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Celebrating Our 25th Year

VOCs: Why They're Still Here and What You Can Do About It

"Sick building syndrome" was one of the first problems the green building community tried to solve. We've come a long way, but we're not done yet.

by Paula Melton

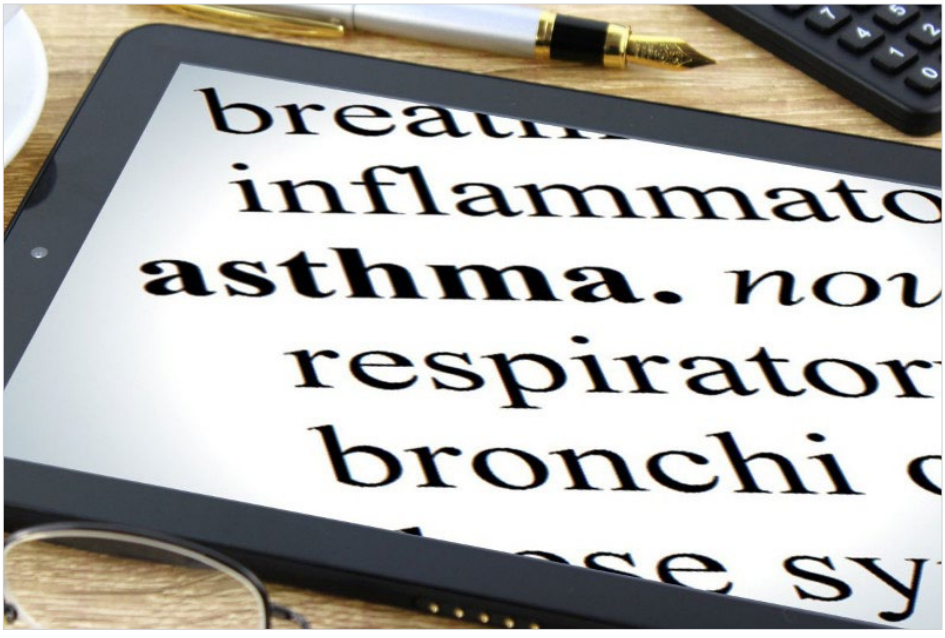
Chalk one up for Team Green. Zero-VOC paints and low-emitting commercial carpets and workstations are now mainstream. We won!

Try telling that to the proud owners of green buildings that turn out to have indoor air quality (IAQ) problems.

After the post-construction flush-out, VOC levels sometimes "start to skyrocket," according to Ryan Dick, founder and COO of Global Innovations Green Algorithms (GIGA). The firm's cloud-based RESET program tracks real-time concentrations of VOCs, particulates, and carbon dioxide in buildings around the world. The results aren't always pretty.

"Building tightness works to the disservice of air quality," Dick told BuildingGreen. "Sealing is good thing, but it allows VOCs to accumulate and not dissipate. Even low-emitting materials will accumulate over time." He continued, "The HVAC system often can't keep up. Day after day, VOCs will accrue as materials continue to offgas. It may never be at a healthy limit."

But wait. Is what GIGA considers a "healthy limit" for total VOCs even based on science?



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Toxicologists, independent labs, industrial hygienists, engineers, certifiers, and other experts on IAQ still have bitter arguments about which VOC metrics matter, which testing protocols work, and which labels actually mean something.

At the same time, in the midst of ever-building demand for greater transparency about *all* the compounds that go into a building product, exposure to VOCs has become almost an afterthought. Many people assume, incorrectly, that this problem has already been solved.

What's a building professional to do? In this special issue, we look at these frequently asked questions:

- Do VOC tests actually limit the most relevant compounds?
- Which is the best VOC label to look for when selecting products?
- Do the approaches in LEED, the Living Building Challenge, and WELL really improve IAQ?
- Why isn't "zero VOC" enough for LEED anymore?
- What's actually wrong with formaldehyde?
- How much do VOC emissions matter in the whole IAQ picture?

In the process, we are probably going to take you out of your comfort zone. But we hope by the end you'll have a much clearer idea of how to prioritize your material selections and design choices to optimize IAQ.

Take a deep breath. Let's get started.

FEATURE SHORTS

How to Get from VOC Certifications to Better Products

The FDA regulates flies in our soup, but no one regulates VOCs in our indoor air. Somehow that's a designer's job to figure out.

by Paula Melton

Every couple years, a revolting list of "food defects" allowed by the U.S. Food and Drug Administration (FDA) hits the Internet, with stats like these:

- Allowable rodent filth in apple butter: 4 or more hairs per 100 grams
- Allowable insects in canned mushrooms: Average of over 20 or more maggots of any size per 100 grams (drained)
- Allowable parasites in red fish and ocean perch: 3% of fillets contain 1 or more copepods accompanied by pus pockets

For some reason, stats like the allowable Dimethylformamide (N,N-) concentration in indoor air based on CDPH Standard Method v1.1 (40 µg/m^3) don't have listicles written about them. They might not sound as gross, but volatile organic compounds (VOCs) like this one are far worse for us than eating maggots.

The Law Didn't Win

There are almost no regulations in the U.S. or Canada controlling VOC emissions from building products, furniture, or consumer items (the exception to this is formaldehyde emissions from composite wood).

Really? Then what do you call the California Department of Health Standard Method for the Testing and Evaluation of Volatile Organic Chemical Emissions from Indoor Sources Using Environment Chambers Version 1.1?

Let's get REL

Some people call it Section 01350, but no one calls the CDPH Standard Method a law—not even in California.

This testing and evaluation method is a science-backed but imperfect standard that underlies a whole set of wildly confusing indoor air quality (IAQ) programs and labels for commercial building products. Much like the FDA's handbook of allowable levels of rodent filth, insects, and parasites in our food, the CDPH Standard Method sets allowable levels of a variety of chemicals in our indoor air.

To do this, it benchmarks against the *chronic reference exposure level*, or CREL, for 35 VOCs identified as non-carcinogenic health hazards by the California Environmental Protection Agency's Office of Environmental Health Hazard Assessment (OEHHA).

These CRELs are based on toxicological testing indicating adverse reactions to VOCs ranging from eye irritation to liver, endocrine, developmental, or reproductive effects. In other words, the tests try to account for pretty much everything but elevated cancer risk, which is covered in California under Proposition 65 and is not taken into account in this particular program (see The Questionable Science Behind VOC Emissions Testing). As a precautionary measure, the CRELs are cut in half for the CDPH Standard Method—the main idea being that multiple VOCs may be emitting from products, with unknown health consequences from the combination of chemicals, so we probably want to reduce our overall exposure to each one.

Though it's not part of any laws, the method is a widely accepted standard in North America and is referenced by voluntary building rating systems as well as a number of voluntary IAQ certifications (see our table for a sampling of the major ones).

It's important to note that VOC emissions testing and labels are completely separate from labels

Confused by all the labels? Read our guide to finding and using credible VOC product labels.

regulating the VOC *content* of wet-applied products like coatings and adhesives. Content-regulating programs don't address human health effects from VOCs, and they are not meant to control concentrations in indoor air. They are designed to prevent smog formation in outdoor air. We discuss these programs in greater depth in Why "Zero VOC" Was Never Enough.

Easing Your Label Pains

Most of the major certifications and labels reference the CDPH Standard Method, accepting both its testing protocols and its allowable concentrations of the 35 target compounds. But the only label that strictly follows the CDPH method is Indoor Advantage Gold.

As you can see in the table, some programs make product-specific modifications. There are also fairly significant differences between CDPH method and the Greenguard and Cradle to Cradle methodologies.

Floorcoverings

For hard-surface flooring products (as opposed to carpet), FloorScore is almost identical to Indoor Advantage Gold—except that for adhesives, the program adds a VOC content requirement. This addition means FloorScore-certified products automatically align with the LEED v4 Low-Emitting Materials credit. This credit requires wet-applied products to meet criteria for both VOC emissions and VOC content (see VOCs

VOC Emissions from Products: Some Major Programs & Labels

Program	Developer	Product Types	What It Covers	Relationship to CDPH Standard Method v1.1	Programs That Recognize This Label
BIFMA Level	Business and Institutional Furniture Manufacturers Association (BIFMA)	Commercial Office furniture	Multi-attribute standard and certification looking at many sustainability aspects of furnishings Emissions testing credit 7.6.1 screens against allowable levels of 4 sets of compounds: formaldehyde, total VOCs, total aldehydes, 4-Phenylcyclohexene Emissions testing credit 7.6.2 screens against allowable levels of 34 compounds from CDPH Standard Method (slightly higher formaldehyde level permitted) Emissions testing credit 7.6.3 screens against allowable formaldehyde level from CDPH Standard Method	Some credits incorporate CDPH benchmarks Associated testing protocol is referenced in CDPH Standard Method for workstation emissions in open-plan offices (ANSI/BIFMA M7.1)	BuildingGreen Approved (Level 3 only) Collaborative for High-Performance Schools LEED WELL **These programs reference the BIFMA M7.1 testing protocol:** CDPH Standard Method v1.1 Cradle to Cradle **These programs reference both the BIFMA M7.1 testing protocol and the X7.1 emissions allowances:** Greenguard Greenguard Gold Indoor Advantage Gold–Furniture
Cradle to Cradle	Cradle to Cradle Products Innovation Institute (C2CPII)	Any product	Multi-attribute standard covering many sustainability aspects of commercial and consumer products Permits a variety of VOC testing methods A variety of hazardous compounds must not be detectable above background levels Limit on total VOCs	References CDPH Standard Method as primary testing and screening method, but allows others Requires addition of product-specific target compounds if not covered by CDPH 7-day test instead of 14	BuildingGreen Approved (Gold or Platinum only) LEED (for material credits, not Low-Emitting Materials)
FloorScore	Resilient Flooring Covering Institute (RFCI) with SCS Global Services	Hard-surface flooring and flooring adhesives	Screens against allowable levels of 35 compounds from CDPH Standard Method Must pass CDPH for both classroom and office scenarios Tests VOC content of adhesives against SCAQMD Rule 1168	Exactly the same for emissions testing Adds content testing for adhesives only	BuildingGreen Approved (must also meet other requirements) Green Globes LEED Living Building Challenge
Greenguard	UL	Most building products and furniture	Screens against threshold limit value (TLV) of 100+ compounds considered occupational hazardous by the American Conference of Governmental Industrial Hygienists; allowable concentration is 1/100 the TLV Additional limits on formaldehyde, total aldehydes, styrene, total VOCs, particulates	Roughly follows CDPH testing protocol but requires that products pass at 7 days Screens against unique list of target chemicals	LEED (accepted for furniture only)
Greenguard Gold	UL	Most building products and furniture	Screens against allowable levels of 35 compounds from CDPH Standard Method Screens against threshold limit value (TLV) of 100+ compounds considered occupational hazardous by the American Conference of Governmental Industrial Hygienists; allowable concentration is 1/100 the TLV Limit on total VOCs	Incorporates ½ CREL benchmark and roughly follows CDPH testing protocol, with some exceptions Adds its own list of target chemicals and allowable limits Adds total VOC requirement: TVOC emissions must be below 500 µg/m^3	BuildingGreen Approved (for products not covered by FloorScore or Green Label Plus) Green Globes LEED Living Building Challenge
Green Label Plus	Carpet & Rug Institute (CRI)	Carpet, carpet adhesive, carpet cushion	Screens against allowable levels of 35 compounds from CDPH Standard Method Screens against additional compounds: 6 for carpet, 2 for carpet cushion, and 7 for adhesives	Exactly the same testing protocol for emissions testing Must meet all ½ CREL benchmarks Screens for allowable levels of additional product-specific chemicals	Green Globes LEED NSF 140
Indoor Advantage Gold	SCS Global Services	Most building products and furniture except products covered by FloorScore	Screens against allowable levels of 35 compounds from CDPH Standard Method Includes onsite audits of manufacturing facilities and third-party testing labs	Exactly the same: a third-party certification that a product has met CDPH Standard Method for its product category, for private office or classroom scenarios (scenarios are listed on the certificate)	BuildingGreen Approved (for products not covered by FloorScore or Green Label Plus) Green Globes LEED Living Building Challenge

Source: BuildingGreen, Inc.

in LEED v4 and Other Rating Systems and Why "Zero VOC" Was Never Enough).

For carpet, Green Label Plus adheres to the CDPH Standard Method, for the most part, but it's designed to be more protective. The Carpet and Rug Institute (CRI) has worked with the Green Label Plus certifying body, UL, to identify a group of compounds that are commonly emitted from carpet products but aren't benchmarked in the CDPH Standard Method. (Under CDPH rules, labs must identify all the measurable VOCs, but in order to pass the CDPH Standard Method, the product only needs to meet benchmarks for these 35.) So Green Label Plus has a list of 12 extra allowable VOC levels to benchmark against in addition to the 35 target VOCs from the CDPH Standard Method.

CRI worked with NSF International on a multi-attribute standard, NSF 140, that incorporates the Green Label Plus certification. Many manufacturers go for the full sustainability label rather than just trying to achieve Green Label Plus, which only covers VOC emissions.

BuildingGreen's take

Look for hard-surface flooring products that meet FloorScore in addition to other sustainability benchmarks. The exception is rubber flooring; here, look for Greenguard Gold.

For carpet, Green Label Plus is acceptable if you're only considering emissions, but we look to NSF 140 Platinum for overall carpet sustainability, including IAQ.

Furniture

Emissions testing is just a small portion of what the BIFMA Level certification measures. It's actually an extensive multi-attribute standard for commercial furnishings.

When it comes to VOC emissions testing, Level is its own animal with its own standards for both the testing methods and the target compounds (of which there are only four sets). One credit in Level offers a point for hitting the benchmarks for those four sets of compounds (see table).

Another credit offers a point for hitting the benchmarks for all 35 chemicals from the CDPH Standard Method—with the exception of formaldehyde, which has a slightly higher allowable concentration in Level. Products that hit the very low benchmark for formaldehyde in the CDPH Standard Method get to add a third point. (We sort out the formaldehyde mess over at The Questionable Science Behind VOC Emissions Testing).

BuildingGreen's take

Choose products that are certified at Level 3 or have at least earned all three Low-Emitting Furniture points. The Indoor Advantage Gold–Furniture certificate verifies that a product has met the BIFMA standard just for VOC emissions.

Cradle to Cradle

Cradle to Cradle (C2C) is also an extensive multi-attribute program of which VOC emissions are a relatively small part. Although it references the CDPH Standard Method, it also allows other testing methods (including BIFMA's test method and various protocols used in Europe).

C2C requires products to meet its own unique VOC requirements in order to hit the Gold or Platinum level of certification. In this system, any VOC that is a known carcinogen, endocrine disruptor, mutagen, reproductive toxicant, or teratogen must not be emitted from the product above "detectable levels"—which means that the amount of that chemical in the testing chamber after seven days shouldn't be above what's considered a normal background level in ambient indoor air.

Additionally in C2C, total VOC emissions must not exceed 500 $\mu g/m^3$.

BuildingGreen's take

We like C2C Gold or Platinum certification as a multi-attribute standard, in part for its treatment of VOC emissions. The most similar emissions-only standard is Greenguard Gold.

Greenguard Gold

Like C2C, Greenguard Gold has a fairly extensive list of unique requirements. Unlike C2C, it's not a multi-attribute standard, so its differences stand out more.

Greenguard Gold is designed to harmonize, in part, with CDPH Standard Method v1.1. The testing protocols are similar, and Greenguard Gold benchmarks against the 35 target chemicals listed there. But in addition to those 35 compounds, products must also fall below emission limits for a long list of chemicals identified as occupational hazards by the American Conference of Governmental Industrial Hygienists (ACGIH).

The ACGIH list establishes threshold limit values (TLVs) for healthy workers who are exposed to manufacturing chemicals at work for eight hours a day—not for sensitive individuals exposed to these same chemicals in their homes 24/7/365. So to be more protective, the Greenguard Gold program cuts the allowable exposure down to 1% of the ACGIH occupational TLV.

For Greenguard Gold, total VOC emissions also must not exceed 220 $\mu g/m^3$.

BuildingGreen's take

We rely on both Indoor Advantage Gold and Greenguard Gold for product categories where VOC emissions are a relevant sustainability measure. Greenguard Gold has a more precautionary approach.

Flies in the Soup

All these programs have merit, and we reference them all in different ways (depending on their relevance to a particular product category) in our

BuildingGreen Approved program. But wouldn't it all be easier if the industry could reach consensus about which methods to use and which chemicals to screen for?

In short, yes—and there is a standard in the works that would do just that. However, the creation of this ANSI standard, NSF/UL 440, began in January 2012, and little obvious progress has been made. So far, the committee has accepted CDPH Standard Method v1.1 as its baseline and managed to agree on little else.

In moving forward with development of the standard, a variety of historical arguments, some of them bitter, will need to be resolved. But many sources told BuildingGreen that work is moving forward in earnest. According to Jessica Evans, director of standards development at NSF International, the groups hope to release a complete public comment draft of NSF/UL 440 by the end of 2017.

The Questionable Science Behind VOC Emissions Testing

We need the protection that product VOC testing provides, but it's far from the last word on human health in buildings.

by Paula Melton

For more than four years, groups in the U.S. have been struggling to reach consensus on how to measure VOC emissions from products and establish protective VOC limits based on sound science. The standard, which may someday be finished, is called NSF/UL 440.

What's taking so long?

It turns out that human toxicology and human politics are both very complicated.

Here we'll take a look—from a scientific perspective—at four major limitations of current VOC emissions standards, primarily CDPH Standard Method v1.1 and UL's Greenguard standard. We also sort through all that science from a building professional's perspective and provide clear guidance on sensible approaches for building projects.

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VOC emissions testing is important, but it is one small step toward better IAQ.

From Test Chambers to Buildings

- All models are wrong, but VOC testing and evaluation are useful.
- Lab tests don't necessarily translate into real-world performance, factoring in things like temperature and humidity—because that's not their job.
- CDPH is a good system for apples-to-apples screening of products for VOC emissions.

1. The Lab Isn't the Real World

In order to be tested, product samples are collected, sealed, and shipped to a lab, where they are placed in a laboratory chamber for 14 days. The volatile compounds that the product releases are then measured using gas chromatography and mass spectrometry. (This process is described in more detail in our primer on the CDPH Standard Method.)

Those results are run through computer models that take into account the typical temperature, humidity, and other conditions in an office, a school classroom, and (optionally) an average California home. Although all the conditions are very tightly controlled, critics and supporters alike have identified imperfections in the science behind the CDPH Standard Method process—starting with how the testing and modeling work.

Only analyzes samples

Although CDPH Standard Method v1.1 describes how to conduct third-party testing and provide third-party certifications, ultimately it's up to the manufacturer to choose representative samples from the production line and prepare them properly.

This leaves some room for errors—as well as some potential for outright fraud. It's happened: an unscrupulous manufacturer that wants to cheat can simply label the products falsely, as makers of Lumber Liquidators laminate flooring in China were caught doing in early 2016.

Certification programs include quality-control audits of the manufacturing plant, though, and it's probably fair to say that most samples are representative. Production conditions can change with weather, hiring of trainees, or changes in the supply chain, though, which throws another possible wrench into the system. "Latex-backed carpet emissions will vary depending on the temperature and humidity in the factory," for example, explains Hal Levin, a former scientist in the Indoor Environment Department at Lawrence Berkeley National Laboratory. That's because it takes the backings longer to cure on some days than others, and on occasion they don't fully cure at all.

Something similar can occur on the jobsite. That's what happened in an office investigated in 2011 by the National Institute for Occupational Safety and Health (NIOSH). Occupants complained of headaches, nausea, and respiratory irritation—classic signs of "sick building syndrome." NIOSH investigators discovered uncured carpet adhesive that had been offgassing into the space for more than three years.

Before being placed into a test chamber for four days, a representative sample of this adhesive would have had ten days to

"condition"—plenty of opportunity to cure properly. In the real world, "incomplete curing of the carpet adhesive can happen when the concrete slab onto which the carpet was installed had excessive alkalinity and water vapor," the investigators wrote.

Doesn't account for all indoor conditions

Models used in the CDPH Standard Method to predict indoor air concentrations of certain chemicals are just that—models. They allow comparison of products on a level playing field under fairly typical conditions. But they don't represent real-world interiors, where temperature, humidity, pressure, and other factors may be atypical.

The method itself can only do so much of the heavy lifting, though. Raja Tannous, co-founder and laboratory director at testing lab Berkeley Analytical, told BuildingGreen, "Building managers and operators need to be trained on these things." If the HVAC system is performing poorly, for example, "the concentration of these VOCs is going to go up. You can't blame the standard for not functioning in extreme situations."

"For a simple approach, [CDPH Standard Method] is a good approach," added Eric Rosenblum, Ph.D., an independent, board-certified toxicologist. "You have a product, and it offgases, and the gas spreads evenly throughout the environment. It doesn't decay; it doesn't stick to anything." Given what we know about fluid dynamics and the nature of VOCs, that's not realistic, but "a simple model is great; it gives you this kind of first pass. It's a method of saying this product is better than that product as far as VOCs go."

Top Ten Chemicals Emitted from Furniture

The Greenguard Gold certification establishes limits for a long list of compounds beyond those targeted in CDPH Standard Method v1.1. This table shows the ten VOCs that UL has found in the most products during its testing of furniture. The CDPH standard does not limit any of them. Greenguard limits those that are occupational hazards. The top ten compounds are published with permission from UL.

Compounds in Order by Frequency of Detection	CAS-RN	Hazard	Greenguard Gold Concentration Limit
Pinene, α (2,6,6- Trimethyl-bicyclo[3.1.1]hept-2-ene)	80-56-8	Acute occupational eye, skin, and respiratory irritant	1,120 µg/m^3
Ethanol, 2-butoxy	111-76-2	Acute occupational hazard, associated with nausea, headaches, and eye and nose irritation	970 µg/m^3
Dodecane	112-40-3	Odorant (not considered hazardous)	–
1-Hexanol, 2-ethyl	104-76-7	Odorant (not considered hazardous)	
Limonene (Dipentene; 1-Methyl-4-(1- methylethyl)cyclohexene)	138-86-3	Odorant (not considered hazardous)	
Cyclopentasiloxane, decamethyl	541-02-6	Not considered hazardous	
Undecane	1120-21-4	Odorant (not considered hazardous)	
Acetate, butyl	123-86-4	Acute occupational neurotoxicant and eye and mucus membrane irritant	7,130 µg/m^3
1-Butanol (N-Butyl alcohol)	71-36-3	Acute occupational neurotoxicant and eye, nose, skin, and respiratory irritant	610 µg/m^3
Longifolene	475-20-7	Not considered hazardous	–

Source: UL 2821, Greenguard Certification Program Method for Measuring and Evaluating Chemical Emissions From Building Materials, Finishes and Furnishings

2. There's an Abundance of Precaution (or Not Enough)

The CDPH Standard Method does build certain precautions into its modeling, though, Tannous pointed out.

For example, in schools it is typical to reduce ventilation levels during the night and resume normal ventilation in the morning. Instead of using ASHRAE's suggested minimum ventilation level during occupied hours, the classroom scenario averages the minimum required ventilation levels during occupied and non-occupied hours, Tannous explained. "It is fairly conservative."

Designers looking for the lowest-emitting products can use this information to help inform their choices: the classroom scenario is more stringent than the office scenario. The optional residential scenario is even more stringent because it assumes very poor ventilation and 24/7 exposure.

Too conservative?

In fact, the residential scenario has been criticized for being unattainable, and detractors have spoken out against other precautionary aspects of the CDPH Standard Method. The methods used in UL's Greenguard program (see below) are even more conservative and are sometimes criticized for that as well—while others praise it for being precautionary.

Still others think neither one does a good enough job of accounting for the tens of thousands of VOCs that have unknown health effects.

The business of assessing exposure risk is a very tricky one and quite difficult to standardize, explains Rosenblum (see Chemical Risk Assessment Comes to LEED v4). The underlying assumptions are everything, and results will differ significantly based on a number factors, like whether you include "babies and grandmas" in your population, as he puts it. There's also dose, frequency, and duration. "If you drink one bottle of wine a year, the effect on your body is going to be different than one bottle of wine every day … or every hour," he said. "There is going to be variation in the published safety thresholds because they are addressing different exposure scenarios."

The CDPH Standard Method builds in certain other precautionary measures based on uncertainty about dose and frequency. Although the State of California thinks it's pretty safe to breathe air that has 60 $\mu g/m^3$ of benzene in it, the allowable emissions from a single product in the CDPH Standard Method is 30 $\mu g/m^3$. California's *chronic reference exposure levels* (CRELs) are all cut in half in this way to establish the emissions limits (with the exception of formaldehyde—see below).

That's to help make up for the fact that the product in question might not be the only product in the room emitting that same chemical. Also, no one knows what happens when we breathe in otherwise acceptable levels of benzene, chlorobenzene, ethylbenzene, and styrene (all VOCs with CRELs) at once, so halving the allowable level helps take care of that as well.

"That's not science-based," said Rosenblum. "It's an uncertainty factor that's arbitrarily stuck in there."

But even though Rosenblum is a scientist, he doesn't really have a problem with that. "Science doesn't dictate a single-point truth. It just suggests a trend," he told BuildingGreen. "I can understand, if someone just barely doesn't pass, they will say it's just some arbitrary decision to divide by one-half," he continued—though not with much sympathy. "There's uncertainty in everything. You just have to draw a line in the sand."

The problem of regrettable substitutions

Meanwhile, over at UL, the owners of the Greenguard standard think the CDPH Standard Method is not nearly protective enough—primarily because its list of target chemicals is too short.

"There are 140,000 chemicals used in commerce," said Scott Steady, product manager at UL. "There are 10,000 emitting from products." But just 350 VOCs have *threshold limit values* (TLVs—an allowable concentration set by the American Conference of Governmental Industrial Hygienists) because they are known occupational hazards. And there are just 35 target chemicals listed in the CDPH Standard Method. "A lot of people saw the list and said, 'This looks good! I'll put whatever I want in the bucket" as long as it's not one of those 35. "The list doesn't line up with what's emitted from products. That's the fatal flaw."

To deal with this issue, the Greenguard program starts with the CDPH target chemicals but then adds its own long list of compounds that have TLVs. Much like the CDPH method does with CRELs, the program takes these TLVs and cuts them all by an arbitrary amount. Allowable concentrations are 1% of the TLV for that chemical.

Though intended to be precautionary, the program gets the side-eye from many in the industry who don't appreciate that it's proprietary and not developed through consensus. (The CDPH Standard Method is developed openly by a government agency and is available for free.) "Their exposure scenarios and their somewhat arbitrary criteria have never been broadly vetted by any scientific body," said Jan Stensland, principal at Inside Matters and one of the original participants in the creation of the Section 01350 specification that eventually became the CDPH Standard Method.

Tom Lent, policy director at the Healthy Building Network, has a different take. "I think the TLVs are often woefully inadequate as long-term exposure standards, even at one one-hundredth," Lent wrote to BuildingGreen. Greenguard's approach, he argued, is better than nothing. But is it "fully protective of human health?" he asked. "Highly unlikely."

Lent claims the CDPH Standard Method "has sparked lots of improvements in products," but he points out that its list of target chemicals was developed more than ten years ago. "It may well not be at all reflective of what is emitting from interior finishes now, after a decade of CDPH-driven substitutions and other formulation changes."

For his part, Steady points to historical data from years of furniture testing in the Air Quality Sciences (AQS) lab that UL now owns. There are very few chemicals in common between these actual emissions and what's covered in CDPH, he told BuildingGreen (see table). Although they are only furniture emissions, Steady argued, "These chemicals are also likely

Common-Sense Precautions

- The CDPH list of target chemicals is backed by extensive toxicological research, but even the developers of the method say the list needs updating. To better evaluate the hazards that may be present, reference ingredient disclosures or choose a target like BIFMA Level 3 for office furniture or Cradle to Cradle Gold for other product categories (see How to Get from Certifications to Better Products).
- TVOC numbers are not a health indicator, but they are an opportunity for dialogue. If they're high, ask why.
- Greenguard Gold uses an extremely precautionary approach—which is either deeply flawed or desperately needed, depending on your perspective. Consider it for certain product types (like rubber flooring) or for buildings with sensitive populations. (See How to Get from Certifications to Better Products.)

Photo: Greg Henshall / FEMA. License: Public domain.

Emergency housing like this, provided by the Federal Emergency Management Agency after Hurricane Katrina, led to widespread health complaints. The mobile homes had elevated levels of formaldehyde, leading to increased U.S. government scrutiny of the compound. But the science behind formaldehyde's health effects still confounds scientists.

representative of chemicals for building products since there is a lot of overlap between laminates, adhesives, composite wood, coatings, insulation, etc. used in the building product and office furniture industries."

That's in part because the CDPH standard takes time and resources to maintain, and efforts to update it have reportedly stalled. In contrast, Steady praised the German Institute for Building Technology (DIBt) for the process it uses to develop *lowest concentrations of interest* (LCIs—analogous to CRELs in the CDPH method) for the AgBB testing framework used in Europe. AgBB limits the combined VOC level for chemicals that don't have established LCIs.

Steady claimed that if manufacturers fail because of these unknowns, they can approach DIBt to request a toxicological review of the compounds that put them over the threshold. This helps DIBt build its list of target chemicals quickly while also ensuring they are relevant emissions to track because they come from actual products. Though UL would like this approach to be part of NSF/UL 440, it could be a hard sell with so many different stakeholders involved, he said.

Total VOCs: Total BS?

Other systems—including Greenguard—don't have that flexible approach, so they use total VOC (TVOC) as a proxy to capture unknowns.

The CDPH Standard Method requires that the lab measure TVOC and report it to manufacturers, but it places no limitation on the number. In fact, the standard calls TVOC "a semi-quantitative measure" because of its poor accuracy as an indicator of health impacts.

"TVOC is useful if you're not going to do the next level of individual VOC testing," said Nicole Munoz, operations manager at SCS Global, which owns the Indoor Advantage Gold standard. "If you have a very high TVOC number, you have to go back to individual VOC testing to really get an idea of what compounds are coming off the product. For a health concern, individual VOC testing is the only way to go."

Steady agrees with that, to a point, saying that not all VOCs are equal. Many of Greenguard's top ten VOCs, like alpha-pinene and limonene, are generally considered harmless (see table)—yet they do show up in TVOC testing, and Greenguard sets a limit on TVOC (220 $\mu g/m^3$) in part because these VOCs can cause nuisance odors, affecting occupant comfort.

LEED v4's Low-Emitting Materials credit newly requires disclosure of TVOC levels, but it does not set a limit. "It's just a marker," said Michelle Halle Stern, AIA, P.E., a former LEED technical committee member. "If I have this range and it's really, really high on this product and it's really, really low on that product, I think that might tell me something."

The Living Building Challenge (LBC), the WELL Building Standard, and the Indoor Air Quality Assessment credit in LEED v4 all set an onsite TVOC benchmark of 500 $\mu g/m^3$.

3. There's "No Safe Level" of a Chemical We Make in Our Own Bodies

Nowhere is a precautionary approach to VOC limits more hotly debated than on the issue of formaldehyde. The topic is more inflammatory than the substance itself.

"There is no safe threshold at which we will have no cancer cases," Lent told BuildingGreen, citing findings from the State of California. "Just say no."

Randal Carter, manager of global codes and approvals at Steelcase, disagreed. While praising the extremely low target level in the CDPH Standard Method (9 $\mu g/m^3$) as "a great, tough target," he also opined, "I don't like it when some person or group has a phobia about one specific thing, and they want to minimize that thing beyond all reason." Especially, he added, when it's a compound like formaldehyde—which we produce in our bodies and which occurs naturally in plants (and thus in wood products).

It's not about cancer

Although formaldehyde has been deemed a known human carcinogen, its presence on the CDPH list of target chemicals is not about cancer; it has a very low CREL because of respiratory symptoms at low indoor air concentrations.

Formaldehyde is a known occupational asthmagen (meaning that healthy workers exposed to it can become sensitized and develop asthma as a result), but its potential effects in more typical, everyday exposure is less well understood. A 2010 literature review by the National Institute of Environmental Health Sciences concluded, "There is limited or suggestive evidence of an association between [non-occupational] formaldehyde exposure and exacerbation of asthma, in particular through enhanced response to other allergens."

Formaldehyde: What to Do?

- To help protect occupants from indoor formaldehyde exposure, specify and install wood products that comply with CDPH Standard Method v1.1 for formaldehyde emissions.
- No-added-formaldehyde (NAF) products are often made with polyurethane binders that are potent occupational asthmagens. Shifting the respiratory risks to factory workers is not a sustainable solution.
- Avoid products made with urea formaldehyde (see our primer on formaldehyde in composite wood products to understand why).
- Ban smoking in or near buildings, and avoid cleaning products that contain formaldehyde.

But the evidence doesn't have to be conclusive for some groups to take action. Eric Rosenblum explained how California's Office of Environmental Health Hazard Assessment (OEHHA) develops its exposure limits. "They take the lowest level of effect [on animals] and then divide by uncertainty numbers." These factors account for the difference between humans and the tested species, for example, and for effects on sensitive subpopulations. These are "over-protective" on purpose, he told BuildingGreen.

Formaldehyde has such a low CREL that it's not feasible to cut it in half for the CDPH Standard Method, as the method does with other VOCs. That's because 4.5 $\mu g/m^3$ would be below the margin of error in detection limits due to formaldehyde's extreme volatility.

But it's still a carcinogen

The extreme volatility of formaldehyde is also why it's best known for causing nasopharyngeal cancer rather than, say, lung cancer, Rosenblum explained. "What tends to happen is that formaldehyde doesn't really make it very far down your inhalation pathway opening," he said.

Tobacco smoke is one of the most common sources of indoor formaldehyde. While specifying low-emitting materials is crucial, remember the importance of ongoing emissions sources as well.

Rosenblum also offered an explanation for why, even when looking at the exact same research, some groups advocate for a zero-formaldehyde approach while others push for de-listing formaldehyde as a human carcinogen due to uncertainty.

"There are different ways cancer can occur," Rosenblum said—and no one's sure how formaldehyde has its effect. One mechanism would be by affecting your DNA directly, causing identical mutations when the cells reproduce. That's where "no safe level" comes in: a single molecule can start this chain reaction of mutations.

Another mechanism would be through "destruction of tissue in the nasal passages," Rosenblum continued, which increases cancer risk because "every time [a cell] divides, there's a chance that it will reproduce incorrectly. That's not a genetic mechanism; it's a cell turnover mechanism."

In other words, the irritation we're trying to prevent could be at the root of the elevated cancer risk as well.

Government agencies in the U.S. and around the globe disagree about what should be considered a safe indoor level of formaldehyde, but an exhaustive 2011 review of studies on formaldehyde's major health effects recommended 100 ppb as a way to "protect even particularly susceptible individuals from both irritation effects and any potential cancer hazard."

Unfortunately, while the green building community has focused on emissions from composite wood, there remain many ongoing sources of formaldehyde, including cigarette smoke, personal care products, consumer items, and cleaning supplies.

4. We're Only Managing What We Can Measure

Believe it or not, VOCs are easy. They offgas pretty predictably, and we breathe pretty predictably. There are widely accepted ways to model how VOCs move from products into indoor air and then into our bodies.

Despite the limitations that we have documented here, VOC-related risk assessments are fairly advanced. In fact, the biggest limitation of all is that VOC emissions programs can only help us manage a tiny sliver of what can go wrong with our indoor space.

Are we focusing on VOCs because they can be easily measured? What are we missing?

Mold and particulates

In a 2014 piece titled 20 Reasons Your Green Building May Not Have Green Indoor Air, industrial hygienist Dale Walsh lists some of the major threats to IAQ that he sees in the field when investigating complaints. Only three of them are related to product emissions:

- off-label uses of low-VOC exterior materials
- use of the wrong tools and metrics for onsite IAQ testing
- over-reliance on the post-construction flush-out

In an interview with BuildingGreen, Walsh chastised project teams for focusing too heavily on product emissions, suggesting that it's easier to select low-VOC products than it is to do the meticulous design work necessary for a holistic approach to building science and IAQ.

"This whole emissions thing does have some value, but nowhere near what they think it does," Walsh argued. "It's such a minor aspect of what causes IAQ problems in buildings." He mentioned placing sewer vents next to outdoor air intakes and many other issues he has identified as higher priorities. "Not using mold food as building materials in bathrooms and

Managing What Can't Be Measured

- Low-emitting products are not the only thing that's important, but they are still very important! A preference for low emissions should be a given on every project.
- Preventing mold is just as essential, and in general, rating systems aren't going to help you with that. Make sure you know how water moves through buildings and how to keep it from doing so.
- Risk assessments for non-volatile chemicals are badly needed, but we have almost no publicly available toxicology data on the tens of thousands of industrial chemicals being used in building products today. The best way to start getting it is to ask for ingredient disclosures like Health Product Declarations, Declare labels, or manufacturer inventories. Increased transparency will make it possible for experts to screen these compounds for potential hazards and assess our risk of exposure.

kitchens and janitors' closets" is high on Walsh's list. "They call it a 'slop sink' for a reason!"

As part of their IAQ credits, most building rating systems do include incentives to pay attention to air intakes and other ventilation details. Few address the more complex issue of moisture prevention through building science (for our take on that, check out The Hidden Science of High-Performance Building Assemblies and related building science work throughout BuildingGreen).

Less urgent in most parts of the U.S. but very problematic in other parts of the world is particulate pollution. "Without proper filtration, 75% of outdoor air is what you see indoors," said Ryan Dick, founder and COO at Global Innovations Green Algorithms (GIGA). The company's cloud-based, real-time tracking of indoor air quality has detected spikes in indoor particulates in large cities during rush hour. Low-emitting products won't affect this, so other approaches are needed.

Semi-volatiles and other compounds

Know what you'll never see on a CDPH Standard Method lab report? Bisphenol-A. Cadmium. Semi-volatile organic compounds (SVOCs) like phthalates and halogenated flame retardants.

"We eat our buildings," said Jan Stensland. "We eat everything that comes into our environment because it gets into the dust. It's entropy." This is especially true of SVOCs, which are heavier than VOCs and stick to dust. Here, exposure scenarios are much more complicated than they are with volatiles. "VOCs are like sprinters," Stensland continued. They offgas quickly and are done. "With SVOCs, they go and go and go and go. You can ventilate until the cows come home, and many will not be affected."

Yet we know that some of these compounds can harm us.

Despite its limitations, VOC testing and evaluation "is the best standardized risk assessment we've got," said Tom Lent, but trying to apply that kind of model to other types of compounds is very, very difficult. "There is far less understanding of the exposure pathways." For example, anyone who's ever met more than one toddler knows that it would be virtually impossible to come up with a science-based model for a "typical" toddler's hand-to-mouth behavior. We also don't yet understand the rate at which SVOCs and other compounds leach out of different types of products. And when they do, we have poor models for how they might actually affect our health, Lent added.

What's next?

"People are recognizing the shortcomings of a hazard-based evaluation" that doesn't take exposure risk into account," said Rosenblum. "The problem is that there are so many different types of products to nail down."

Although some groups might like to create "an automated risk approach" rather than going laboriously through the process chemical by chemical and product type by product type, that might be too difficult to get right. Rosenblum hopes that someone will begin developing such an approach, though. "Someone just has to create it. And then down the road, it might be a great product."

In the meantime, as Rosenblum puts it, "Hazard assessment works in the absence of anything better."

Why "Zero VOC" Was Never Enough

We used to look for coatings, adhesives, and sealants that contained no VOCs. Great for smog prevention, but IAQ and installer health are also important.

by Paula Melton

What if we told you that the original purpose of reducing volatile organic compounds (VOCs) in wet-applied building products was to prevent smog in cities—not to improve indoor air quality (IAQ)? And that certain hazardous VOCs are "exempt" from being counted because of that? And that "zero VOC" doesn't come anywhere close to meaning a product contains no VOCs?

We'd be telling you a lot of truths that a lot of people don't know. We'd also be explaining the main reason why at least two major green building programs (LEED v4 and the Living Building Challenge) now require wet-applied products to show that they have both low VOC *content* and low VOC *emissions*.

Photo: United Soy Bean Board. License: CC BY 2.0.

For years, we have specified low- and zero-VOC products. That prevents smog but does not address indoor air quality at all.

By using both metrics, we can prevent smog while also protecting installers and building occupants.

Smog vs. IAQ

Let's not get ahead of ourselves: cleaning up outdoor air is at least as important to our health as cleaning up indoor air.

VOC content regulations are meant to reduce photochemical smog (a.k.a. *ground-level ozone*), and that's good for us. Ground-level ozone forms when VOCs (from manufacturing emissions, architectural coatings, aerosol cans, etc.) and certain nitrogen compounds (NO_x from manufacturing emissions and vehicle exhaust) combine. This reaction is catalyzed by sunlight (the "photo" in photochemical), with very unhealthy results.

According to the U.S. Environmental Protection Agency (EPA), ground-level ozone causes serious respiratory issues (from coughing to asthma attacks to lung damage) and can make our lungs more susceptible to infection and disease. An American Cancer Society study has found that excessive exposure to ground-level ozone increases the risk of premature death, even in otherwise healthy adults. MIT researchers have found that in the U.S., air pollution (not just smog) is responsible for more than 200,000 premature deaths annually.

From Content to Emissions

The first VOC limits for building products came out of Southern California in the late 1970s. The South Coast Air Quality Management District (SCAQMD) was formed then to address severe smog in the densely populated Los Angeles and Orange County region.

Measuring VOC content

That program places legal limits (in the regulated district only) on the VOC content of wet-applied products per unit volume—usually expressed as grams per liter (minus the water in the can). The assumption is that eventually all those grams will volatize, and the most effective way to control smog creation is to prevent the photo-reactive VOCs from going into the can in the first place.

Photo: Alexandre Giesbrecht. License: CC BY 2.0.

Vehicle and manufacturing exhaust combine with VOCs from coatings and other sources to create deadly smog.

A few years after the formation of SCAQMD, concerns began to grow about building-related illnesses, especially what was dubbed "sick building syndrome"—a set of acute neurological and respiratory symptoms that were eventually traced to indoor air quality. Many people focused blame (and continue to focus—not without controversy since mold can also be a major factor) on a combination of poor ventilation and VOC emissions from building products. Selecting low-VOC coatings, adhesives, and sealants became a standard green building strategy during construction and renovations.

Yet VOC content is a very poor answer to people's real questions about the solvents and other chemicals in site-applied products:

- How much of this compound will be in the indoor air?
- How long will it stick around?
- Can it hurt me?

To answer those three questions, you need an emissions testing and evaluation method like CDPH Standard Method v1.1. Until recently, though, green building rating systems like LEED sidestepped these questions for wet-applied products by focusing on VOC content (because that information was already available) and encouraging a massive, energy-intensive "flush-out" of the space before occupancy. There are good reasons to phase out this relic of the past.

What's low outdoors is not low indoors

For years, LEED has referenced SCAQMD rules—especially 1113 for paints and other coatings, and 1168 for adhesives and sealants.

Have you looked at the regulatory limits for these "low-VOC" products lately? Many of these are not the kinds of products you want to be applying indoors while occupants are around (though we all know it happens, despite the manufacturers' instructions). Masonry coatings, for example, can contain up to 100 g/l under SCAQMD regulations. It's common to see "green" coatings like this one claiming low VOCs—in this case, 95 g/l. That's actually quite good, given the performance and durability these kinds of coatings are meant to provide.

The low-VOC label, though accurate in terms of outdoor air quality standards, is not useful for judging the coating's possible effects on IAQ. Section 3 of the safety data sheet (SDS) for this coating shows a list of compounds indicating that at least 3.8% of the product is xylene and ethylbenzene—two chemicals whose emissions are limited by the CDPH Standard Method—and that it's at least 70% comprised of occupational hazards like acetone and 1-Chloro-4-(trifluoromethyl)benzene.

We know from the SDS that these are harmful compounds, but without emissions testing, we have no way of estimating how much of them will be in the indoor air and for how long. Emissions testing is imperfect, but it gives a sense of the level of exposure we can expect in typical indoor conditions. (This is the classic issue of hazard assessment vs. risk assessment; emissions testing takes the hazard information and performs a standardized type of risk assessment. Read more about the science behind VOC testing.)

Some VOCs don't get counted

What's more, most "zero-VOC" interior paints are not free of VOCs. Even mineral-based coatings have small amounts of volatile solvent in them to help with application and curing. Zero VOC really means that the product contains less than 5 g/l of VOCs—but not *all* VOCs, just those that affect outdoor air quality.

That means that a wet-applied product can be labeled as having low (or "zero") overall VOCs by incorporating volatiles that don't contribute to photochemical smog. Based on their molecular weight and behavior (they evaporate in ambient conditions), these compounds are chemically considered VOCs. But under smog-related regulations, they are "exempt" and don't get counted. The low-VOC masonry coating discussed above is at least 20% acetone, and since acetone doesn't contribute to smog, it doesn't have to show up in the company's 95 g/l count.

The manufacturer isn't doing anything illegal or wrong; it's just that the rules for outdoor VOCs don't work well for evaluating indoor VOCs. The U.S. Occupational Safety and Health Administration (OSHA) limits occupational exposure to acetone; the American Conference of Governmental Industrial Hygienists (ACGIH) and the State of California have stricter exposure limits.

Acetone is complicated, though. It's not really considered a major hazard (you may have rubbed it on your fingernails in the form of nail polish remover). It also isn't on the list of target chemicals in the CDPH Standard Method, though it will show up in the total VOC (TVOC) results from this testing. Since it is listed by ACGIH, it is restricted under Greenguard Gold to 1% of the allowable occupational exposure limit. The widespread use of relatively low-hazard VOCs like acetone is a beneficial result of reformulation based on the SCAQMD rules—but there can be regrettable substitutions as well.

Some exempt VOCs do have IAQ-based limits in the CDPH Standard Method—like dichloromethane (methylene chloride), 1,1,1-trichloroethane (methyl chloroform) and tetrachloroethylene. At least one other exempt VOC (formic acid) has an IAQ-based limit under Greenguard Gold.

Some VOCs aren't harmful

There's another side to this same coin. Just as some compounds affect IAQ but don't contribute to smog, other compounds contribute to smog but aren't considered harmful in indoor air. These show up in the VOC count, but it's meaningless for IAQ. An example of this is ethyl alcohol—a common ingredient in your paint can, your gas tank, and your mojito.

New Approaches in LEED and the Living Building Challenge

The limitations of using VOC content as an indicator for IAQ are clear, but there are also limitations to using VOC emissions testing and benchmarking for wet-applied products—one of them being that coatings or adhesives are "conditioned" (left to offgas) for ten days and then left in the chamber for four more days; it's those four days of offgassing that actually get measured. This helps determine their effect on building occupants after curing.

So the volatiles that are occupational hazards—that might be inhaled by those applying the materials or those occupying the space during curing—don't get captured in the final test results. Also not captured is what happens when curing is never completed due to application errors or moisture conditions.

You need both

This is why the Living Building Challenge 3.0 (LBC) and the Low-Emitting Materials credit in LEED v4 now require project teams to seek out wet-applied materials that meet requirements for low VOC content as well as low VOC emissions (see VOCs in LEED v4 and Other Rating Systems).

Although products that have both may not be available yet in some cases—and both these measures are imperfect—when the market catches up to the new requirements, these products will hopefully provide greater protection in all three areas of concern: smog formation, installer health, and occupant health.

VOCs in LEED v4 and Other Rating Systems

Most building certifications encourage low-emitting and low-VOC products, but they all do it differently. Here's how it all fits together.

by Paula Melton

A lot of building projects these days are targeting certification in multiple rating systems. You'd think that if these programs were all working toward the same goal—like indoor air quality—they would get the basics pretty much the same.

They don't.

We rely on these whole-building rating systems to define the current best practices for incorporating low-emitting products in a way that's designed to protect building occupants and the environment as a whole. Developers of LEED, WELL, and the Living Building Challenge (LBC) have worked to harmonize them over the last few years, but certain differences remain.

We look at the how and why behind product certifications and indoor air quality (IAQ) in each.

Photo: Michael Gaida. License: Public domain.

It should not be this hard to keep our building rating systems straight.

Living Building Challenge

Well known for its Red List of banned substances, early versions of the Living Building Challenge did not have specific requirements for products' VOC content or emissions (except added formaldehyde, which was always on the Red List). Instead, up until the current version, VOCs were measured through onsite testing only.

VOC content

That changed with the addition of certain product requirements on the Red List and in LBC's imperative on a Healthy Interior Environment. The goal? To protect installers.

"The requirement was strengthened through the inclusion of a limitation of VOCs in wet-applied products," James Connelly, director of the Living Product Challenge, told BuildingGreen. "The new requirement not only ensures good indoor air quality in the final project but protects construction workers from harmful VOCs during installation that may volatilize quickly and would not be picked up by the air quality testing."

These VOC content requirements are based on California air quality regulations and thus align with those used in LEED. They are required for both interior and exterior wet-applied products.

VOC emissions

Additionally, all products inside the building envelope must meet allowable emissions levels under CDPH Standard Method v1.1.

These requirements align LBC more closely with LEED v4 and WELL, with the most salient difference being that all imperatives in LBC are required—so meeting the requirements for 100% of products is not negotiable.

Required air testing

LBC also still requires onsite air quality testing and sets allowable concentration levels for a variety of pollutants, including certain VOCs—formaldehyde, total VOCs, and 4-phenylcyclohexane (or 4-PCH, which commonly offgases from styrene butadiene rubber, sometimes used in carpet backing).

WELL

The WELL Building Standard officially came on the scene in late 2014 with an exclusive focus on occupant health and well-being. Overall, its requirements are intended to align with those in both LEED and LBC, and it has much in common with both when it comes to VOCs. That said, WELL covers a smaller set of products than either of these other two rating systems.

Unlike in LEED, all VOC-related requirements are "preconditions"—WELL's word for prerequisites.

Content and emissions conflated

WELL has a unique method of managing VOCs for wet-applied products. Where LEED and LBC require both low VOC content and low VOC emissions, WELL allows you to choose between them.

VOCs and Whole-Building Rating Systems

PRODUCT VOC LIMITS			
	LEED v4 Low-Emitting Materials	**Living Building Challenge**	**WELL**
Furniture	Include if in the scope of work	Include for all projects	
Banned VOCs	Methylene chloride Perchloroethylene (North America only)	Formaldehyde Chlorobenzene	Urea formaldehyde above 100ppm in furniture, laminate adhesives, insulation
VOC Emissions	CDPH Standard Method v1.1*		
VOC Content: Paints and Coatings	CARB 2007 SCM or SCAQMD Rule 1113	CARB 2007 SCM	CARB 2007 SCM* or SCAQMD Rule 1113
VOC Content: Adhesives and Sealants	SCAQMD Rule 1168		
ONSITE VOC LIMITS			
	LEED v4 Indoor Air Quality Assessment	**Living Building Challenge**	**WELL**
Formaldehyde	27 ppb (16.3 ppb for Healthcare projects)	50 ppb	27 ppb
TVOC	500 µg/m^3		
Other VOC Limits	4-PCH: 6.5 µg/m^3 All CDPH Standard Method v1.1 limits	4-PCH: 3 µg/m^3	–

**For wet-applied products in the WELL Building Standard, project teams may choose between meeting emissions requirements or content requirements. In LEED and LBC, products must meet both emissions and content requirements.*

Source: BuildingGreen, Inc.

Product categories covered are interior adhesives, sealants, paints, and coatings. Exterior products are not addressed.

In addition to the content requirements for wet-applied products, WELL has a unique limitation on the concentration of urea formaldehyde in furniture, laminating adhesives, and insulation. Content may not exceed 100 parts per million in these materials.

Handful of emissions requirements

For non-wet-applied products, compliance with CDPH Standard Method v1.1 is required—but the product categories covered are unusually small in WELL. Only flooring, furniture, and insulation installed to the interior of the weather barrier (both thermal and acoustic) must meet the requirements.

Onsite testing

In WELL as in LBC, onsite air quality testing is required for a variety of pollutants. Limits are set for formaldehyde and total VOCs.

LEED v4

On its surface, the Low-Emitting Materials credit in LEED v4 looks pretty similar to the same credit in prior versions, but that's superficial. First-timers are finding this out (and in some cases abandoning the credit) when they attempt it.

There are also significant changes to the post-construction IAQ credit—which sets up the most stringent onsite VOC testing protocol of the three rating systems discussed here.

New: Content and emissions both required

For wet-applied products, LEED v4 newly requires that all interior paints, coatings, adhesives, and sealants meet California regulations for VOC content—the amount of volatile compounds measured in the can or tube. Most of these products (at least 90% by volume) must also meet the emissions requirements of CDPH Standard Method v1.1.

Sara Cederberg, AIA, technical director of LEED at the U.S. Green Building Council (USGBC), explained that emissions testing is "a more accurate way of testing products for health-based criteria than the

content-based methods. Content-based methods … were created to control smog and therefore are not looking at the same compounds or exposure potential" (see Why "Zero VOC" Was Never Enough).

Cederberg also explained why it may be taking some time for manufacturers to catch up with the new requirements. "Certain sectors … have a challenge ahead of them because a single company could create thousands of products." The cost of testing thousands of products is a serious barrier for manufacturers.

For the Healthcare and Schools rating systems, exterior wet-applied products must meet content limits as well.

New: Most interior materials covered

In prior versions of LEED, a very limited set of non-wet-applied products had emissions requirements under Low-Emitting Materials credits: flooring systems and composite wood. But in LEED v4, almost everything within the weather barrier must meet CDPH Standard Method v1.1. Product categories include:

- flooring
- walls and ceilings
- insulation (both thermal and acoustic, if inside the weather barrier)
- composite wood (if not covered in the other categories)
- furniture, if it's in the scope of work for the project

Why everything inside the weather barrier? "The credit has changed significantly from the past in that we want you to consider the entire building, not just parts of it," Cederberg told BuildingGreen, adding that "yes, that can be a documentation challenge" for the time being.

But wouldn't concrete or gypsum finishes create an air barrier between the interior space and other parts of the wall assembly?

Not necessarily, says Michelle Halle Stern, AIA, P.E., president of consulting firm The Green Facilitator and a former member of LEED's Indoor Environment Quality Technical Advisory Group (EQ TAG). She claimed that VOCs "have a potential to get inside the building through ventilation. Is that seal at the top of the wall 100%? I don't think so. The idea is that if we have a weather barrier, that is at least relatively impermeable. We are keeping the outside outside and the inside inside."

Halle Stern added, "What if you have to cut a hole in the wall? That has the potential of creating exposure" both for those working on the building and those who may still be working in the space.

Additionally, there is some evidence that VOCs can permeate drywall, according to Raja Tannous, co-founder and laboratory director at testing lab Berkeley Analytical. "There are some studies that show if you look at the emissions of small molecules like formaldehyde, they do go through gypsum. It's fairly permeable." In addition, he added, "For commercial buildings, the way the architecture is, the walls recirculate the air from the area above the drop ceilings. Most of the materials in the wall find their way somehow into the interior." How the materials in these spaces will behave compared with materials in the intentionally conditioned space will depend on temperature, pressure, and humidity, though, he added.

"The exposure scenario in CDPH is based on air changes per hour based on ASHRAE and a 'typical' office or classroom," acknowledged Cederberg. Although it's "not a perfect fit, perhaps" for assessing what might be going on between the wallboard and the weather barrier, she continued, "it is the best available health-based standard in the U.S. that we're aware of at this time."

New: TVOC disclosure

One of the lesser-known aspects of v4's version of Low-Emitting Materials is its requirement that manufacturers disclose the total VOC (TVOC) range from their CDPH Standard Method test report. The product doesn't have to meet a certain level, but Cederberg suggests that TVOC can be used as a precautionary measure in the case of unknown emissions.

"Many commenters wanted a limit on TVOC," said Cederberg, but TVOC is a poor toxicological indicator. "In the absence of solid health-based criteria, the EQ TAG chose not to establish a TVOC limit." So why require disclosure? "TVOC is one factor we expect project teams to utilize in product evaluation and selection," she continued. "TVOC is a good diagnostic test; if your overall number is higher than you'd expect, it's a good way to know that you need to look into your product further."

We discuss the science behind TVOC limits in The Questionable Science Behind VOC Emissions Testing.

New: IAQ testing against full CDPH slate

In addition to the new elements of Low-Emitting Materials, the v4 version of the "flush-out" credit, called Indoor Air Quality Assessment, incorporates significant updates.

According to Cederberg, the idea here is to "get better feedback on how well these products perform in the space." Right now there is very little evidence that a handful of representative product samples perform in a controlled chamber the same way that thousands of real products perform in an occupied space.

The new credit looks at all 35 chemicals included in CDPH Standard Method v1.1, going far beyond the VOCs measured for WELL or LBC. The allowable concentrations differ from those in the CDPH method, though. Formaldehyde is still permitted at 27 parts per billion (lower for Healthcare projects), and all the other VOCs are allowed at California's chronic reference exposure level (CREL—see VOCs in LEED v4 and Other Rating Systems). "We're hoping that LEED v4 will provide an incentive

for more data so that we can have a better understanding of where the issues are," Cederberg said.

Too new?

"People are saying they can't do the credit because they can't find products," said Halle Stern, who serves as the LEEDuser Expert on the v4 Low-Emitting Materials credit, adding that it went from "the easiest credit in the rating system to now we can't do it at all."

Halle Stern foresees that manufacturers will eventually catch up, reminding project teams that low-emitting materials weren't available at all 15 or 20 years ago—until building professionals began demanding them. "[Manufacturers] don't know until people ask, and that's really the bottom line. The market drives."

OP-ED

Why Standing Rock Matters to Green Building (and How You Can Help)

The green building community must choose its battles carefully. And Standing Rock should be one of those battles.

by Jennifer Atlee

I can't believe how hard it is to write this op-ed piece. All I want to say is that building professionals who care about the health of planet and people should actively support the growing movement at Standing Rock—where Native American tribes and their supporters have gathered to stop development of the Dakota Access pipeline.

It's hard because I'm stepping out of my comfort zone, out of the domain that I consider within my professional scope, and into the understanding that unless I take direct action in support of the struggles of those harmed by racism and systemic injustice, I am complicit in that injustice.

And part of that stepping up for me personally is making the case to you that this is also true for us as an industry.

Interconnected struggles

I thought I was going to make a different case for why Standing Rock matters to our industry. It goes like this:

The math of climate science is stark, and it will take more than our best efforts to keep 80% of known fossil fuel reserves in the ground. Given that a different kind of math holds sway in the fossil fuel industry, those standing directly in the path of fossil fuel pipelines are green building's vital allies.

I'd then proceed to lay out a similar argument about so much else we strive toward in green building, and how those priorities benefit from the largest gathering of Native Americans in 100 years, coming together to protect the Missouri River, which is the Standing Rock Sioux water supply. But that wasn't the crux of it.

Taking a supportive role is powerful

Standing Rock presents us with a vital opportunity to look deeply at the systemic and historical roots of today's sociopolitical and ecological crises, and how truly interconnected our struggles are.

Both Bill McKibben and #BlackLivesMatter have given voice to the game-changing potential of Standing Rock in potent statements of solidarity. By supporting this native-led struggle without subsuming it, they model how we best strengthen each other's movements toward shared goals.

We are already doing critically important work in the built environment to reduce fossil fuel use and address the environmental and human health impacts of buildings, materials, and infrastructure. As an industry, we are also increasing our focus on the direct social justice implications of design, construction, and procurement. We are working to advance in our practice the healing concepts of regenerative design and living buildings.

But we in the green building community can't truly create a living future until we acknowledge the scope of our power and privilege and leverage that—in solidarity and humility—in direct support of the struggles championed by others.

Our attention matters

We in the green building movement have resources and clout, both

Photo: Jake Green/Montana Kaiman

Supporters from around the United States have joined the Standing Rock Sioux in protesting development of the Dakota Access pipeline.

individually and collectively, that we could bring to bear. Architects/Designers/Planners for Social Responsibility (ADPSR), the International Living Future Institute, the U.S. Green Building Council, the brand new group Architects Advocate, and others could put out statements of support.

Even just keeping our eyes on what's going on makes a difference. It's harder to get away with using mace and private security attack dogs on peaceful Native American protesters while bulldozing ancestral graves if business professionals and white people are paying attention and outraged.

If we keep paying attention, much more becomes possible. Last Friday, the Obama administration paused construction, pending further discussion. The wording of the statement by the Office of Public Affairs cracks open a door to reform. But this will only happen if we all stay involved. If the statement simply defuses tensions and deflects attention, it is a loss, not a gain.

We all have to pick our battles, and a continued focus on our own work to address sustainability and social justice directly within the built environment is vitally important.

At the same time, what we do now is pivotal. Will we simply go about "our" business of making the world a better place—by our definition only? Or will we pay attention, listen deeply, and act in humble solidarity?

Our collective choice will reveal our true capacity to manifest the world we strive for.

How to support the efforts at Standing Rock

1. **Join one of many** solidarity actions scheduled across the country through September 17.

2. **Call the White House** at 1-888-369-5791 and demand that President Obama take further action to stop the Dakota Access Pipeline, or add your voice by signing here. Demand more than a temporary halt to construction of DAPL. As Bill McKibben has pointed out, after halting the Keystone Pipeline, fast-track review of everything else has become the norm. Substantive review would look at the environmental and social impacts of construction and possible oil spills, climate change impacts of burning the fuel, and native rights.

3. **Consider providing direct** financial or material support to the protectors' camps at Standing Rock, or contribute to the Sacred Stone legal fund.

4. **Share information** and keep this on your radar. Talk with friends and colleagues, and keep an eye on social media #NoDAPL, #ReZpectOurWater, and #StandWithStandingRock to understand and share what is going on. Continued public scrutiny makes a difference.

5. **Make this your responsibility**. The more we recognize our shared struggle, the more effective we become. Think creatively: if this were your local community and your water source at risk, you'd pull out all the stops, right? Who do you know who could influence decisions going forward? Do your investments support companies making the pipeline happen? How could you energize groups that you are part of to engage in acts of solidarity?

Op-ed contributor Jennifer Atlee is principal at Atlee Research. Her work has focused on improving the capacity of the green building industry to assess the sustainability of products and make actionable sense of our rapidly evolving materials ecosystem. She has engaged in research, writing, speaking, and consulting on sustainability issues since 1999.

NEWS ANALYSIS

Forced Labor Common in Producing Bricks, Timber

Modern slavery in construction—some of which occurs in the U.S.—is linked to an estimated $34 billion of profit annually.

by Candace Pearson

Construction is one of the primary industries fueling modern slavery, according to a recent report by LexusNexus Business Information Services, a U.K.-based company that provides due diligence services. The report documents human rights violations involving construction workers as well as violations in the building material supply chain.

The report calls on contractors to demand transparency in the labor value chain and on architects to avoid sourcing products from regions that are known to exploit workers for the production of certain materials. Resources are provided that offer guidance on how, but compared to what's been developed in other countries, tools targeting the U.S. market lag behind.

Not a problem on U.S. soil? False

The 2016 Global Slavery Index defines modern slavery as "situations of exploitation that a person cannot refuse or leave because of threats, violence, coercion, abuse of power or deception"—exploitations that happen nearly everywhere.

The report highlights a human trafficking case that occurred in Texas and Mississippi in 2015 involving 500 workers from India who were recruited to build off-shore drilling rigs for the construction company Signal International. The workers paid exorbitant recruitment fees and were promised permanent residency even though the company only obtained guest visas.

The company also forced the men to live in guarded labor camps in unsanitary conditions, deducting fees

Paul Keller. License: CC BY 2.0.

Human Rights Watch has pointed to labor injustices against construction workers in Dubai as an example of how slavery manifests itself in the modern era.

from their paychecks that reduced their payment below minimum wage. The company made $730,000 in one year from the rent payments it collected and avoided $8 million in labor costs, according to the report.

Key steps for construction companies

In this case, Signal International was clearly a bad actor and was ordered by a Louisiana District Court to pay settlements that ultimately forced it into bankruptcy. However, other construction companies might be complicit and not even know it.

General contractors often hire several subcontractors, each of whom may use a different labor provider to recruit workers. According to the report, this complicated supply chain can obscure abuses—like a labor provider charging recruitment fees, or a supervisor who only hires workers who sublet accommodations from him.

The report recommends several resources for mitigating these risks and adopting best practices:

- Stronger Together, a multi-stakeholder initiative based in the U.K.
- Guidelines for a Better Construction Industry in the Gulf Cooperation Council, a report by Human Rights Watch
- Human Rights Compliance Assessment Tool: Contractors and Supply Chain, an assessment tool developed by the Danish Institute for Human Rights

While useful, none of these guidelines were developed specifically for the U.S. market, highlighting a lack of tools for U.S. construction companies.

Key steps for design professionals

The other way that the construction industry contributes to modern slavery is by purchasing materials that were manufactured using forced or child labor.

Bricks and timber purchased from certain countries have a particularly high risk of being linked to forced labor, according to the report. China and India—both in the top three countries of worldwide brick exporters—have documented problems with forced and child labor, along with 19 other countries. Timber from Brazil, Peru, North Korea, and Cambodia is similarly problematic, according to a register maintained by the U.S. Department of Labor.

Until recently, products like these that are known to be produced by slave labor have been allowed into U.S. markets if there was not enough supply through other routes to meet consumer demand. That loophole was recently closed with the Trade Facilitation and Trade Enforcement Act of 2016.

However, the legislation is expected to affect only 136 goods—only a portion of which are construction materials—while an estimated $34 billion of profit made annually in construction and manufacturing is generated worldwide by forced labor, according to the report. This leaves much of the responsibility of closing the gap to consumers and procurement professionals.

Ethical sourcing guidance for designers can be limited (and quickly change based on current events), but the U.S. State Department recently launched a useful tool that identifies which countries have a high risk of modern slavery by commodity. The tool highlights particular concern with bamboo, bricks, charcoal, copper, and granite and other stone.

NEWSBRIEFS

Architects Go Political For Climate Change

Architecture firms are taking it upon themselves to call for climate change legislation with the new Architects Advocate campaign.

by Candace Pearson

A grassroots campaign started by a small number of Chicago-based architecture firms has quickly caught fire. The group, *Architects Advocate for Action on Climate Change*, now has 114 architecture firms as signatories and has just gone nationwide.

The goal of the initiative is to make the voice of the architecture community

Architects Advocate Action on Climate Change

The grassroots campaign seeks to unite architecture firms in calling for climate change legislation.

heard by legislators and the general public. Supporters of the initiative are asked to display the campaign's logo or advocate statement on their firm's website, engage with the media or contact legislators, and encourage other firms to join.

With more momentum, the group plans to expand the campaign to other industry groups. The work will only be done when "meaningful legislation to mitigate climate change" is adopted, according to a press release.

HPD User Guide Helps with LEED, WELL Product Selection

Just in time for LEED v4, a guide for using Health Product Declarations is being released.

by Candace Pearson

Do you know what it means if the checkboxes for "characterized" and "screened" are checked off on a Health Product Declaration (HPD), but the box for "identified" is left blank? (See the answer at the end.)

This and other nuanced questions about how to use HPDs are answered in a new handbook—*Project Team User Guide: Using Health Product Declaration (HPD) Open Standard, version 2*—which the HPD Collaborative has announced will be available publicly (and for free) in early October. The guide has already been released to members of the Health Product Declaration Collaborative.

The guide walks through how to evaluate whether HPDs meet requirements in LEED v4 and WELL (also see What's an HPD? Health Product Declaration FAQs) and presents other ways to use the data, including:

- Setting material selection goals
- Screening for high-priority chemicals
- Gauging the chemical hazard profile of a project by comparing HPD data from real product selections against generic products (through the Quartz database, for example)

The guide acknowledges that specialized consultants and third parties will likely need to be engaged for these latter uses of HPDs. However, case studies demonstrate how HPDs are already being put to use to screen for Living Building Challenge Red List chemicals, inspiring company procurement policies to include a preference for product transparency data, and prompting engagement between product teams and their suppliers.

So, what does it means if the checkboxes for "characterized" and "screened" are checked off on a Health Product Declaration (HPD), but the box for "identified" is left blank? Answer: The manufacturer is not disclosing all of the product ingredients by name but is still reporting information about the potential hazards associated with its contents. Bonus point: This kind of HPD can still be used to comply with the LEED v4 Materials credit. See our HPD Quick-Start Guide for visuals.

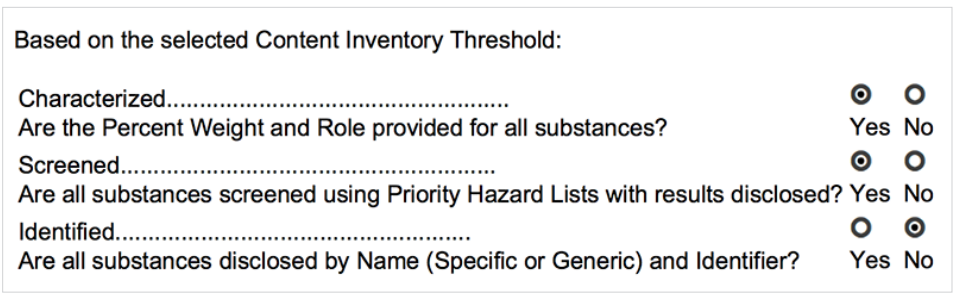

Image: Screen capture from Gold Bond eXP Sheathing HPD

These checkboxes could mean the difference between a LEED-compliant HPD and one that is not. Do you know how to tell?

PRODUCT NEWS & REVIEWS

BuildingGreen Announces Top 10 Products for 2017

These innovative products reduce stormwater and wastewater, improve efficiency and IAQ, and contain fewer hazardous materials.

by Brent Ehrlich

For the past 15 years, BuildingGreen has recognized green building products that significantly improve upon standard "business-as-usual" practices. These products help transform the industry by conserving energy and water, reducing emissions, and fundamentally changing how we approach our building systems.

This year's BuildingGreen Approved winners:

- Accoya acetylated wood
- Aquion's Aqueous Hybrid Ion "saltwater" battery
- Designtex textiles
- d-Rain Joint Rainwater Filter Drain
- enVerid's HLR (HVAC Load Reduction) Ventilation
- HyperPure water piping
- Mean Green commercial electric lawnmowers
- Nextek Power Hub Driver (PhD)
- Phoenix composting toilet
- Securock ExoAir 430

Aquion Energy

Aquion batteries being used as part of a grid-tied nanogrid at the Illinois Institute of Technology in Chicago.

Aquion's Aqueous Hybrid Ion "saltwater" battery

Renewable energy is finally being taken seriously as an alternative to utility-scale power generated through fossil fuel consumption. Localized photovoltaic (PV) systems that were once niche products are now mainstream.

But not being able to store this power in an environmentally safe manner remains a significant drawback to wider adoption. Without a battery storage system, most grid-tied PV systems cannot be optimized for efficiency, nor can they provide energy security in case of outages. Yet current battery backups usually use toxic lead-acid batteries (relatively inexpensive) or lithium ion batteries (such as Tesla's Powerwall, a former BuildingGreen Top 10 winner). Lithium ion storage has great potential but is still expensive, has flammability issues, and requires rare earth minerals as electrolytes.

Aquion's aqueous hybrid ion (AHI) "saltwater" battery is a safer alternative that uses a non-hazardous sodium sulfate electrolyte instead of lithium salts (lithium ion) or sulfuric acid (lead–acid). Though Aquion uses a cathode made of lithium manganese oxide—the same technology used in some lithium-ion batteries—its sodium titanium phosphate anode is the key to the system and its environmental benefits.

This anode reacts selectively with sodium ions, allowing for the long, slow deep-cycle discharge that is critical for energy storage. Both the electrolyte and the anode materials are cheap and abundant and create a simple, low-maintenance system that is inexpensive to manufacture and safe to operate, with impressive environmental credentials: it is the first battery to meet Cradle to Cradle standards (C2C Bronze, though Silver in Material Reutilization and Water Stewardship), and it has eliminated all PVC from its system, even in the wiring.

Aquion batteries can operate at ambient temperatures between 23°F (–5°C) and 104°F (40°C) and are available in the S-line module (a single 2 kWh stack) or the M-line module (comes in stacks with 25 kWh of storage). They are also available in bulk for large-scale storage needs.

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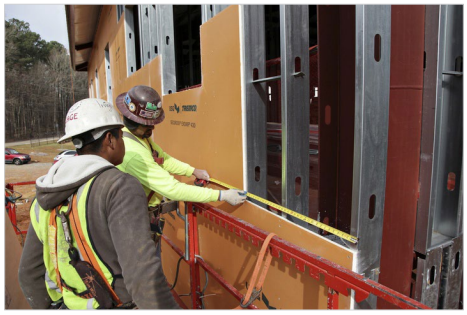

USG

Securock Exoair 430 combines USG's Securock fiberglass-faced sheathing and factory-applied Tremco weather barrier, which speeds installation and helps ensure weather barrier performance.

Securock ExoAir 430

Preventing air and moisture penetration in building is critical to its long-term performance, but weather-resistive barriers (WRBs) can be difficult and time consuming to install.

And though fluid-applied products can provide a great solution, they have to be applied at a consistent thickness, they require the building to be clean and dry, and they require a curing time—so weather and sub-contractors' availability can impact the installation schedule. There is also the potential for human error that could compromise performance.

Securock ExoAir 430 combines USG's Securock fiberglass-faced sheathing with a factory-applied Tremco fluid-applied barrier to simplify installation. With no fluids or tapes to apply onsite, fewer trades are required, and there is less waste on the jobsite and no overspray. Most importantly, after hanging the panel, 80% of the barrier is installed. This speeds up installation and inspection time and reduces the chance of human error. (If the edges are sealed, the system can be left exposed for up to six months, providing scheduling flexibility.)

Securock ExoAir 430 uses Tremco's Dymonic 100 and additional Tremco sealants that are tested for compatibility and color-coded for easier installation and quality control. It passes ASTM tests for air and water vapor permeance and for assembly air leakage and water penetration. And though the system uses polyurethanes and acrylics that can be respiratory sensitizers during application, Exoair is factory applied, where emissions can be controlled, minimizing worker exposure onsite, and the Tremco sealants are certified Greenguard Gold—a certification more often found on interior products.

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Designtex textiles

Many textiles are made in countries with few environmental or labor laws. Their production requires significant water and energy, and their dyeing and finishing create hazardous industrial pollution. As a consequence, the global textile industry has one of the worst environmental and social-equity records of any industrial product.

Sustainable textiles *are* readily available, but complex supply chains

Designtex

Designtex's website can be searched for sustainability metrics such as Facts Gold and textiles that don't require fluorinated compounds, both of which are met by the company's Bouclé Two-Tone.

can make finding these products difficult. And even if you find them, they may not meet design needs or be applicable for the performance requirements.

Designtex has earned Top 10 recognition not for a specific product but for the work they have done to simplify sustainable product selection.

The company has a catalog with more than 8,000 materials and a sophisticated website that allows a designer to filter for a number of sustainability and performance metrics. Along with fabric materials, patterns, and colors, they can search for:

- certifications, including Cradle to Cradle Basic through Gold, Facts Silver and Gold, and more
- carbon-neutral shipping
- "optimized chemistry," which includes alternatives to PVC, non-halogenated flame retardants, cleaning protocols to replace PFCs, and no harmful phthalates
- potential LEED compliance

Performance filters include flammability, abrasion, light-fastness, and cleaning. All fabrics filtered by the company for sustainability attributes also meet the warranty for end use.

The company tracks all of its textile information and keeps the database updated, and it can provide customized data to clients and update the categories as client needs and the industry evolve.

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Nextek Power Hub Driver (PhD)

Much of our building equipment—LED lighting, computers, and motors—uses direct current (DC) power rather than alternating current (AC), but that equipment requires AC-to-DC power conversion equipment. Converting from AC grid power to DC at each device adds materials and costs, creates e-waste, and reduces reliability, performance, and efficiency.

Nextek Power Systems

Nextek's Power Hub Driver (PhD) converts AC power to safe-to-handle 24-volt current for use with LED lighting and other low-voltage building equipment.

Converting to a DC system can save energy, create better power quality, and improve resilience when batteries are used, but it can be expensive and complicated to install.

Nextek's Power Hub Driver (PhD) solves these problems by providing an all-in-one AC-to-DC power solution. The unit converts AC as it comes into the building to 380-volt DC; it then converts that power to safe-to-handle, low-voltage 24-volt current. PV, batteries, and other renewable-energy sources can feed into the unit, and energy from these sources can be optimized for performance. When renewables are available on the site, that energy is used first, but it's supplemented with DC converted from grid-supplied AC when necessary. PhD's power is supplied through 16 class 2 channels that can carry 100 watts of 24-volt current, for a total of 1,600 watts.

LED lighting is one of the best uses for the PhD system. The power supply allows for simple, safe installation and eliminates the need for drivers—often the first component to fail in an LED system. This saves money and reduces conversion losses while also eliminating problems with flicker and color quality.

The PhD can also be used to dim LEDs and can be controlled using wired or wireless communication—BACnet, ZigBee 3, or 6LoWPAN—allowing greater connectivity and the possibility of being used as part of the Internet of Things (IoT).

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HyperPure water piping

Copper, chlorinated PVC (CPVC), and cross-linked polyethylene (PEX) all have advantages as potable water piping. But each has drawbacks as well: copper is expensive and vulnerable to theft, many consider CPVC's environmental profile to be problematic, and PEX is not recyclable and can leave an unpleasant taste or odor in the water.

HyperPure from Legend Valve & Fitting is a flexible potable water pipe made from *bimodal polyethylene*, also known as PE-RT pipe (for polyethylene-raised temperature). Used in Europe for more than 20 years, PE-RT is a drop-in replacement for PEX that does not require cross-linking. This makes Hyperpure's polyethylene easy to recycle and should eliminate the chemical taste in the water that some PEX is known for.

Hyperpure is chlorine resistant and strong, boasting the highest rating for burst tests, but at the same time is more flexible than PEX, making installation easier. Hyperpure currently uses standard PEX fittings, but it can be thermally fused, and when that technology is available, it will eliminate the need for most fittings and provide a robust system. Legend claims this thermal fusion technology is under development.

Legend Valve & Fitting

Legend's Hyperpure polyethylene potable water pipe does not require cross-linking chemicals and is recyclable.

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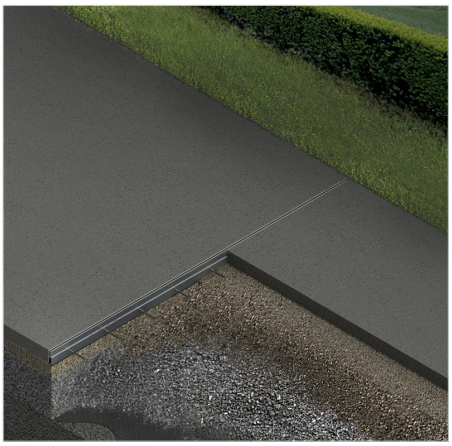

Bio-Microbics, Inc.

The d-Rain Joint installs and looks similar to a standard expansion joint yet manages onsite stormwater from impermeable surfaces.

d-Rain Joint Rainwater Filter Drain

Stormwater running off impervious surfaces carries pollutants into watersheds, raises the temperatures of those waters, and causes flooding and erosion; and that water no longer recharges aquifers. Permeable surfaces such as pavers can be expensive solutions that might not meet design needs, and many onsite stormwater systems are expensive to install.

The d-Rain Joint Rainwater Filter Drain installs and looks like a standard expansion joint used in concrete slabs, yet it provides a gap slightly smaller than 1″ wide that allows water to flow through to subsurface drainage. Available in aluminum or in gray polypropylene, it comes in 8′ lengths and can be installed in concrete or asphalt driveways, sidewalks, and other applications. The d-Rain allows drainage at 2 gallons per minute per linear foot, up to a maximum of 5 gpm/linear foot. They can be doubled up to increase drainage and can be "tuned" to match jobsite requirements. The joints come with a replaceable filter to keep debris from clogging the system.

Used in place of pavers and other drainage systems, the d-Rain offers a cost-effective solution to stormwater runoff that could also reduce the size or need for retention ponds and other associated systems.

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Accoya acetylated wood

Wood is a fantastic building material, but left exposed to the elements, it is vulnerable to insects, rot, and decay—especially when used in contact with soil or water.

The preservatives and other chemicals used to treat wood products usually contain copper, which has a heavy environmental footprint and is an aquatic toxicant, along with proprietary biocides that can leach into the environment. You can use recycled plastic products, but they don't always look that great.

Accoya, from Accsys Technologies, offers Forest Stewardship Council-certified (FSC) radiata pine wood products treated with acetic anhydride (really strong vinegar) under pressure in a process called *acetylation*. This treatment changes the chemistry of the wood's cell walls, creating a dense wood that is impervious to moisture and rot. Insects do not like it, and since it does not absorb water, swell, or shrink like most other wood products, it is dimensionally stable, making it a good choice for exterior woodwork.

Accoya's modified wood is available for windows and doors, decking, cladding, and engineered products for structural applications—and it now has International Code Council (ICC) approval for ground-contact applications.

Though Accoya has a large shipping footprint and high first costs, it also has solid environmental credentials, including an environmental product declaration (EPD), FSC certification, Cradle to Cradle Gold certification, and a Platinum Cradle to Cradle Material Health Certificate—so it can be applied to all three Building Product Disclosure and Optimization credits in LEED v4.

Accsys Technologies

Kelowna Marina in British Columbia incorporates Accoya wood in its cladding, trim, and louvers.

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Photo: Alex Wilson

Phoenix's Neptune Foam Flush toilets at the Bullitt Center drop waste into basement composters. Both leachate and compost are taken monthly to amend soil in a nearby forest.

Phoenix composting toilet

Water-efficient toilets are now available that perform better than California's 1.28 gallons per flush (gpf) requirements, so what incentive is there to become even more water-efficient?

Well, there is more to treating human waste than water.

After the initial flush, there is a significant amount of energy and additional water required to move the waste offsite, treat it, and then transport it. And during processing, waste is often mixed with more-toxic industrial or stormwater streams, ruining potentially useable fertilizer and complicating disposal.

Phoenix composting toilets offer an alternative system that composts waste onsite with no odor and minimal upkeep.

The sophisticated but simple system uses a biochamber that requires some maintenance: a small amount of wood shavings are added daily, and a handle, connected to special tines, is then turned to mix the compost.

A 4-watt fan creates negative pressure for ventilation and ensures the system remains aerobic with no odor. After 18 months or more, depending on use, the compost is removed, and if local regulations allow, the compost can be used as a non-food crop fertilizer. The Phoenix system keeps the natural waste nutrient cycle local and doesn't require municipal waste disposal or a septic system.

Once used primarily for off-grid homes or remote locations, the Phoenix now offers both a "dry system" that can use one or two toilets and the Neptune Foam Flush Toilet for larger applications, which looks similar to a conventional toilet and is used where more than two stories separate the toilet and the biochamber. The Neptune system uses roughly 4 to 13 ounces of water to generate the foam, based on calculations from its motion sensor, and its biochamber is a vermicomposting system that uses worms to compost the waste.

Though not for every owner, the Neptune system has been installed in several Living Building Challenge projects, including the six-story Bullitt Center, which uses ten Phoenix composters connected to 25 Neptune toilets.

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Mean Green commercial electric lawnmowers

Landscaping operations (particularly turf maintenance) can be one of our worst sources of pollution. Running a 24-horsepower commercial mower for an hour produces emissions equivalent to those of 88 cars driving at 55 miles per hour.

And those emissions include carbon monoxide, VOCs, particulates, and the carcinogens benzene,1,3 butadiene, aldehyde, and formaldehyde—right on the building site.

Mean Green offers 52″ or 60″ ZTR commercial riding electric mowers or 48″ stand-on models that use its "Green Lithium" Lithium Energy Modules (LEM) battery technology.

Mean Green

Mean Green commercial mowers have no emissions—a significant problem with conventional fossil fuel-powered models.

Engineered to last 10 to 15 years, the batteries operate from two to seven hours, depending on model options, with recharge times of 9 to 12 hours (a "fast" 45A/220V charger is available).

These units produce no emissions, require no fuel and almost no maintenance, and are quiet. Prices start at around $13,299 for the stand-on models and $13,988 for the riding option, but the company claims $7–$8 operational savings per hour using these mowers, and with rebates and incentives, first costs are likely to be significantly less.

Use of these mowers can help earn a credit under LEED v4 for Building Operations and Maintenance (LEED-EBOM) for use of electric-powered equipment.

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enVerid's HLR (HVAC Load Reduction) Ventilation

Removing VOCs, CO_2, and other indoor contaminants from our buildings is good for our health and has been linked to better employee performance. But most HVAC systems achieve this by replacing indoor air with outside air—losing the energy used to condition the air and, in polluted areas, introducing additional contaminants into the building.

EnVerid's HLR (HVAC Load Reduction) Ventilation uses technology similar to that used on submarines—cleaning indoor air rather than venting conditioned indoor air and replacing it with outdoor air.

Indoor air is run through a proprietary sorbent to remove CO_2, VOCs, formaldehyde, and other contaminants, but the system also brings in enough outdoor air to maintain positive pressure. The recyclable sorbent cartridge (the company won't say what it's made of but claims its sorbent is "non-toxic") is automatically cleaned of contaminants, creating a low-maintenance system. This cartridge needs to be replaced about every year, depending on use. Sensors provide real-time feedback to maximize indoor air quality and energy savings based on building needs—achieving, on average, 20% energy savings and a greater than 40% reduction in peak HVAC load, according to company estimates. The system can also default to economizer mode, bringing in outside air when the temperature is right, such as to provide natural cooling in the fall.

The enVerid is a modular system that can be installed onto a wide variety of HVAC systems, with each unit managing approximately 20,000 ft^2 of space, depending on the number of occupants, and can be doubled up for larger areas. According to the company, the payback for a retrofit application through energy savings is 1.5 to 3 years. In new construction, use of the system can reduce the size of other HVAC components, including chillers and boilers. According to the company, the system essentially pays for itself by reducing first costs.

Photo: enVerid

This enVerid unit improves indoor air quality and saves energy by removing contaminants from indoor air rather than replacing conditioned air with outdoor air.

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PRIMER

VOC Testing: What It Can and Can't Tell You

"Section 01350" has come a long way since it acquired its curious nickname. Here's what it can tell you about indoor air quality—and what it can't.

by Paula Melton

You've checked the box and specified interior products that are certified as low-emitting. But are you actually protecting building occupants from hazardous VOCs?

Yes!

Okay, maybe. Mostly.

Indoor emissions labels are a useful shortcut, but if your ultimate goal is better indoor air quality, you need to understand their strengths and limitations.

Apples to apples

Emissions testing of building products began in the 1980s, but that was mainly for research purposes. People began seeing the potential to use such tests to compare products, but for that to happen, the testing had to be repeatable: any lab should be able to analyze the same product and come out with the same results.

The beginnings of this standardization process were humble. A group of researchers in California wrote an emissions testing protocol into the specs for a state building project (the Capitol Area East End Complex) in 1999. That specification eventually became the California Department of Health Standard Method for the Testing and Evaluation of Volatile Organic Chemical Emissions from Indoor Sources Using Environmental Chambers Version 1.1-2010.

This mouthful is typically shortened to "CDPH Standard Method v1.1," but it goes by another name as well. Because the original 1999 protocol was written into specification section 01350, people still casually call the standard "thirteen-fifty."

Graham Hills. License: CC BY 2.0.

Furniture, carpets, flooring, coatings, and more … all are potential IAQ killers. Do you know if VOC labels are really protecting occupants?

What really happens in the lab

The name isn't all that's evolved. With lots of lessons learned under their belts, government officials, scientists, certifying bodies, and manufacturers have agreed on a long list of conditions that must be controlled in order to get accurate results.

Here are some of the things the CDPH Standard Method standardizes:

- How manufacturers must choose their samples
- Specific methods and timing for placing the product samples in airtight packaging
- How the samples should be tracked through chain-of-custody documents
- Proper handling of the samples once they get to the lab
- How to prepare different kinds of materials for the test chamber (like paints vs. sealants vs. whole pieces of furniture)
- The test chamber itself—size and other characteristics
- How and when air samples are collected
- Protocols for identifying and measuring specific VOCs
- Use of test results to predict real-world effects of a product's emissions (more on this below)
- Reporting of results
- Laboratory quality control, accreditation, and management of conflicts of interest
- Proper use of lab results in marketing claims

Using the results to predict IAQ

It's important to keep in mind that the test chamber does not mimic the real-world conditions in your office or bedroom. It's just a tightly controlled space where the product is left to offgas for a couple weeks before air samples are collected.

Once the lab takes those air samples, it identifies and measures the VOCs that were emitted from the product samples. Those results are then used to predict VOC concentrations in different types of real-world buildings.

Target Chemicals and Allowable Levels: CDPH Standard Method v1.1

Volatile Organic Compound	Chemical Abstract Service Registration Number	Allowable Concentration µg/m³
Acetaldehyde	75-07-0	70
Benzene	71-43-2	30
Carbon disulfide	75-15-0	400
Carbon tetrachloride	56-23-5	20
Chlorobenzene	108-90-7	500
Chloroform	67-66-3	150
Dichlorobenzene (1,4-)	106-46-7	400
Dichloroethylene (1,1)	75-35-4	35
Dimethylformamide (N,N-)	68-12-2	40
Dioxane (1,4-)	123-91-1	1,500
Epichlorohydrin	106-89-8	1.5
Ethylbenzene	100-41-4	1,000
Ethylene glycol	107-21-1	200
Ethylene glycol monoethyl ether	110-80-5	35
Ethylene glycol monoethyl ether acetate	111-15-9	150
Ethylene glycol monomethyl ether	109-86-4	30
Ethylene glycol monomethyl ether acetate	110-49-6	45
Formaldehyde	50-00-0	9
Hexane (n-)	110-54-3	3,500
Isophorone	78-59-1	1,000
Isopropanol	67-63-0	3,500
Methyl chloroform	71-55-6	500
Methylene chloride	75-09-2	200
Methyl t-butyl ether	1634-04-4	4,000
Naphthalene	91-20-3	4.5
Phenol	108-95-2	100
Propylene glycol monomethyl ether	107-98-2	3,500
Styrene	100-42-5	450
Tetrachloroethylene	127-18-4	17.5
Toluene	108-88-3	150
Trichloroethylene	79-01-6	300
Vinyl acetate	108-05-4	100
Xylenes, technical mixture (m-, o-, p-xylene combined)	108-38-3, 95-47-6, 106-42-3	350

Source: California Department of Health Standard Method for the Testing and Evaluation of Volatile Organic Chemical Emissions from Indoor Sources Using Environmental Chambers Version 1.1

The CDPH Standard Method details multiple modeling scenarios, including a private office, an open-plan office (for whole workstations), a school classroom, and (in an appendix) a single-family home. All the same numbers get plugged into these scenarios, so what makes them different?

All these scenarios make different assumptions about:

- volume of the space, plus floor area, ceiling height, and surface area of floor and ceiling
- product types expected, and amounts of each
- number of occupants
- air changes per hour
- number of rooms (for the single-family home only)

The modeling results for each scenario predict the concentration of individual VOCs within each type of space.

These concentrations are then compared against the allowable concentration for each chemical the standard lists as a "target chemical" (see table). If the concentration is predicted to be lower than the allowable level in a specific building type, the product passes the test for that specific building type. If it's higher, then it fails the test for that building type.

What VOC testing can't tell you

These models are based on averages in the State of California, and its list of target chemicals hasn't been updated for years. And therein lie the major limitations of VOC testing programs.

The standard builds in some protective measures for worst-case scenarios (like setting its thresholds at one-half of the State's actual allowable concentration levels). But no VOC test or label can:

- make up for of an off day on the production line, when the wrong glue was used or the binder didn't cure properly
- tell you whether a product is appropriate for a space with inadequate ventilation (that shouldn't happen, but we know it does)
- make predictions for a space type not covered by the standard (what about a dorm room?)
- account for the possible effects of breathing in multiple VOCs at otherwise safe levels
- address semi-volatile organic compounds (like phthalates and halogenated flame retardants) or other chemicals that we touch, eat, and inhale via dust rather than as gases

No one ever said the CDPH Standard Method was meant to guarantee safety in all conditions—which is why the standard includes guidelines on marketing claims.

It's a first step toward protecting building occupants from the known health effects of inhaling VOCs.