HOUSE OF COMMONS

Environmental Audit Committee

Oral evidence: Heat resilience and sustainable cooling, HC 1671

Monday 18 September 2023

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Watch the meeting

Members present: Philip Dunne (Chair); Sir Christopher Chope; Barry Gardiner; Clive Lewis; Caroline Lucas; Jerome Mayhew; Claudia Webbe.

Questions 1 - 70

Witnesses

I: Professor Jason Lowe OBE, Head of Climate Services, Met Office Hadley Centre; Professor Lea Berrang Ford, Deputy Director and Head, Centre for Climate and Health Security, UK Health Security Agency; and Dr Laurence Wainwright, Departmental Lecturer, the Smith School of Enterprise and the Environment, University of Oxford.

II: Dr Eric Laurentius Peterson, Visiting Research Fellow, University of Leeds; Martin Passingham, Head of Product and Training, Daikin UK; David Broom, Managing Director, Kensa Contracting; and Dr Chiara Delmastro, Energy Analyst Buildings, International Energy Agency (IEA).

Written evidence from witnesses:

Met Office

UK Health Security Agency

Dr Laurence Wainwright

Dr Eric Laurentius Peterson

Daikin UK

Kensa Group

Examination of witnesses

Witnesses: Professor Lowe, Professor Berrang Ford and Dr Wainwright.

Q1 **Chair:** Welcome to the Environmental Audit Committee for our first oral evidence session in our new inquiry into heating and cooling systems and the impact of climate change on how we live our lives in the UK. I am delighted that we have two panels of experts before us today and I would like to welcome our first panellist, Professor Jason Lowe from the Met Office. Jason, could you explain what you do at the Met Office that is relevant to our inquiry?

Professor Lowe: Thank you. I am representing the Met Office, which is an executive agency of the DSIT. It provides weather forecasts and also the national severe weather warning service. It also provides climate scenarios and interpretations of past and future climate through the Hadley Centre climate programme. My particular role focuses on the climate change aspects and in particular pulling climate science through to a place where it can be used in decision making.

Q2 **Chair:** Thank you very much. We are also joined by Professor Lea Berrang Ford from the UK Health Security Agency.

Professor Berrang Ford: Hi, it is a pleasure to be here. I am Professor Lea Berrang Ford. I lead the UKHSA's Centre for Climate and Health Security. It is a new centre within the UK Health Security Agency, responsible for bringing together all of the work and insights related to climate change within the agency, and growing our expertise and capacity with the goal of providing health expertise, curating evidence and providing guidelines and toolkits to support public health.

We have three main themes and teams that we work across. One is working across vector-borne disease, supporting surveillance and response to vector-borne disease—mosquito and tick-borne disease. One is doing climate and health assessments. The third one, most relevant here, is extreme events and health protection; that is responding to things like extreme heat, floods and cold.

Q3 **Chair:** Thank you. We are also joined by Dr Laurence Wainwright from the Smith School of Enterprise and the Environment at the University of Oxford.

Dr Wainwright: Good afternoon, it is a distinct pleasure and privilege to be here. I am departmental lecturer and my research looks at the intersection between human health and heat, particularly the impacts on mental health. I also hold a posting in the department of psychiatry and we have been looking at the fascinating crossover between these two worlds.

Q4 **Chair:** Thank you. This Committee has taken an interest in heatwaves previously. In the previous Parliament we did a report in 2018. I think the whole world is taking an increased interest in the temperature of the

planet as we have seen such significant changes in our expected seasonal climate in recent years, not least this year. I would like to start by asking Professor Lowe about the role the Met Office plays, and improved weather forecasting techniques that are now available around the world, to enable us to predict with greater accuracy or otherwise—I would like you to tell us how accurate they are—anticipated changes in temperature.

Professor Lowe: I can go some way on the short timescales. My expertise is mostly on the longer timescales so I will take that into account, but we can add any further written evidence if necessary.

If, for instance, we look at the next-day temperature forecast, we routinely assess the accuracy of those, comparing the forecast with what actually happens at 119 sites around the UK. Typically, we find that we are within plus or minus 2° of the actual temperature more than 92% of the time. Those forecasts are being picked up, so we also track the public perception of the forecast. Independent surveying by YouGov finds that 80% of the public trust the Met Office forecast. I would also highlight work commissioned by DEFRA to look at users of weather forecasts and weather information. We find there that the Met Office is in the top three in terms of trust.

In terms of the quality of the forecast, the level of skill or accuracy that we have now for a four-day forecast is the same as we had for a one-day temperature forecast 30 years ago. That improvement is coming through a mix of improvements in observations. Maintaining an observational dataset is absolutely vital for forecasting. It is also coming through improvements in the physical understanding of the science and it is coming through the ability to run better models that have more spatial detail on the larger supercomputer.

We also see improvements in techniques referred to as seasonal forecasting. That does not give us a day-to-day view of the future but it gives an indication of whether a season ahead might be statistically warmer than we would expect or cooler than we would expect or wetter or drier.

Looking further forward into our climate projections, the Met Office launched a product called UKCP18—United Kingdom climate projections—beginning in 2018, and we have added to that since. That consists of a number of datasets; again, there are observations of what has happened in the past going, back to 1884 in the case of temperature, but also projections into the future on a very fine grid scale down to 2.2 km. We have more than 10,000 users taking up that data.

Q5 **Chair:** How far into the future?

Professor Lowe: For that particular dataset it depends which of the products we look at. The sea-level product goes out to 2300, the so-called probabilistic projections go out to 2100 and the most detailed high-

resolution information goes out to 2080. These are projections that correspond to the life scale, for instance, of infrastructure development.

Q6 **Chair:** How fascinating. One of the immediate challenges that everybody is conscious of is what is happening in the here and now and the immediate short time. The Met Office we tend to think of as informing the weather forecasts that we receive through our media channels each day. There have been some notorious misses in the recent near past. In fact, only on Friday I was looking at the weather forecast for my area because we were about to start our potato harvest today. We noticed that in France there was a location that received over 500 mm of rain in 24 hours. There was a storm predicted for Sunday where they were anticipating 20 mm where I live, but there were only about 2 mm. We put off our harvest today and we hope to start tomorrow.

That is obviously not indicative of the climate across the world and over a long period, as you have just identified. However, it is relevant to the increasing severity of storms that we are potentially facing in the here and now. What can you tell us about what the climate might look like in 25 years' time? We have just gone through 10 years of record heat. Seven of the hottest years have been in the last 10 years. What is it going to look like?

Professor Lowe: First, 2022 for the UK was the hottest year on record. If you take the temperature over the full year, it was the first time that the annual average for the UK had been above 10°. So it was not only that we saw the first event that went above 40°; it was also the first time we had seen an average over the year above 10°.

If we step forward in time, beginning with mean temperature, we expect all locations in the UK to warm. We project more warming in the south of the country and we project more warming in the summer months than in the winter months. You can probably picture the geographical distribution where it is already warm—for instance, in the south-east of the country—getting a greater increase. The amount of warming depends on the future global influence of greenhouse gases. What we typically do is look at a low scenario compatible with the Paris Agreement and also a high scenario that is above the current pledges and involves backtracking. It is used for risk assessment.

If we take the high scenario, I will give you a couple of numbers from here. If we take summer of 2018, which was the warmest summer on record, the probability of a summer like that happening now is somewhere between about 10% and 25%. By the middle of the century—in that 20-year period that you are describing—we estimate the value to be between 50% and 62%. Therefore, what was still quite a rare event becomes, on average, every other summer. If we look later in the century, that type of event becomes a cool summer.

If we look in the model and in the observations at the type of very high temperature we had on 19 July last year, that is still a rare event in the

present-day climate, probably around a one-in-100-year return-period event; on average, the gap between those events is that big. However, we are shifting those probabilities. When we search through a model that is based on laws of physics that is evaluated against observations, we see more of those events happening as we go further into the future.

A statistic that we might put with that is exceeding 30° for two or more days. In the baseline climate that would happen roughly once every four years. When we look to the 2070s, a little bit further into the future, we are seeing that increasing by a factor of 16. Therefore, high-temperature extreme events are becoming more common, the mean temperature of the summer is becoming hotter, and when we look at rainfall in the winter we see a greater chance of warmer, wetter winters—we expect increases in rainfall—whereas in the summer we are expecting a greater chance of hotter, drier summers.

How we manage water is also likely to need to be different based on the pattern of precipitation. That has a knock-on effect to temperature because of feedbacks, for instance, through how dry the land surface is, and that can amplify locally the temperature.

Q7 **Chair:** Does that also mean that we can anticipate much greater precipitation at the end of a hot period in the summer and, therefore, a much greater risk of flooding because the ground will be baked and will not be able to absorb the water?

Professor Lowe: Exactly. When we look in the most spatially detailed model, we see so-called convective precipitation events. The intensity of those is projected to increase. If we look at a one-in-two-year event, we might expect the rainfall associated with that to increase by between 25% and 30% from where we are.

Q8 **Chair:** Do the other panellists feel able to comment on these predictions of accelerating increased warming that we just heard about from the Met Office? Is this widely accepted across the scientific community?

Professor Berrang Ford: It is.

Dr Wainwright: Yes, it is. It is deeply concerning, and these feedback loops that you allude to exacerbate problems in ways that we understand but we perhaps cannot comprehend the implications of.

Q9 **Chair:** Would it be fair to characterise this as a climate breakdown?

Professor Lowe: I would be reluctant to use that terminology. First, we do see this type of event in our climate models and we have seen this event in our climate models. We have always experienced extreme events, but what is happening now is that many of those extreme events are happening on top of a bigger baseline, a warmer background climate, and there are some local feedbacks.

However, I would not personally characterise those events as a tipping point. I think that what has changed is that we have become much more aware of those events and the impact associated with them is starting to become much more noticeable.

Q10 **Clive Lewis:** Professor Lowe, you mentioned that the south-east could be particularly affected by the increase in temperatures, and I want to pick up on how geography affects temperatures. Could you elaborate on the differences between coastal, urban and rural areas in terms of how heat may affect them?

Professor Lowe: Of particular interest here is rural/urban, if we start with that. The urban heat island effect is well known. We could go out and look at observations, we could travel across the city now—we could come in from Windsor Great Park and we could come here to the centre and measure the temperature as we go. We would see that it is warmer here than it is in the surrounding area. The difference between the surrounding rural area and the centre of a large city like London is that you can see an urban heat island effect that goes as high as 6° to 8°. That is at the higher end.

Why does it happen? It happens because of differences in how moisture, momentum and heat is exchanged with the land surface. If we think of what is a city like, there are lots of dark surfaces that absorb incoming solar radiation—sunlight. There are lots of hard surfaces and a drainage system that takes water away from the surface so that it is no longer available to evaporate and help cool the ground. There are also changes in the momentum because of the structure of the buildings. When we put those together, we see that the centre of a city tends to be warmer.

An interesting and relevant question is whether that will change going into the future. There has been a lot of research in this area. If we take London as an example city, because there are lots of observations for London, we see some of the earlier studies showing an increase in the urban heat island effect, especially at night. When we look at some of the more recent studies, there is less of an apparent signal, especially when we can separate the signal into a component due to climate change and a component due to urbanisation. The latest papers that are picking up the view for London—Bassett et al—suggest that the change in the urban heat element is maybe not as great as we might expect.

When we look to the future there have been a number of studies. Again we will focus on the UK. Those using slightly coarser climate models—those that do not separate the UK into such fine spatial detail—tend to show an increase at night. The more recent models that better represent the physics of the real world are not showing an increase. That does not mean that it will not get hotter—it will get hotter in both the rural area and in the city—but the difference between the two may not increase as one might imagine.

Q11 **Clive Lewis:** To the other panellists, is the heat island effect something

that you are aware of and want to comment on?

Professor Berrang Ford: Certainly, from a health perspective, the impacts of these changes of health, an urban heat island effect means that you have higher temperatures in cities and you may in some cases have higher risk because of that. That does not mean that the health risks due to extreme heat are restricted to cities but it does mean that the urban heat island effect is a factor that increases risks associated with urban areas.

Dr Wainwright: During the last heatwave, the highest proportion of excess mortality, unsurprisingly, was in Greater London, the south-east and the eastern regions of the country.

Q12 **Clive Lewis:** Professor Lowe, what learning have you identified from something called the Belfast pilot—which I think you are aware of—and the heat services in cities. What are we taking from that and what have we learned?

Professor Lowe: The very first thing that we learned is that when you engage with a new city, often it is not a case of going in with data to make a decision. There is a stage to go through to raise awareness and to provide tools to the local authority and the local council that allows the stakeholders within the city to raise awareness.

In our case we provided something called a city pack. That described what we might see in terms of climate change but related it to the local region. If you were at the coast it might talk more about sea-level risk. If you were far in land it might talk more about the urban heat island effect. So the first stage was to raise awareness.

When we have raised awareness, it is important to co-develop what comes next. As climate scientists or impact scientists, we might imagine what users want, but going along and sitting down and developing a common language turns out to be vital. When you do that, the uptake within the city seems to be much greater.

In Belfast, for instance, the written reports and also the datasets that we produced—files for graphical information systems—have been used in risk assessments for the city. They have been used in a project called One Million Trees, to help to understand where you might site those. They have been used to refine the weather extreme plan and they have also been used to provide climate literacy training to new members elected to the council. We are seeing this type of information being used in multiple different ways and it seems to be a progression from awareness raising through to decision making and embedding in plans.

Q13 **Clive Lewis:** Thank you. For the whole panel, what can we take from that particular pilot, in your opinion, in terms of learning for other cities and other urban areas to remedy and combat? Is it possible, given the levels of heat that we may be talking about in some urban areas? Is it the case that it is dampening down the—I am not going to say the fires, but

keeping things down as you can, but that some deaths are inevitable given the temperatures we are heading towards?

Professor Berrang Ford: From a health perspective, certainly there is evidence that the levels of heat that a population can adapt to or respond to depend on what they are historically used to. Over time populations can adapt incrementally to change. For example, in London the level of heat that traditionally we can experience before people start to get ill and we start to notice increased mortality is lower than you might see in places like Spain. So there is local adaptation. That is simple things like knowing, for example, not to go out for a run at 1 pm, having shutters on your windows, knowing that you want to close your windows if it is hotter outside and cooler inside. We close our windows to keep out the cold but typically people do not close their windows to keep out the heat. There are lots of very small adaptations—closing blinds and curtains. There is quite a bit that is behavioural that can be done for the population to incrementally become more adaptable to heat, and we see that over time.

As Professor Lowe says, it is a transition and we can facilitate that transition through our communication on what behaviours make us more resilient to heat. As heat increases—and depending on the level of warming that we experience—there may need to be other solutions; it is not just individual behaviour.

On the urban heat island effect, for example, we could be cooling cities: greening buildings, greening cities, providing shade and cool surfaces. Dark surfaces in playgrounds, for example, can get so hot that they can even burn a child's skin during an extreme heatwave, so it is about having surfaces that reflect heat rather than absorbing it. It is not just individual behaviours but we can have a number of community infrastructure behaviours.

The same thing applies to looking at buildings in the UK, which were not designed to hold high levels of heat, and thinking about how cooling measures could be integrated there. The third area that I flag is early-warning systems so that people, institutions and organisations know when the heat is coming.

Q14 **Clive Lewis:** Can I follow up on that? In terms of some of the ways that people can adapt and perhaps mitigate, in my own constituency and across the country we now see communal warm rooms—we did this winter—because of the price of energy and the fact that some people could not heat their homes. Can you envisage a future where people are using, for example, communal areas that may be air conditioned or that may have adaptions that allow them to stay cool, which they could not otherwise do in their homes?

Professor Berrang Ford: Certainly, that is something that we are starting to see and look into. At the moment, there is insufficient evidence and experience with cooling centres for us to be able to

comment and declare on their efficacy to make sure that that is working and that we are not putting people at additional risk trying to walk in the heavy sun to get to a cooling centre, to make sure that there are no unintended consequences. It is something that we are looking at and it is something that would be relevant in the future. We do not have enough experience and data to quite give you a better answer than that at this point.

Clive Lewis: Dr Wainwright, any comments on those points?

Dr Wainwright: Yes. Congruency and coherency between local, regional and national plans is absolutely essential. There should be clear, targeted public health messaging that speaks to the most vulnerable groups, whether that be those in certain occupations, from a low SES background, experiencing energy poverty, or those living in poor housing, taking certain medications, pregnant, elderly—there is a very long list.

I have been quite clear about helping the public to not overestimate their coping abilities in heat. Heat tends to bring positive associations. It is warm, it is sunny, we want to be out and about, and people tend to be aware of the risks but they think, "That does not apply to me. I'm okay." In fact, the evidence is quite the contrary.

We need to break away from this siloed, fragmented perspective and see that this is a holistic issue that cuts across health, transport, economic productivity factors and infrastructure, which in turn impact back on health.

Q15 **Barry Gardiner:** It is exactly the health and wellbeing aspects that I want to probe with you. Could you start by helping me to understand the Office for National Statistics' analysis of the 2022 summer and the five heat periods there? It talks about excess deaths and 3,271 deaths above the five-year average, but it also talks of 5,000-odd deaths above the average in those aged 70 and over.

What I am trying to get a grasp on is, when it says that there were more deaths than usual, are we talking about what we would understand as excess deaths caused by the excess heat? Because we know that the European figure is that there were 61,000 people who died in Europe as a result of the heat in the summer of 2022. That is what we are told. How much of that is a direct result of the heat? How much of that is in things such as excess suicides, which you have talked about, Dr Wainwright, within that period? How much is it from the vectors that you spoke about, Professor Berrang Ford—the other vectors that come in, the disease vectors and so on? When we are dealing with this, can you give me a better handle on it in terms of health and wellbeing?

Professor Berrang Ford: I will take that one and my team can poke me in the back if I am getting it wrong. Typically, the estimates of excess deaths are not about that number of individuals, so 3,000 individuals died directly from heat. It would be calculated statistically based on what we

would expect: how many people we would expect to die during that period versus how many people we did see die. In a sense, it is very similar to covid. The deaths can be from multiple causes due to heat.

What we do in the statistical models is try to control and remove the effect of some factors that we might be aware of. We might want to remove the impact if there was a covid surge going on at the same time and so on. So yes, those are usually based on it being statistically more than expected at that time, controlling for the things that we would like to—how many people died during those periods vis-à-vis the baseline?

Q16 **Barry Gardiner:** I think what I am hearing is that when we hear there were so many excess deaths during that heat period, it is a modelled number, not that these are the number of people who will have "excess heat" on their death certificate; is that correct?

Professor Berrang Ford: That is correct.

Q17 **Barry Gardiner:** Thank you. Professor Lowe, can you tell us how the level of humidity is a significant factor in how dangerous heat can be? At the Met Office I understand you have done what you charmingly call wet-bulb calculations. Could you explain for the public exactly what that is, and how that impacts on human health and wellbeing and people's perception of their body's response to heat?

Professor Lowe: There are a range of what you might think of as apparent temperature metrics. One that receives particular attention is wet-bulb globe temp. Essentially, what you are trying to do is to combine into a temperature scale not only the effect of heat and temperature but also the effect of, for instance, moisture. Why might you want to do this? You will know that if you go out on a very warm day it feels very different. The amount that you can cool down is different depending on whether the humidity is higher or lower. So the idea of metrics like the wet-bulb globe temp is to take account of the degree of saturation of the air.

Q18 **Barry Gardiner:** If it is more humid my sweat—of course, I do not sweat, I perspire—does not evaporate as quickly, is that right?

Professor Lowe: Exactly. So the danger is that your core temperature will then increase and get to a dangerous level.

Q19 **Barry Gardiner:** How does your wet-bulb calculation help us with that?

Professor Lowe: Because it takes account of the moisture loading in the air. Rather than it just being a function of the so-called dry-bulb temperature—which is what you would go out and measure with a thermometer—you are also taking into account the moisture context of the air by wrapping a piece of cloth around the bulb of the thermometer. Of course, that has moisture evaporate from it and that gives you a new temperature reading.

Q20 **Barry Gardiner:** You literally wrap a wet flannel around your

thermometer?

Professor Lowe: Historically that is how it would be done. These days it is done electronically, but the principle of evaporating moisture from that cloth gives you a concentration of the moisture in the air and, therefore, how easy it will be for you to lose heat through sweating, for instance. But you really need to talk to someone with medical knowledge.

Professor Berrang Ford: I will add to that. Having lived for a decade in a part of Canada where humidity is exceptionally high, I am quite familiar with the difference between dry heat and wet heat, which can be useful for a "feels like" factor in communication. That is something that I will defer to Professor Lowe on.

In terms of our heat health alerts, when we put out alerts we find that, from an epidemiologic perspective, the value of using humidity as well as temperature in our alerts is unclear. While it may be relevant to experiences individually, when we do alerts and when we understand at what point mortality increases, in our alerts we use only temperature because we do not see, in our modelling data, the value of adding to that the estimates of humidity.

That means that when we are alerting the public, temperature matters and there are a few other things that matter—for example, duration of temperature, whether it is hot at night. There are a number of factors: if there is something else going on, if there is a covid outbreak, if there is influenza. There are a number of other factors that will affect the health impact of heat, but we do not find that it is useful to include humidity in those analyses. That does not mean that they are not useful from a Met Office communication perspective, but from our heat health alerts they do not improve our models.

Q21 **Barry Gardiner:** I thought you were giving us a nice recommendation for our Committee that we should be publishing or publicising the humidity levels, but it seems you are saying that that does not make a difference in the excess deaths statistics that you see. Is that not a function, perhaps, of education, quite simply because the public has never heard of a wet bulb and does not understand how it is affecting their own physiognomy?

Professor Berrang Ford: I will defer to the Met Office on that, but from personal experience I have seen actual temperature and a "feels like" temperature. High humidity might feel hotter, so it is not necessarily about publishing a wet bulb. What I am saying is that for heat health alerts, when we are deciding when to cascade warnings and actions to the public and to public health agencies, we do not use humidity, or at the moment we do not see sufficient evidence to use humidity there.

Professor Lowe: I am wondering about other nations that use a heat index that has a moisture component as part of the warning. In terms of providing weather information, we do provide forecasts of relative

humidity alongside temperature, rainfall and so on, so the information is there, but that is not part of a heat health alert.

Professor Berrang Ford: No, it is not part of a heat health alert. In Canada there will be a humidex that will be an adjusted temperature considering humidity, both cold and hot, but that is personal not professional experience.

Q22 **Barry Gardiner:** I am trying to localise this to the UK at the moment. Would it be helpful for our people who stand up and give our weather forecasts—just before or after the evening news—to be talking about the effects of humidity on people in an excess heat period?

Dr Wainwright: I would say very much yes. There is a study from my home country of Australia that found that for each slight increase in humidity there is an increase in the proportion of the population reporting high or very high levels of psychological distress. That is hardly surprising, given how humid it can get down there.

I have also looked at the impact of humidity on some of those taking medications. About 30% of the British population taking a certain group of medications would be impacted by very high levels of humidity exacerbating the side effects of some of those medications, particularly things like sweating and perspiration, which sound minor in isolation but if the body is not cooling down properly that can lead to further problems.

Professor Berrang Ford: To give you a slightly clearer answer, physiologically there is evidence that humidity matters in moderating heat impact on the body. In our data in the UK we are not seeing it coming out as important as a predictor of mortality. That does not mean that we will not see and consider that in the future in our health alerts. It may be that we are simply not getting high enough humidity levels for that to be detectable.

Q23 **Barry Gardiner:** Thank you. Dr Wainwright, I want to continue with you because you have looked at a much broader range of impacts in terms of mental health, in particular. Can you tell us about the impact of heat and excess heat periods on mental health and the other factors that you have examined.

Dr Wainwright: Sure. Thanks for asking that important question. Conversations around heatwaves have typically been dominated, unsurprisingly perhaps, by impacts on physiological health. Recent research, however, has looked a lot more at the impacts on mental health, both in the general population but also the 16% of the UK who live with a psychiatric illness, whether that be a depressive, anxiety or a bipolar disorder.

For both groups the implications are concerning. To start with suicide attempts and complication, there is overwhelming evidence that higher temperatures mean higher rates of suicide both in the general population

and in those with underlying conditions. Suicide risk in the UK will double when there is a temperature of 32°C versus 22°C. Roughly speaking in other countries, for each 1° increase in mean monthly average temperature, rates of suicide go up between 1% and 2%.

For those with bipolar disorder, extreme heat can act as a switch into a certain phase of the condition—a mania or a depressive phase. The way that some of the medications used in bipolar disorder work—lamotrigine and lithium—changes the exacerbation of side effects in some of those commonly used antipsychotics like quetiapine in depression. It can act as a switch into a depressive phase and severity of symptoms are worsened.

Again, there are issues with some of the medications used and anxiety exacerbation. Schizophrenia has terrible outcomes. Risk of mortality more than doubles during heatwaves, and this very, very vulnerable group uses a class of medications that make them particularly susceptible to the impacts of heat.

Sleep is such an important one and it cuts across everything that we do. In this country we lose 1.5% to 2% of our GDP every year—£60 billion—as a result of people not getting enough sleep or getting interrupted sleep.

Q24 **Barry Gardiner:** I do not want to interrupt your flow, but I want to pick out and emphasise that you are telling us the impact of heat on people's mental and physical wellbeing has a huge impact on economic productivity as well.

Dr Wainwright: Yes, it does. When temperatures are above 30°, admissions into A&E go up by 26%. As you know, that costs about £1,500 for each admission. There is a 2.6% decline in productivity for every degree increase beyond 24°C. If someone is working outdoors, there is a big decline in productivity. The economic costs during the 2010 heatwave, purely based on lost productivity of workers, was in excess of £700 million. That is just one small measure.

The problem is very significant. When we speak about mental health we are talking about wellbeing. We are talking about productivity and cognitive impacts. In a very famous Canadian study that put one half of the room with air conditioning at 21°C and the other half at 25°, there was a 13% decline in performance between those two groups. It does not take much to think about—if we put the numbers together and calculate for this country—what we are dealing with.

Q25 **Barry Gardiner:** I want to ask you about two additional areas that you have not yet mentioned. One is domestic violence and the other is alcoholism.

Dr Wainwright: We have data that suggests that heat leads to a rise in some forms of violent crime; it leads to a slight decrease in others, like some forms of burglary. However, there is data suggesting a link

between increased temperatures and forms of violent crime. I do not have the data with me on domestic violence but I can get that.

Q26 **Barry Gardiner:** Send it to us. We need to press on but I want to get to the message here. I understand that you have suggested that we need much better and much more holistic policy messaging in terms of our attitudes and language pertaining to heat and health, and you think that they need to be reframed. How would you put that into a recommendation that this Committee could put into its report?

Dr Wainwright: We could update the Health and Social Care Act 2012 to include consideration for climate change and heat risk. We could update the workplace regulations from 1992 to include a maximum safe working temperature. There is a minimum at the moment but there is not a maximum. We could work with the NHS in distributing information to patients who are at high risk of suffering the effects of extreme heat, particularly when being prescribed certain medications.

The national adaptation plan mentions the word "heat" seven times, compared to floods 251 times, despite the fact that floods have killed 36 people in the last 10 years whereas heatwaves have killed 5,000. I have a whole list of recommendations, but we need to get mental health at the centre of our response to heat because it is integral and it is having cross-cutting impacts.

Chair: Thank you very much indeed. Do send us any written material that you have not had a chance to discuss today.

Q27 **Caroline Lucas:** Going back to the heat health alert system, I have a question for Professor Berrang Ford and Professor Lowe. How has the response to heatwaves changed under the adverse weather and health plan published earlier this year? In particular, can you explain to us how the new traffic-light heat health alert system works and how decisions on categorising alerts are made?

Professor Berrang Ford: The UKHSA and the Met Office have worked closely on the new heat health alert system, so we will do this jointly, but I will start us off. This is part of the adverse weather and health plan that we launched in April this year, which brings together the cold weather and the heatwave plans for England. This is to have a more co-ordinated approach to our extreme weather and our health response to that.

The heat health alert system is transitioned to an impact-based system. What that means is that it is not just temperature that matters. We do not just have a temperature threshold but we have additional considerations about what might create risks, and what might make those temperatures have greater impacts for health.

We will consider concurrent risks—for example, whether there is a drought, whether there is an infectious disease, whether there is a risk of escalation, whether we anticipate that the heat event will get worse over time, whether there are multiple regions involved, the intensity and the

duration that are anticipated. It is going beyond one threshold number and thinking broadly about multiple factors that might make a particular set of temperatures climatologically have a greater impact on health. This makes the heat health alert more flexible and applicable specifically to health.

Once the heat health alert system is issued and there is a traffic-light system, the lowest level is most relevant to highly vulnerable people. For example, the majority of healthy individuals may either be inconvenienced or maybe even like the higher levels of heat, so our lowest level is focused on taking care of those for whom even small changes in temperature can impact their health.

Moving up to higher thresholds, higher levels of heat, moving up to the red—which many of you will know we experienced last year—those are higher thresholds. We would only reach that when we had likely higher temperatures for a longer duration and are potentially anticipating severe impacts.

What we have from the heat health alerts is over 29,000 organisations and individuals have registered for this. This was higher than we expected. We had huge interest in registering and there is a cascade of action. We would cascade these heat health alerts to the public via social media and news, the Cabinet Office, the Department of Health and Social Care and other Government organisations. This goes to NHS England, which then cascades to regional teams and integrated care boards. It also goes to the UKHSA regional teams and to local authority directors of public health and local resilience forums, who then cascade to a number of social services, including daycare centres, residential homes and local health resilience partnerships.

So the heat health alerts have a cascade but they are not just limited to letting people know what is going to happen. They are associated with signposting to guidance and heat health alert cards that are designed for different organisations to provide them with guidance on what they can do to protect people in different settings. That guidance is specified for different settings such as care homes, for example. I will stop for a minute and see if Professor Lowe wants to add anything at this point.

Q28 **Caroline Lucas:** Maybe I can lob another question in for Professor Lowe so he can put the two together, because I am slightly worried about time. Have you identified any emerging lessons from the first summer under this regime?

Professor Lowe: First, to pick up on the heat health alerts. One other thing worth highlighting is that now we have a consistency between the heat health alerts and the national severe weather warning service. We use a coloured, impact-based scheme for both of those. If we see the signs of an extreme heat event, we will see it in both of those measures. Also, from a Met Office perspective, we have a series of 22 civil contingency advisers who help to understand and explain the messaging

of the national severe weather warning in local resilience forums, which is an important part of the service.

In terms of lessons, the lesson from the Met Office perspective around forecasting is that we very much did see an indication of the hot event last year quite some time before. We saw hot temperatures predicted in the seasonal forecast at the end of June and we started to see the meteorological situation changing and supporting high temperatures. The lesson is very much making sure that we are using those multiple sources of evidence to get the warnings out as early as possible.

There is also quite a strong lesson around warnings being great but you need to put them in the context of something. One of the recommendations from your earlier report was to make more information available—for instance, through the Met Office website. We have a dedicated page that focuses on high temperatures and the actions one might take. We also have pages that talk about our forecast accuracy and our climate tools. It is possible to go along to those pages and help to build the context in which the warning sits.

Q29 **Caroline Lucas:** Moving on quite quickly, how effectively do the UKHSA, the Met Office, Government Departments, local government and other stakeholders work together to mitigate the impact of extreme heat? In particular, are there ways in which joint working be improved further?

Professor Berrang Ford: Always, is the short answer. In the launch of the heat health alerts, or the weather health alerts, between the UKHSA and the Met Office, this was a critical step change, which is the start rather than an endpoint.

With the UKHSA establishing a centre for climate and health security and developing a broader adverse weather and health plan, it is creating an infrastructure around the heat health alerts and for a response. We are not just alerting people, we are creating guidance and constantly pushing it out and re-evaluating.

We are currently working on the cold-weather alerts, moving into the cold weather season. There is quite a range of activities on evaluation, developing more into public health. There are quite a number of collaborations on the research side, as well as on the operational side, to look for those opportunities. So to some extent, from the UKHSA side, we are launching into delivering improved services for climate and health.

Professor Lowe: One key aspect of that is the so-called idea of seamlessness. We think about weather in a near-term response but we also think about the response on a seasonal timescale, a five-year timescale, a 20-year or 50-year timescale, and link together over those timescales the types of information that are available for decision making so that they can be used in a consistent way, with guidance.

Q30 **Caroline Lucas:** Dr Wainwright, the adverse weather and health plan

aims to prevent mortality and morbidity linked to adverse warming. However, with typically thousands of people in the UK dying every year from the effects of heat, and heatwaves becoming more frequent and severe, how realistic do you think that the objectives of that plan are?

Dr Wainwright: The first thing is to commend the UK on the adverse weather and health plan. It is a significant step up from the heatwave and cooling plans—the fact that they were separate and are now integrated.

I would also like to commend the plan sincerely on its integration of mental health. It gets considerably more coverage. In the old heatwave plan the word "suicide" was not mentioned once. Mental health was mentioned five times and it was all fairly superficial bullet points. I think the UK is heading in the right direction with this plan.

As far as stopping mortality and morbidity, which is our goal, it all comes down to execution. You can have the best plan in the world but it depends on how this actually works in reality. There is a big gap between what we know and what we do and there is a big gap between what the general population do and what they do in interpreting message so we have to be very, very good. We know what we need to do now and it is a matter of getting it done, with that integration between different agencies, making sure that we are all working on the same scorecard and that we are supporting each other with mutually reinforcing decisions and synergies rather than pulling in different directions.

Professor Berrang Ford: One really important point that I want to make sure that we come out of this room with today is that those who are dying and those who are most vulnerable to both heat and cold are, by and large, very specific populations, particularly the over-65 and elderly. While for many of us heat, even extreme heat, is an inconvenience, when it comes to the severe effects on health in the UK there is a very focused, identifiable population where we could target our interventions.

The vast majority of heat deaths are preventable, often using very simple measures that can be targeted at people we know are highest risk. It is a huge challenge, yes, especially if we end up with higher levels of warming. We do not know what level of warming we will face because that depends upon global decarbonisation, but we do know who is at risk and there are very good measures to protect them specifically. The feasibility is improved by knowing that there are simple measures for our older population. It is important as these are preventable deaths in many cases.

The other thing that I want to add is that moving forward into the next decade or more, one of the drivers of heat and cold-related deaths will be climate but it will also be an ageing population. The greatest driver of vulnerability is again the over-65s. We have an ageing population so, even if we adapt, we may see rising deaths due to heat and due to cold

simply because we have more people who are vulnerable. Even if we are doing a good job of adapting, we are facing a battle that is demographic. It is important to remember in this space that age is the greatest risk, but it is also the greatest opportunity for targeting support.

Q31 **Jerome Mayhew:** Dr Wainwright, you told us a moment ago that about 5,000 deaths have happened as a result of heat in the last decade, is that right?

Dr Wainwright: There were 3,000 in last summer's heatwave. It will be 6,000 or something like that.

Q32 **Jerome Mayhew:** Something like, so a significant number. Professor Berrang Ford, you have told us that the cohort who are adversely affected are quite a tight cohort. It is not the general population but it is a highly focused group where age is the predominant determinator, plus underlying health conditions, I am sure. Back in 2018, a previous Committee of ours identified public perceptions of heatwaves as undermining their seriousness. Are we getting to the kernel of the problem here, which is that for the vast majority of people at worst they are inconvenient but they are not actively dangerous, but for a tight cohort it is the opposite and they are extremely dangerous? To what extent have we made progress over the last five years in ensuring effective communication for the people who need to be communicated with?

Dr Wainwright: That is an important question and I am aware of the work that you did in 2018. Progress is being made—again, I commend the work of the adverse weather and health plan—but changing this public perception is incredibly difficult. Coming from a very warm, sunny country, we are aware of the dangers of heat down in Australia but here the data is that people are underestimating the seriousness of health.

Yes, the over-65 group is very concerning and the vast percentage of deaths, but cutting across these other groups, the vulnerable groups often have multiple characteristics in common with them, as you alluded to. They have an underlying condition, they might be taking a host of medications, they might be living in poor-quality housing and that makes them particularly susceptible.

We need to be clear with public messaging that this is not a doom-and-gloom advertising campaign. This is just telling people that there is a risk: "Don't underestimate yourself. You're not a strong as you think you are. You can't defy the laws of thermoregulation. You can't beat the body trying to cool down. It is a battle that you won't win ultimately." We still have a long way to go and I think that it is a cultural thing ingrained in the UK that heat equals good, sunny weather equals good, and it is so rare.

The invisibleness of it is the other thing. The reason why floods have been so dominant in these documents is that you can see them and they

are on the news. For a heatwave you just have the same old shot of a scorching sun.

Q33 **Jerome Mayhew:** There is one way that you could deal with it, as has been suggested by some people who have written to us: by naming heatwaves. Then you get the counterargument from some of the newspapers saying that this is harbingers of doom and, "Why can't we enjoy the summer any longer?" That would be the alternative. Are we beginning to understand why you get those two different focuses when the cohort at risk is very tight? For many people you can enjoy the summer and it might be inconvenient, but to have a named heatwave or weather forecasting as entertainment is not the right way to go. What do you think?

Professor Lowe: The problem has many more dimensions to it in that when we think about health impacts. It is not just the direct impacts of temperature. There are also the indirect impacts—for instance, of wildfires becoming more prevalent. There is an impact on air quality associated with high temperature and the weather regimes associated with high temperatures, so we may need to think a bit more broadly about other health impacts.

We certainly need to think about the other impacts of temperature on society—impacts on the transport network, the energy network, the communication network—and take a more holistic view when it comes to thinking about the consequences.

I am reminded of a study that collected data in late 2019. It was part of the RESIL-RISK. It was notable in that the public respondents did note concern around flooding, but they also noted concern around high-temperature events and recognised that it was having an impact. That was one of the first studies that stood out in the UK for also recognising temperature. There is a shift towards understanding some of the consequences of high temperature, but I suggest there is value in taking this broader view of the consequences.

There is also a shift in thinking about co-benefits. If one were to take action to deal with particular impacts of, for instance, high temperatures—we heard some of the ways you might adapt a city—there are also co-benefits from that: nice green spaces outside, better wellbeing, better air quality. When it comes to the messaging, increasing evidence shows some of the co-benefits that people start to experience alongside the changes that they have applied for adaptation.

Professor Berrang Ford: Evidence shows that previous experience with extreme heat improves people's uptake of protective behaviours in the future. This lies behind this likely incremental adaptation over time that we tend to see in populations. To some extent, the population will incrementally adapt their behaviours through experiences. The problem is that those at most risk often do not have the capacity or control over

their environments, so we may need to be more active in protecting particular populations at risk.

At the UKHSA, we support the position of the World Meteorological Organisation on the naming of heatwaves. At the moment there is insufficient evidence that it is effective. Heatwaves are different from storms. Storms are localised and have a short duration. Heatwaves are different. There are some potential trade-offs. The WMO has a position statement on that. We support that and so do not support naming at the moment.

I would like to re-emphasise Professor Lowe's comments on co-benefits. While we do need to be specific and focused on this range of people, this range of people who are most highly vulnerable is not as small as we would like. We could have a large number of interventions that do not have to do with individual behaviour, or even health systems, but have to do with the way that we plan and design cities. It is serendipitous and fantastic news that a lot of the interventions that protect us from extreme heat also have significant co-benefits for health and economically.

Things like green space can improve energy efficiency, can reduce costs of energy, can provide shading for people and can improve mental health. There are some potential risks. We have to make sure, for example, that we do not create new habitat for mosquito vectors or vectors of disease, but we have a huge opportunity for win-win solutions. We are quite lucky that many of the interventions that reduce risk of heat at the community level are also good for health and other benefits.

The idea in the space of providing improved guidance for decision making on what interventions are most effective but also tick other boxes is an area of significant development. It is also an area that the UKHSA and the Met Office have been discussing together for early work.

Q34 **Chair:** Are you advocating air-conditioning units, for example, for these vulnerable groups when you cannot retrofit some of the other things that you mentioned because it is not possible in existing housing?

Professor Berrang Ford: Yes. Air conditioning is an example of a significant trade-off. Air conditioning is incredibly effective at cooling and protecting people, but it also increases and has substantive energy requirements. In some ways, it is promoting more heating by contributing to greenhouse gas emissions.

Chair: We will come on to that with the next panel. Is there a yes or a no from you on whether that is a suitable method to alleviate problems for the vulnerable?

Professor Berrang Ford: It is an effective cooling mechanism.

Chair: I am afraid we are rather overrunning on this panel. I am keen for Claudia Webbe to come in quickly with her questions.

Q35 **Claudia Webbe:** I will come in quickly. Before I go on to my structural questions about cities, which will build on what you have already said, why is there insufficient academic and scientific information about the effects of heatwaves on the menopause?

Professor Berrang Ford: I will have to get back to you on that. I do not have evidence specifically on that. Let me take note and I will see if we can provide anything and follow up.

Q36 **Claudia Webbe:** I note that the Office for National Statistics said in 2022 that there were more excess deaths among women as compared to men during 2022, but there did not seem to be much mention about the impact of heatwaves on women.

What are the best ways of making towns and cities more resilient to heat? You have touched on some of this. It is an open question.

Professor Lowe: Shall I start? First, one has to look across timescales. On the shortest timescale, the idea of warnings that come with context, the idea of cooling centres and, ideally, people knowing where their cooling centres might be can be effective.

If we look at longer timescales, we have also heard about the use of trees for shading and also affecting the moisture exchange with the atmosphere and so leading to cooling. Cool roofs are another way we can let the physics work with us. Making surfaces more reflective rather than more absorbent is one way to go. It is also possible to do something similar with making permeable pavements. The way they handle moisture and how moisture is available for evaporative cooling can be quite effective.

As I am sure you will hear later, many factors involve buildings, from shades to building orientation when planning new builds. Of course, you have discussed air conditioning and how that is used in some cases within the city.

Q37 **Claudia Webbe:** What will that mean for the most vulnerable groups that you have identified in particular areas?

Dr Wainwright: It is not just about mortality; it is about being able to live a good quality of life. We do not want this country to just survive a heatwave. We want people to be able to thrive and be their best productive selves.

For someone taking a host of psychiatric medications, we are talking about constantly dripping sweat, tossing and turning at night, unable to work productively during the day. That will not be captured in any national statistics, but that person suffers significantly and needs help. The same goes for any number of groups identified here. It is a matter of framing the conversation away from hard numbers to look at what it means to live a decent quality of life and how we can help people to be their best selves.

Q38 **Claudia Webbe:** In terms of the way towns and cities are designed, how will some of the structural infrastructure help? What can we talk about when we talk about the most vulnerable people?

Dr Wainwright: My colleagues in the panel coming up are in a much better position than I am to speak to this. Quickly, sleep is so seminal to everything across health. Seven of the leading 15 causes of death are affiliated with not getting enough sleep. We need to give people cool, sustainable sleeping environments, however we do that. Again, my colleagues later will be able to figure that out.

Professor Berrang Ford: People need to be able to keep their bodies cool. That means they need to be able to have spaces where they can be cool, be that at home, work, on public transport and in urban environments. In many cases, that is not necessarily a health response. You do not want to wait until somebody gets to the emergency room. In many cases, we are talking about structural changes to our buildings and our urban and rural spaces so that they are cooler. Greening often comes up as an effective way of creating shade and cooling cities and spaces and making sure people have access to those spaces.

Again, the UK housing stock is not designed for heat. That is a challenge that goes outside of the health sector. In the health sector, we can be a voice on that and provide evidence on that but that is outside of our remit. One of the challenges in responding to heat is that a lot of the most effective interventions are outside of the health sector, even though they have health implications, so we can lead on things like emergency response and behavioural guidance. The health sector needs to rely on and work with other sectors on having cooler buildings, cooler spaces and cooler urban environments.

Q39 **Claudia Webbe:** In your assessment, where is the Government in relation to the necessary policies and plans and, indeed, those of other statutory bodies in being able to meet this agenda?

Professor Berrang Ford: From a UKHSA perspective, we have now—and we are building—one of the leading examples of emergency response and guidance on heat. We are contacted regularly by other nations interested in the professionalisation of climate resilience for health. The adverse weather and health plan and the weather heat alerts are the best in the world at the moment.

I cannot comment on progress going on outside of the UKHSA with those developments because I am not familiar with the plans in action, but certainly we look to and collaborate extensively with other organisations to look at some of those structural issues. This panel has mentioned that an integrated approach is relevant; we are doing that in the UKHSA and others are looking at it, but I am not in a position to critique, challenge or comment on other Government Departments.

Chair: Thank you. I am afraid we will have to finish there because we

have gone on a bit. I conclude the panel by thanking Professor Jason Lowe, Professor Lea Berrang Ford and Dr Laurence Wainwright for joining us.

Examination of witnesses

Witnesses: Dr Peterson, Martin Passingham, David Broom and Dr Delmastro.

Q40 **Chair:** Welcome to the second panel of our inquiry into heating and cooling today. I am pleased to welcome Dr Eric Peterson from the University of Leeds. Could you explain your role there?

Dr Peterson: I am a visiting research fellow. I live on soft money and I also work as a chartered engineer. I serve on ASHRAE's climate information technical committee. I am a professional engineer from the United States and Australia but I have recently been chartered here with CIBSE. I manage to get some research funding and I sometimes do projects in the space of sustainable heating and cooling.

Q41 **Chair:** Thank you. David Broome is here from Kensa, a supplier of heating and cooling equipment.

David Broom: Yes. Kensa Group is, first and foremost, a manufacturer of ground-source heat pumps based down in Truro, but the other parts of the group provide infrastructure funding to own and operate ground-source heat pump infrastructure. My part of the company delivers design and project management to install heat pumps at scale.

Q42 **Chair:** Thank you. We have Dr Delmastro from the International Energy Agency.

Dr Delmastro: I represent the International Energy Agency. We work with Governments and provide reliable data towards a sustainable future. We cover the whole energy sector, so we are energy focused. I will not explain all our activities, but in terms of space cooling, we look at future outlooks and which solutions and policies can help us with the impact of space cooling.

Q43 **Chair:** Thank you very much. We also have Martin Passingham from Daikin.

Martin Passingham: I am head of product and training within Daikin UK. My team and I support our organisation from a product point of view, technology, application, legislation, compliance, working for Daikin, which is a global HVAC company.

Chair: Thank you. We will remain quorate for about 30 minutes so we will get our questions in quite quick and fast, starting with Caroline Lucas.

Q44 **Caroline Lucas:** Thank you very much. I am afraid I need to go as soon as I have asked my question, which is rude, but I have a meeting at the

other end of the estate shortly. I will combine all my questions into one, which is essentially about a holistic approach to thermal comfort. Given that thermal comfort requires homes to be warm in the winter and cool in the summer, the question is: how can insulation and ventilation be most appropriately balanced and what is the best approach to retrofitting buildings holistically, taking into account both heating and cooling needs?

Dr Peterson: Yes. I recommend the Australian approach, the Nationwide House Energy Rating Scheme or NatHERS, which calculates in this EPC equivalent both the heating and cooling impact of the dwelling. You can play around with it. It is climate specific. You can get minimum compliance but then you can decide to tweak it the other way. I believe the UK is more advanced with the overheating regulations part O, which is world leading. The UK is taking a great step forward here, which will help with that.

David Broom: It would be good if it also showed on the EPC. The overheating requirement is a requirement of the building regs but it is not visible on the EPC. That might be useful to do.

From our side of it, from a ground-sourced heat pump perspective, I absolutely agree that having that balance of heating and cooling is essential and we have to work to decarbonise both elements of heating and cooling. We look to increasingly do that through the deployment of large-scale ambient networks, whereby we can take forms of waste heat in whatever form, whether it is domestic or non-domestic forms of cooling requirement, take that into the ambient network and recirculate that energy and make it useful elsewhere, providing heat and also using the ground as an inter-seasonal storage mechanism. Rather than taking waste heat and rejecting it to the atmosphere, we take that waste heat and transfer it around a network and make it useful elsewhere.

Dr Delmastro: I have two points. One is about the real need to understand thermal comfort for retrofit. In some countries like perhaps the UK, the focus was very much on heating and cooling was excluded. A training and awareness campaign for practitioners and also for new curricula design on building quality can be a relevant measure to bring cooling considerations into retrofits.

The second is the establishment of a local helpdesk, for example, where people can go and ask and receive information on how to do retrofits properly. There is a good example of this in Ireland and I am happy to share that information.

Martin Passingham: If you take a holistic approach, as you mentioned, the most important thing is you think of new build and you think of retrofit. For new build, part O, the overheating regulations, and various other decarbonisation regulations that are coming at the moment look after the new build to some extent but are mainly focused on heating, as we have already mentioned, not on cooling. In some ways, part O is a

reaction to the fact that we have gone too far in one direction in sealing our houses up.

In terms of retrofit, we can do a lot of measures from an insulation point of view and passive measures. Also, when it comes to cooling once we have exhausted all those measures, we can do that in combination with decarbonising heating. We can combine the two approaches, effectively. At the moment, that has not been addressed as a direction.

Caroline Lucas: Thank you very much and many apologies that I need to go. Maybe you could pick up, Chair, the bits that I have left.

Q45 **Chair:** Thank you, Caroline. If I can pick up on what was said at the end of the previous panel about the need to increase cooling capacity, Dr Delmastro, your report on cooling in the UK estimated the increased electricity capacity required to cope with the growing demand for air conditioning. Could you illustrate or quantify what that looks like?

Dr Delmastro: Sure. The report was a global analysis and maybe used data from the past. We noticed that from 2000 to 2020, electricity consumption for space cooling increased by three times and in Europe this was 20%. This had impacts not only on energy, as we heard before, but stressed the power grid.

Over a certain period, this can have issues like blackouts in certain countries. At the moment, in Europe we see that the impact of cooling on peaks is about 20%. In the UK, we estimate it is 14%. In countries with growing demand, this is higher: up to 50% to 70%. Clearly, that can cause blackouts. The impact goes beyond air pollution, health and acclimatisation, which were mentioned.

That said, based on our analysis, we do not expect the growth of electricity consumption associated with cooling to stop unless serious measures are taken into consideration. For Europe, we expect that with no policy action the increase of space cooling consumption can be up one third already by 2030. In the next seven years, we could have one third more consumption. As I mentioned, this can have several implications.

Which solutions do we see? The first is to do measures as much as possible to reduce the energy needs. This means the introduction of passive solutions and more realistic planning, as was mentioned before—the greening of urban areas and so on. Where these measures are not enough, it is about the deployment of low-emission, high-efficiency, active solutions. This means super-efficient air conditioners but also alternatives, as was mentioned before, like ground-source heat pumps—the sequence—with cooling and other solutions that are out there.

The third is to put in place measures to optimise how these technologies operate, and make sure we operate efficiencies through controls, coupled with renewables and storage. With these measures, we think we can keep consumption constant. It requires some policy measures on

regulation, finance, education and planning in particular, as was mentioned before as well.

Q46 **Chair:** The former BEIS Government Department produced a report called "Cooling in the UK", which has informed this session. That suggested that if we moved to US standards of air conditioning in the rest of the world, it would impose a multiple increase in electricity demand. Does anybody have a sense of an estimate for the UK?

Dr Peterson: I read the report over the weekend. I had to speed-read it. It has a lot of material. They used the model from Professor David Sailor from Arizona State University, but they found that the update already has not been as fast as it has been in the US because we have a different type of air conditioning conundrum here. We have a hydronic hot water system. We do not use ducted furnaces to heat our homes, as they do in North America, so it is difficult to retrofit and make a cooling system in a UK dwelling. It is an expensive and disruptive operation. Brits wait longer because it is a big inconvenience and a big capital expense and then it is a big operating expense when there are a lot of alternatives.

If you look at the modelling in the report, there will be an update. The way we are going, in mid-century people will not be able to handle it any more, perhaps the vulnerable population. There will be an update. They refitted Dr Sailor's curve to the UK with the availability data, so they made a pretty sound model for how it will track in the future. It will be passive first, but then there will come a point when you have to bring in other measures. It is inevitable, no matter what happens.

Q47 **Chair:** What can we learn from other countries? You mentioned that you felt the UK's part O of the building regs were world leading. What is happening in other countries that are further advanced in the introduction of heat pumps, for example? We are way behind most other countries.

Martin Passingham: We are significantly behind other European countries in the introduction of heat pumps in the UK.

On hydronic systems, air-to-water heat pumps are the main focus of our drive to decarbonisation at the moment. When we talk about air conditioning, we should talk about air-to-air heat pumps because they are heat pumps, exactly as air-to-water. They move the energy from the air into the environment through a medium of refrigerants rather than through water, so they are still heat pumps.

Air conditioning units can both heat and cool. Pretty much every single air conditioning unit sold in the UK can heat as well as cool. If you look at the heating load compared with the cooling load, in the UK, as it is today—not projecting forward for what the climate might do—the heating load is about 80% to 20% with a cooling load. If you have a hydronic air-to-water system in your house, that can cool as well as heat. For example, you could have cooling in the summertime and heat in the wintertime as well as having hot water.

You might think that is a bit of a mad idea but the rest of Europe has been doing this for the last 10 years. If you take in the UK, for example, all the air-to-water systems we sell in the UK—speaking for Daikin—about 1% of all the heat pumps we sell are reversible and can heat and cool. In France, it is about 50%. They are way ahead of us in terms of heat pumps. If you look at the different markets, you can get a good feel for what is possible.

Chair: We will come onto that in a second but I would like to move on to Barry Gardiner.

Q48 **Barry Gardiner:** Thank you, Chair. I want to focus on passive measures because they cost the least. As you said, Dr Peterson, you do those first. Could you distinguish for us heat protection, heat modulation and heat dissipation as the three elements of passive measures you can put in place?

Dr Peterson: Protection avoids the sun coming in or taking the cooking area outdoors, as they do in a lot of warm countries, on to the veranda, outside the building envelope. With modulation, you would somehow reduce that heat, maybe through your windows. You could have tinting if you do not have an external screen. To dissipate that heat passively, you would ventilate it. You would open the windows and let the cross-ventilation blow it right out the window.

Q49 **Barry Gardiner:** Great. Having established that—perhaps Dr Delmastro and you would focus on that area—how would the solutions differ for new build installation and for retrofit? How would you employ different elements from those three in the different scenarios?

Dr Peterson: It is different. If you build now to super-airtight standard, you will put a completely different kind of ventilation system in than you would in an existing house. In an existing house, you want to get massive ventilation to cool off during the evening and then close during the day to protect the coolness inside.

In a modern passive house standard, if we push things to a future homes standard where maybe a lot of us think it ought to go, you would have a mechanical ventilation heat recovery system or MVHR. You would recover the coolth from the exhaust air as you bring in the required fresh air to always maintain good-quality indoor air. You would have good insulation to stop the heat from coming in.

Dr Delmastro: Maybe to complement that, with the new buildings, there is literature now to integrate all three quite easily. For renovations, it is a bit more complex, and so probably the easiest is heat protection. Innovative materials for heat modulation can be integrated, but this requires a bit of research. In this area, maybe if increasing research is warranted to look into smart materials, they can play an interesting role.

Q50 **Barry Gardiner:** Are those thermal mass materials quite expensive?

Dr Delmastro: Some like storage are. Others have different levels of coating that can be applied to existing layers. At the moment, these cannot be manufactured at scale, but it promises to be quite cheap in the future. Now the static ones are already quite cheap. They are maybe not as performing in heating and cooling areas, but for innovation in the future there is material that can adapt for heat and cool climates that is quite promising, so it is an interesting area of work.

On the passive measures, we see that there is a lack of integration of passive measures into standards. There are some good case studies where they have mandated to prioritise passive measures in standards. For example, in Singapore shading is to be prioritised and also in Switzerland passive measures are to become the norm in construction design. There are other quite interesting measures in voluntary standards—for example, LEED and ASHRAE could be good standards to look at. I could send documents.

Q51 **Barry Gardiner:** That would be helpful. It is always helpful if you can frame your answers in the sense of a recommendation that the Committee might adopt, so thank you for that.

Radiative cooling panels and films have been tested and in fact deployed in the United States. Do you think that we are approaching a point where those should also be utilised in the UK? How would we begin to roll out that technology?

Dr Delmastro: Yes. As I mentioned before, there is a distinction. First is the static one, which is reflective to cooling and these panels are quite performing in hot weather. There was the Million Cool Roofs Challenge that was applied in Africa in particular and they worked very well. In areas with heat and cool needs like the UK, there is some evidence that this might increase heating consumption over the winter, so perhaps a quick application of the static ones can be in urban environments—for example, over parking lots and bus shelters—can be easily deployed there.

For the others, maybe these materials that are radiative panels, but they can react to temperature, humidity or light conditions and reflect high solar radiation during the summer, but lower during the winter. This is probably most suitable for a climate like the UK on a building, for example, on a building envelope or a window or a roof. That is of course my personal opinion.

Barry Gardiner: Dr Peterson?

Dr Peterson: I think you have covered that quite well.

Q52 **Barry Gardiner:** Great. Is there anything that Mr Broom or Mr Passingham want to contribute on this? I know you are active heating or cooling specialists.

Martin Passingham: From a ground source point of view, passive has a big impact.

David Broom: Yes. We have an area of cooling that kind of sits in between the two. Once you have installed the infrastructure required to provide the energy to a ground-source heat pump, we can provide what we would term as passive cooling, where we take the cold from the ground and bypass the heat pump and then distribute that directly into a cooling distribution system.

It cannot go directly into your radiators, which most people would have at the moment, so we would need a dedicated distribution system, but what that means is we can take the cold from the ground, distribute that directly into the building and provide that overheat protection and that cooling direct. Because we are not running the compressor, we are not running the heat pump, the operating cost of that is very low and, therefore, the carbon impact is low, and we are also reducing any impact on peak energy demand when everyone is turning the air conditioning on.

Q53 **Barry Gardiner:** Is that different from the reversible heat pump?

David Broom: It is, yes. It is a kind of a stage in between, so we do not need to reverse the heat pump itself because the ground temperature's steady state is around 10°. Obviously the primary benefit of ground-source heat pumps is that when we are providing heat in the winter, the ground temperature is higher than the air temperature, so therefore it is more efficient at providing heating. The same is true in the summer, where the ground temperature is much cooler than the air temperature and therefore it is more effective at providing cooling.

Q54 **Barry Gardiner:** How expensive are those units?

David Broom: To operate or to install, sorry?

Barry Gardiner: You have just told me that they are cheaper to operate than the reversible heat pump, so how expensive are they to install?

David Broom: Yes, they are cheap to operate in terms of it is just the cost of an operating pump, so pence a day to operate. It is just a circulating pump, the same kind of pump as you would get in any domestic heating system, so a very low cost.

Barry Gardiner: That was a sales pitch. Now the question.

David Broom: I am getting to it. On the infrastructure cost side, the heat pump element itself will be similar to an air-source heat pump or an air-conditioning system, but we have the ground array infrastructure to install as well, which is obviously a significant infrastructure cost that goes with that. A typical retrofit—

Barry Gardiner: You should go for a life in politics. Just give me a price.

David Broom: A typical retrofit installation is somewhere around £22,000, so that is end-to-end infrastructure all the way through to heat-pump installation.

Dr Peterson: I should comment. I am concerned that these radiant panels sound like chilled beams—sometimes in the industry we call them rain beams—and the problem is that if you are running at normal kind of chilled water temperatures, you get a lot of condensation and water can form. What I like about this concept he is describing is it is not that cold. It will not be as powerful as a chiller, but I think there is a bit less risk and it is a lot simpler.

I do not think you can patent your idea. I think I can steal your idea too because it is such a beautifully simple idea. Chilled beams work well in dry climates, but in humidity it is dangerous. You are better off with a fan coil unit with condensation control and just ducting your air conditioning with traditional air-conditioning methods.

Q55 **Barry Gardiner:** Briefly, what should be done to prioritise the people who are most vulnerable in terms of passive measures?

Dr Peterson: Of course, the truly vulnerable probably need to be issued with air conditioning subsidised by the NHS, if that is possible. That is what they do in New York City and Chicago—they map it out and they go around to the grandmothers and they install it.

As we age, before we turn 65 and we go into that demographic, I think in these cooling centres we need to share how to do it at home—DIY information—and share these tricks and tips about how to adapt yourself. Rather than having the cooling centre be air conditioned, let's do a passive cooling centre at the local makers' space, the men's shed, the library—these places in the community—and disseminate it.

There are so many tips and tricks and they are very local and specific, so what you do in the London men's shed will be different than what you do in the Leeds men's shed and in Glasgow you will come up with a different set of solutions. Let it be something that evolves over time as the climate changes and we will figure out what the right solution is in each place.

Dr Delmastro: I have maybe just one thing to add. I was also thinking in the previous panel that very often the people that are the most vulnerable are also the ones living in the worst living environments, with some of the worst housing conditions. Programmes to overall prioritise low-income households for energy efficiency measures can also help aspects of cooling for the most vulnerable.

Barry Gardiner: That would be a good recommendation for this Committee, would it?

Dr Delmastro: All right, yes.

Chair: I think Barry could be accused of putting words into the witness's

mouth. I think you would like to say something, Martin, but I will just pass on to Jerome Mayhew and perhaps you can get it into an answer to the question from him.

Q56 **Jerome Mayhew:** We have heard about passive heating and now I will talk about active heating because, Dr Peterson, you said that it is inevitable that by mid-century we will be looking at elements of active heating. We have also talked about insulation and the future homes standard, which is great for new builds, but we have about 28 million existing residential properties in the country. Most of those will still be up and running, one hopes, in 2050, as well as the commercial sector. Let's start off with fans. Are they good? Will they be enough? Who has a view on fans?

David Broom: It is kind of a progression of measures. Once you have done everything you possibly can to mitigate impacts through passive—

Jerome Mayhew: Yes, we have done all that bit.

David Broom: We have done all of that, then fans and air movement and ventilation is the next natural step because it is the lower capital cost, lower operating cost, end user, lower—

Jerome Mayhew: Easy to do.

David Broom: Exactly that: low intervention and relatively simple. Again, back to what the previous panel said, for the majority of people, where the heat isn't overly an issue, that is generally enough.

Jerome Mayhew: Or a health issue.

David Broom: Exactly, it is a comfort thing, rather than—

Q57 **Jerome Mayhew:** Collectively or individually, are you suggesting to the panel that we should be authoritarian in this—that we should be directing to consumers that they can only buy fans rather than active air conditioning? What do you think?

Martin Passingham: I think putting that question to the first panel would have been quite interesting because basic fans—you have one on your desk there—work based on evaporative cooling, so they evaporate moisture from the body and that in itself has a health impact. I am not a health expert so I cannot answer the question, but my question might be: what impact does that have on an individual where you are evaporating the moisture from them to gain cooling through evaporation? Because it has consequences: it is not like you are just reducing the temperature and maintaining the body's moisture content. You are having a direct impact on it. I do not know if there are studies on that, but I would be interested to understand it.

Jerome Mayhew: Any other views, Dr Peterson?

Dr Peterson: I do not want to say that air conditioning will be required everywhere mid-century. I just mean that it will start to appear under the building O regulations, that the consultants will probably conclude on more occasions that it is the right choice for certain clients, but we hope not generally, even by the end of century.

Q58 **Jerome Mayhew:** We have talked about fans and reversible heat pumps have been mentioned. Am I right in a part assertion that reversible heat pumps will be hard to work for residential properties, given that we have standard radiators and with the retrofit I think I'm right in saying you would have to have ducting for forced air? There are three nods and one shake. Let's start with the shake. Where have I gone wrong on that?

Martin Passingham: I think there are significant people within Government at the moment who are putting in measures to try for the implementation of air-source heat pumps within society as a whole, within the housing environment as we have it at the moment. They are doing that based on the fact that those air-source heat pumps can give heating, hot water, but also cooling in the summer. They are doing that based on decarbonisation.

Q59 **Jerome Mayhew:** How did I get the wrong end of the stick? Because my understanding with air-source heat pumps is that they feed into the water-based heating system that we have in the vast majority of houses and that if you turn that into cold water, you get the condensation that you have been talking about, and that is not a good thing.

Martin Passingham: In that instance you would need heat-pump convectors, which are a slightly different design to a radiator. If there are some rooms where you need cooling, you could have two circuits. You could have a circuit with radiators that you do not touch during the summer, but then you have a different circuit with the heat-pump convectors with the colder water going through those and cooling the room.

Q60 **Jerome Mayhew:** And it is very expensive and disruptive because you have to do extra plumbing—double the plumbing; is that not right?

Martin Passingham: Not expensive, because you are replacing what you have at the moment. What you should—

Q61 **Jerome Mayhew:** Just hold on there, because my understanding is that the way in which we keep our retrofit costs down is that in a large number of cases you do not replace the existing plumbing and you take advantage of the existing plumbing but change the boiler.

Martin Passingham: Correct. I think there are steps you should take when you decarbonise when you are looking at a heat pump. The first step should be fabric first, so you always insulate the house, you always make sure—

Jerome Mayhew: We have done that.

Martin Passingham: We have done that.

Jerome Mayhew: We will move on, looking at the time.

Martin Passingham: The next step would be to look at your system and you think, "Okay, I have under-floor heating. Fantastic. It works brilliantly with an air-source heat pump, no problem." If you have radiators, you can have a high-temperature heat pump, so you can have much higher flow temperatures in your system, say 70°. It is not optimum because the new building homes standard talks about 55°. At 55°, you really need to have heat-pump convectors in, so you gradually—

Jerome Mayhew: Or double up the size of your radiators?

Martin Passingham: Yes, or have more larger radiators. You have choices, but you can do that over a period of time.

Q62 **Jerome Mayhew:** There is a retrofit cost associated with all that, I take that. Given what we have heard about heat pumps and the various different types, which is the best? I will start with Kensa here because you are the manufacturers. Other brands are available, I am sure, but what heat-pump technology is the best for providing cooling?

David Broom: We have to decarbonise heat, so we will have to make a transition to heat pumps to do that. In doing that, it makes sense to integrate the ability to provide cooling as well as heating because all heat pumps provide hot and cold; that is what they do. Our view would be the use of ground-source heat pump infrastructure would always provide the best because where you are taking the energy from is always warmer in winter, and then you can cool the air temperature in summer.

There is a trade-off there because you have the extra infrastructure that I was looking for us to put a number on, but against that infrastructure with the extra efficiency, you are reducing your peak demand both at heating and cooling periods because in heating periods it will operate more efficiently so we have less peak power draw, and then also in the summer, because we are not running the compressor, we are not running reverse cycle and we are avoiding that peak summer requirement.

To get to mass-scale decarbonisation, the view would be to roll out wide-scale ambient temperature networks, so we put that infrastructure in the street, so all of the areas where it is difficult to retrofit individual air-source heat pumps or it does not have the density for district heating networks—

Jerome Mayhew: Then go for a district system.

David Broom: In areas where it is not dense enough for district heating, we can install these ambient loops down the streets, as we have done in our trial project down in Cornwall. We can install the infrastructure. That is there, that is funded, owned and operated separately and then for the homeowner it is a lower cost of intervention. It is switching out a gas

boiler for a heat pump and then you have the opportunity to have the heating or the heating and cooling infrastructure available. Obviously, in that scenario, you are probably aiming at the able-to-pay market. The people who will be most able to enjoy the additional comfort are the ones that can afford it, but what we heard earlier is that the people that cannot afford it are the most vulnerable that will probably need the support.

Q63 **Jerome Mayhew:** I will cut you short because of the time. You have talked about your ambient heat loop pilot—that is not easy to say. Have you provided information to the Committee as to your findings from that pilot scheme?

David Broom: I do not think we have given the original report, but we can—

Jerome Mayhew: We would be very grateful to have some information about that.

David Broom: Yes, we can certainly send that through.

Q64 **Jerome Mayhew:** Just finally, is there a risk that the deployment of technology such as reversible heat pumps will lead consumers to the sort of "get out of jail", where they go straight to active cooling methods rather than passive ones? Is there an argument that it could be counterproductive? There is an argument that if you make it too easy, you are just plugging in and using energy when perhaps other measures could have been tried first.

Dr Peterson: It is a behaviour thing. People are basically lazy. You will just pick up the remote and have some cooling rather than get out of the couch and go open the window. It is just too easy, so I—

Q65 **Jerome Mayhew:** I am in favour of easy, but is it damaging?

Dr Peterson: They already had to fire up the coal-fired station this summer. It was true they were servicing a nuclear power plant. There were some other issues. The cable from Norway, one channel was not working, but the temperature was going up and the National Grid said, "Fire up the boiler," and they did. It cost £500,000 just to light the fire and get the smoke going up the stack. Air conditioning is correlated with this demand surge, this peak demand.

In Australia they found that when people install an air-conditioning unit, they should charge them for the cost of all the poles and wires. It is a big inrush of current when that compressor comes on and that is a big load on the network and just a few pence per kWh maybe isn't enough because it is such a short time—just a heatwave.

Q66 **Claudia Webbe:** I want to turn to the notion of cooling systems having a detrimental effect on our environment, and the issue of F-gases in particular. Could you just explain why cooling systems can have such a

negative impact when it comes to F-gases?

Dr Delmastro: Yes, very briefly. We know now that this equipment has refrigerants inside. The majority of refrigerants are so-called HFC, containing substances that have big global warming potential, higher global warming potential compared to CO_2, and that is why now there is discussion about phasing them out or phasing them down. Estimates from IPCC say that this is now 2.5% of global greenhouse gas emissions and air conditioning, and refrigeration and heat pump is 85% of this.

The first is because they have a high global warming potential. The second reason why they have a high impact is because they have short atmospheric lifetimes compared to CO_2, for example. When there are leakages of these refrigerants—and there are from these technologies—the impact on the rise in temperature is visible quite soon compared to others. Maybe someone can give a stronger view on the type of refrigerant.

Q67 **Claudia Webbe:** Thanks for that explanation because I think that is important. Martin, could you explain how we can support the UK to transition to lowering the consumption of HFCs—these gases—while still delivering efficient cooling systems?

Martin Passingham: It is very interesting. The F-gas regulations came in in 2015. At that point, all of the manufacturers in the UK and all the manufacturers supplying the UK had been working to reduce the GWP—the global warming potential—of the products within their units. They had been pretty successful at doing that. The GWP has come down from significant thousands to numbers less than 1,000, I would say, generally across equipment. Inevitably with these things there is a journey, but the most important thing is getting the balance.

When we look at a heat pump—we do not call it air conditioning; it is a heat pump that does heating and cooling—we look at four main factors. One is obviously environmental impact, one is efficiency, one is the cost, because somebody has to pay for it, and then the final one is all about the safety of the product, from the point of view of whether it is safe and can be installed in somebody's house. We have to balance all those elements.

When we are looking to develop new products with significant changes within them in terms of components, that could be five-plus years. We started in 2015 looking at the previous F-gas, to reduce the HFC content of those products, and we are still going. We are still doing it; we are still moving through our range and we have been totally focused on it. That is eight years ago and we will continue to do that. I think my message would be: give long-term clear direction, but give manufacturers time to be able to develop the technologies so they are safe, they are energy efficient and they do not cost so much that our homeowners cannot afford them or businesses cannot afford them. So on the direction, no

problem—it is just about making sure that we work together to get the timing right.

Q68 **Claudia Webbe:** Effectively, these refrigerants can clearly be quite dangerous when it comes to global warming. Countries like Denmark, France and Netherlands, when it comes to recycling and so on, they have adopted a take-back scheme. Is that something you would recommend for the UK?

Martin Passingham: It is something we are already doing in the UK. We are working with a partner in the UK—a company called A-Gas—and we have an offer to our customers where all of the gas at the end of the life can be taken back, cleaned and then put back into use. That has been fantastic. What it means is that it avoids having to produce the products again. We take the reclaimed clean product and put it back into new kit, so that is perfect.

Claudia Webbe: Is that UK-wide?

Martin Passingham: We are doing it and we have a special process going on, but within the F-gas regulations there is a legal requirement to recover the gas at the end of the lifetime of the product. All suppliers have to do it, but the most important thing is they need to clean it and reuse it.

Q69 **Claudia Webbe:** Finally, in terms of the relationship between the global warming potential of refrigerants and their energy efficiency, what is that relationship? Maybe if I can ask David or Dr Eric.

David Broom: It depends on the nature and the mix of the refrigerant, but generally there is a bit of a compromise to make on the global warming potential. Depending on the actual nature of the refrigerant itself, some of them become less efficient, dependent on the nature of the heat pump and the application.

If you are looking at embodied carbon just purely at the point of installation, you would favour a low-GWP heat pump right now. If you are looking at total lifetime, there is a bit of a trade-off because a high-GWP unit may get you lower carbon overall, because we assume that within the heat pump itself we do not lose the refrigerant. It is there for the lifetime. It is brought back at the end and recycled and leakage rates are very low, so the lifetime carbon is therefore very low.

Obviously, as the carbon intensity of electricity reduces, that embodied carbon element becomes increasingly more important as the grid further decarbonises. Essentially, it will become more important over time to harness the lower-GWP refrigerants within products.

Q70 **Claudia Webbe:** What would be the one recommendation you would give to enable us to get to the more natural form of refrigerants quicker?

David Broom: I would echo what Martin said. I think it is about market certainty. It is about having the indicators in the market in the long term

that allow us to plan and invest, because a significant amount goes into R&D and product development. Having those long-term indicators on the direction of travel of the market, the market scales and the pace of that transition, when we have certainty of that, that is when we can start to go through the gears and improve faster.

I guess what we have at the moment is a long-term strategy that points in the right direction in terms of heat-pump deployment. Depending on which report you read, it is 600,000 or 1 million heat pumps a year by the end of the decade or thereabouts, which is a great indication. What we do not have right now is the policy environment or a set of market conditions that are impacting immediate deployment and starting to get us on the path that will get us to that level of deployment. I guess the recommendation would be to look at ways and mechanisms that we can, in the shorter term, give that level of certainty and confidence for the market that that is the direction of travel.

Martin Passingham: One of the key points is that there is different legislation here. There is the energy-related products directive in the European Union, which talks about efficiency. That has made great strides. In fact, next year the seasonal energy efficiency ratio, SEER, is going up to 6 for air-to-air heat pumps—that is, air conditioning. That efficiency level of 6 is fantastic. That has been moving over the last number of years.

However, while we are developing heat pumps for optimum efficiency, we are also being asked, "Well, develop heat pumps for natural refrigerants," which is okay, but there is a certain amount of resource that needs to be focused on these areas. It is very important to understand what the priorities would be. From a consumption point of view, and the fact that we keep the refrigerant inside the units, and the leakage rates are miniscule, for me it is about efficiency, because then the requirements on the grid and the investment on the grid over the next five, 10, 20 years will be significantly less.

Chair: Thank you. That brings our panel to an end. I would like to thank Dr Eric Peterson, David Broom, Dr Chiara Delmastro and Martin Passingham for joining us today. I would like to thank our specialist advisers, Dr Radhika Khosla and Nicole Miranda, who recommended this inquiry after an event that we held at Imperial College earlier this year. Thank you both for supporting us, and thank you to Gary O'Key for preparing our brief.