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Radical overhaul of construction industry needed if UK to have any chance of net zero by 2050 – new research

January 20, 2022 10.24am GMT

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As I entered the construction site in England a decade ago, I was filled with excitement. This was a new state of the art housing development. I was there to provide independent evidence as to whether the development stood up to its claims of superior energy performance – the construction company promised that the finished buildings would consume far less energy than the norm. As I put my high visibility jacket and helmet on, I noticed a TV crew unloading their equipment. This was clearly a high profile site.

The site manager took me to the first house, where I was going to set up equipment for an air tightness test. I would use a large fan to create negative pressure in the building by extracting air from it, then use a pressure difference instrument to measure air flow through gaps and cracks in the building. A site operative with a mastic sealant gun told me: “I made it ready for you, mate.” The TV crew was right behind me – they were going to film me doing the test.

But as I started a routine visual inspection of the house, I noticed a pea-sized hole in one of the window frames – it turned out that the operative hadn't done a very good job after all. As a result, the air tightness test had to be postponed, and the TV crew got an extended coffee break until we found the man with the mastic gun.

This incident is representative of my career. I've very rarely come across a building that actually lives up to its claims.

Now, my new research reveals that even the best aspects of the UK's current building plans don't go nearly far enough. We have found that due to embodied carbon emissions – the emissions that derive from making building materials and constructing houses, rather than heating and powering them – only building all new housing using naturally grown materials with negative embodied carbon will allow the UK housing industry to be net zero by 2050.

This story is part of Conversation Insights

The Insights team generates long-form journalism and is working with academics from different backgrounds who have been engaged in projects to tackle societal and scientific challenges.

Numerous UK local authorities have declared a climate emergency, and are committed to constructing buildings to net zero carbon emissions, in many cases aiming to reach this by 2030. But the current UK building regulations do not even require new buildings to achieve operational zero emissions – that is, emissions from building use. Embodied emissions – emissions from making and using building materials – are not even on the radar of the local authorities.

The problem is that there isn't enough joined-up thinking. Builders are trained how to build, but are not trained to know how their work affects building energy performance. Government initiatives are introduced by one department to reduce energy consumption and discontinued by another department to enable enough houses to be built cheaply, with no consideration for unintended consequences. Building standards are not ambitious enough and take years to change. Developers do not want to exceed these standards as this would increase their costs and reduce profits. The industry is fragmented, and operates in silos.

Quality of workmanship

Even when intentions are good and houses are designed to the best specifications, lack of training standards in construction mean they often aren't built properly.

I started working in the construction industry while doing my PhD on the energy performance of a new “solar village” in Bournville, Birmingham. The houses in this new village were what we call “passive solar”: they had been extremely well insulated and were designed to admit heat from the sun through large, south-facing glazing, and to retain warmth within the concrete floor slab and the dense concrete blocks in the walls. This heat, slowly emitted, warmed the houses, reducing the need for a central heating system much of the time.

As the desired effect is only achieved in an airtight building – so that heat cannot escape the house – my team tested the air tightness of a demonstration house. We were surprised to find that the test instruments were telling us that the building was not airtight at all – there was a significant air leak. The search for the air leak took us to the attic space, where we found that heating pipes running from the solar hot water system on the roof into the house were routed through unnecessarily large and unsealed holes. We sealed the holes and carried out a successful air tightness test. The year was 1985.



Houses with solar panels on the roof.

Modern houses with solar panels on the roof for alternative energy. Shutterstock/esbobeldijk

This has happened to me many times over the years. Buildings are rarely as airtight as construction companies claim them to be. This is often due to large holes drilled for small electricity cables; window frames peppered with holes; air leaks through loft hatches and door thresholds; air leaks through electrical sockets in walls and through holes for pipes in the floors.

Read more: Embodied carbon: why truly net zero buildings could still be decades away

Big house builders consider that it is too onerous to improve air tightness, and some argue that this may be why the regulations haven't changed for years.


Meaningless assessments

Carbon dioxide emissions came on the horizon in the first decade of this century as something that needed to be better controlled in buildings.

In 2006, I was cautiously optimistic about the future of house building in the UK. The EU's Energy Performance of Buildings Directive had just been adopted in Building Regulations in England and Wales. This meant that the assessment of building energy performance would become mandatory in the UK. Energy Performance Certificates (EPCs) would be required for every commercial or residential building when constructed, sold or let, and Display Energy Certificates (DECs) would be required in buildings with a floor area of over 250m², occupied by public authorities and frequently visited by the public.

As an academic who is also a practising engineer, I received authorisation to assess energy performance of buildings and to issue EPCs and DECs. But soon I realised that there were various routes to the same qualification. Under some of these schemes, it became possible for people with no previous qualifications or experience in building performance to retrain from unrelated vocational qualifications and become government-approved energy performance assessors in just a week.

Soon, the market was awash with poorly-trained energy performance assessors. While shadowing one of the on-site assessors, it astonished me that they did not even consider the orientation of the building, thus missing crucial information on heat gains and losses. Instead of improving the overall performance of the building stock, boxes were ticked and the buildings appeared to be better on paper, while in reality they were not much better than they had always been.

 Energy efficiency form and a calculator.

How much do these energy performance certificates really mean? Niyazz/Shutterstock.com

Failed government initiatives

Similar failures have followed. England's Green Homes Grant, for example, was recently described as a "slam dunk fail" by the public accounts committee. This scheme, launched in 2020, was to provide £5,000 grants for improving the thermal insulation of homes. Only 47,000 homes out of the 600,000 planned were upgraded, and more than £1,000 per upgraded home was spent on administration. The scheme was scrapped in 2021.

This is not the first time we've seen a government scheme scrapped. There have been multiple grants that have been poorly planned and have turned out to be inadequate, with some of the new ones likely to only scratch the surface.


Looking back, the construction industry has a long history of substandard performance. The industry faces a titanic struggle for skills that appears to be long term and structural. Many energy performance assessors are not sufficiently trained and can qualify in five days with no prior experience, rendering energy performance certificates nearly meaningless. And the government has discontinued multiple green subsidy schemes, which is the only way the general public will be encouraged to retrofit or improve the housing stock.

Yet many new developments have been trumpeted as "green" in one way or another, with no rigorous analysis of that green status. For instance, it is not uncommon that a prefabricated building system is claimed to be net zero by its manufacturer without calculating the total embodied emissions contained in the individual materials used in its manufacture. This is due to the lack of long term coordinated thinking.

We know how to do it

The thing is: we actually know how to build a truly zero carbon house. So why are we not doing it, on a massive scale?

I have used the Birmingham Zero Carbon House as evidence of this since 2010. This is a retrofitted house, based on an 1840, end-of-terrace brick house. Retrofitting is a process of adding something to a building that was not done or available at the time of construction. This includes thermal insulation, measures for improving air tightness, and adding renewable energy systems and other heat sources. In 2009, the house was extended and retrofitted with super insulation – thermal insulation that is two to three times thicker than regularly used.

 A modernist extension on a red brick traditional house.

John Christophers' Zero Carbon House. © Ljubomir Jankovic, Author provided

Three energy sources were installed: a photovoltaic system that converts the sun's energy into electricity; a solar thermal system that uses the sun's energy to heat and store water for domestic use; and a wood burning stove, run on fallen tree branches from the garden, which is used on a handful of days during the cold winter months.

The owner and architect of this house, John Christophers, did not have problems with poor workmanship during the retrofit. He avoided this by briefing the workforce on site before they started work and explaining the consequences of high quality work on building performance. Thanks to their superlative work, the house achieved a record-breaking level of airtightness, ten times lower than required by the UK's building regulations.


In 2010, while I was installing scientific monitoring instruments in the house, a representative from a gas company showed up unannounced – they expected some wrongdoing, as the house had been disconnected from the gas supply and had never been reconnected. In fact, the gas supply was no longer required as the Christophers used electricity collected from the sun for cooking and fallen tree branches for heating.

On one cold winter's night, when I brought my lab's heat detecting camera to search for heat escaping from the house, the images it produced were almost completely dark – indicating minimum heat loss.

As early adopters of a Feed In Tariff when the house was retrofitted, the Christophers currently receive over £1,500 annually for electricity generation. Combined with the £4,200 they save annually in energy costs compared with a conventional house of the same geometry, they are £5,700 per year better off than living in a conventional home.

The return on investment of the Birmingham Zero Carbon House is 193% over the 25 years following the retrofit, and is forecast to make the owners just over £91,000 over that period. Christophers and his family are thrilled. He said:

Living in the zero carbon house puts us more closely in touch with the rhythm of days and seasons: we're very conscious of the abundance – or occasionally the precious scarcity – of solar hot water and electricity, and the quality of natural light. Even after 12 years, it still feels miraculous that it can be below freezing outside, yet warm inside and generating hot water at over 50°C while cooking on solar electricity.

 A crane lowers down a wall and windows over an existing house.

Installing external insulation in the retrofit project. © Ljubomir Jankovic, Author provided

The benefits of living in efficient buildings are not just monetary or climate-related. They also impact on health and wellbeing. Emma*, who lives in a building I coordinated the retrofitting of in a different project, told me: “I did not need heating when outside temperature dropped below freezing yesterday. The house feels like home now – no damp, no dust, no noise.” Cynthia*, who lived next door, said, “I have stopped using my asthma puffer.”

The last comment touched me deeply. This was the consequence of better internal conditions: no damp due to higher internal temperatures, and no dust due to filtering of air in the mechanical ventilation system. It was gratifying to see how much our work had transformed this person's life. Retrofitting more of the UK's buildings would not only drastically decrease the UK's carbon emissions, but could also improve health across the population and put less pressure on the NHS.

We know how to build or retrofit zero carbon houses – but we need to be doing a lot more of it. This is because big developers fear higher costs. This perception has resulted in zero carbon projects run as private and one-off initiatives.


Read more: We can't afford to just build greener. We must build less

Today's housing

My team and I wanted to look more deeply into how today's housing can be improved, over and above building regulations, and went into collaboration with a local council in Hertfordshire. We looked for a housing development that had received planning permission, but had not yet been constructed. We found a cluster of six family houses with planning approval to be built in accordance with UK building regulations, with no requirement for net zero performance.

We wanted to find out what it would take to redesign these houses in a way that would make them net zero houses. Crucially, we also wanted to include embodied emissions in this assessment – not only taking into account the energy usage of the house once built, but also the carbon costs of the building materials and the actual construction of the house. What, we wanted to know, does it take to build a house that doesn't contribute to the climate crisis at all?

We used computer modelling to redesign these houses with improved thermal insulation, heat pumps and solar electricity panels. We then calculated the embodied emissions of all the conventional materials which went into building the houses using the materials from the original design. We found that the combined emissions – when balanced out by the excess renewable energy generated by the completed house – would not reach zero until 2065.

 Blue architectural computer model of a building against green background.


A computer model used in this research into embodied emissions. © Ljubomir Jankovic, Author provided

But we found that replacing the brick, concrete blocks and conventional insulation with hempcrete – a form of naturally grown hemp bonded with lime – drastically cut the home's embodied emissions. Hempcrete has negative embodied emissions: -108 kg CO₂ per cubic metre. This is because the hemp crop absorbs more CO₂ as it grows than is released while making it into hempcrete. By making the switch to hempcrete, the starting embodied emissions of the homes were 83kg of CO₂ per square metre of floor area. That was much lower than the 161kg per square metre if the same building was made using conventional materials.

When combined with renewable energy systems, we calculated that the total emissions of this hempcrete building would reach zero by 2045. Hempcrete is of course not the only possible material – straw bale and timber construction and other bio-sourced materials also have the potential to reduce embodied emissions.

In addition to drastically ramping up the energy efficiency requirements for new builds, we should also urgently develop regulations for retrofitting existing houses. In 2050, 19.1 million of today's homes, some 80% of the current 23.9 million, will still be in use. And to retrofit 19.1 million homes to net zero operational emissions by 2050 we need to retrofit approximately 1,870 homes every day. This is simply not going to happen given the current scale of government pledges and the state of the construction industry.

Even if retrofitted to meet the best energy efficiency standards, these existing buildings will take some time to reach net zero once combined embodied and operational emissions are taken into account. This is even true of the Birmingham Zero Carbon House, which was retrofitted from a Victorian brick building. I calculated that it will reach embodied and operational emission net zero in 2030.

 Scaffolding surrounds an orange house under blue sky.

An external thermal insulating foam facade is installed outside a home in Scotland, 2018. Doug Houghton/Alamy

Going forward

I did some simple calculations and found that the energy our planet receives from the sun in approximately one hour is sufficient to meet the world's energy consumption requirements for an entire year. But we do not yet have the technology to take advantage of this. We need to scale up investment, research and development towards this goal. After all, it is often said that we already have the tech to do this, it is just the willpower that's missing.

Nothing should be off the table when it comes to bringing climate change under control. We need to tap into the vast amount of solar energy that literally goes over our heads while we continue to use fossil fuels. And we need to use innovative financial models to supplement conventional finance, which is always in short supply and not easy to secure.

Better education of architects, engineers and construction managers is required. Increased understanding of the ingredients of good building performance will lead to better choices of building materials and distribution of these materials. It will become more widely understood that excessively glazed buildings use excessive energy for heating and cooling, and that buildings built from photosynthetic materials, such as hempcrete, straw bale, and others are superlative.

Detailed modelling of buildings will be required, too. The cost of high-end building simulation pays for itself within two months of construction – so education and training programmes for building simulation professionals must be developed to empower them to design better buildings. And every building should be equipped with built-in sensors, to inform the user of its performance in real time. This is already a standard practice in cars, but buildings are much more expensive and use more energy.

Most property developers will always comply with the minimum required standard. But these regulations are sub par. My hopes for change grew ahead of an update to part of the UK Building Regulations last December. But my views after the update aligned with the “extremely disappointing” verdict of the wider professional community. Policy after policy falls far short of what is needed to achieve net zero targets. These regulations urgently need to be improved – along with guidance for the retrofitting of existing buildings. And all of these measures will only lead to improvements if we increase the quality of workmanship.

The construction industry, then, needs a radical overhaul. Only then can we expect the industry to meet net zero. If not, it simply will not happen.

**Some of the names in this article have been changed to protect anonymity.*

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