Digital Buildings

How smart technology can decarbonise buildings and combat climate change

A WPI Strategy report for Vodafone UK

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About WPI Strategy and authors

WPI Strategy is one of the UK's leading political communications consultancies, with a track record of delivering high impact public affairs campaigns. We offer senior strategic counsel and work extensively with our sister company, WPI Economics, to ensure that campaigns are underpinned by evidence-based content.

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About Vodafone

Vodafone UK connects people, businesses and devices to help our customers benefit from digital innovation. Our services span mobile, fixed line, broadband and the Internet of Things (IoT). We employ around 11,000 people across the UK, and operate more than 400 retail stores nationwide.

Having made the UK's first mobile phone call and sent the first text, Vodafone has a history as a tech pioneer. In 2018 we made the UK's first live holographic call using 5G, and were the first to start carrying live 5G traffic from a site in Salford, Greater Manchester. Today we serve over 18 million mobile and fixed line customers in the UK, with 4G network coverage at 99%. Vodafone has launched 5G in over 50 places across the UK so far. Our customers voted us the UK's Best Network Provider at the 2020 Trusted Reviews Awards. To help deliver Gigabit UK, we are rolling out full fibre broadband across 12 towns and cities in partnership with CityFibre, reaching one million homes and business by 2021.

Our ReConnect programme is supporting women and men back into work after a career break, our IoT technology is working to create a low-carbon society, and our free Digital Parenting magazine is helping families across the UK to navigate the online world safely. For two years running, we have been named one of the UK's 25 Best Big Companies to Work For by the Sunday Times, and a Top 100 Employer by Stonewall.

We are part of Vodafone Group, one of the world's largest telecommunications companies, with mobile operations in 22 countries, partnerships with mobile networks in 42 more, and fixed broadband operations in 17 markets. As of 30 June 2020, Vodafone Group had approximately 300+ million mobile customers, 27 million fixed broadband customers and 22 million TV customers, including all of the customers in Vodafone's joint ventures and associates.

For more information about Vodafone UK, please visit: **www.vodafone.co.uk**

Foreword

When people think about how new digital technology will change the world in the next decade, they might think of gigabit internet speeds, smarter 5G phones, virtual reality, artificial intelligence, robotics – and they're right. But digital technology could also play a big, but invisible part in the fight against climate change by helping us cut carbon emissions from buildings: both new buildings and the existing building stock.

This report looks at the contribution that smart buildings, equipped with Internet of Things (IoT) and Artificial Intelligence (AI) technology, can make to reducing our carbon emissions – especially in non-residential buildings like offices, factories, warehouses and hospitals. They can do this by monitoring how space is used and using energy more efficiently as a result.

For example, smart heating, ventilation and air conditioning (HVAC) systems can ensure that only spaces that are actually occupied will be heated or cooled. Motion sensors can facilitate smart lighting, ensuring that again only occupied spaces are lit and to the correct levels. And smart buildings can learn about occupancy patterns and then suggest how workplace conditions can be optimised for both workforce comfort and energy efficiency.

Reducing carbon emissions from buildings may not be the most eye-catching example of what new smart technology can do, but it may turn out to be one of the most important. After all, buildings are responsible for well over a third of the UK's carbon emissions. And while improving energy efficiency in new housing and non-residential developments will make a big difference, we can never achieve the reductions we need without a focus on the buildings we already have. Most of the buildings we use and will keep on using for years to come are already here – as much as 65% of the building stock we will be using in 2060 has already been built.

The Government has focused on improving the energy efficiency of both new and existing housing in particular. The Green Homes Grant, £2 billion to help homeowners make energy-saving home improvements such as installing loft insulation, lagging and double glazing, will make a massive difference, as well as helping to create tens of thousands of green jobs. But the carbon footprint of non-residential buildings is tougher to reduce, because so many of them have been designed in a way that makes these traditional energy efficiency measures hard to put in place.

There are other benefits to smart buildings technology too. Devices such as Vodafone's Heat Detection Camera can accurately screen people for raised body temperatures with no direct bodily contact so that social distancing can be maintained. Where workplaces need to be reconfigured and work patterns changed to accommodate social distancing, smart technology can help to optimise and plan building use, supporting Covid-19 resilience.

The Government has announced ambitious plans to decarbonise the public sector and smart technology can help achieve this goal. The state owns a massive square footage of offices, hospitals, schools, prisons and other public sector buildings around the country. Improving their energy efficiency can have a big impact: for example, the NHS alone is responsible for 5.4% of the UK's greenhouse gas emissions. In fact, new analysis in this report shows that smart technology could help the public sector estate reduce its carbon emissions by up to 15% – enabling a fiscal saving to the taxpayer of between £264 million and £380 million annually.

But most non-domestic buildings are not in the public sector. The UK's privately-owned non-residential building stock, from offices to shops to factories to warehouses, is unsurprisingly enormous. In the UK, smart technology fitted to non-domestic buildings could be used to achieve savings of between four and eight million tonnes of carbon emissions. This is the equivalent of between 5% and 10% of the emissions of all buildings. And of course lower energy use means lower bills too, at a time when all businesses are under pressure to cut costs.

Everyone wants to see our emissions reduced, and there's no doubt that the Government is moving in the right direction. But it needs to get the policy environment right to encourage large-scale adoption of energy efficiency measures, including the use of smart technology that already exists and is ready to be deployed in the buildings we all use. This report is part of Vodafone's contribution to helping us all get there.

Anne Sheehan, Business Director, Vodafone UK

Executive summary

Once the UK moves from tackling the immediate crisis of Covid-19 and gradually start using more workplaces again, the management of people and buildings is set to be more complex than ever before. The way we think about using our offices and other working buildings is going to have to change. At the same time, Government, building developers and occupiers must recommit to the decarbonisation agenda, which prior to the pandemic was already becoming increasingly prominent. Technology can play a central role in meeting both of these challenges.

Covid-19 caused an immediate and unexpected change in working patterns and building use whose long-term implications are still being worked out. But we already knew that the decarbonisation of our economy and society requires sweeping policy action to change how we generate electricity, travel, and heat our buildings; and we already have the tools in place to use smart technology to help us do this.

In the UK and EU, buildings are responsible for 36% of overall carbon emissions.[i] When considering how to reduce this, we need to focus on retrofitting existing buildings rather than designing new ones: in OECD countries, 65% of the buildings we will be using in 2060 have already been constructed.[ii]

Progress in reducing emissions from the UK's building stock appears to be stalling. The independent Committee on Climate Change (CCC)'s most recent progress report to Parliament said that, when adjusted for winter temperatures, emissions associated with non-residential buildings actually increased by 1% over the past year, while emissions for domestic buildings fell by 2%.[iii] In the same report, the CCC highlighted a major policy gap in relation to the energy efficiency of buildings, particularly around improving the market in energy efficiency for SMEs and decarbonising heating systems.[iv] So it was very welcome that the Government's ten point plan for a green industrial revolution, launched in November, included commitments on making public buildings more energy efficient.

While the Government has stepped up to the plate in tackling climate change as a whole, it faces a challenge to make significant improvements in non-residential buildings, where there is an opportunity to embrace new digital technology to improve both productivity and environmental sustainability in our building stock.

Internet of Things (IoT) devices can be used to improve the efficacy of building functions, creating so-called "Smart Buildings". The added value from IoT in buildings can include additional comfort and safety for occupants, improved workplace productivity, and a more efficient use of energy and other resources.

Smart Buildings with digital technology can dramatically reduce energy usage, and this report describes a range of use cases in detail. For example:

- Smart Heating, Ventilation and Air Conditioning (HVAC) systems which coordinate through the exchange of data to optimise the efficiency of each function;
- Predictive maintenance through smart technology to eliminate wasteful replacement and breakdown of a building's assets;
- The use of motion sensors to prevent wasteful cooling, heating and lighting of empty or under-covid conditions/ low utilised spaces.

Modelling by WPI Economics has found that, in the UK, smart technology fitted to non-domestic buildings could be used to achieve savings of between and **4 and 8 million tonnes of carbon emissions**. This amounts to a saving of between **5% and 10% of the emissions of all buildings**. In particular, smart technology could **help the public sector estate reduce its carbon emissions by up to 15% – enabling a fiscal saving to the taxpayer of between £264 million and £380 million annually**.

But the benefits of Smart Buildings are not only in reducing emissions. Offices, schools, hospitals and other non-domestic buildings are far more than simply structures which consume energy and resources. They are places of work, care and productive activities which generate benefits for wider society. Smart technology can be used to improve the indoor environment of a building in terms of its air quality, thermal comfort, lighting and space utilisation. As well as reducing carbon emissions and energy bills, this also generates benefits in the form of improved staff wellbeing and productivity. Smart technology such as Vodafone's Heat Detection Camera can accurately screen people for raised body temperature with no direct bodily contact so that social distancing can be maintained, with discreet alerts via a secure central console which allow further action to be taken discreetly and while protecting privacy. And in a world in which workplaces may need to be reconfigured, and work patterns changed, to accommodate safe social distancing for health reasons, smart technology can help to support Covid -19 resilience, optimise and plan building use.

Policy action is required to seize this opportunity

Digital technology in buildings is a growth area, partly because the cost of sensors has fallen dramatically. The average cost of a basic IoT sensor fell from $1.30 to $0.60 between 2004 and 2014.[v]

However, barriers still prevent further take up and realising the full benefits of the technology for both the public sector and non-domestic buildings more broadly. These barriers include upfront cost, the need to realign incentives, as well as interoperability of technological standards. Based on our extensive analysis we would recommend pursuing the following policy areas for exploration and action:

1. The Government should **review the Building Energy Efficiency Survey (BEES) carried out 2014/15** and explicitly collect data on the use of IoT and smart technology by public sector buildings.

2. The data this generates should be used to inform the development of **a firm target for using smart technology to improve the energy efficiency of the public sector estate**, which our modelling suggests could reduce its carbon emissions by up to 15%.

3. The Government should **consider how the wellbeing and productivity of the public sector workforce could benefit from the use of IoT in buildings**. This could, for example, be explored in the context of the NHS People Plan.[vi]

4. In addition, when procuring this technology, the Government should seek to drive **consistency in the adoption of IoT security standards**, especially in the way the operations systems of devices manufactured by different companies interact with each other.

5. The Government should create, in addition to Energy Performance Certificates (EPC), **a mandatory certificate system for large commercial buildings that includes a rating based on its operational energy performance**. This could be based on the model of the Display Energy Certificate (DEC) or the Australian NABERS rating.

6. And it should trial either **grant or subsidy-based incentives to encourage businesses to put in place energy efficiency measures**. IoT can provide a better understanding of how and where energy is produced, which would allow Government to promote renewable energy at all levels, not just large factories. Government should encourage investment in this technology by opening up access to renewables incentives.

Smart Buildings and the climate emergency

The scale of the climate crisis facing the world is increasingly being recognised in the language it deserves – as an emergency. The days when climate change denial was a mainstream political view are long gone and the UK Government, like many others around the world, has made environmental sustainability a top priority.

Last year the UK became the first major economy to enshrine a date in law from which its contribution to global warming would end, by promising to become carbon neutral by 2050.[vii] There is a broad political consensus in the UK amongst all major parties for reducing emissions. The Scottish Government has initiated an earlier net zero target of 2045,[viii] Labour made a green industrial revolution a central plank of their recent manifesto[ix] and local councils across the county have declared climate emergencies, demonstrating their commitment to combating the worst effects of climate change.

The Government has taken steps to incorporate reductions in carbon emission into broader Government policy, most recently with the publication in November 2020 of what it calls a ten point plan for a green industrial revolution. This strategy is framed around the agenda of 'clean growth', to ensure that the UK takes advantage of major global changes, improves people's lives and increases the country's productivity. Reducing the UK's carbon emissions isn't just viewed as an objective in itself, but also as an opportunity to help British households and businesses as part of the Government's broader agenda of 'levelling up' the country, ensuring that all regions benefit from inclusive growth.[x]

1,432
Jurisdictions have declared a climate emergency...

28
...across 28 countries...

820,000,000
...covering 820 million people.

Fig 1: Declarations of climate emergency

Source: Climate emergency declaration[xi]

Included within the Government's ten point plan is a commitment to make our homes, schools and hospitals greener, warmer and more energy efficient. This is very welcome: if we are serious about reducing our emissions further then we have to think more broadly, including by looking at the impact our buildings have on carbon emissions. We are already seeing some good work in this area, but there is much more that can be done to improve the energy efficiency of existing buildings, especially commercial and non-residential buildings.

By embracing smart IoT technology that, for example, adjusts a room's temperature depending on the number of occupants at any one time, we can take a vital step in reducing unnecessary energy wastage, limiting the carbon emissions coming out of our buildings and helping us to meet our environmental sustainability targets so that the UK can play its full part in tackling global climate change.

The urgency of addressing building emissions

The buildings in which we live and work represent one of the greatest sources of emissions globally, and as a result must be a priority area for action in order to prevent catastrophic climate change. To provide some scale of the problem, it is worth understanding the following:

- The existing building stock produces **36% of total carbon emissions** in the UK and EU countries combined;[xii]
- In the UK, emissions from non-domestic buildings fell only slightly between 1990 and 2009 but **will need to reduce by at least 80% by 2050** if the UK is to remain on track to meet its net zero 2050 target;[xiii]
- Across the UK and EU, 97% of all existing buildings require energy efficient retrofitting in order to meet the 2050 net zero emissions target, but **at present only 0.4-1.2% are renovated each year**;[xiv]
- A BEIS Building Energy Efficiency Survey in 2016 found that there is potential **for a 37% energy reduction potential for non-domestic properties**;[xv]
- Within OECD countries, **65% of the building stock we will be using in 2060 has already been constructed**.[xvi] This highlights the need to focus on retrofitting, as opposed to just new builds.

There are a number of means by which the efficiency of buildings can be improved. These include the utilization of materials which help to naturally, or passively, regulate a building's temperature and indoor environment. In addition, designing buildings in a way which maximises the use of natural light can help to save on the need for electric lighting.

Box 1: Internet of Things (IoT)

Devices which are able to transmit information about their own status over the internet to other internet connected devices. The connectivity provided by IoT has been embraced by individuals and businesses in a variety of forms, such as wearables that help keep track of our health status and connected cars.

Source: Adapted from Vodafone and Goldman Sachs[xxiv]

Clean green digital buildings

In the context of managing a building or its functions, the descriptors 'digital' or 'smart' refer to a broad set of instances in which IoT devices have been used to improve the efficacy of various building functions. Smart technology can be used to optimise the energy consumption of both domestic and non-domestic buildings but the added value from IoT in buildings comes in a range of forms, such as additional comfort and safety for occupants, improved workplace productivity, as well as a more efficient use of energy and other resources.

A 'Smart' or 'Digital Building' will make use of a range of IoT technologies to reduce its consumption of energy. This tech can then be integrated and controlled by a Building Energy Management System (BEMS) which is used to optimise the different applications and functions within a building and coordinate them with each another.

The IEA has suggested that the range of digital technology employed to improve buildings' efficiency could reduce energy use across all buildings by 10% between 2014 and 2040.[xvii] Some of the components of a 'smart' approach to managing a building's energy consumption are set out below.

- **Smart Heating, Ventilation and Air Conditioning (HVAC) systems** – around 40% of a building's energy consumption is spent on the activities of heating, ventilation and cooling.[xviii] Smart technology can optimise the performance of these systems including through controls which tailor the use of HVAC to occupation of spaces in a building, as well as diagnostics which help to reduce breakdowns as well as wasteful over maintenance or repair.[xix]

- **Smart lighting** – smart lighting typically combines user preferences with data gathered through sensory IoT to optimise lighting use in a building. This can include sensing whether a room is occupied and therefore requires lighting, or how much natural daylight has made its way into the room. Various studies of the effect of the smart lighting technology in practice suggests that the energy savings can be significant, ranging between 38% and 68% of electricity used to light buildings.[xx]

- **Predictive maintenanc**e – connected IoT helps demonstrate the optimal points for repair of an asset to take place throughout its lifecycle. This minimises both the level of downtime typically faced by businesses as a result of faulty equipment, as well as reducing waste as a result of broken or poorly looked after building facilities.

These functions have been deployed by several organisations to achieve significant reductions in their energy consumption.

Box 2: IoT NxT

IoT NxT is a platform which uses enhanced technology to help create the offices, buildings and cities of the future. A key aspect of this technology is the integrated platform which brings together all the data from the various occupancy sensors and contactless screening. These facilitate real-time monitoring of where people are located in a building and also where the empty spaces are. These capabilities are also utilised for desk bookings.

The collecting and recording of data relating to air quality, temperature and humidity and lighting levels is also used to determine precisely which settings are most suitable for locations throughout a building, optimising energy consumption. For example, this enables people to sit in parts of the building that are warmer or colder dependent upon their preference.

Vodafone's Paddington Office

Vodafone has rolled out this technology at its Paddington office. This has created an integrated system, minimising energy costs and increasing comfort of its employees. The information is obtained from sensors and edge devices to provide real-time information on occupancy and energy on the one platform. This has created a step-change across efficiency, comfort and energy.

IoT.nxt virtual V-RaptorTM technology integrates the various subsystems in use at the office, providing an end to end solution where everything can be controlled in the one system. It also maximises comfort for employees as the real-time data collates information on air quality, water quality, temperature and humidity in the building and ultimate helps monitor how much energy is being used at any time of the day and why.

Changing attitudes and behaviours

Ultimately, there is a limit to which the functions of a building can be taken out of the hands of people. There are certain basic decisions that will be taken by building management, such as around scheduling for functions or acceptable variations in temperature. Naturally these decisions will to some extent draw upon the views and feedback of an organisation's staff. As a result, any comprehensive strategy to shift the dial on building energy efficiency must take into account how to win the hearts and minds of the people who use and reside in buildings, and not solely on outsourcing decisions to automated processes. This is another area where smart tech could add value.

The need to change human behaviour in order to conserve energy and reduce emissions is a reasonably well explored area and a major driver behind Energy Performance Certificates (EPCs), which are outlined in Box 3.

Box 3: Energy Performance Certificates (EPCs)

Currently in the UK, it is mandatory to display an EPC upon the sale or rental of any property (domestic or non-domestic). An energy efficiency rating of A to G is given based on a review of a property's energy efficiency carried out by an energy assessor. An EPC is based on an asset-based assessment of a property's energy efficiency, looking at things such as the age and type of house, its materials, windows, and type of insulation.

In addition to the rating, the certificate also includes a range of pieces of info such as estimated energy costs and recommendations for improving efficiency

EPCs have been beset by several issues since their inception, including questions about their accuracy in actually being able to predict how much energy a building will consume.

Source: Carbon Trust and UK Green Building Council[xxv]

One type of messaging which can be effective is around comparative energy use. Humans commonly guide their behaviour using the behaviour of others as a benchmark for what is good or acceptable. US energy company Opower has deployed this principle to produce a Home Energy Reporting Program for its customers, which compares their energy use to neighbours and provides personalised feedback to consumers on how to address this. This has been demonstrated to result in consistent energy savings of between 2% and 3%.[xxi]

Following four field experiments conducted by the Behavioral Insights team, a Smart Thermostat developed by Nest was found to provide on average a 6-7% reduction in a home's yearly heating gas consumption at its basic functionality. The thermostat reconfigures itself based on feedback from those residing in the home.[xxii]

Smart technology creates an opportunity here. Data on a building's energy use and how this compares to other buildings (or even different sections of the same building) could be gathered through IoT sensors and then displayed to occupants to encourage them to reduce their energy consumption. One example of a non-domestic building make use of such technology effectively is Defra Lion House (Box 4) building in Alnwick, Northumberland.[xxiii]

Box 4: DEFRA, Lion House

This Department for Environment, Farming and Rural Affairs (DEFRA) office in Alnwick, Northumberland was designed to be an exemplar public building for sustainability, replacing the previous 1960 era office. Among its key sustainable features are a biomass boiler, 110m² of solar photovoltaic panels, three wind turbines, high performance building fabrics and rainwater harvesting technology.

In addition, the office makes use of a BEMS system to monitor and control heating, ventilation, lighting, power and hot water. The data from this system is displayed digitally to occupants and visitors with energy consumption and carbon emissions shown in real time. This helps to demonstrate to a building's users how their behaviour can improve the energy efficiency of the building.

Sources: Welsh Government and Tech UK[xxvi]

Quantifying the energy efficiency benefits of smart tech

Defining the benefits

The previous sections have drawn upon a broad range of existing research to describe the potential energy efficiency benefits of smart technology. In order to progress a policy debate about how to realise the benefits of IoT to the UK's non domestic building stock, WPI Economics has set out to provide some estimate of the scale of the benefits that could be achieved if smart technology was universally adopted by (a) all non-domestic buildings and (b) public sector buildings only.

- **Reducing carbon emissions associated with the use of non-domestic buildings** – the use of electricity and gas to power and heat a building results in emissions (expressed as "CO_2 equivalent").
- **Reducing carbon emissions associated with the use of public sector buildings in particular**
- **Financial savings to the public sector from reduced energy consumption** – reduced energy consumption by public sector buildings results in lower spending on energy bills by government, which can be redirected to a reduction in taxes or be spent on other government spending priorities.

As discussed in the following chapter, there are broader benefits to smart tech than energy efficiency, such as lower levels of staff absence and improved productivity. These are not included in this model due to difficulties in quantifying this impact across organisations of many different types.

Results

A full explanation of the methodology and primary sources used in calculating these results can be found in Annex A. The high-level results can be found below:

- The carbon emissions reduction from all non-domestic buildings amount to **between 4 and 8million tonnes of CO_2 equivalent a year**, the equivalent of between **5 and 10%** of the emissions of all of the UK's building stock.
- The carbon emissions reduction from all public sector buildings could be **up to 1.2 million tonnes of CO_2 a year**, with the reduction in overall energy usage of **15%**.
- The fiscal savings to the public sector are **between £264 million and £380 million annually**.

People centred buildings – how smart technology can improve wellbeing and mental health

Beyond energy efficiency

Offices, schools, hospitals and other non-domestic buildings are far more than simply structures which consume energy and resources. They are places of work, care and various other productive activities which generate benefits for wider society. And as we come out of Covid-19 lockdown and re-evaluate some of the ways in which we use buildings as workplaces in the shorter and longer term, making sure that they are safe environments for their occupants while remaining useful, managing the interaction of buildings and people will become more complex than ever before. This is worth bearing in mind when considering the value of digital technology in the built environment, in addition to energy efficiency.

There are various ways in which connected IoT technology can improve the experience of a building for its occupants which adds value in several ways including safety, enhanced staff wellbeing and productivity. With respect to the core focus of this report, this is an important area to explore for three key reasons.

Firstly, the objectives of improving occupants' experience of buildings and making buildings more energy efficient are usually – although not universally – complementary. An office with the smart controls to manage light, temperature, and air quality is equipped to optimise these to the comfort and safety of staff but is also well placed to minimise the wastage of energy.

Secondly, making the case for take up of smart tech with key decision makers about purchasing and installing these devices requires an articulation of wider benefits that extend beyond lower gas and electricity bills, as the bulk of the business benefits are primarily around supporting and retaining staff. JLL has articulated the "3-30-300" rule of thumb[xxvii] which illustrates that per square foot, per year, a company spends:

- $3 on utilities
- $30 on rent
- $300 on payroll[xxviii]

As a result, improvements made with respect to staff retention and productivity will be reflected in a company's bottom line at magnitudes greater than any energy efficiency savings. Purely focussing on energy efficiency therefore does a disservice when examining the technology from a business perspective.

Finally, making buildings more people centred is relevant to levels of sickness absenteeism/presenteeism in the workplace. The physical conditions within a building, such as low air quality, have been known to contribute to the ill health of occupants – a phenomenon which has been described as 'sick building syndrome'[xxix].

Smart technology for people

Indoor air quality

Indoor air quality plays a significant contribution to people's health, a fact acknowledged by the World Health Organisation as early as 1983.[xxx] This is particularly important in a world in which many people spend the vast majority of their time inside, around 90% according to a survey by Opinium.[xxxi]

Poor indoor air quality, and its associated ill health effects, is closely related to how buildings are ventilated and air conditioned. In order to avoid a reduction in air quality, it's important that a HVAC system can:

- Ensure a good supply of fresh air, which replenishes the supply of oxygen and dilutes any pollutants. Some experts have suggested that a mix of fresh and conditioned air can provide an optimal environment of occupants.[xxxii]
- Provide effective ventilation that helps to remove pollutants caused by office activities such as printing and photocopying, or from carpets, finishes and adhesives.[xxxiii]

These are both things that can be readily facilitated by smart technology:

- The data collected through connected IoT devices in a building can be used to gather evidence about the level of pollutants in different parts of a building and take action to address these.[xxxiv]
- Linked to the above, cloud-based systems can allow employees to check the air quality in different parts of a building on their mobiles or other devices, something particularly pertinent in countries with very poor air quality such as China.[xxxv]
- Predictive maintenance can ensure that faulty or blocked HVAC systems are addressed more quickly which, in addition to previously discussed benefits about energy efficiency, can help to more rapidly remove pollutants from the air.[xxxvi]

Better take up of smart tech would help to reduce illnesses associated with poor air quality and also creates a return on investment for businesses in the form of better productivity, lower levels of sickness absence and improved staff retention.

Infection monitoring and control

At a time when everyone is justifiably concerned about the risk of spreading contagious airborne diseases in the workplace, discreetly monitoring staff for the early warning signs of infectious conditions such as Covid-19 can increase both safety and the willingness of staff to enter the workplace – even with social distancing measures in place. IoT-enabled heat detection cameras can detect high body temperatures to an accuracy of 0.3°C at a range of 1-5 metres, with no need for human contact to help capture data. Alerts can be provided to a secure central console, allowing action to be taken quickly, while protecting privacy.

Thermal comfort

Another important indoor condition for the wellbeing and productivity of occupants is thermal comfort. It is closely related to air quality, as there is a temperature range (between 16C and 24C) within which the health risks associated with low indoor air quality are reduced.[xxxvii] Furthermore, offices that are too hot have been associated with falls in staff performance of 6% and offices that are too cold are associated with falls in staff performance of 4%.[xxxviii]

As discussed in the section on energy efficiency, IoT sensors can be integrated with smart HVAC systems to perform heating and cooling conditions in a way that is optimised to the actual conditions within an office. Furthermore, predictive maintenance can ensure these systems are operating at their optimum performance as consistently as possible, limiting the potential for intermittent extremes in temperature.

Natural light

Access to natural light is regularly stated by employees as being a major preference in relation to the kind of office they would like to work in, and often eclipses other benefits such as gym membership or staff cafeteria.[xxxix] There is no shortage of evidence supporting this preference - natural light is essential for vitamin D synthesis in humans, and also helps to maintain a circadian rhythm which is an essential part of a healthy sleeping pattern.[xl] There is evidence to suggest that employees sat by windows enjoy an average of 46 minutes more sleep each night.[xli]

There are a whole range of building design options that are important for establishing good access to natural light for staff. Clearly, this includes an ample number of windows and a floor plan that ensures that a maximum number of staff are situated near these. The location of a building is crucial too, as there is a need to ensure that vision of the sun is not obscured by other buildings or parts of the landscape.

Smart tech fitted to buildings can also help to realise the benefits of natural light to occupants, although this may at first seem counter intuitive. There are two ways in which smart tech can add value:

- IoT sensors integrated with automated lighting controls can ensure that the strength and brightness of electrical light changes in response to natural light throughout the day, ensuring that natural light is utilised as far as possible.[xlii]
- Put simply, buildings cannot in all circumstances be built in a way that ensures that all of their occupants have ready and consistent exposure to natural light. Happily, technology exists to make indoor lighting change according to the exact colour and brightness of the natural light outside. This can mimic some of the benefits of natural lighting insofar as maintaining a circadian rhythm.[xliii]

Consequently, businesses should ensure they consider the potential benefits of smart technology in maximising the benefits of natural light for their staff, in combination with a range of other considerations about the features of a building.

Box 5: VGreet

Vgreet is a unique visitor and workplace management solution that uses technology to create a seamless guest experience. The system ensures that all visitors to a building can get to their destination as quickly and safely as possible, whilst also providing all the required information. This enhances the visitor experience and reduces costs by eliminating waiting through the automation of routine tasks, supporting existing front-of-house teams at busy times, providing a fast and straightforward check-in progress and ensuing that visitors never get lost.

Box 6: VSpace

The Vspace solution is a consolidated digital platform that shows building occupancy. The platform provides insight into how the building is being used and how this can be optimised to improve productivity and enhance the employee experience. This is done through real-time visualisation and reporting on total occupancy, occupancy per floor and occupancy of defined areas on the main floor building

Space utilisation

Managing how employees use space in an office ought to be a major business focus for all companies. There are two major drivers for this:

- Renting, purchasing or maintaining office space is a major expense for businesses that they will seek to minimise by ensuring they are not paying for more space than is necessary for their commercial operations. Broadly speaking, there is evidence that businesses could dramatically reduce the amount of buildings space they use for their

commercial operations – according to JLL most office space worldwide is under utilised by about 50% on any given day.[xliv] This becomes particularly important given that many anticipate that a mix of remote working and office work is likely to persist in the medium term future, following the Covid pandemic, and so businesses will be looking to carefully assess their office requirements on an ongoing basis.

- Managing physical space is also important for encouraging employees to interact with each other more, or for maintaining a safe distance. This can help to improve productivity and support innovation as a part of creative processes, such as product development[xlv] or, at a time when social distancing in the workplace is being encouraged, as during the gradual relaxation of Covid-19 lockdown requirements, it can be essential to keeping workers safe or even enabling a workplace to function at all.

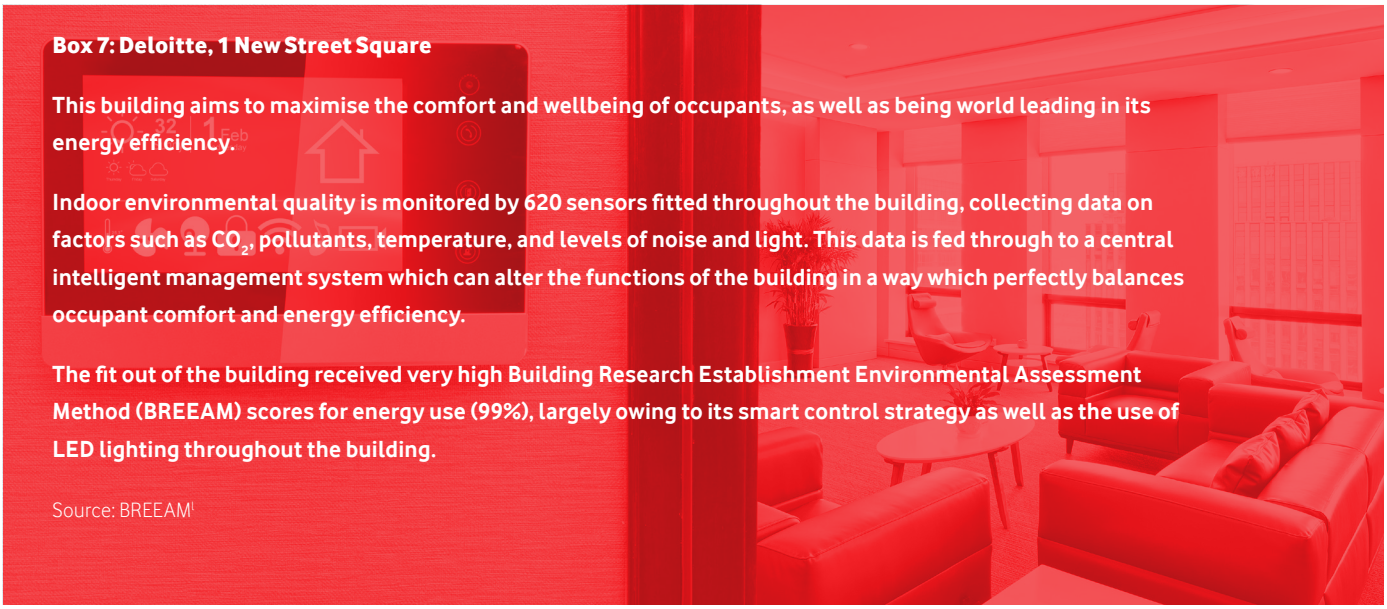
One way to obtain information about how occupants use different spaces within a building could simply be to ask them. However, this is not always reliable as there can be a disconnect between what employees claim to be the extent of their use of certain spaces and how they actually use them. IoT sensors combined with analytics technology provide a much accurate way of determining actual space use. This allows a company to make better-informed business decisions about their requirements in terms of office space, and potentially make significant savings in relation to their real estate costs.[xlvi]

Combined with cloud technology, these sensors can also help other employees to find out which of their colleagues are at their desks at a certain time of day, and the availability of space to conduct meetings. This makes it easier for workers to plan how they engage with and collaborate with their colleagues.[xlvii] Furthermore, analysing how employees move around different workspaces can provide evidence about how to reconfigure how office layout to enhance the number of "collisions" – chance encounters between relevant members of staff that lead to conversations which spark creative ideas. There is evidence to suggest this improves organisational performance.[xlviii]

This technology can also be used, when the situation requires it, to ensure that workspaces are optimised for health-related social distancing: planning shift patterns so that different parts of the building are not too full at any given time, and ensuring that employees can move around safely without putting themselves or their colleagues at risk.

A commercial as well as an environmental opportunity

As well as being a good thing for the health and satisfaction of occupants of office buildings, better building conditions have been demonstrated to provide a return on investment for businesses, paying dividends in the forms of higher rates of productivity, lower sickness absence and staff retention. In combination with each other, smart building features can deliver substantial savings when it comes to return on investment. Some of the findings are set out in the box below.



Box 7: Deloitte, 1 New Street Square

This building aims to maximise the comfort and wellbeing of occupants, as well as being world leading in its energy efficiency.

Indoor environmental quality is monitored by 620 sensors fitted throughout the building, collecting data on factors such as CO_2, pollutants, temperature, and levels of noise and light. This data is fed through to a central intelligent management system which can alter the functions of the building in a way which perfectly balances occupant comfort and energy efficiency.

The fit out of the building received very high Building Research Establishment Environmental Assessment Method (BREEAM) scores for energy use (99%), largely owing to its smart control strategy as well as the use of LED lighting throughout the building.

Source: BREEAM[l]

Table 1: Business benefits of people centred smart tech

Smart Buildings value-add	Benefits
Productivity	An average across a range of different types of studies suggest: • 8-10% productivity gains attached to improved thermal comfort • 6-8% gains from better ventilation • 6-9% gains from better air quality
Health and wellbeing	Studies found that better ventilation could result in a 30% to 57% reduction in absenteeism due to improved air quality, and a 15% reduction could be achieved by more daylight.
Retention	The added value in terms of staff retention attached to specific pieces of tech are not well quantified. However, we know that some employees do cite dissatisfaction with a physical workspace as a key reason for leaving a company.

Adapted from Stok (2018)[xlix]

Making buildings smarter

In order to realise the full range of societal benefits of Smart Buildings and IoT technology that we have set out, there is a case for broader take up of this tech to be supported by the policy environment. The use of this technology results in significant positive externalities across a range of fronts, however the biggest and most urgent one is tackling climate change, and so this is the area that we focus on.

For policy interventions in this space to be most effective they should also encourage other building energy efficiency measures in addition to the use of smart technology, such as better materials and insulation (or at the least not detract from encouraging them). From a public policy perspective what is important is the outcome – reducing emissions and contributing to the delivery of global climate targets – not the precise means by which it is achieved.

To identify interventions which could improve take up of smart tech, it is important first to look at the some of the barriers to take up that exist at present.

Barriers to take up

Cost and communicating the value

There can be substantial upfront costs attached to implementing certain types of this technology to buildings, which is compounded by complications that arise as part of their integration with certain buildings systems (see more under "standards and interoperability"). As a result, it can be a significant step for a business to decide to upgrade the facilities in their building, and consequently this can only happen at the point of breakdown and repair of existing facilities.[li]

In order to overcome these barriers and invest in smart and energy efficient retrofitting of buildings, businesses need to be reasonably well appraised of the value and return on investment of fitting technology to their building. In the experience of Vodafone's digital buildings team this is true of some digital applications that reduce energy usage in buildings (such as LED lighting) but is less true of others.

There is a role here for introducing policies that:

- Communicate the benefits of fitting smart technology (and energy efficiency generally) in a way which is clear, reliable, and accurate to a business and its relevant stakeholders including investors and customers.
- Using targeted subsidies or incentives to support energy efficiency measures, including the fitting of smart tech.

Split incentives between landlords and tenants

There is a well identified problem that in many cases the party paying for building energy efficiency measures (often the landlord) will not be the one benefitting from the changes in form of reduced energy bills (the tenant). As a result, there can be an underinvestment in the installation of energy efficiency measures to buildings, including the use of smart tech. The Carbon Trust identified this as one of the major barriers to achieving meaningful improvements to the non-domestic building stock, and a significant market failure in trying to improve building smart controls and system diagnostics.[lii]

The issue of split landlord tenant incentives in this sector is something that Government has sought to address with the introduction of minimum standards for EPCs in the non-domestic sector, a policy which is set out in more detail in Box 8. However, there are significant issues with the accuracy of EPCs which we set out in more detail later in this section. Other jurisdictions, such as Australia, have sought to directly address landlord and tenant split incentives through their own prescribed rating system.

Box: 8 Energy Efficiency minimum standards in the non-domestic private rented sector

These minimum standards were introduced in 2015 to incentivise improvements in energy efficiency in the non-domestic private rented stock, with the objective of ending the use of very inefficient buildings of this type.

Since 1 April 2018, these changes have meant that landlords of non-domestic buildings have been unable to grant a new tenancy, or to extend or renew an existing tenancy, unless their property has at least an E rating for energy efficiency with their EPC. This is subject to certain exemptions, the primary one that property alterations must have a payback period of seven years or less. From 1 April 2023, these standards will extend to existing leases.

The Government issues a consultation in October 2019 on whether these standards need to be strengthened, and non-domestic buildings in the private rented sector should be required to meet an EPC rating of B by 2030. The Government has also rightly acknowledged that EPCs alone cannot tackle the issue of energy efficiency buildings, and has committed to consulting on an operational rating system in 2020.

Source: Non-Domestic Private Rented Sector Minimum Energy Efficiency Standards: Trajectory to 2030[lvi]

Standards and interoperability

In order for IoT devices collectively to be effective in managing and reducing energy consumption in a building, different devices need to be able to communicate information about their own status with each other. Unless this is possible, the benefits of smart tech will simply not be realised as devices involved in, for example, heating, would not be able to optimise their processes in response to the physical conditions within a building based on information from sensors. As a result, the ability of different devices to work together, otherwise referred to as interoperability, is vital.

However, there are a number of reasons why interoperability of devices is not always possible, and this can act as a barrier to the deployment of IoT in buildings:

- **Lack of common standards** – the European Network Information Security Agency (ENISA) has highlighted that while, there are dozens of possible security standards from organisations such as the International Organisation for Standardisation (ISO) which currently exist for IoT devices, there is no common accepted view in the market on what standard, or combination of standards, makes a device secure. This means that the interoperability of different standards is not guaranteed.[liii]
- **Use of proprietary technology** – partly because there are no standards, a provider will often purely make use of their own proprietary technology when it comes to the security of their IoT devices, which don't then recognise the security standards of other devices. They may then seek to leverage their technology to grow their market share.[liv]
- **Legacy systems** – many building management systems are based on old technology which can have difficulty processing data gathered by more modern and accurate sensors. This can discourage businesses from purchasing new IoT for their building, as cost will become a major factor if they need to upgrade their whole building management system.[lv]

Government should lead the way by encouraging the adoption of certain standards through how it procures technology for its own building stock. As well strengthening take up of carbon saving IoT tech across all buildings, this could also allow the government to realise the cost savings and carbon emission reductions outlined earlier in the report.

Policy recommendations

There are a number of potential policy levers available and based on our extensive analysis, we have recommended the following areas for exploration and action:

1. **Collect data on IoT in the public sector** - The Government should explicitly collect data on the use of IoT and smart technology by public sector buildings – possibly as part of re-collecting the Building Energy efficiency Survey from 2014/15. Following this, firm targets could be set for measures to improve energy efficiency, including the potential for a specific percentage target for the adoption of IoT.

2. **Boosting wellbeing and productivity** - The Government should consider how the wellbeing and productivity of the workforce in different parts of the public sector could benefit from the use of IoT in buildings. This could, for example, be explored in the context of the NHS People Plan.

3. **Drive closer standards through public procurement** - The UK Government is a sizeable purchaser of goods and services, spending around £284bn in 2017/18 on procurement. It regularly uses its procurement budget as a means of effecting various types of commercial, cultural and organisational changes among its suppliers and within broader society. By insisting on adherence to a specific security standard or set of standards for commercial IoT that it procures for its buildings, Government could steer the broader market towards those standards. This would then go some way to improving the level of interoperability in the broader IoT market generally.

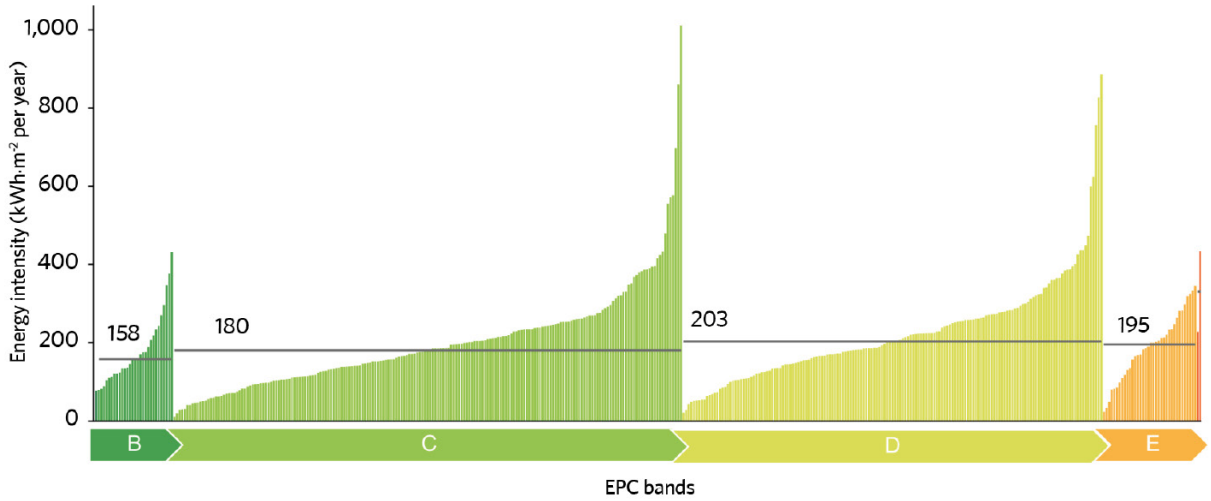
4. **Implement operational energy certificates for large commercial buildings** - Currently, the UK relies on EPCs [Box 3] as one its core policies for improving the energy efficiency of the UK's building stock. However, EPCs measure how a building's design could theoretically perform in terms of energy efficiency, not how it actually performs, the difference between which has been described as the performance gap. A review of literary sources based on 62 non-domestic buildings found that measured energy consumption was typically 32% higher than modelled consumption.[lvii] The performance gap for EPCs in domestic properties is set out in Fig 2. The Government has rightly identified that without, in addition to EPCs, an alternative certificate that also measures buildings performance, gains in the actual energy performance of buildings will never be fully realised. We propose a mandatory certificate system for large commercial buildings that includes a rating based on its operational energy performance. This could be based on the model of the Display Energy Certificate (DEC) or the Australian NABERS rating.

5. **Incentivising energy efficiency measures** – building on the new measures of energy performance developed, Government could trial either grant or subsidy-based incentives to encourage businesses to put in place measures that improve their performance against these metrics, the such as installing IoT devices which manage energy consumption. Current incentives for energy intensive businesses to generate their own power do not help companies like Vodafone, and should be reformed to take account of this. IoT can provide a better understanding of how and where energy is produced, which would allow Government to promote renewable energy at all levels, not just large factories. Government should encourage investment in this technology by opening up access to renewables incentives.

These policy recommendations would help society realise the benefits that smart technology and IOT devices could have in being part of the strategy to deal with the worst effect of climate change.

With the UK hosting the potentially seismic COP26 conference, there is an opportunity for the Government to show leadership on the global stage by demonstrating that it is taking the necessary steps to reduce carbon emissions, and is doing so by embracing innovative new technology that could transform the energy efficiency of our buildings.

Figure 2: EPC ratings of domestic properties in London compared with actual energy use



Source: London Energy Map[lviii]

Annex A: Quantifying the energy efficiency benefits of smart technology - methodology and key sources

Quantifying the benefits

Quantifying financial savings and emission reductions through the installation of economic modelling requires the following data points:

- Energy use associated with non-domestic buildings, and public sector buildings in particular;
- The potential reduction in energy use which can be achieved by smart tech;
- The financial savings associated with this reduction in energy use;
- The emission savings associated with this reduction in energy use.

We have identified sources for each of these data points which, combined with a series of assumptions, allow us to provide some reasonable estimates of the reduced carbon emissions and financial savings possible from Smart Buildings.

Building Energy Efficiency Survey (BEES)

The Building Energy Efficiency Survey (BEES)lix looks at the energy efficiency and consumption of the non-domestic building stock in England and Wales, broken down into 10 identified sectors, as well as into public and private. This is the primary dataset we made use of in order to quantify energy sue across the non-domestic building stock.

One concern with this dataset is that it was collected some time ago, the collection covers the period 2014/15, but there is no equivalent updated dataset which provides us with the granularity required. However, the CCC analysis of BEIS figures suggest that building energy consumption generally has remained fairly static between this period and today.lx

Smart Buildings: Using Smart Technology to Save Energy in Existing Buildings

The best attempt to quantify the reduction made possible by this range of technology that we have identified is in a report by the American Council for an Energy Efficient Economy (ACEEE) in 2017 entitled Smart Buildings: Using Smart Technology to Save Energy in Existing Buildings.[lxi]

One drawback of this data is that it is US based, and therefore may not represent what could be achieved in the UK. For example, air conditioning units in the US are around 20% less efficient than in Europe, according to the International Energy Agency (IEA).[lxii] This could mean that a smart HVAC system in the US has a greater impact than in the UK, as it tends to be reducing the energy output of a less efficient system. It is worth being aware of this limitation, however we have not identified any similar UK data and through benchmarking results to UK data about overall building energy efficiency potential (such as the abatement potential in the BEES survey) we are able to properly contextualise the results of our model.

Carbon emission reduction

The Government publishes guidelines around how the use of different fuels corresponds to emissions.[lxiii] This includes figures for:

- Natural Gas
- Electricity
- District Heating

Energy Cost

BEIS publishes annual statistics on gas/electric prices per KWh, which we have used to quantify the costs savings attached the energy reductions we have calculated using the BEES and ACEEE figures.[lxiv]

Benchmarking the WPI Economics calculations

Benchmarking cost savings with abatement potential figures

By comparing our energy saving figures with the abatement potential estimates in the BEES survey, and associated clams about cost reductions, we have developed a lower bound estimate of **£264 million** for the savings that could be achieved by fitting smart tech to public sector buildings. This allows us to benchmark our own calculations, creating a range for our savings of between **£264 million and £382 million**.

Benchmarking emissions figures

Our current estimates of potential emissions reductions seem high, likely because they assume that current take up of smart tech is non-existent among non-domestic buildings. We know this is not the case given the anecdotal examples of buildings in which smart tech has had a positive impact that we have outlined in this report. However, even assuming a high take up rate of smart tech among non-domestic buildings of 50% at present, this still gives the potential for additional take up of smart tech to deliver a reduction in emissions of 4 million tonnes of Co2 equivalent or 5% of the current emissions of the entire building stock.

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