A New Carbon Architecture

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> This would be easy if it weren't so hard.
> —Yogi Berra

Recently I was driving in America and pulled up at a stop light behind a Tesla. You know Tesla, right? The latest and most talked about electric car, renowned for its power, handling, and just overall coolness. I drove one once and can attest: it was great!

This particular Tesla had a license plate that read ZEROCARB — meaning, presumably, that the owner was proud of his zero carbon emissions car. No climate villain here! There's no way to know for sure, but I'd guess that this owner believed his claim, believed that his driving had no effect on the climate, unlike the rest of us bozos in our gas-powered stinkers.

Bruce T. King

As I sat there pondering behind that license plate, I was thinking what you maybe thinking: "Huh?" Because that Tesla doesn't get recharged by twinkle fairies, and didn't appear by magic in the world — and neither do ovens or shoes or buildings. By some estimates the energy required to make a smartphone, just for one example, is more than 70 times the energy it takes to charge it for a year — not to mention all the waste products, water, and emissions of many sorts that are involved. There is work and energy and rearrangement of some stuff into other stuff to make a Tesla — or a building. To believe otherwise is ignorance, to pretend otherwise is disingenuous and even somewhat dangerous. That Tesla moment sparked me to focus even more on the so-called *embodied or up front carbon* of buildings, and on the many emerging technologies that will turn buildings from climate villains (which they now very much are) into climate champions that can safely store carbon that was soaked out of the air: imagine a building made of sky.

> *The primary task of any good teaching*
> *is not to answer your questions,*
> *but to question your answers.*
> *—Adyashanti, The Way of Liberation*

As long as we're imagining, imagine:
Walking into a brand new building and immediately sensing that something is different. The structure is all exposed wood — columns, beams, even floor and roof are all great curving slabs of timber elegantly joined together from smaller pieces. The skin and insulation, which you can also see, are straw bound into shapes that shed rain and insulate walls. The foundation is soil from the site transformed by invisible microbes into strong concrete to hold everything up, and the warm, leatherlike floors need no additional covering. It should look and smell like a barn but doesn't, and feels more like an inviting bedroom or an elegant museum. It's nicer than any building you've ever been in before.

And it's not a handmade house in the woods — it's a new downtown office building, nine stories high, full of people, and filling half a city block. It gathers all the power and water it needs, is elegantly lit by daylight, and processes all of its own water and wastes into soil for the courtyard gardens. And, though you can't see this, compared to what might have been built a decade earlier, its construction put thousands of tons less carbon into the air — and pulled thousands more tons out of the air to serve as its walls, floors, and roof.

The New Carbon Architecture: buildings made of sky. For the first time in history, we can and should build pretty much anything out of carbon that we coaxed from the air. We can structure any architectural style with wood, we can insulate with straw and mushrooms, we can make concrete — better concrete — with clay, microbes, smoke, and a careful look in the rearview mirror and the microscope. All of these emerging technologies and more arrive in tandem with the growing understanding that the so-called *embodied carbon* of building materials matters a great deal more than anyone thought in the growing movement to halt and reverse climate change. The built environment can switch from being a problem to a solution. (And it doesn't really matter whether or not you accept that climate change is anthropogenic: all the technologies of a new carbon architecture make sense for a host of reasons, not least that they are much nicer buildings to occupy, and just happen to pull carbon out of the air.)

But to back up a bit . . .

Human beings started building about eight thousand years ago with the dawn of the agricultural revolution, and that extended worldwide moment was arguably the most disruptive in history for us and the rest of life on Earth. Rather than hunt and forage about the landscape for our food, we grew it in one spot, and next thing you know there was architecture, political states, wealth and poverty, Gutenberg and Einstein, global tension, Lady Gaga, and drive-thru WiFi-enabled hamburger stands in Cairo.

And billions more of us.

We've been developing the art and science of building for these thousands of years, mostly learning from trial and error, but as of the last few centuries also learning and developing via science. We know an awful lot more about how things work than we ever did, but can also dimly see how much we still don't know, such as what most of the universe is made of.

Speaking of what things are made of, in many ways the history of architecture follows the development of materials — the history of people messing around with things they found in the landscape to get bricks, then boards, then toilets, then building-integrated photovoltaic roofing tiles. People learned to fire clay to make pottery and bricks, and when the kilns were made of limestone they discovered that the intense heat also changed the rocks: lime plaster, concrete, Pantheon. In some places the potters saw shiny metal come oozing out of certain heated rocks: copper, bronze, iron, Golden Gate Bridge. Two hundred years ago, the predecessors of modern structural engineers in England placed iron bars in newly invented Portland cement concrete, and architects went wild like they never could before: the Sydney Opera House and every downtown skyline in the world with lights, plumbing, and comfort hundreds of feet in the air. In some places people saw oil oozing out of the ground, then drying to tar: vinyl siding and the interstate highway system, not to mention plywood and air conditioning. And so on. Seems like the party would never stop, but of late the many large and hidden costs have come due, and we have to change not just the way we build, but what we build *with*.

Every modern industrial society has codified systems and materials of construction that are based on abundant fossil fuels, and on having an "away" where we can throw things. All the laws, standards, and codes are still rigidly based on doing things that way, even penalizing and inhibiting those who seek better ways to build. For the past century, it has been increasingly easy and cheap to extract, process, assemble, and transport everything we use in construction, but that won't last much longer. The climate is definitely changing, and the effects are arriving harder and faster than we expected even ten years ago. The "heat, beat & treat" approach to making and processing materials is killing us, as is the notion that we can throw anything we want into landfills, water, soil, or air, because building materials account for about 10 percent of global carbon emissions and 25-40 percent of solid wastes. That just has to change. We have a new ball game.

Some of us who design and build have lately started noticing that nature builds all sorts of things, and has been doing so for the four billion years of life on Earth. She has a hell of a head start on the trial-and-error path; maybe we can and should peek over her shoulder and see if we can't cheat a bit. How does a mussel build its shell? How do spiders spin their webs? How does a redwood tree stand and remain very much alive at 120 meters — and why doesn't it grow higher? How do birds stay warm and dry at night?

When facing design challenges from the small (How can I illuminate a surface or keep out rain?) to the large (Can nine billion human beings live on Earth without wrecking everything for themselves and the other critters, maybe even be a welcome presence?), we might ask: *What would Nature do?*

Some simple and semi-obvious things come right to mind: Nature runs on solar and geothermal energy with no other external energy inputs, and Nature uses what is at hand either by growing it like a clam grows its shell, or harvesting nearby resources as birds do for their nests. She doesn't bake rocks, ravage landscapes, or poison air and water to get shelter for her citizens. There's no FedEx, there's no power grid, there are no artificial chemicals to worry about.

Metropol Station in Seville, Spain. Image courtesy of Arup.

Wood structure + straw insulation – the Europeans are leading the way. Image courtesy of EcoCocon.

But you and I live in a highly interdependent industrial society, where the sudden disappearance of FedEx, the power grid, a huge multitude of problematic chemicals, and all the other trappings large and small of modern life, would make for a whole lot of suffering for a whole lot of people. We've built a better life for more and more of us, but at the same time made quite a mess, so can we clean it up? Can we wean ourselves off of the fossil fuel habit? This ship doesn't turn very fast, but can we plot a course to a world that works for everybody?

Sure. Technologically, we're scarily clever creatures. It took less than two and a half years between Franklin Roosevelt authorizing the Manhattan Project and the first atomic explosion in the New Mexico desert (for better or worse). It took only eight years between John Kennedy's proclamation and Neil Armstrong's foot stepping onto the Moon's surface. And both of those projects were designed and executed by men and women using slide rules, unreliable wire telephony, and computers far less powerful than the average laptop of today. When we collectively set ourselves to do something, for better or worse, we tend to get it done. Of late, there's been plenty of the better but also far too much of the worse. How about let's change that, and get more better and less worse.

We can already see a path to a fantastically better built environment, a new palette of materials for a new century. "Net Zero" buildings that use less energy than they generate are a good start, but don't go nearly far enough. Imagine buildings that not only protect people but also heal the damage done to the world around us. Imagine buildings and cities made of sky, a New Carbon Architecture.

What kind of difference might this make? Various and multiple studies assign to building materials 5 to 15 percent of global emissions, there being no consistent methodology nor data sets to draw from. Call it 10 percent of global emissions, and there's your impact. We propose to reduce that number to zero — and then beyond by a new "carbon positive" architecture that builds with the carbon enticed from sky. We are in technological reach, within a generation, of a global construction industry that is not only "Net Zero," generating more energy than it needs to operate, but in its materials pulls more carbon out of the air than it puts up. We can reverse the emissions engine that construction now is.

The materials of architecture are not the only component of climate-friendly design, much less of climate work writ large. But we do want to make clear that carbon sequestering architecture is an essential component among the many emerging technologies and strategies for climate *cooling*, from energy to transportation to agriculture to waste management to water. In particular, we have a keen eye on agronomy and the study of soils, and all the gazillions of amazing little creatures therein, for it's starting to look like that's where we will find real wealth and the wisdom to grow food, clothing, and shelter in fantastic, lovely, and healthy new ways — not to mention sequester stupendous amounts of carbon.

It's a whole new and lovely, not to mention essential, ball game. Most of this article was written before the COVID-19 pandemic of 2020, and is here being amended from the middle of the worldwide lockdown of March/April, when we don't know how bad the damage will be to people or economy, not to mention political freedoms or stability. By the time you are reading this, you know more about that than anyone knows now. But one thing is certain: COVID-19 will run its course while the climate keeps cooking to the detriment of every human being and most every other living creature on Earth. The task before us is clear and will be with us for our lifetimes even as other emergencies, no matter how large or compelling, come and go. We are each called from our own personal stories to take an active part in the unfolding of the global story of humanity. It's one hell of a time to be alive!

A word about "Carbon"

I know you believe you understand
what you think I said
but I'm not sure you realize
what you heard is not what I meant.
—Richard Nixon

Carbon. It's a good thing. Right up there, Number 6 in the periodic table, and one of the most common elements on Earth. Carbon is here because a very, very long time ago uncounted millions of first-generation stars created it by nuclear fusion in their cores, then offered it by supernova explosion to the universe. Along with all sorts of other elemental fusion dust, it floated around, eventually to condense by gravity into planets and the world we know. And, as many have noted, it is the party animal of elements: it loves to bond with things like nitrogen, iron, hydrogen, and oxygen to make all sorts of interesting delights such as giraffes, redwood trees, poodles, and you. You read these words with carbon eyes, and hold this book with carbon hands. Please enjoy; not every blob of stardust gets to be conscious for a brief few moments under the sun and run around on a lovely planet with all sorts of other delightful carbon blobs. Congratulations, you lucky dog!

Carbon is a good thing, but too much of anything in the wrong place becomes pollution, or even poison. A new carbon architecture is but part of the effort to reverse the increase of gaseous carbon in the air, which is disrupting the climate in ways that we can't fully predict, and so far mostly don't like. So we enthusiastically join the growing conversation for climate solutions, but must first be clear about the terms we use. *Carbon* is bandied around a lot, but people often mean slightly different things by it.

Carbon and carbon dioxide (CO_2), for example, are two different things, though they get interchanged quite a lot in climate conversations. The fraction of carbon in carbon dioxide is the ratio of weights: the atomic weight of carbon is 12 atomic mass units, while the weight of carbon dioxide is 44 because it includes two oxygen atoms that each weigh 16.

You switch from one to the other with this formula: one ton of carbon is equivalent to 44/12 = 3.67 tons of carbon dioxide. (Methane, or CH_4, another major greenhouse gas with 86 times the warming potential of CO_2, has an atomic weight of 16, so the ratio is less pronounced: a ton of carbon in your building equals 16/12 = 1.33 tons of methane in the air.) Plants like straw (about 35-50 percent carbon) or softwoods (about 50 percent carbon) *sequester* (that is, durably store) carbon by absorbing carbon dioxide and releasing the oxygen.

They feed us oxygen with their respiration, and we oxygen-breathing creatures feed them CO_2 with our respiration. Cool deal, huh? A ton of carbon in the forest or field — or as part of a building — represents or simply is 3.67 tons of carbon dioxide absorbed from the air.

Also, following convention, we sometimes use CO_2e to denote carbon-*equivalent* emissions from carbon and other gases such as methane, calibrated according to each one's *global warming potential* (GWP) because some gases have ten or a hundred or even thousands of times the heat-trapping effect of carbon dioxide.

Finally: *embodied energy* and *embodied carbon*. Be warned that terms like *zero energy* (aka ZE), *net zero energy* (aka NZE), *zero net energy* (ZNE) are all increasingly tossed about in loosely interchangeable ways in conversation around building energy efficiency. Even more confusing, their close cousins *zero carbon* and *zero net carbon* are also appearing more frequently. This is a rather complex matter in itself, as terms change meaning with scale (product, building, community, nation, or globe?), with grid efficiency (coal, hydro, nuclear, wind? etc.), time frame (daily, annualized, or lifetime?), and other factors. Generally, those terms move in tandem; that is, though the units for measurement are different, they rise or fall roughly in parallel. (Sometimes they do diverge, as when products are manufactured with electricity from a coal-dependent grid vs. a hydropowered grid.) The growing consensus is that zero carbon (vs. zero energy) should be our societal goal across all industry, and so we must develop a *carbon positive architecture* defined by more carbon sequestered than is ever emitted.

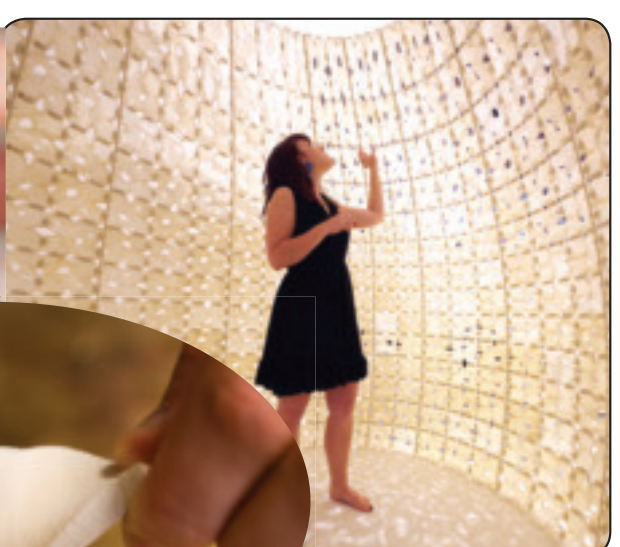
A few thoughts on carbon, written by a lump of carbon for other lumps of carbon, on how to build carbon shelter to protect us from a sometimes hostile carbon planet.

Shall we dance?

Excerpted from "The New Carbon Architecture" *by Bruce King, New Society Publishers, 2017. A registered structural engineer with 30 years of private consulting experience and 25 years of leadership in the green building movement, Bruce has served as a Green/Clean Tech advisor to numerous startups, worked on high-rise structures in San Francisco, and passive solar designs all over the world. He has lectured and taught ecological building practices in international settings and is co-founder and Director of Ecological Building Network (EBNet) a non-profit coalition of engineers, builders, and architects developing and disseminating best technologies for the built environment He is also co-founder of Green Building Press, a small publishing enterprise and author of three books.*

(Above)
bioMASON makes bricks using only enzymes from natural bacteria. Image courtesy of bioMASON.

(Right)
Flexibility of Ecovative mushroom insulation. Image courtesy of Ecovative.



(Above)
"Saltygloo" – an igloo made of 3-D printed salt. Image courtesy of Rael-San Fratello Architects.