Thank you for that kind introduction. It's a pleasure and honour to be here with you today to talk about the nexus of green buildings, global health, sustainable development and the move and push towards healthy buildings. So we think about what's happening in the world. We have massive population growth, rapid urbanisation, increasing demands on our natural ecosystems, and there's been a plan put forward for how we can go about doing this better. And here is the Sustainable Development Goals that many of you are likely very familiar with, 17 goals to promote sustainable, equitable, environmentally conscious development.

We've been doing a lot of thinking on our end about what that means for buildings in particular, and we wrote a report reorganising the Sustainable Development Goals around public health, starting with a public health foundation. In fact, Goal three is good health and well-being. And then thinking about four pillars of health, one being indoor health, and those goals related to time spent indoors and the places where we work and live and travel. Second pillar is around resource health, so responsible consumption and production, that's goal 12 and in particular a subgoal which is environmentally responsible management of chemicals.

And we've talked about that today too. Third, economic health. How do we think about buildings as engines of economic growth? And fourth is the relationship of our buildings to our natural world and how our health is influenced beyond the four walls and buildings play a key role here, too. Now, I brought this up because I want to use this as the chapters of the presentation today. I'm going to talk about it in these four pillars here, indoor health, resource health, economic health and environmental health.

And I'm going to start by combining two, indoor health and economic health. And really, I'm going to start with this big picture reality that we are an indoor species at this point. We spend the vast majority of our time indoors. In fact, join me in a thought experiment. Take your age, multiply it by 0.9. That's how many years you've lived indoors. So I'm forty five. That means my indoor age is 40. Yet when we think about this, we tend to think about the place where we spend the 10 percent of our time.

We have regulations for things like outdoor air pollution in the United States, where we have the national ambient air quality standards. We don't have a corollary for the indoor environment, really. So the indoor environment is having this big impact on our health. But if I gave you another thought experiment and asked you to think about how you know what you know about healthy living, I'm sure all of you would go to the same things you would say. We need to exercise.

We need to be physically fit to lead a healthy life. That's right. You would also say we need to eat healthy. This looks like a nice, healthy meal. You would likely tell me that outdoor air pollution is bad for you. You would say that cigarette smoking is bad for you. How do we know about these things? Well, there are these great human epidemiological cohort studies that follow tens of thousands of people over time to see about their lifestyle behaviors and the outcomes that happen.

And we've learned a lot about what constitutes healthy, healthy living. But the reality is these studies don't talk about the place where we spend all of our time. They don't talk about the role of the indoor environment on our health. This is a glaring hole in our understanding of what it means to lead a healthy lifestyle. Now, that's changing a little bit this year with the pandemic, because I think maybe for the first time in history, people are now acutely aware of how the indoor environment is influencing their health around one aspect of health, disease and disease avoidance.

We know that buildings can help us fight disease and promote health. In fact, we knew that buildings would play a key role in any future pandemic. Here is an editorial I wrote with a colleague of mine in December 2019 before covid-19 first hit. And in that article, we talk about the power of healthy buildings, research to advance health for all. And in that article we mentioned pandemics. It was never a question of when or if a pandemic would hit.

It was a question of when, we narrowly escaped to other coronavirus pandemics just this in the past 20 years. And so we didn't know that this would be the year for a pandemic, but we always knew that

one would come and when that came, the buildings would play a key role. Unfortunately, unfortunately, it took a long time for widespread recognition that buildings were key. A few months after that, when we were deep in covid-19, I continued to write, here's an article I wrote in March 2020 in The New York Times, talking about the strategies that we can deploy in our buildings, buildings as the first line of defense against this novel coronavirus.

Bring in more outdoor air, better filters, use of portable air cleaners with HEPA filters and of course, social distancing, good hand hygiene. These are the strategies that we know. But the reality is it took a long time for this kind of guidance to permeate through in the US, in the CDC, for example, the WHO, the World Health Organization, has not fully embraced. The importance of things like ventilation and filtration. And the reason is, is because there's a fundamental misunderstanding about how this virus and others spread, they spread through the air.

And so to understand of buildings makes sense as a control, you first have to understand how this virus is spread, so it's spread, spread through close contact through the air. It was thought it was spread through surfaces as well, and certainly beyond one metre, beyond two metres can happen. But that didn't get a lot of attention. The reality is, is that there's a lot of evidence, what we call far field airborne transmission within room transmission happening beyond two meters or six feet.

Basic aerosol physics. When we talk, breathe or sing, we emit respiratory aerosols that carry the virus. These aerosols are small enough that they would travel beyond two meters. They will stay aloft for 30 minutes. Some of the small ones will stay low for hours until they removed out of the air. So we should have known that this type of transmission can happen. We've now seen air sampling data showing that this kind of transmission can happen and we have cases high profile, super spreading events happening all over the world where the main or common risk factors are time indoors, no masks and low to no ventilation.

Doesn't matter if it's a bus or a restaurant or a choir practice, a faith based organisation like a church, on a school bus. Everywhere we see these outbreaks happening at the same fundamental factors. Here's a study my team did looking at the Diamond Princess cruise ship. Figure on the left shows that the majority of our exposure or transmission is happening through aerosols, the finer aerosols that travel in space, whereas a minor contributor or the droplets and as their name implies, these drop out of the air, but the vast majority stay aloft.

The figure on the right shows that the short range, close distance, small aerosols accounts for the majority. Right behind it is longer distance but longer distance. I mean, beyond two meters or six feet fomites or surface transmission is something we've known is a minor route of transmission at this point. So all of the evidence shows us that airborne transmission can happen and that means buildings play a key role. Now we can start to think, well, what do we have to do in buildings, and the guidance really hasn't changed.

Our guidance hasn't changed for over a year, 14 months. We've been giving the same guidance just recently where I am in the US, the CDC, Centers for Disease Control and Prevention also started updating their guidance, very similar to what we're talking about. They recommend three things: bring in more outdoor air. Number one, two; increase the level of filtration in your recirculated air. Most buildings have what's called a mervat filter. We recommend a 13 filter or higher Three; supplement with portable air cleaners with HEPA filters, and we recommend targeting four to six air changes per hour.

So you get a lot of turnover in the air. Here's why this is a problem. If you look at the history of ventilation standards that apply globally. A hundred years ago, we used to design buildings with infection control in mind, we used to have and set high ventilation rates where this dotted red line is. Over the years, we've lost our way, we started tightening up our building on envelopes, limiting the amount of fresh air that can come in.

And we set our ventilation rates for energy, not for human health. That is a fundamental problem. So many places during this pandemic are finding that their buildings were designed for a standard that

wasn't designed for health. And it has been difficult to bring that standard up higher, to bring in more outdoor air, more fresh air and more clean air. This is nothing new. We've known this for a very long time. Here's Florence Nightingale. One hundred and sixty years ago, the only defense a true nurse either asked or needs fresh air from an open window.

Of course, it's not quite that simple, but the logic is correct, fresh air, we know we have to dilute indoor contaminants. I also want to place healthy buildings or engineering controls in the context of other risk reduction techniques. It's not just engineering controls or healthy buildings square in the center of this diagram. It's other aspects of controls. It's what we call the layered defense approach. This here is called the hierarchy of controls. It's a framework we use in the field of public health and worker health and safety for decades, and it has five parts and helps make sense and organise the information you want to eliminate the hazard where you can.

Some countries have done this quite well. Other countries have not. How do you then substitute certain activities so you get lower risk activities? Three; engineering controls in our indoor spaces, more air, better filtration. Four; administrative controls. How do you limit large gatherings? How do you limit or maintain physical distancing. And last up top, PPE personal protective equipment in this context, wearing masks. So my colleague and I, John McCumber from Harvard Business School, wrote about this in Harvard Business Review in this article and this on the screen.

We wrote about this last year, and it's been a useful framework for organisations. Now, as we think about what else constitutes a healthy building or what else needs to be done, we have to recognise that health is not just disease avoidance. So certainly during the pandemic, we have been thinking a lot about disease avoidance, and that's important and good and correct. But health is also wellbeing and flourishing and cognitive performance, all these other attributes of health that we don't always capture.

My colleague and I have enrolled in Harvard Business Review about the use of health performance indicators to help guide us towards healthier buildings. And here we talk about HPI, health performance indicators. And this box is a two by two looking at leading and lagging indicators. And above the horizontal line are those indicators related to people and we can track those illness trends, sick days, that's good, but also can be difficult to do. And we like to focus on is what's below the line.

If you focus on the building, we know you can improve. You can improve all of those indicators above the line, you can improve the people factors, what we actually care about the health and performance of people and we can do that by leveraging the building. And I want to share a study called the COGA study that looked at cognitive function of workers related to indoor air quality. So in a study we did a couple of years ago, we enrolled knowledge workers to spend time with us in this environment here.

And unbeknownst to them, we change the air in subtle ways each day, at the end of the day we administer cognitive function test and we looked at three different factors: ventilation, so bringing more outdoor air, carbon dioxide. And also common chemicals that are in surface cleaners that off gas from carpets and furniture. We find is that when people spend time in this optimised indoor environment, they perform significantly better on these cognitive function tests. Across all of these cognitive function domains, which I think you'll quickly recognise and agree are quite relevant to what's happening around the world today and every day, how do you respond to a crisis?

How do you have strategic thinking and you seek out information, utilise that information as part of the work you're doing, everyday work you're doing. And so the big takeaway from this research was even minor improvements to indoor air quality. Controlling for all other factors can lead to better improvement on higher order decision making performance. What's interesting, too, from a business perspective, is that this leads to bottom line performance, better performance in the company when we apply the findings of that research, to an economic analysis, we find that the costs for these improvements are on the order of tens of US dollars per person per year, and the benefits are on the order of six to seven thousand US dollars per person per year. So I put up here a couple resources for you that you might find interesting. My colleague and I, Harvard Business School, wrote a book that came out last year called Healthy Buildings, where we walk through the science and the business

rationale for Healthy Buildings.

So he's a colleague at the Harvard Business School and at the Harvard School of Public Health, remerge our disciplines and talk about the business case and the health case for healthier buildings. And for the shorter version of that, we have to a couple of Harvard Business Review articles that talk about what makes an office building healthy and where where are the responsibilities in terms of employers for making sure health extends beyond the workplace into our homes and schools. So we had a lot of attention focused on indoor air quality through this pandemic and even that study I just mentioned focused on ventilation and air quality, but there's more to a healthy building than just air quality and a framework my team released a few years ago and called the nine foundations of a healthy building.

So we've gathered all of the scientific evidence collected over decades on all of the ways that buildings influence our health through better acoustics, lighting, reconnection with nature and biophilia design and lighting and views, mold and moisture, the chemicals that reside in our dust. Thermal conditions in the space influencing how well we think. And so would be mindful that this is a holistic approach to healthy buildings. Now, one of the key questions is how do you do this in practice?

How do you operationalise these kind of studies? So at Harvard, we treat our campus as a living laboratory. We've done work with the Harvard Office for Sustainability. And here's a little insight into how we're approaching it. So what do we care about? We care about health, happiness, people, equity, well-being, mental health, flourishing, disease avoidance sure, productivity, safety. And so how do we take that and think about what that means for our buildings?

Well, we have the higher order interest in help. We have these nine foundations of a healthy building and then we can think about these health performance indicators. We're trying to address things you can do on the ground. HVAC system, choosing healthier materials, focusing on biofuel design, fire life and safety systems. And what's interesting about this framework is you can start to connect the dots. If we're interested in immune health right now with this virus circulating, well, we have to think about ventilation and that means we have to control our HVAC system and monitor it, and monitor indoor air quality.

As we know, air quality is associated with immune health as well. If we think about hormone health or reproductive health, well, we know that the air we breathe and the dust in our in our offices and homes actually carry chemicals that we'll talk about, that it can actually interfere with hormone help. And we can do a better job here by selecting healthier materials. So this is the way to think about higher order interest in health, the nine foundations of a healthy building and also what we have to do to operationalise that.

And so let me use this as a jumping off point for thinking about healthy materials, to talk about one of these other pillars in our framework here, resource health and specifically Gold 12 there on responsible consumption and production of materials. So if I ask you how many chemicals are in commerce, you might be surprised to know that there's tens of thousands of chemicals in commerce. Maybe that's not surprising or will be surprising is how many are actually fully tested for health and safety.

In the US, it's very few, couple hundred. More surprisingly, where I am, even fewer are regulated, meaning there's no real enforcement against many of these chemicals that we know are toxic. And I want to give you an example of the problem here. It's not just a regulatory problem. Certainly there have been failings on the regulatory side, meaning we have tens of thousands of these chemicals in commerce with very few with enforceable regulations. But it's also been a failure in the market side of this.

So here's an op ed, an opinion piece I wrote in The Washington Post two or three years ago, talking about the games we play with chemicals in our products. I'm going to read you the opening paragraph or two, two paragraphs. So hopefully some of you are familiar with BPA, bisphenol A, this was a

chemical that was widely used in many products and BPA free products started showing up on shelves all over the United States. When new parents see the words BPA free and a baby bottle or a cup, they're meant to assume the product is safe.

This may well not be the case quite to the contrary. In fact, in some cases, hormone disrupting BPA or bisphenol A has simply been swapped for similar chemical BPA or bisphenol S that may well pose even greater dangers to Child's health. In this way, manufacturers have done an end around on the much publicised dangers of BPA without addressing the underlying problem. Even more disturbing, what's happened with BPA baby products is the tip of the iceberg points to a phenomenon known in the world of public health as a regrettable substitution.

The cynical replacement of one harmful chemical by another, equally or more harmful in a never ending game. Being played with our health is a carnival game in the United States called Whack a Mole. Every time one pops up, you hit it. Another one pops up here, you have to hit it. That's what we're playing with chemicals. As we start to limit BPA, other bisphenol take its place. This didn't just happen with kids baby products. It's happened with many other products.

And we're going to talk about one in particular. And that's the use of flame retardant chemicals in products. These products or these chemicals are used widely in products in our buildings, but first got attention back in the 1970s because they were used in children's pajamas until this one study was published, that showed really simple study, the children who are in pyjamas treated with this flame retardant chemical, Trius. When they tested the urine of the kids in the morning, they found the metabolites of that chemical.

So why is that important? It shows the chemical came out of the product, was absorbed into the bodies of these kids, and we knew the chemical was mutagenic and potentially carcinogenic. This was removed. Trist was then removed from the market, but it comes back. We have another class of chemicals called PBBs Poly Brominated biphenyl, used in all sorts of consumer goods for flame retardancy, products we put in buildings. This was used in the 1970s and 1980s until a really remarkable thing happened in the US here, the company that manufactured PBBs also manufactured cattle feed supplement and started mislabeling the bags.

So PBBs were shipped off as cattle feed supplement farmers started noticing their cattle or had lost their appetite. Not surprisingly, many became sick and died. And these chemicals are fat loving. Their lipophilic chemicals that build up in the tissue of these animals entered the food supply. It wasn't until several months later that this was all discovered and by then it already entered the food supply. Many people who lived in the state of Michigan, in the United States, had already been eating these animals and thereby these chemicals were accumulating in them as well.

And millions of animals ultimately had to be cold. But here's this regrettable substitution issue. Should we have made better decisions at the time? Well, I'll show you just one study at Harvard where I am, published in 1978 on these chemicals showing, that they laterally enter the fetus. At low doses, they're toxic. Teratogenic interfere with the immune system potentially carcinogenic. So we knew we knew these could be a problem, and so when we finally discovered this problem with the switched bags for that one manufacturer, what did we do?

Well, we took these PBB's we had an oxygen and we created PBDEs. So technically it's a new chemical, but to our bodies, it looks quite the same. We use these chemicals all over the world for decades. They are persistent chemicals. We find them all over the world and the polar ice caps in the oceans and in all of us. They are toxic and they bioaccumulate again that lipophilic chemicals. Here's a study I did with a colleague of mine, several colleagues of mine, showing that people have higher concentrations of these chemicals in their body.

Women have higher rates of thyroid disease, three fold higher for women or post menopause. These chemicals have also been linked with thyroid and other thyroid disorders, neurological developments, and reproductive effects. So here's why I'm bringing this up as a problem and why we have to do things better. Trust me, I'll get to solutions. So we have these PBB's that were banned in the 70s,

PBDEs I just showed you, with all these replacements that are coming in each time we're told the replacement is safer than the last replacement.

Well, here's a weird or sad twist in the story. Those chemicals that were banned in the children's pajamas in the 1970s, a chemical cousin related chemical was reintroduced without anybody really knowing 30, 40 years later in kids products, also a tris instead of bromine, it was chlorine. It was a chlorinated tris. So this game or the industry policing itself has really not worked, and the latest set of chemicals, flame retardant chemicals that were we were told were safer, turns out they don't look so safe either. Here's a study by a colleague of mine showing that women are at higher concentrations of these chemicals, these supposedly safer flame retardants, at decreased rates of fertilization, decrease rates of embryo implantation, decreases in clinical pregnancies, and a decrease in live births from these chemicals that are now in products used in things like couches and chairs and all over our buildings and in our homes and schools. So this has to change.

And I'll give you one more story to give you another recent example. And this has to do with a class of chemicals called P fast chemicals, poly, fluorinated chemicals that are characterised by the carbon fluorine bond. And we string these together. It's carbon, chlorine bonds, because the carbon chlorine bond is the strongest one of the strongest bonds in all of organic chemistry, and so we put these together, some really useful properties appear, air can pass through, but things like grease and soil and dirt can't. So we use these products widely. For their Stain Repellency properties, non-stick pants, stained repellency on ice and water repellency and outdoor gear and on carpets and furniture and even in glass. The issue with this is that these carbon chlorine bond is so strong that it actually never fully degrades in the environment. And that's why a couple of years ago, I rebranded them as Forever Chemicals. It's a play on the carbon fluorine bond, the CF, but really talks about their fundamental problem. They persist in the environment. Not for decades. For millennia. And I felt like the public was these chemicals are hard to talk about if you use their technical name, Peardon, Polli, Florelle, alkyl substances. So this is difficult, the chemistry is difficult. And there was no way to talk about these. Chemicals that are used widely in our products and persist in the environment forever, so you might ask, is there a health effect associated with these? And the answer is yes. One of these chemicals in this class elicits the most immune dramatic immune suppression ever observed, an environmental toxicant, the words of a colleague of mine showing a relationship between reduction in antibiotic concentration after immunisation for kids who have higher concentrations of these chemicals.

Another colleague of mine show that these chemicals are BC genes. Women gained back weight faster. Women in a weight loss program gain back weight faster if they had more of these chemicals in their body because these chemicals interfere with lipid metabolism. These chemicals are also being associated with testicular cancer and kidney cancer. And here's another colleague of mine showing that these chemicals are in widespread use and environmentally and can be found in the water. All over the United States. At a level that is not safe and here are the numbers, she estimated that six million Americans have these chemicals in the drinking water above the safe level. Others estimated at a hundred million people has extremely persistent chemicals.

This is a research out of my lab. Dr. Anna Young finds that these P fast chemicals, PFAS, these forever chemicals in dust, they come out of their products, they settle in, they come out of the air, they're in the dust. The dust itself and we submit this to hormone analysis actually binds to thyroid hormone receptors and androgen receptors. And these other chemicals also bind to estrogen receptors. So the dust, the dust is hormonally active. Think about that for a second. Dust is hormonally active. That's not right.

All right, so we've been working really quite hard on solutions, that's a bit of the problem side of this, but I always want to focus on solutions. So again, in our living lab project on our own campus, we've changed our purchasing products practices. This can be done. We have over 40 capital projects, three million square feet, where we've said we no longer want these classes of chemicals in our products and we've been quite successful.

Most notably, just last just a couple of weeks ago, our brand new science and engineering complex received the Living Building Challenge Pedal certification for materials, beauty and equity, where we

really stopped purchasing products for our buildings that had these classes of chemicals in them, which we know can impact health. And the really good news is that when we act, we see a difference. So this is the work of my team again. We looked at these healthier buildings versus conventional spaces to see was there a difference in the concentrations of these chemicals in dust.

And sure enough, we see decreases in these forever chemicals. That's the P fast the flame retardants, those PBDEs and OPEs, you see, they're so significant decreases in the levels in the spaces when we act and intervene. So big picture. We want to follow the precautionary principle. We have a health first mindset. Less toxic is not nontoxic. A class approach is warranted. We don't want to be playing chemical whack a mole. We just for some classes of chemicals. We just don't want any of them. We don't want we don't need the flame retardants. We don't need the forever chemicals. And last may be most important is innocent until proven guilty, which is the basis for criminal justice in the United States, might be good policy for criminal justice, but it's actually terrible chemical policy. So we can't play innocent until proven guilty. We've been burned too many times.

Last part of my talk, I want to move into thinking about environmental health. And that is the relationship of our buildings to the natural world. Primarily and impacting our health and primarily through our energy choices, so it's really quite simple. Eighty percent of the world's energy coming from fossil fuel combustion, buildings consume 40 percent of that energy. When we burn fossil fuels, we release air pollutants into the air that cause immediate harmful effects. Through the criteria, air pollutants and harmful effects, through downstream effects from climate change and the logic here is quite simple if we green our buildings, use more energy efficient technologies, we reduce the demand and burden on the electrical grid and on site combustion. And we decrease the amount of air pollutants and that comes with a health benefit, an immediate health benefit and a benefit through climate. So what are we talking about? We think about the health impacts here, these criteria, air pollutants, PM two point five NOX and SOX and impacts on premature mortality, heart attacks, respiratory systems, missed workdays, manifest in hospital and hospital admissions, and impacts from greenhouse gases, including increases in infectious and water borne disease. We also, of course, have climate mediated impacts, sea level rise, ecosystem disruption, impacts on forestry, fisheries, construction industries, property damage, extreme weather, and on and on. So buildings are playing a key role in the problem, which means they also are playing a key role in the solution or they need to play a key role in the solution. And here I want to introduce a tool my team built. We call Cobe with the co-benefits of the built environment. And this will be interesting to you, because it's a way to quantify. It's a way to quantify the health benefits of your green building decisions. So how does this work? Well, we take a couple inputs there. We look at energy use intensity UI and how much can be reduced. We look at emissions factors associated with that energy use reduction, depending on where you are and where your energy comes from.

So if you use less energy and you're pulling from a coal fired power plant that's going to lead to a reduction in emissions, then we can look at what happens with the impact of those reduction in emissions. So we say if we know that a certain amount of air pollution causes a certain amount of disease and death. If we reduce it by X amount, we know there's a concomitant reduction in morbidity and mortality. We can quantify that. And that's what this COBE tool does. And we can look at what these impacts are. For example, on the screen in that small letters there, these are the impacts from the green building movement in the United States. The averted costs, averted number of sick days, averted number of asthma attacks, prevented deaths, hundreds of preventable deaths, due to the reduced demand on the electrical and energy grid.

So we start to do this again with this living lab approach, and we now have several examples of this on our website, if you're interested. Our website, by the way, is forhealth.org. the top there. And here's an example, you can go around and play with this calculator yourself to see what happens. So this is taking the COBE tool and not just looking at the green building movement, country level analysis, but actually looking at building level portfolio analysis. And this time we used Harvard's campus. And if you click through, like the graph on the left, if you just click some of the energy efficiency in buildings, you can see that Harvard saved with our old energy plan over eight years, about one hundred million US dollars, one hundred and twelve point eight million dollars US dollars, what hadn't been quantified or the health and climate co-benefits? There was another twenty three point two million dollars US

dollars in health and climate co-benefits that had not been accounted for when we put in all of our sustainability measures. Now, moving to that figure and graph on the right, almost one hundred one hundred sixty five million dollars in energy savings, but another forty five million US dollars in health and climate co-benefits. This becomes powerful because it extends the value proposition. Green buildings are not only good for energy conservation, which saves money for the building owner. Comes with health and climate benefits, so it comes with a social benefit. These buildings perform better in terms of market performance. We've also seen evidence that these buildings perform better in terms of indoor environmental quality performance. And this kind of brings it full circle, if we start thinking about the healthy building movement, the green building movement and what it means, we have to think of it as a health movement. It's a public health movement. Buildings are at the center of all of these issues. Vast majority of our time spent indoors, we are indoor species, indoor health, the products we put in our buildings and used to build our buildings and our resource health. The economic health of our buildings, recognising that they are engines of growth and also can influence human worker productivity and last environmental health, the impacts of our buildings on life above water, below water, mitigated through our decisions, not just through choices of products and consumption of materials, but also in our energy choices, wrapped in a big picture. Of global equity. Central to all of this is that this healthy buildings movement cannot be a movement for elite buildings in the world's greatest cities only for those who can afford it. This has to be a movement for all or else it'll be a gross failing. And we're at a precipice here. We're at a precipice, we're dealing with a global pandemic, we have the climate crisis right at our doorstep. Buildings are central to this solution, so much so that the decisions we make today regarding our buildings will determine our collective health now and for generations. So thank you for inviting me today. Really glad to join you and I'm looking forward to the question and answer.

What a fantastic presentation. I don't know about you, but I was delighted with my indoor age for about ten seconds before I was freaking out about chemical whack a mole. So please put your hands together to welcome with us live professor Dr. Joseph G Allen. So, Professor, I don't know if you can see me, but it's Nadine here with 450 of my closest friends in the green building sector and we've got a ton of questions here for you will try and get through as many of them as we can.

This is the top rated one performance metrics should we use to help reconcile the tension between operational energy and carbon and the benefits of healthy buildings?

That's a great question and really a pleasure to be here, and I totally agree with you on the indoor age, it can be unsettling for there for a minute. So I think that's one of the most important questions we have right now is thinking about how to get healthy buildings without while being mindful of the climate crisis. I think this is really where the merger of smart buildings and healthy buildings will come into play, specifically thinking about that ventilation question. If we normally in buildings, we bring in air and haphazardly dump it all over the building, well, we can be smart and you do things like demand control, ventilation to bring in air when and where it's needed, not wasting energy. Similarly, there are other ventilation techniques that increase what we call ventilation effectiveness. So, for example, if I had underfloor ventilation, we could bring in less air because it's delivered right to my breathing zone. I actually meet those high ventilation targets while using less energy and of course, more energy efficient systems and a cleaner energy grid so that the costs, the energy cost and environmental costs from electricity use are lower. I think we wrap all those things together. We can do this. We've been presented with that false choice. It's either a healthy building or an energy efficient building. That can't be the case. We have to have both.

The environmental product declarations. This is a question from, well, going far enough in labeling dangerous chemicals and materials being selected and construction.

That's a great question. Maybe I'll flip it a little bit. I really like the health product declarations, HPDs. I don't think they'd go enough, but at the same time, it's a great first step because what it does, if I think about the healthy materials problem, I laid out the problem there with the toxic chemicals. But the biggest problem is that we simply don't know what we're putting in our buildings and health product declarations and EPDs environmental product declarations are the first step because they start to get to transparency. Right now we're buying it's like buying food without knowing the ingredients. You get

a chair carpet. No one really knows what's in it. Well, with HPDs, at least it's disclosed what's in the product. That's a big first step. Transparency. Then you can optimise for health. Then you can say, oh, I see the list of things and we've decided we don't want chemical class one. We don't want forever chemicals. We don't want flame retardants. Then you can start making decisions. For the first part is that transparency that's been lacking for decades.

How have you seen the property sector respond to your research? Are they upgrading their building's ventilation and filtration?

Yeah, they are I mean, a lot of this I'd say there were leading companies, even pre covid-19 that we're doing this. Covid-19 has brought everyone into the game in our country where it's just been wildly uncontrolled, thanks to poor leadership. I'll just be blunt about that. And so it's forced schools offices to address the shortcomings of their ventilation and filtration systems. So I'd say, yes, across the board, the companies I work with are eager to get people back into their restaurants, shops and offices and schools and universities. They have upgraded their ventilation systems. Now, my hope is that this doesn't just go away when the covid threat goes away due to widespread vaccination. These are things that should have been in place before covid and should stay well after covid is controlled, whenever that is.

Could that equally go in the opposite direction with more people working from home, many businesses reducing their commercial footprint and people all heading back to potentially their unhealthy homes to do their work?

Yeah, you know, I think it's it's it's a movement that helped build these movements here to stay for this reason. Who is going to go back to a building that's not a healthy building right now? Here in the States, no one wants to go back to these buildings. We all know the risks. And so it's the new norm has to be the new norm. And what we think will happen to the market is that if your building is not a healthy building where you haven't made these improvements or you're a building that can't build these kind of lower grade buildings are going to be the ones that that don't get invested in. Right, they don't keep their value. And the market is going to move to this healthy building space, simply because the demand pressures are so strong from consumers and workers right now. And we see that leading executives that I work with are talking about resilience, businesses don't like to be closed for an entire year. They don't have to. And they're recognising that one of the things that's kept them close is that their buildings could not perform the way they needed to. So they want to design that resilience into this into their buildings. And that means having healthy buildings.

Professor, does this mean there is a fundamental clash between the principles of Passive House, which prioritises low ACH/energy and healthy buildings?

I don't think it's a fundamental misalignment, right? Like I said earlier, we have to have energy plus health and there are many ways to do it. And it also depends on your geography with the ambient conditions are. So there's plenty of room in this space for natural ventilation, passive house, mechanically ventilated spaces. I think the big picture is we need to design in such a way that buildings are energy efficient while promoting health and we can choose any pathway we need to get there, including better ventilation, better filtration, but also being a lot smarter about the products we put into those buildings. Like I mentioned, the healthy materials, off gassing of common BOCs or volatile organic compounds. So if we do source control, that's key. So choose better products to make sure we're not polluting or bringing in enough outdoor air filtration. And this can be done through any of these different mechanisms or approaches. Passive house, natural ventilation, mechanical ventilation, what have you.

What was the cost or the investment to get the savings for the Harvard campus? And what about the payback period?

So in terms of the healthy materials, so I'd say on the ventilation side of this payback is very quick in terms of what we see from the cognitive function studies that the productivity gains are instant, right? You improve the air quality. People are breathing better, they perform better, they feel better. They're

more awake. That's instant. I think it's trickier to think about return on investment for healthy materials. And I'll describe it this way. I've been in design charrette so meetings with architects, designers on the Harvard campus and elsewhere. And I've been asked that question and my comeback is, well, what is the cost or value? What is the cost of having products in our buildings that we know interfere with a young woman's or young man's reproductive health? And that changes the conversation because how do you do the ROI on that? We have an obligation to provide our students, our staff, our workers, our guests with healthy indoor environments that are not going to adversely impact them. Not everything is so simple as a the ROI calculation on energy, for example, or even by the productivity analysis I did, is relatively simple. But to start to think about these sub chronic impacts on our hormonal functioning is really it's really quite difficult night for me. It's we have to prioritise health. And even if we can't do that, quite do the ROI, how many years that payback back is invaluable.

Professor, we've got so many questions here for you, but we are out of time. So thank you very much for joining us today and for your presentation. Put your hands together, please, to Dr. Joseph G Allen.