HOUSE PLANNING HELP

Episode 262

Where do you put a low energy The Cube micro home? – with Mike Page

The show notes: www.houseplanninghelp.com/262

Mike: I read engineering science at Oxford in the late 1980s and then I went into artificial intelligence and became a cognitive psychologist.

I'm a strange mixture of cognitive psychology and engineering. But actually, for the job that we have to do on global warming, climate change, that's probably not a bad place to be. Because I suspect that the mitigation of climate change is going to be as much changing behaviour, which is psychology, as technology, which is engineering.

So, not a bad mixture it turns out, but an odd career path.

Ben: We're going to talk about the Cube Project today and some of the issues that you came up against. There's quite a lot in here too; particularly I'm hoping to touch on land, which I know maybe you're not so keen to talk about. But that seems to be one of the big challenges.

So, first of all, how did the whole Cube Project begin?

Mike: I work at the University of Hertfordshire and in about 2008, there was a little more money around, before the financial crisis, and there was money around for cross-department work and cross-department projects.

I'd been interested in green building techniques and potentially looking at the psychology of pro-environmental behaviour change for a while. I'd seen the Munich Compact Home which was a two-point-six by two-point-six by two-point-six metre micro-home, and I said to my colleagues, 'why don't we do something like that but with an emphasis on demonstrating to people all the things they could do in a building of any size' – that was very important – 'to live a low or zero carbon life but with modern comforts? Not in a yurt in mid-Wales with a bucket and spade.'

So, I suggested this project called the Cube Project to this cross-departmental funding body in the University, and somewhat to my surprise they said yes. So, I launched into the design and actually getting companies to come in and talk.

We had talks from people about composting loos and reed beds; we had talks from Mitsubishi Electric who are nearby in Hatfield about Ecodown and air source heat pumps.

The idea behind it really was to try to find out what the best thing to do would be, as I say, in a building of any size, and then put it in to a building of a small size so that we could take that building around and show people.

Wittgenstein said that some things have to be shown. They can't just be explained. And I think there's some truth in that with regard to eco-housing or particular technologies. You have to show people that these things work and they're not overcomplex. Like LED lighting. People were very suspicious of it because they'd associated it with compact fluorescent tubes saying, 'it takes a long time to warm up. It's full of mercury' et cetera.

Now, that was not true of LED lighting. None of it's true of LED lighting. But I suppose the idea was to do low environmental behaviour change by design, so that people didn't always have to think so hard about what they were doing. Because if you rely on people thinking hard about trying to save energy, most of the time in psychological terms they're getting on with their lives and they're not thinking hard about saving energy. So, what you've got to do is make it the default so they can almost do nothing else in a house. But you've got to make it so that they have their comforts and the sort of quality of life that they want.

That's what we were trying to do in the Cube Project. Trying to pull together a suite of things, some of which we'll probably talk about, all of which will contribute to a low-carbon lifestyle but none of which will impinge on anybody having a decent quality of life.

Ben: Having that small building, the Cube, to begin with, that's probably one of the most ecological things you can do. So, that being important too. I know you're saying that you wanted to demonstrate it on all houses.

Mike: Absolutely. I have boats as well. I'm interested in boats. I built a boat once. So, there is that idea of compact living.

In a boat, you can have something which is a galley-kitchen one minute, and then it turns into a place to sleep. And then sometimes

it's an office where you chart a course or whatever. It's a multifunctional space.

There are some things you can do – you can have a large house and then have zoned heating such that you try to arrange it so that you're only heating the bit that you're in. Or you can have lighting so that the lights turn off in the bits that you're not in. That's one way of doing it. We have quite complex controls to make sure you're not heating or lighting bits that you're not in.

The other way of looking at it was to always be in the same place and make sure you could fulfil all the different functions. That was the sort of conceit. And for QB1, which was the first project – and people can see pictures of these on cubeproject.org.uk – we decided upon a three by three by three metre space in which one person or a friendly couple could live a comfortable modern existence but with a minimum environmental impact mostly characterised as carbon emissions, and we took that in 2011 to the Edinburgh Science Festival. That was QB1.

Subsequent to QB1, lots of people got in touch and said, 'I'm quite interested in that.' Even though we hadn't set it out as a 'we want people to live in small spaces' project…

Ben: That's interesting. People were then starting to think, 'I'd like a small space,' but that wasn't your intention.

Mike: Absolutely. So, lots of people came around and said, 'hey, that's really cool. I'd like a space like that.' Well, then I realised that QB1 was slightly restricted. The bed wasn't a full sized double bed, it was what's called a small double bed, and there were some restrictions. You could only have two people sitting down to eat.

So, I designed QB2 which was like a stretched QB1. It was three metres by four metres in plan, and three metres internal height. So, that's thirty-six cubic metres. And that gives you a whole lot more flexibility. It gives you a really decent set of spaces. A decent four metre long bathroom, a galley kitchen, a full sized double bed, four seater table, lots of storage space, a place for a washing machine and everything – everything you'd want to do, you can do. A couple of people could live quite happily in QB2.

Now again, I wasn't saying that everybody either should or would want to live in it, but we got a lot of enquiries from people saying, 'I'd love to live in a place like that.' And I had to say that whilst I absolutely am not saying that people should live in small spaces – and that's particularly important to say on a day like today when the

Children's Commissioner has had to report that there are two-hundred-thousand children in the UK living in very inadequate accommodation; whole families stuffed into shipping containers and things like that…

Ben: Yes, but I think we've got to draw a line here and say that there's something very different between a person choosing to live like this, and I think for one person, I can actually imagine myself if I was on my own, I would almost be tempted. It would be either going down the co-housing route and joining a group, or it could well be going into a tiny house of some description.

So, just on the size again, when you're doing these sorts of prototypes, the second you have more space, even if we're talking a metre, ten metres, everything changes.

I know that you were trying to demonstrate that this can happen in all sizes of houses, but you have a lot of bits and pieces in there that would move this way, move that way…

Mike: Absolutely. We had some constraints as well. I didn't want anything that folded up. I didn't allow any ladders.

Ben: Why?

Mike: Because if you have something that folds up like a table or something like that – so the original Munich Compact House had a bed which folded up and then the table was underneath – it was my view, and this might be the psychologist coming out or it might just be me being lazy, but basically whenever you want to fold something up, it's always going to be inconvenient.

If you have to fold away a table to go to bed, you're going to have coffee cups and computer work, you've left the work and now you're going to have to tidy it all away to go to bed – it's inconvenient. Or what if that one person is still in bed but you still want to use the table? It's always going to be inconvenient to have things folding up.

I did have some things. The table slid to the side so that you could have more space, or you could have four people, two on each side, or you could slide it to the wall and have a space where you put your feet up to watch TV. That was configurable. But never was there a place where you would have to get something out of the way to fold something up and then you couldn't use it. So, everything was always usable. That was a design rule which we had.

The other design rule was that we wouldn't use technology that was only appropriate to small spaces, because of this wider view that we had that we wanted to demonstrate what could be done in any size house or any size building; the size of the Pentagon, you could all use LED lighting, air source heat pumps, heat recovery ventilation was another thing we had, we had a composting loo in there, low flow water outlets, particularly hot water.

That was an interesting thing to demonstrate to people. All the energy in hot water is basically in the 'hot', not in the water. It takes about a kilowatt-hour of energy to get a tonne of water to your cold water tap. And if you put another kilowatt-hour into it, you'll warm that tonne of water up by just under a. degree centigrade. So, you're going to warm up the hot water by thirty, forty degrees centigrade. So, thirty, thirty-oneths of the energy is in the heat, not in the water. So, you want your low flow shower head in energy terms at least, much more than you want low cold water flows.

Now, you might be in an area of water drought, as it were, or water scarcity. So, that would be another reason. But from an energy point of view, you want to restrict the flows of hot water.

We actually had a composting loo in there as well, which also was…

Ben: That's taking things… well, I don't know. Is it taking things a bit far?

Mike: Well, we worked with Andy Warren who's in mid-Wales in Llanidloes and works a lot with the people at Machynlleth at the Centre for Alternative Technology. And we found that whilst it was going a little bit far, it does allow you to have one more degree of separation. It's one fewer thing to connect when you're moving the Cube. Having said that, you still need something for the kitchen waste. So, it's not quite as brilliant as it sounds.

But the composting loo itself worked really well, but it gave some really nice technical problems about what you do when you've got a composting loo but you've also got heat recovery ventilation. So, you've got an extract in the kitchen. Now, these things can't be very far apart in the Cube. So, if you put a big extractor fan in the kitchen, it starts sucking air back through the loo, which is not what you want to do. The composting loo wants to have a continuous flow of air into it.

So, we actually managed, even in that compact space, to have air going into the composting loo, through the composting loo so it was drawing air into the loo so it never smelled, and it really didn't smell,

and then it went through a heat exchanger before going out, and then fresh air was coming in somewhere else. So, we had an air heat exchanger even though it was being drawn into the composting loo. And then we had a recirculating hood in the kitchen.

It was really quite complex and there were some decisions we really couldn't get wrong because if you have an extract of a normal case, it would have sucked smelly air back out of the loo.

So, there were some lovely design problems and some lovely spatial problems, which I hope we solved in an interesting way.

We had two metre head height throughout the whole thing. We had all mod-cons, as it were, and we didn't have anything less than two metre head height anywhere in the Cube. We used every cubic centimetre, effectively. We had a full size shower, a four burner induction hob, an air source heat pump, fan coil heating, a thirty-two inch LED TV.

Ben: This is sounding a bit like a playground. Did this get road-tested?

Mike: Yes, people have lived in it. We had various celebrity road-tests. Tom Heap from Radio 4's Costing the Earth stayed in it a couple of nights.

We then lent it to a place of housing need and there were people living in it for several years. And we then gave/sold it to a housing agency who as far as I know are still operating it.

So, it was tested in anger, as it were.

Ben: What feedback did you get from that?

Mike: Great. They actually had two people living in it and one of them had allergies against a lot of the things that they would have got if they'd been in the sort of hostel for people who didn't have permanent homes to go to, in a London borough. They had a lot of allergies and so, they really couldn't live in there. And because all of ours was wood and cork and nice materials, no outgassing, very little dust, there was a couple of people who lived in there very happily for over a year and got really good feedback.

I didn't meet everybody who stayed in it over the years, but we got really good feedback.

One problem, not a problem but one issue was the fact that it had an alternating tread staircase in it. It sounds ridiculous in something

that's only three metres from floor to ceiling, but it was actually a really important way of getting up to the bed which was above the living area. And there was a sort of standing off place for the kitchen which then you could put the tanks underneath. All sorts of things like that. But obviously, for people with restricted mobility, that wasn't perfect.

That then led me to design QB3, and QB3 was the same internal volume but it was all on one level. So, six metres by three metres in plan, and two-and-a-bit metres from floor to ceiling. And in that, which we did for the Edinburgh Science Festival in 2016 with my colleague Marek Schubert, we had a different solution to how do you make multiple use of the floor space you have in plan.

So, in QB2, we had things above other things. We had the bed above the sitting, dining and living area. That's not available to you when you've only got two metres of floor to ceiling height.

We had moving walls so you could actually step out of the kitchen, wind the wall past you, and step back on to the same floor which was now in the bathroom. That was a nice bit of fun.

And going right back to the original point, you only have to insulate that small space. You only have to light that small space. The same light, when you can move a wall, does for the kitchen as does for the bathroom. And in fact, we had two moving walls. So, the bedroom then swapped with the lounge as well. So, you only have to insulate a small perimeter and you can have light and other things which do double duty. We had triple glazed windows and doors and all sorts of things like that.

Ben: Going back to the people who have shown interest, did you ever want to take things further? Or was it always just research?

Mike: We actually licensed the build and sale of these to our very good colleagues in a company called Bolton Buildings – they're not called Bolton because they're in Lancashire but they're called Bolton because they bolt things on they have a licence to actually build Cubes, QB2 or QB3 would be the natural ones to build.

But the problem has always been – and we had taken it to Grand Designs Live in ExCel in London; ten days, there was never a time in ten days from nine 'til six or whatever when we didn't have a queue of people waiting for the tour of the Cube Project. We literally must have showed three-thousand people through in just that week.

We did it in Birmingham, we'd been in the Edinburgh Science Festival, and every time people would say, 'oh, I'd love one of

these. My son or daughter is going to university. She would love one of these. Or if we had one of these in the garden for my mother or the carer' – so, we had loads and loads of interest and it was always founded on an issue which I guess is close to your heart as well, which is the availability of land.

All the people who wanted one were exactly the same set of people who didn't have land to put it on. And because the Cube Project is a self-contained dwelling house, although we were very careful to keep it within the definition of a caravan under the Caravan Act 1968 or whatever it is – it fits all the descriptions of a caravan; it's mobile, it's got the right dimensions, in fact a caravan can be twenty metres by six-point-eight metres on the outside so, ours is vastly smaller than the biggest caravan you can have – it meets the definition of a caravan but even a static caravan that's treated as a separate dwelling house needs planning permission. You need land with planning permission.

I suspect that people were thinking, 'if I had land with planning permission, then I wouldn't need to build a microhouse, I'd just build myself a normal house. And if it was in the south of England, probably then I'd sell it and move to the north of England, or to Wales where I come from. But that was the issue. It came down to a land issue.

Whilst people could put it in their garden, you could put a Cube in your garden, you can put a caravan in your garden, its use has to be incidental to the use of the house. It can't be a self-contained dwelling house.

Now, you and I have both heard stories I'm sure of people living in sheds in London rented to them by landlords who ought to know better, but we weren't prepared to go down that line. And another thing, we never wanted it to be for people living in isolation. We always thought, as you mentioned earlier, that a group of young people could get a site in the city even.

We didn't want it to just necessarily be up in the Scottish Highlands miles from anywhere. City living is eco-friendly living in many ways because you're not having to get in vehicles and move around. It's quite sustainable to be in the city with public transport. But if young people could get access to a small amount of land, and we went to various boroughs and pushed with them, where they could build a small community of Cubes maybe around some common space and maybe around some growing space, some allotments or something like that.

Ben: What about thinking of a caravan park? Can you just take something like this and put it on there or does it have to have wheels?

Mike: No, you can take something and put it on there. If a site has been designated for static caravans then yes, that would be perfect. And indeed, if a council had such a site, we could easily put Cubes on there. It could be private, it could be council-owned, or it could be something that's previously had permission and has fallen into disuse or whatever. That would be a perfect place to put such a community.

Of course, however, the temptation is because you can pick up a highly uninsulated, fan electric heated, static caravan for, say, ten-thousand pounds, that the council or a private landlord might then be tempted to put very shoddy housing on there and the energy use would be enormous and that wasn't the aim of our project.

So really, the aim of our project was about demonstrating low energy and if we had access to a caravan site or a place with permission for static caravans, we could build a very, very low energy community. I think we could build a nice community.

But as I say, what we really need are full size houses and so, that's something I've been concentrating on more recently.

Ben: I'm going to keep you on this for a while. So, tiny houses, do they exist at the moment in the UK?

I lived in a house that was perhaps not tiny, but in a terraced house that was maybe sixty square metres and a very good space for a couple. Perhaps when the kids came along it was not so ideal. But going smaller than that, how does it exist in the UK?

Mike: The term 'tiny house' comes from the US and we started this in 2008, as I said, and it really wasn't a term then but there were some people who had been doing it. And they're often trailable, they're often mobile, tiny houses in the US. And that's fine if you're happy to basically lodge it somewhere but then move around.

That puts restrictions on it. If it's going to be mobile, if it's going to be towable behind a car, then it's going to have to be less than two-point-five metres wide, it's going to have to be less than a certain weight.

And there are caravans, of course, that tow behind vehicles which obviously are functionally equivalent to tiny houses. But there's not

a very big population that I know of, of static tiny homes that are not just static caravans on park homes and things like that.

Ben: Is this the problem, that that is what happens when you divide up the land like this, you tend to adopt that model?

Mike: Yes. They tend to be therefore in holiday places or retirement places. And you can actually make a nice static caravan for a retirement village, but they tend to be in privately owned sites and they charge big leaseholds to be there, and it's difficult for you to sell them on. There's been stuff in the news recently. It can be difficult to sell them on without paying a big premium to the caravan park owner. So, there's not a very friendly set – and these sites obviously that have permission to do this are in limited supply.

So, whilst there are what we'd call tiny homes physically, they're not of the type that we were doing which was eco-friendly and meant to be fairly static and not moving around. QB2 was five-point-two, five-point-three tonnes and so, you couldn't really tow it behind a vehicle. It was three-point-five metres wide so, you couldn't tow behind any car, you had to put it on a lorry. It was mobile, so it met the definition of a caravan which is quite a broad definition. But it wasn't the sort of thing that people have done.

There'd been lots of one-offs, people towing things, people turning horse boxes into tiny – and George Clarke's Amazing Spaces programme has been very good at showing these individual efforts. But there's been no concerted effort to make some sort of planning arrangement that would allow groups of people to come together and maybe decide that that's what they wanted. A little network of smaller houses.

Ben: One of our Hub members, Emma, is just currently researching the idea of trying to move into something smaller, and I'm going to read out a few of her questions because I think it's quite good for context.

"If tiny houses are under the same regulations as mobile homes, can they be permitted as a permanent residence in the same way that mobile homes are permitted for the retired?"

Mike: Yes, I mean, 'mobile home' is a bit of a misnomer really because most of them are static homes. So, they're static caravans. They all come under the Caravan Act if they meet the definition of the Caravan Act, which all of ours do. But it has to be less than three-point-oh-five metres from floor to ceiling, for instance, which is why we've made it three.

So, yes. Basically, the tiny homes that we make and a lot of people make would come under the Caravan Act, which is the same thing that covers static caravans.

Ben: This one here is interesting because we sort of touched on this.

"There are many mobile home parks marketed for the over forty-fives. It would make sense that other plots of land can have mobile homes for younger families of any age. It would also make sense if this means one can build a mobile home on their own private plot of land as well. If not, then why is this not permitted when it is accepted for the retired generation?"

Mike: Well, very much along the lines of what I've been saying really, that they are there for the retirement community but not for young people, and particularly for young people in cities. So, I couldn't agree with Emma more, apart from her classification of people of over forty-five as being elderly. I take exception to that!

Ben: We might find ourselves repeating a little bit here.

"Are the building regulations potentially discriminating against the younger working force of this country to have access to the same building rights as the over forty-fives?"

Mike: I need to say that I'm an engineer turned cognitive psychologist. I'm not a lawyer. But caravans are not buildings. So, building regulations don't apply to caravans.

Obviously, safety regulations apply to caravans. They can't be fire boxes. But they are not buildings and therefore building regulations don't apply.

But taking the spirit of Emma's question, I think it's more the planning regulations that are conspiring against what we wanted to do with the Cube Project which is to let people live in their own private spaces with groups of other people nearby, in pleasant and low carbon surroundings. And I think it's a planning issue, not a building regulations issue.

I'm all in favour of building regulations because I think every new home that's built in the UK should be zero carbon or carbon positive. That's another issue which we're not talking about now, but we could.

Ben: "If a tiny home is built to meet all of the UK's building regulations in the same way a regular home would be built for permanent residence, would this be then allowed on a privately owned piece of

land? So, even if it is under the regulation of a mobile home, can it be accepted as permanent residence as opposed to a temporary holiday or caravan home when parking it on a plot of land is limited to a specific period of time?"

Mike: There's lots of stuff there. Taking into account what I just said about a caravan not being under building regulations, you can live in a caravan. Indeed, that's probably the legislation that these static home parks are operating under. But they do need planning permission because they are self-contained homes.

And that's the issue. You need planning permission for a self-contained home in the form of a static caravan.

But absolutely, that would be one thing you could do. But it's nothing to do with building regulations per se.

There was another bit in the question, and in the previous question, about potentially building on your own plot of land and putting one in your garden or a plot of land that you own.

That comes back to the previous part of our conversation where I said yes you can put something in the curtilage of your main dwelling house, but its use has to be incidental and not separate from the use of the house. So, it can be an annex to a house, it can be a bedroom for your teenage child if they're coming into the house to have their meals or to bath or whatever, but it can't be a separate dwelling house where someone else lives. I suspect that if they gave permission to do that without being very careful about it, it would licence the sorts of very sharp practices you see in London where people are just putting families in their sheds, which is clearly not satisfactory.

Ben: "What planning permission is needed to have a tiny home parked on a plot of land that has previously had any building with foundation built on it refused? Tiny homes are typically built on trailers with minimal impact on the surrounding environment."

Mike: If you're going to have it as a self-contained home and it's coming under the Caravan Act, which it would do if it's got wheels, it's likely to anyway come under the Caravan Act, then you would still need permission for a static caravan to act as a self-contained home on a piece of land. And it might constitute a change of use.

Now, you can have one there whilst you're building another house, but I think you would need planning permission, I suspect. Check with a planning lawyer, but I'm pretty sure you'd need planning permission if you wanted to just draw up to a derelict house and live

in a caravan next to the derelict house. I don't think you can just take the permission for the house to imply permission for the caravan.

Ben: Do you think these are common thoughts? Are a lot of people thinking this and just give up, similarly to the self-build of, 'I want to build my dream house' and then you actually can't find any land just normally?

Mike: Great point Ben. Yes. I think these are common thoughts. They certainly were very common amongst the thousands of people that we had coming through the various Cube Projects at the Edinburgh Science Festival, at the Grand Designs Lives that we did.

But people would say, 'I really like this space. I'd love to have this space. Have you got any land I can put it on?' And I just shrug my shoulders and say, 'I haven't got any more land than you have.'

But I did say, as you said earlier in the conversation, that there were times in my life when I was a doctoral student, when I was a post-doctoral student, I was sharing in houses. Had I had access to the sort of facility that I had in the Cube Project, it would have been absolutely fantastic. Not that I didn't get on with my fellow housemates but I was living with housemates until I was thirty-something.

Ben: What needs to change?

Mike: I think it's a common-place really that planning doesn't really serve members of communities, or members of the community. And that comes down, I think, to land. George Monbiot and colleagues have recently written a report about land reform and there are other colleagues whose names I would have to dredge up out of my memory who have written about land. Colleagues from Shelter and other places. There is a big issue to my mind of land reform. There are lots of people who have got lots of land.

So, you may be thinking about this. We're in Hertfordshire. We're really not very far from the first garden city, Letchworth Garden City, and indeed a lot of work at the University of Hertfordshire looks at the history of Letchworth Garden City and the garden city movement.

Now, Letchworth Garden City and the other garden cities, but uniquely now Letchworth still, had a different way of administering the land. I'm not a super expert on it and I'll probably get the language wrong, but that land was bought up at agricultural prices originally and it was put into the Letchworth City Corporation or

whatever, and still owned some of it by the Letchworth Garden City Corporation, so that you didn't get what you get now, is that agricultural land can be bought by developers who then hang on to the land as long as possible until housing need becomes so desperate that they then eventually get planning permission because local authorities are so desperate for housing, they then eventually get planning permission at which point the land value goes up ten-fold. They can then build it out because they've waited so long, relying on a huge pent-up demand, and they realise all the increase in land value via a decision that has been made by a public authority.

That wasn't what happened in the Garden City movement. What happened in the Garden City movement was that the land was basically sequestered, as I understand it, through an Act of Parliament – I won't get the details exactly right; you can look it up – but it was bought at agricultural prices and only then, once enough land had been bought, then permission was granted for the building out of Letchworth Garden City, but there wasn't a huge mark-up which was then realised by a private developer.

What they could then do was use the money that was realised by the increase in land value to pour back into the city to build all the facilities of schools, roads and things which a city or a small town needs.

Whereas a developer can simply take the massive uplift in land value, walk away with that, buy some more land somewhere else, and leave it to the local authority to provide the schools, the roads, the drainage and other things like that.

Now there are Section 106s and things like that which stopped them doing it entirely, but as I understand it, these are not anywhere near as effective as they should be.

So, it's not just an issue of planning. It's an issue of land.

There's also an issue of zero carbon building. We are in a climate emergency. I totally agree with my friends and colleagues in Extinction Rebellion about this. What absolutely amazes me is that there is any house being built now that is not either zero carbon or carbon positive. It's very, very cost effective and possible now to build houses which are on average zero carbon or even zero carbon at all times, not even on average. In other words, they can pretty much be self-sustained.

They have to be connected to the Grid because they can draw on wind power from the North Sea. You don't want to put a wind turbine next to every house.

And yet, when I look at every house that I see being built, I drive past housing being built, I don't see any houses that are optimised to being zero carbon. I see virtually no houses that have got solar photovoltaic cells instead of slates across the whole roof, where that roof is oriented towards the sun, maybe a mono-pitched roof.

I was in Freiburg recently where they have a suburb which has got such houses. Beautiful houses, lovely gardens, you can walk amongst them, the people love them. They have all mono-pitched roofs, just about. Entirely mono-pitched roofs on their houses, on these rows of houses, facing south which are made up entirely of solar cells.

Now, the extra cost of doing that for a typical roof might be about ten-thousand pounds. And then that would make you zero carbon on average for the next twenty-five years. And the cost of that, when you amortise it across a mortgage, it's much less than supply. So, the only expensive thing is having a battery big enough to get you through the bits where you're not bridged with either sun or wind blowing in the North Sea or probably some baseload nuclear somewhere.

I've done simulations of that. I'll be writing that up in a paper. So, what amazes me is that given that we're going to have every house that's got to be zero carbon basically by let's say 2040 – Extinction Rebellion say earlier, the government says slightly later, but let's say 2040 – why would you build any house in 2019, 2020 that would need retrofitting to meet that standard if you knew that that house was going to stand for sixty, seventy, eighty years? Why would you do that? That seems absurd. And yet just about every house I see being built is not of this type. It's nowhere near being zero carbon.

I simply don't understand it. That's a psychological problem.

Ben: Mike, let's leave it there then. Thank you very much for your time.

Mike: Ben, it's been nice to meet you and if people want to get in touch with me, I'm at the University of Hertfordshire and you can find out my contact details through cubeproject.org.uk.