each order for a new project, renewed by each order for stock that anticipates market demand, months or years before they are ever noted in a singular building's carbon tally. Each bag of cement, concrete block, steel beam, or pallet of bricks ordered renews the cycle for the next batch of stock, emissions released for an entire lot.

As noted in the *Global Status Report* for 2018, the carbon embodied in our built environment is "primarily based on material demand." And worse yet, these upfront contributions to atmospheric carbon can take a decade or more of future operating reductions just to compensate. Moreover, not only do embodied emissions nullify the value of future operating gains, they kick-start an acceleration of the rate of global warming. In simpler terms, any reduction in embodied carbon retards the rate of change of global warming at the onset.

VI. So What Is the Solution?

With the singular exception of wood, no ideal building material exists. There are no magic bullets for architects, engineers, or designers who seek to alleviate these problems. Growing wood removes carbon from the atmosphere, which it sequesters unless it decays or burns. Used as a building material, the carbon in wood is sequestered for the life of the building. But there are limits to its availability and a limit to the building height it can sustain. There are no ideal sustainable design techniques or products that are universally applicable, and few as beneficial as their marketing purports. Many fail to account for their carbon footprint, or their maintenance, efficiency loss while ageing or their eventual abandonment. Many fail to consider their end-stage carbon footprint or mitigating environmental damage caused by their disposal. When one wades through the fine print or calculates the embodied carbon in a design, surprises emerge. Referring to his award winning AIA Green Project, Larry Strain, FAIA, noted:

My own "a-ha" moment on this front was when my firm calculated all the embodied carbon emitted from building the Portola Valley Town Center. It's a very efficient project and has performed better than expected, but when we ran all the numbers we found that construction still emitted

1,000 tons of carbon—roughly the same as 10 years of operating emissions.³¹

He was referring to a building certified LEED® Platinum.

When it comes to the building blocks of architecture, the most effective actions revert to material selection and the elementary practices of “reduce, recycle, and re-use.” Though deceptively simple in concept, success requires meticulous design with a heavy emphasis on “reduce,” both in mass and inherent carbon footprint—without waiting for decarbonization of our energy supply. According to the IEA in 2019, nearly 800 billion square feet (ft²) of floor space (77 billion square meters (m²)) will be built from 2020 to 2030 and 200 billion ft² (20 billion m²) of existing buildings will be renovated; and sadly, “the global energy sector is not on track for a low-carbon transition.” “Despite efforts to reduce GHG emissions, the world’s energy supply still is almost as carbon intensive as it was nearly two decades ago.”³² Over this 10-year period, embodied carbon would be responsible for approximately 60% of these new buildings’ emissions, two to more than three times the operating emissions released in 6 of those 10 years. 70 billion m² of renovations will increase the embodied emissions even more,³³ and none of this includes those attributable to the interior finishings, furniture, and fixtures that make buildings complete.

Carbon emissions incurred over the next decade cannot be reversed. We must reduce them through diligent design and construction. *The challenge is clear.*

VII. What Hinders Low-Carbon Design?

We lack user-friendly tools to evaluate materials, to compare structures: to analyze their properties against their carbon emissions in terms relatable to building design decisions. Masonry, concrete, or steel; aluminum, vinyl, fiber cement, or glass? Or should it be wood? We also lack user-friendly tools to assess the value of energy-efficient appliances and building systems, their annual emission savings against those embodied and their useful lifespan. Current databases are awkward to use and lack useable content. Some materials are evaluated by weight, some by surface area, and others by volume—rarely relatable to products on the market without performing extensive calculations. When mitigating embodied carbon is the intent, evaluating alternative material choices can be difficult. Calculating a product’s carbon footprint from an embodied carbon database can yield confusing and sometimes counterintuitive results at first glance. The culprit lies in how the source expresses carbon intensity. A material’s carbon intensity—the primary indicator of carbon emissions—is derived from the mass of emissions released

while processing and fabricating the product, from its raw materials to the factory’s rear door.

Embodied emissions are typically expressed in kilograms or pounds (kg or lb) of emissions per kg or lb of the material: kgCO₂/kg or lbCO₂/lb. As most construction materials and components are not designed in by the kilogram or pound, sometimes their emissions are expressed by surface area or by the piece: kgCO₂/m² or lbCO₂/ft² or per unit of use. But this too can be problematic: emissions per square meter or square foot depend on a component’s thickness, when expressed for a single piece like a brick or a concrete block, they depend on its mass—such properties may vary from vendor to vendor. Comparing carbon intensities alone, without analyzing the property equivalencies, is another source for erroneous assumptions when applied to a construction project’s carbon footprint. The requisite quantity for a specific use, i.e., the material mass, is the overriding factor in ranking emissions. For example, even though steel emissions are as much as 15 times more than concrete by mass, steel structures have lower embodied carbon than similar structures of concrete because steel structures have less mass. By material mass, concrete structures require significantly more concrete to carry a load than the amount of steel in an equivalent steel structure. Similarly, though aluminum and vinyl emit more embodied carbon per unit of mass than brick, clay, and ceramic—their thickness and mass are much less when used for cladding. As such, aluminum and vinyl *cladding* can be better than brick, clay, and ceramic depending upon the particular product’s profile and composition.

Ranking materials by their emissions per unit of mass, from worst to best, yields surprising results:

Embodied Carbon—kgCO₂/kg³⁴ Highest to Lowest Footprint by “Mass”

Aluminum
Polyvinyl Chloride (PVC) and Vinyl
Steel Sections
Glass for Glazing
Cement
Ceramic Tile & Cladding
Clay Tile
Common Brick
Concrete

But when accounting for the mass of their volume as typically employed in construction materials, the sequence of worst emitters is dramatically different. Concrete leads the list followed by steel. “Twice as much concrete is used in construction as all other building materials combined.”³⁵

31. AIA, *10 Steps to Reducing Embodied Carbon* (Mar. 29, 2017).

32. IEA, *PERSPECTIVES FOR THE CLEAN ENERGY TRANSITION: THE CRITICAL ROLE OF BUILDINGS* (Apr. 2019).

33. Based on GLOBAL STATUS REPORT 2020 prorated for 77 billion m² of new construction (IEA, *PERSPECTIVES FOR THE CLEAN ENERGY TRANSITION: THE CRITICAL ROLE OF BUILDINGS* (Apr. 2019), with building sector emissions rate for a 235 billion m² global building stock (IEA, *GLOBAL STATUS REPORT 2017*).

34. Circular Ecology Ltd, *Inventory of Carbon and Energy (ICE)*, Database Version 3.0 Beta (Aug. 9, 2019): Aluminum: 6.6+ kgCO₂/kg with world average recycled content; PVC general: 3.1 kgCO₂/kg; Steel sections (beams, etc.) & plate: 1.6 - 2.5 kgCO₂/kg world average; Glass general: 1.4 kgCO₂/kg; Cement: 0.83 kgCO₂/kg UK average; Ceramic Tile & Cladding: 0.78 kgCO₂/kg; Clay Tile: 0.48 kgCO₂/kg; Common Brick: 0.21 kgCO₂/kg UK; Concrete general/average/high strength: 0.10/0.16/.19 kgCO₂/kg UK.

35. COLIN R. GAGG, *CEMENT AND CONCRETE AS AN ENGINEERING MATERIAL: AN HISTORIC APPRAISAL AND CASE STUDY ANALYSIS* (Elsevier Ltd. 2014).

Two heuristics that help identify *high* emission materials are based on the *temperature levels* required for manufacturing, and the *total mass* required for a project application. The *higher* the process temperature and the *higher* the mass used in construction *the more emissions* released. High temperature manufacturing places steel, cement, porcelain, ceramics, brick, aluminum, and glass high on the list when compared by unit of mass. Substantial energy is consumed while generating high temperatures, which in turn generates abundant carbon emissions. The second rule of thumb concerns the quantity of a material used; *the more material used the more the embodied carbon emitted*. This rule applies when selecting the thickness of tile or brick or even glass; *the thicker the specific material or product the more the embodied carbon*. PVC and vinyl sit high on the list due to their chemistry. But many building products are a composite of materials, some a laminate of material layers such as many vinyl cladding products. What is the footprint of multi-layered vinyl cladding? That depends on the thickness of the vinyl. General guidelines can facilitate general comparisons, but cannot quantify the actual emissions. Heuristic guidelines can be helpful, but for meaningful whole building analyses, data-based values are a must.

For most architects and designers, existing product data are not sufficient to analyze construction schemes in their early stages of design conception. The design/build profession needs analysis tools that are tuned to commonplace trade specifications and ordering units, be they by weight, surface area, volume, linear length, or by the piece. They must have the ability to compare apples with bananas in the units they order as alternatives for the recipe. Current capabilities entail intensive research and spreadsheet work using a limited array of data sources with an inconsistent array of materials data. Better databases and computer programs dedicated to simplifying the carbon buildup *specific to building design* are crucial to intelligent selection, especially at the early stages of conception. Whether made available at no cost by an institution or a reasonable cost commercially, computer software of this nature could be developed within a year or two. Without this we remain handicapped, flummoxed by the carbon footprint of concrete versus steel, or of aluminum siding versus vinyl, or brick or glass; flummoxed with design choices for a proposed schematic. Differing compositions make this more complex as chemical treatment, finish, and other specifications for the same product may double emissions or more. Material choice is key to reducing carbon emissions, both embodied and operational, but product performance characteristics are key as well. Complexity, lack of clarity, and misinformation significantly hamper effective design.

Integrating sound sustainable methodologies with a physical aesthetic and the programmatic characteristics of the architecture is a complex task, especially after a building's schematic has been formatted. The lack of clarity regarding material and product performance render meaningful solutions a problem, and so do wishful fantasies and the trade's romance with the "symbols" of green design. This includes the inclusion of solar panels, green roofs, sun screens, double-skin facades, and the like, all valuable for specific site conditions—none universal for all.

What is understood to be sustainable in general, often lacks sustainable value in application. Such reality is hard to decrypt even by architects, planners, and policymakers. Given the technical complexity and a general lack of transparency regarding performance requirements, this is not surprising. This holds particularly true for material selection in all facets of design and construction, from the specification of insulation to the methodology of a building's structure, and even to the colors of the brick from natural to grey or black. The choices made often encourage unworthy enthusiasm fed by misinformation, as well as certification or recognition for buildings that are environmentally unsound. Examples are lauded on a small scale while general construction on a large scale continues to ignore its contributions to atmospheric carbon, and false hope is proffered from the "potential" of undeveloped ideas. And sadly, we are up against marketing campaigns.

The February 2020 issue of *Architect*, the official journal of the American Institute of Architects (AIA), contained a full-page ad courtesy of "Build With Strength," a coalition of the National Ready Mixed Concrete Association. The headline read:

**What building material absorbs carbon
for the entire lifespan of the building?**

CONCRETE IS THE ANSWER.

True, exposed concrete surfaces do absorb CO₂ slowly over time, as do some rocks and soil. But the decades required for meaningful absorption nowhere near compensate for the enormous emissions spewed daily by cement manufacturing. No, concrete is not the built environment's answer to eliminating the carbon problem, though some architects reading that AIA journal ad might be influenced to believe so.

Our 30-year flirtation with sustainable design has been insufficient to alter the course of global warming. Educated design focused on the reality of *net-carbon* can turn that around; targeting the embodied carbon first emitted, while designing for operating efficiencies at the same time. Carbon emissions attributable to each new building built, and each retrofit or renovation, can be reduced by design—both the immediate and the long term.