GeSI Mobile Carbon Impact

How mobile communications technology is enabling carbon emissions reduction

GeSI
GLOBAL e-SUSTAINABILITY INITIATIVE

CARBON TRUST

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Acknowledgements

Lead authors:

Andie Stephens, Marta Iglesias, Jamie Plotnek

The Carbon Trust team:

Martin Barrow, Jamie Clark, Andrea Dahlén, Daisy Goaman, Hugh Jones, Ainslie Macleod, Ana Muñoz, Simon Pickstone, Susan Poupard, Dheeya Rizmie, David Sanders, Aleyn Smith-Gillespie, Paul Swift, Veronika Thieme, Joseph Thornton

The Carbon Trust would like to thank the many individuals and organisations that have contributed to the development of this report by sharing their expert knowledge and guidance, including:

Anders Andrae, Huawei; Dustin Benton, Green Alliance; Pernilla Bergmark, Ericsson; Emily Bosland, Verizon; Craig Donovan, Ericsson; Simon Driver, Future Thinking; Jens Malmodin, Ericsson; Emma Fryer, techUK; Gabrielle Ginér, BT; Solène Hanquier, Bell Canada; Louise Harry, EE; Saul Jamieson, Telefónica UK; Jonathan Koomey, Stanford University; Jan Kristensen, Telenor; Chris Lloyd, Verizon; John Ponter, EE; Pascal Salina, Swisscom; Mark Shackleton, BT; Markus Terho; Chiara Venturini, GeSI; Dominic Vergine, ARM; Nicki Woodhead, Vodafone

This report was funded by:

GeSI GLOBAL e-SUSTAINABILITY INITIATIVE

EE

BT

Telefónica

vodafone

Special thanks goes to Machina Research for providing access to M2M data and supporting analysis.

Machina Research

About GeSI

The Global e-Sustainability Initiative (GeSI) is a strategic partnership of Information and Communication Technology (ICT) companies and organizations committed to creating and promoting technologies and practices to foster economic, environmental and social sustainability.

Formed in 2001, GeSI's vision is a sustainable world through responsible, ICT-enabled transformation. GeSI fosters global and open cooperation, informs the public of its members' activities to improve their sustainability performance, and promotes innovative technologies for sustainable development. GeSI's membership includes over 30 of the world's leading ICT companies; the organization also collaborates with a range of international stakeholders committed to ICT sustainability objectives.

These partnerships include the United Nations Environment Program (UNEP), the United Nations Framework Convention on Climate Change (UNFCCC), the International Telecommunications Union (ITU), and the World Business Council for Sustainable Development (WBCSD). Such collaborations help shape GeSI's global vision on evolution of the ICT sector, and how it can best meet the challenges of sustainable development.

For more information see www.gesi.org.

About the Carbon Trust

The Carbon Trust's mission is to accelerate the move to a sustainable, low carbon economy.

We are an independent, expert partner of leading organisations around the world, helping them contribute to and benefit from a more sustainable future.

- We advise businesses, governments and the public sector on their opportunities in a sustainable, low carbon world.
- We measure and certify the environmental footprint of organisations, supply chains and products.
- We develop and deploy low carbon technologies and solutions, from energy efficiency to renewable power.

We have approximately 180 staff with 30 different nationalities, based in the UK, China, Mexico, Brazil, South Africa and the USA. The Carbon Trust's experts come from a diverse range of professional backgrounds, including engineering, policy, academia, and business.

Key findings

- The carbon emissions abatement enabled by mobile communications technology today is approximately five times greater than the carbon emissions from mobile networks.
- Use of mobile communications technology is currently enabling a total reduction of **180 million tonnes of CO_2e** a year across the USA and Europe. This amount is greater than the annual carbon emissions from the Netherlands and equivalent to **1.5 percent** of all greenhouse gas emissions from the USA and Europe.
- **70 percent** of current abatement comes from the use of machine-to-machine (M2M) technologies in the buildings, transport and energy sectors, where devices are able to communicate automatically with each other without requiring human intervention.
- **20 percent** of current abatement comes from use of smartphones to enable behavioural changes in lifestyles and working patterns.
- Significant future opportunities exist to reduce emissions from cities, healthcare and agriculture through the use of mobile communications technology, although the impact of these areas today is relatively small.
- The total carbon emissions abatement from mobile communications technology is expected to grow at least three times larger over the next five years (to about **500 million tonnes** of carbon emissions abatement per year across the USA and Europe), given current projections of the increase in deployment of M2M technologies.
- International consumer research shows high levels of willingness for smartphone users to adopt behaviours that will result in reduced personal carbon emissions, enabled by functions or apps on their mobile devices. The greatest impact today is through connecting with family and friends using voice or video calls, replacing physical journeys.

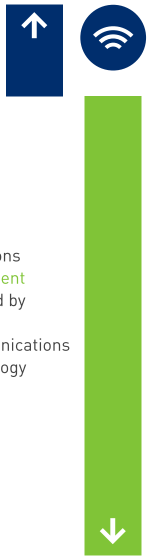
The carbon emissions abatement enabled by mobile communications technology is approximately

5X greater

than the carbon emissions from mobile networks.

Carbon emissions from mobile networks

Carbon emissions abatement enabled by mobile communications technology



70%

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machine-to-machine (M2M) technologies in the buildings, transport and energy sectors.

Mobile communications technology is currently enabling the

reduction of 180 million tonnes of CO_2e a year

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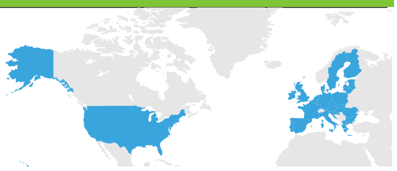

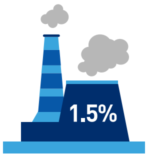

and equivalent to 1.5% of all greenhouse gas emissions from the USA and Europe.

This amount is greater than the annual carbon emissions from the Netherlands.

20%

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mobile devices to enable behavioural changes in lifestyle and working patterns.

Significant future opportunities exist to reduce emissions from cities, healthcare and agriculture.

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3X

Increase in carbon abatement over the next five years.

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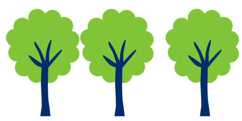


Mobile users are willing to adopt behaviours to help reduce their carbon emissions.

International consumer research shows high levels of willingness for smartphone users to adopt behaviours that will result in reduced personal carbon emissions, enabled by functions or apps on their mobile devices.

4 in 10

drivers would consider using a self-driving car in future.

Just under half

(48%) would be more likely to use public transport if they had an app to see precisely when the next service would arrive.

Foreword from GeSI

A decade ago a number of leading organisations from across the Information and Communications Technology (ICT) sector came together to create the Global e-Sustainability Initiative (GeSI). Our purpose is to work collaboratively to find solutions to the environmental and social challenges faced by the world. We do this by harnessing our industry's capacity for innovation and technology deployment to promote low carbon growth and shared prosperity in the developing and developed world.

In the decade since GeSI was founded, mobile communications has gone through a period of rapid technological advancement and tremendous growth. As governments, businesses and individuals have realised the potential uses for this technology, it has increasingly become an important building block to help create a better society and grow the economy.

This report details, for the first time, the actual impact that mobile communications technology is having today on reducing carbon emissions. In the USA and Europe this is approximately five times greater than the total direct emissions associated with mobile, creating a net positive effect.

Currently the greenhouse gas emissions from these regions are being reduced by around 1.5 percent thanks to mobile, an amount greater than the entire annual national emissions from the Netherlands. This is impressive, but it is also only a fraction of the full potential for the technology.

These findings are timely because 2015 is an important year for global agreements on climate change, with political leaders gathering in Paris to decide how to avoid dangerous climate change at the same time as we continue to grow national economies and improve prosperity.

It is commonly believed that any agreement that is reached will require difficult trade-offs. But the fact that the deployment of mobile communications technology is enabling carbon emissions reduction at the same time as improving economic and social progress indicates that there are plenty of win-win situations.

We believe that a global ICT transformation, with mobile as a key element, will put the world in a better position to meet the challenges of climate change and sustainable development. If businesses, policymakers and citizens actively support this transformation then over the next decade the impact can be magnified and multiplied many times over.

We encourage you to join us in making this transformation a reality.

I hope you will find this report interesting and informative.

Luis Neves

Chairman
GeSI

Foreword from the Carbon Trust

Amongst global businesses, ICT and telecommunications companies have been some of the most progressive and collaborative when it comes to sustainability. This goes beyond being merely responsible. These businesses recognise the fact that their core products and services have a major role to play in enabling a sustainable, low carbon future. There is a real business case for accelerating the transition.

Innovation has been key to the success of the sector, because successful innovation brings tangible rewards. This is especially true when it comes to low carbon innovation, where economic benefits are accompanied by reduced environmental impacts. And thanks to continued investment into developing and advancing mobile communications technology, a wave of low carbon innovation has been unleashed across many other sectors of industry and society.

Greater levels of mobile network availability and higher bandwidth speeds, have combined with improved processing power and falling technology costs in everything from sensors to smartphones, to create a multitude of new possibilities.

For some years now there have been inspiring discussions about the opportunities that might exist in areas such as big data, smart cities and the sharing economy. Commentators have described how technology could make the world a better and more sustainable place to live. And now those possibilities are becoming a reality.

At the Carbon Trust we are pleased to be working with GeSI to undertake the most detailed analysis to date to quantify the actual impact that mobile is having on reducing carbon emissions today. This has established that mobile communications technology is doing a lot more than just opening up new possibilities. It is already having a very real impact today in enabling global efforts to mitigate the impacts of climate change, the equivalent of abating the entire annual carbon emissions from an advanced economy the size of the Netherlands every single year.

Despite this remarkable progress, the research we have done highlights that what is happening today is only a fraction of what is theoretically possible through the use of mobile communications technology. Climate change is an urgent and formidable challenge. There is therefore a real need to demonstrate what works and deploy it at scale, so that the greatest possible enablement effect can be achieved as soon as possible.

We encourage businesses and governments to recognise this clear opportunity and to seize it.

Hugh Jones

Managing Director, Advisory
The Carbon Trust

Executive summary

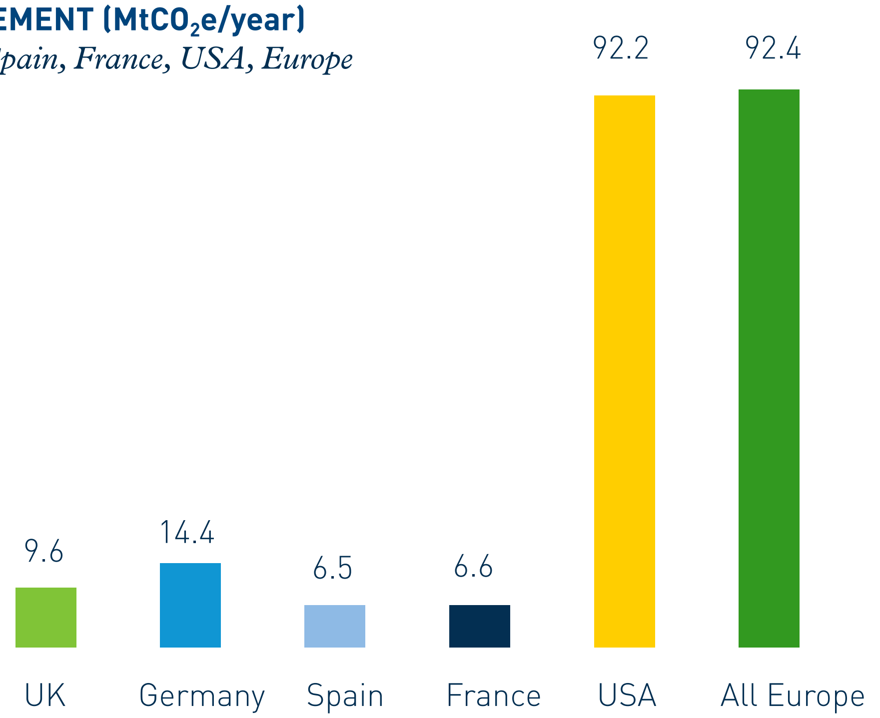
Mobile communications technology has long been recognised to have considerable potential to enable carbon emissions reduction across a variety of applications in a wide range of sectors. But this enablement effect is already having a meaningful impact on global carbon emissions, with the opportunity to grow this impact many times over as new technologies are adopted more widely.

The Carbon Trust has completed the first ever bottom-up quantification of the significant areas of carbon emissions abatement enabled by mobile communications technology across the USA and Europe. This analysis has found that currently, annual savings are in excess of 180 million tonnes of carbon dioxide equivalent (CO_2e). To put this number in context, a country with annual emissions of this size would be amongst the world's top 30 national emitters, ranking above countries such as the Netherlands, Vietnam and Pakistan.[1]

Comparing this annual saving with the emissions resulting from mobile networks,[2] means that the carbon emissions abatement enabled by mobile communications technology is approximately five times greater than the carbon emissions associated with mobile networks.

Additional analysis completed for the UK, Germany, Spain and France found that over 35 million tonnes of carbon emissions abatement can be attributed to the use of mobile in those four countries. This amount is similar to the annual carbon emissions from Ireland or Switzerland.[3]

CARBON ABATEMENT ($MtCO_2e$/year)
UK, Germany, Spain, France, USA, Europe



The Carbon Trust's research identified ten categories where mobile communications technology is having a material carbon emissions abatement impact. Within these ten categories over one hundred individual mechanisms were identified, of which some sixty mechanisms were analysed in detail as they were shown to have a clear abatement mechanism with credible data to support the carbon abatement calculations.

1 This comparison uses 2011 data from the World Bank, available at: http://data.worldbank.org/indicator/EN.ATM.CO2E.KT/.
2 Emissions from mobile networks have been calculated from other studies. See box on page 17 for details.
3 World Bank (2011), *op cit*.

For all the mechanisms, the estimated carbon abatement has been enabled by mobile. Within the context of this report mobile has been defined broadly, to include both machine-to-machine (M2M) connections and the functionality of smart devices.[4] Each of the mechanisms analysed was grouped within one of the ten categories, which are:

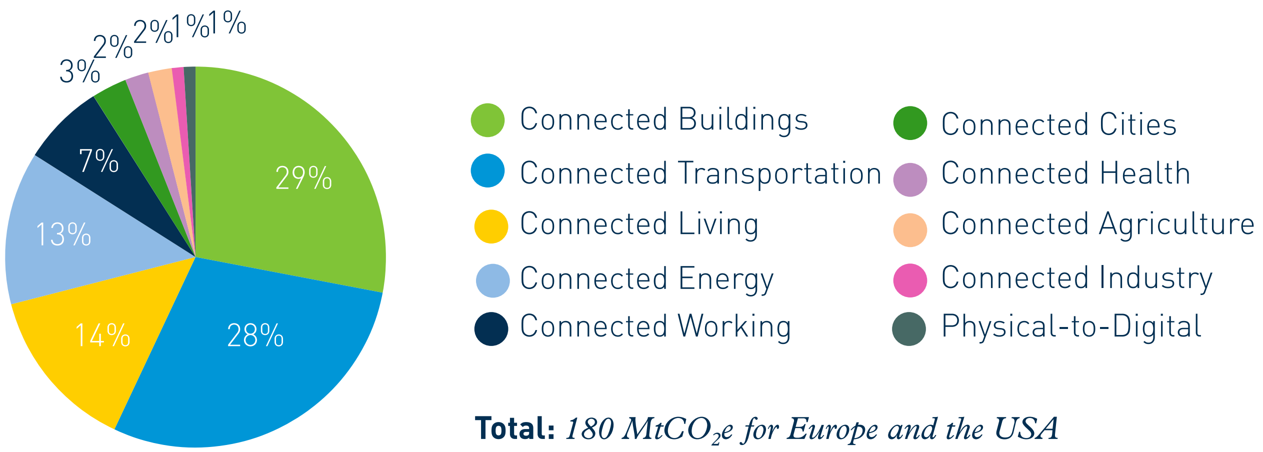
- **Connected Agriculture:** *improving the efficiency of farming methods and increasing yields.*
- **Connected Buildings:** *more effective monitoring and management of electricity use, heating and cooling.*
- **Connected Cities:** *enhancing city infrastructure and the provision of public services by government or local government.*
- **Connected Energy:** *enabling a more efficient distributed system of low carbon energy generation and smart grids.*
- **Connected Health:** *remotely providing non-emergency healthcare or home care and improving health and wellbeing.*
- **Connected Industry:** *supporting more efficient business operations and supply chain management in sectors including manufacturing and construction.*
- **Connected Living:** *using smart devices or digital services that enable individuals to have lower carbon lifestyles.*
- **Connected Transportation:** *improving logistics, vehicle use, vehicle efficiency and use of public transportation.*
- **Connected Working:** *enabling more effective remote working or education.*
- **Physical-to-Digital:** *multifunctional devices and digital services replacing physical products.*

The total carbon abatement for these categories has been quantified for the USA and Europe.[5] The figures for Europe have been based on specific calculations that were completed for the national carbon emissions abatement in four countries: the UK, Germany, Spain and France.

70 percent of the savings currently being made come from the use of machine-to-machine (M2M) technologies. These savings are most prominent in the operation of buildings and transportation, thanks to improvements in areas such as building management and route planning, which lead to reduced energy and fuel use.

The other key area for M2M technology, which is of growing importance, is in enabling smart electricity grids. This allows for the effective connection of distributed sources of energy generation, such as small-scale renewables, in order to provide a low carbon electricity infrastructure.

RELATIVE SIZES OF CARBON ABATEMENT BY CATEGORY



Total: *180 $MtCO_2e$ for Europe and the USA*

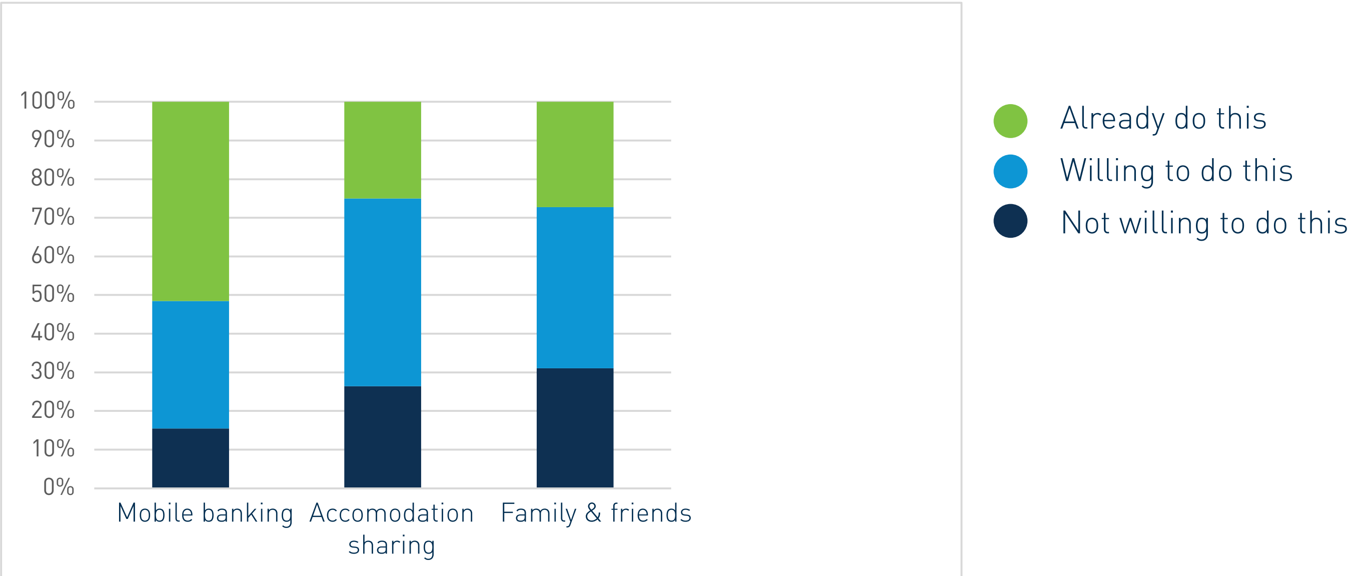
4 A more detailed explanation of what has been included in the definition of *mobile* within this report can be found in the *About the Research* section on page 15 and in Appendix 1. Similar effects may also be achieved through fixed connections. However, the carbon abatement figures presented in this report only relate to mobile connections.

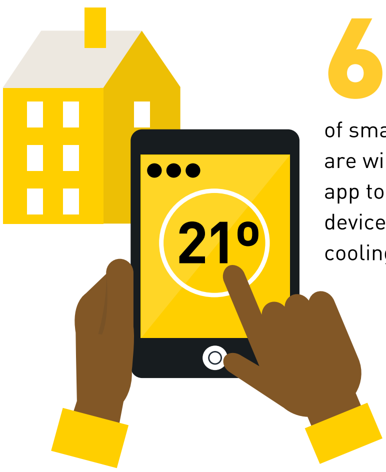
5 This includes all countries in Europe, including Russia and the Caucasus republics, Turkey, Greenland and Iceland.

There also appears to be significant potential for individuals to live more sustainable lives thanks to the use of smart devices. As part of this research, the Carbon Trust commissioned a global study of 4,000 smartphone users across the USA, UK, Spain, South Korea and Mexico. These countries were selected to provide a global sample of smartphone use in countries with relatively high levels of device penetration and existing mobile data infrastructure.

The survey data showed a number of areas of behaviour change being adopted that are making people's lives easier and are also delivering significant carbon savings. The data collected was used in part to support quantitative analysis. This found that behavioural changes in lifestyle and working patterns, enabled by the use of smartphones, are responsible for 20 percent of the total carbon abatement identified. These include the use of mobile banking, accommodation sharing services, satellite navigation apps, and replacing visits to family and friends with voice or video calls.

WILLINGNESS TO USE MOBILE DEVICES RESULTING IN REDUCED PERSONAL CARBON EMISSIONS



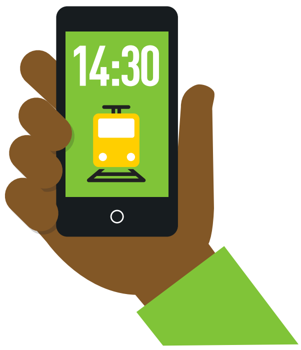


68%

of smartphone users are willing to use an app to control electrical devices and heating or cooling at home.

48%

would be more likely to use public transport if they had an app to see precisely when the next service would arrive.



Consumer research also found high levels of willingness to adopt behaviours that could result in even more substantial future reductions to personal carbon emissions. Responses suggest that a number of technological advances and digital services that are currently under development, or not yet widely adopted, could rapidly accelerate the growth of the carbon abatement effect from smart devices in the next few years.

In some other categories that have been considered in this report – such as agriculture, health and industry – the data does not demonstrate a significant impact on carbon emissions today. However, these sectors have been identified as areas with very high opportunity for future carbon abatement through the use of mobile communications technology.

Although the focus of this report is on quantifying the present level of carbon abatement for 2015, it is possible to use the analysis to create a simple projection for what the scale of abatement might be in 2020. This was done by considering the impact from the expected growth in M2M connections,[6] then taking today's impact from M2M and scaling it up appropriately. By doing this it is possible to predict an annual carbon abatement of about 500 million tonnes of CO_2e in 2020, which is nearly three times the figure for 2015.

To fully leverage the potential of mobile, the report outlines a number of key barriers and opportunities which are highlighted in more detail in the body of the report. The Carbon Trust's research has highlighted four main areas where action can be taken to accelerate the benefits of mobile communications technologies on carbon emissions abatement:

- **Enabling technology:** *there is a need to invest in innovative or disruptive new technologies that enable better, low energy access to mobile communications, as well as creating the enabling network infrastructure for connections around the world.*
- **Implementing solutions:** *businesses and governments need to adopt and scale up the mechanisms that are effective in reducing carbon emissions today, as well as exploring novel uses for mobile communications technology that can achieve further reductions.*
- **Policy landscape:** *governments can accelerate progress by supporting common standards and developing appropriate regulatory oversight, as well as advancing deployment by the use of incentives and disincentives, such as support for improved connectivity or putting a strong price on carbon emissions through cap-and-trade schemes and taxes.*
- **Changing behaviour:** *there is a significant opportunity to use mobile to support organisations and individuals by developing simple, useful tools that offer lower carbon options and services.*

This report finds that the use of mobile communications technology is already having a substantial positive influence on reducing global carbon emissions, which is far greater than the direct emissions related to providing the technology. It is having a net positive impact and there is a clear potential for the power of this abatement effect to continue multiplying.

Given the urgent importance of mitigating the worst effects of climate change, the world needs to rapidly reduce carbon emissions across every sector of society. Mobile communications technology is a powerful tool to help achieve these reductions. Serious consideration should be given by government and industry on how to strengthen its deployment and increase its effect in addressing one of the greatest environmental, social and technical challenges ever faced by human civilization.

6 M2M connection data (both actual and predicted) was provided by Machina Research.

Background

Mobile communications technology has gone through a period of explosive growth over the past decade. According to the International Telecommunication Union (ITU), the United Nations agency for information and communications technology, there are 7.1 billion mobile connections in the world in 2015, up from 2.2 billion in 2005.[7] This is allowing unprecedented levels of connectivity and information sharing, which can unlock new efficiencies and enable different behaviour patterns.

This step change in the availability of mobile communications technology is having a transformative effect. It is changing how society functions, allowing businesses, governments and individuals to find new ways of doing things more productively or efficiently.

It has been argued that the growth in mobile is enabling and accelerating the adoption of a new techno-economic paradigm of mass connectivity.[8] The impact from this is fundamentally changing the structure and infrastructure of the economy, in a way that is not dissimilar to the scale of impact from the steam engine, the railway or the computer.

The underlying network infrastructure required to provide access to increasingly large amounts of data around the world does have an environmental impact. However, efficiency is improving rapidly and many mobile operators are transitioning to the use of cleaner energy sources to operate their network infrastructure. The recent SMARTer 2030 report produced by Accenture for GeSI projected that, despite the expected growth of the ICT sector, which includes mobile operators, the relative carbon footprint is anticipated to remain around 2 percent of total global emissions as far ahead as 2030. More importantly, the future carbon emissions abatement potential of the ICT sector as a whole, including mobile, was estimated at 20 percent of global CO_2e emissions by 2030.[9]

However, alongside the growth of mobile, the world faces an enormous challenge: to create a system that meets the needs and wants of a growing global population, at the same time as addressing the risks of climate change. It is therefore critically important that socio-economic advancements are decoupled from growth in carbon emissions, helping to meet the long term challenges faced by society.

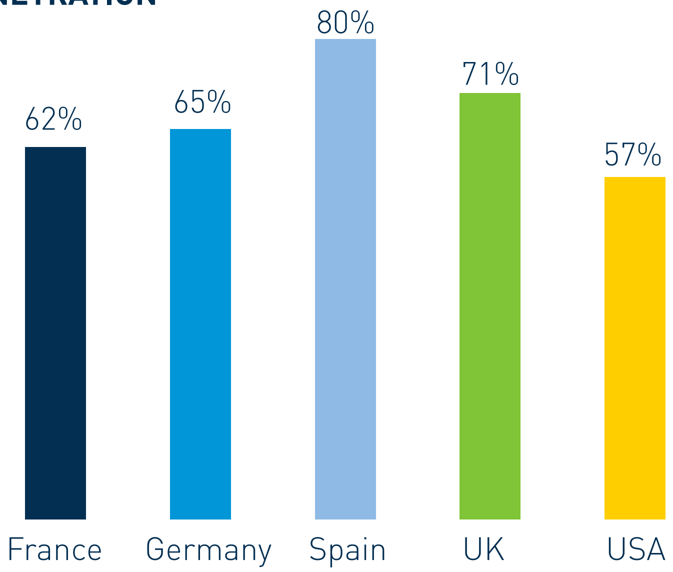
Mobile communications technology can support carbon emissions reduction and the creation of a low carbon economy, by enabling new and less environmentally damaging ways of doing things. But although there have been predictions and projections about the future potential for mobile to cut carbon emissions, very little work has been done on quantifying the actual impact the technology is having today.

In order to better understand the scale of this enablement effect, the Carbon Trust was commissioned by GeSI to produce this report on how mobile is already helping to tackle climate change today by enabling carbon emissions reduction globally.

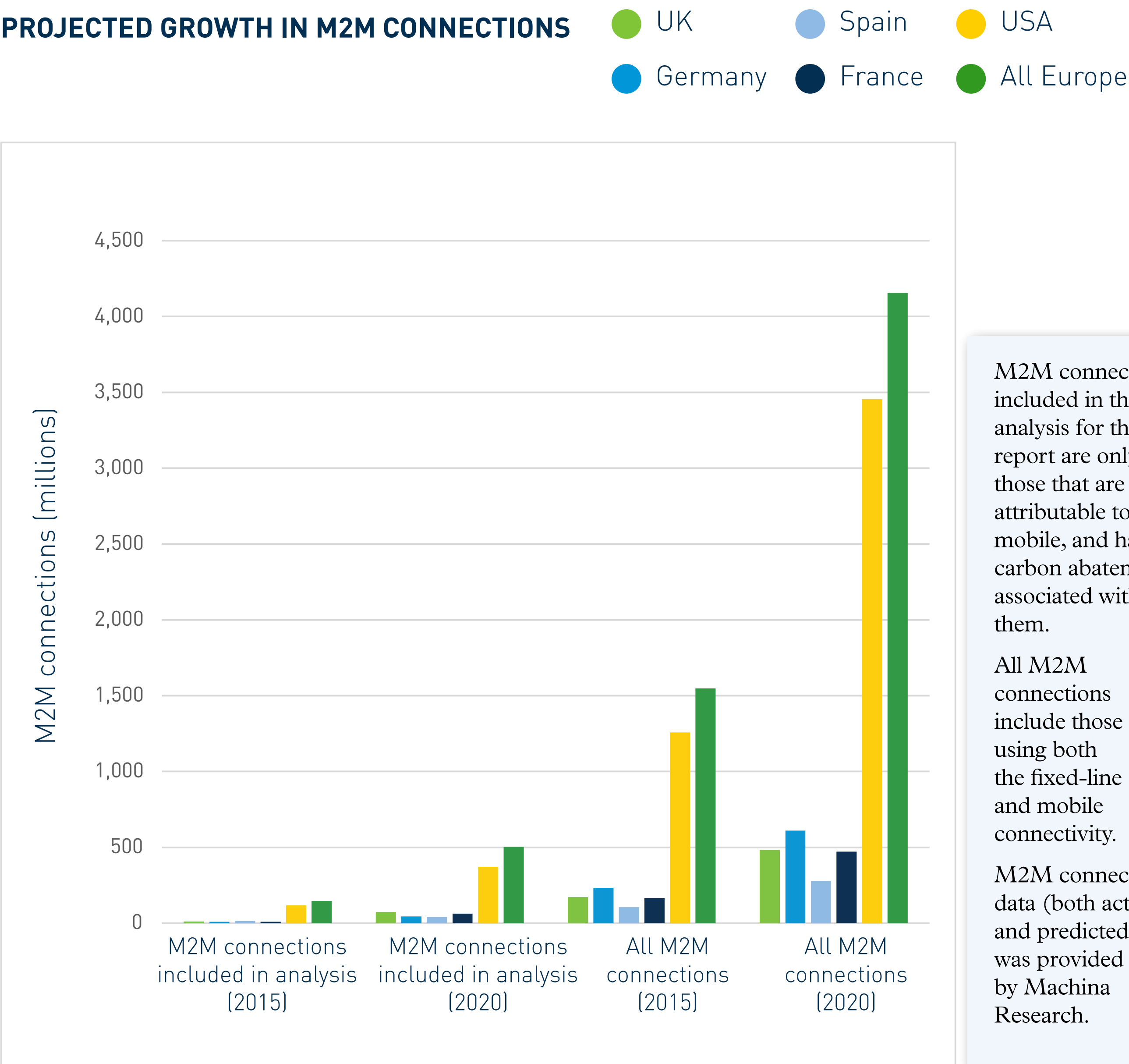
The Carbon Trust's comprehensive assessment looks at the various ways in which mobile is enabling carbon emission abatement across a variety of sectors and industries. This includes a quantification of where the most substantial impacts are happening today. It also provides a perspective on where the greatest opportunities could exist in the future, as technological advancement and global connectivity continue on their rapid growth trajectories. It is hoped that this assessment will provide a useful guide for businesses and policymakers to ensure that mobile communications technology can be effectively harnessed as a tool to help solve the challenges of climate change. To support this, significant opportunities and barriers have been highlighted within the analysis, with recommendations provided within the conclusion on some of the actions that could be taken to further accelerate progress.

7 ITU (2015) *Key 2005-2015 ICT data for the world, by geographic regions and by level of development*.
8 Perez, C. (2009) *Technological revolutions and techno-economic paradigms. Cambridge Journal of Economics,* vol. 34(1), pp.185-202.
9 Accenture Strategy (2015) *SMARTer2030: ICT Solutions for 21st Century Challenges.* Global e-Sustainability Initiative. Brussels.

SMARTPHONE PENETRATION [10]



PROJECTED GROWTH IN M2M CONNECTIONS



M2M connections included in the analysis for this report are only those that are attributable to mobile, and have a carbon abatement associated with them.

All M2M connections include those using both the fixed-line and mobile connectivity.

M2M connection data (both actual and predicted) was provided by Machina Research.

10 Data from Google's Consumer Barometer with surveys administered by TNS Infratest between January-March 2015. Available at: http://www.consumerbarometer.com.

About the research

Mobile communications technology has a wide variety of current and potential applications across a broad range of economic and social activities. Many of these applications could result in some measure of carbon emissions reduction.

In order to quantify how mobile is enabling carbon emissions reduction today, the Carbon Trust has taken a bottom-up approach to identify and include the most significant areas of impact, where data was also available or could be readily collected.

Alongside this, the research process provided the opportunity to highlight potential areas of future impact and best practice case studies. These help to illustrate the areas where the current influence of mobile on carbon emissions is limited, but the future opportunities are significant.

What is *mobile*?

Within the context of this report the term mobile is used as a shorthand way to refer to a variety of mobile communications technologies that allow for the transfer of information without fixed lines.

These include:

- mobile phone networks;
- public Wi-Fi networks;
- metropolitan area networks;
- Low Power Wide Area networks (LPWAN); and
- satellite networks.

The assessment looks at various devices that make use of these networks. This goes beyond just looking at mobile phone usage and incorporates a range of machine to-machine (M2M) communications.

The definition of mobile used here also includes the functionality and features of mobile phones or smartphones, including the use of smartphone apps.

Allocation of abatement impacts to mobile

Carbon abatement is included from mechanisms where mobile has a fundamental role in providing the enabling effect (in other words the outcome would not happen without the existence of the mobile technology). No attempt has been made to allocate the abatement between different technologies in cases where mobile technology is only partly responsible for the carbon abatement and other technologies such as laptop computers or software systems also contribute to the carbon abatement.

However, in the cases where the effects of the abatement mechanisms can be achieved through the use of either fixed-line or mobile connections, then the analysis only considers the abatement that is attributable to mobile. Where the abatement mechanism is based on M2M technology then the allocation between fixed and mobile uses the categorisation of the M2M connections. In other cases, assumptions have been made to allocate an appropriate percentage of the overall effect to mobile.

In the analysis, the Carbon Trust only considered carbon abatement from mobile communications technologies, and not included that from fixed wired connections. While some mechanisms only work with mobile technologies, a number of the carbon abatement mechanisms can be achieved equally well by fixed connections.

Currently, many of the existing implementations of ICT solutions are provided by physical wired connections; however, it is expected that, in many cases, mobile and wireless networks will play an increasing role in future deployment. This is because technological advances have made these the favoured option in many cases. Wireless connection can deliver high energy efficiency, lower cost and comparative ease of installation, which makes the use of mobile more suitable for remotely located buildings where fixed connections would be a more disruptive, costly alternative.

The Carbon Trust's research involved a number of stages, making use of both qualitative and quantitative sources. Research steps included:

- desk research and a detailed literature review of over 200 pieces of material, including peer reviewed academic research, industry studies, and influential media sources, identifying potential areas where mobile is enabling carbon emissions reduction. The desk research also included an evaluation of materiality across all the M2M categories within the Machina Research M2M Forecast Database;
- expert interviews with stakeholders from the mobile telecommunications industry, government, communications regulators, consumer and environmental groups, academia and think tanks;
- quantification and analysis of the areas where mobile is materially enabling the abatement of carbon emissions today in the USA and Europe, with a particular focus on the UK, France, Germany and Spain (see methodology detailed in Appendix 1 and data assumptions and sources detailed in Appendix 3);
- commissioning a global survey of 4,000 smartphone users across Mexico, South Korea, Spain, the UK and USA to understand current behaviour and future propensity to use mobile in a way that can enable carbon emissions reduction (see findings from consumer research in Appendix 5); and
- assessing the most promising areas for future enablement of carbon emissions reduction by mobile, as identified in the literature review, as well as identifying the key opportunities and barriers to implementation.

Because quantification only included the most significant sources of emissions, where data was also readily available, it is likely that the carbon reduction numbers presented in the report, are an underestimate of the actual impact of mobile. It is probable that the cumulative addition of the many unquantified impacts would be substantial, therefore numbers produced within this report should be seen as conservative, underestimating the real scale of impact.

Before outlining the findings below, it is also necessary to provide some brief discussion on the boundaries to the scope of the assessment undertaken by the Carbon Trust.

The results from the analysis show the total enablement effect of mobile on carbon emissions reduction. It does not include the embodied or direct carbon emissions from the production and operation of the assets required for mobile, such as data centres, mobile network equipment or phone handsets.

In order to provide context for the abatement analysis this has been compared to network carbon emissions from previous studies to calculate a ratio of carbon abatement to the overall carbon footprint of mobile (see box).

Carbon footprint of mobile networks

The GSMA[11] calculates the global annual carbon footprint due to the energy from mobile networks as 70 $MtCO_2e$, and a report by Fehske et al[12] calculates the total annual global footprint (including energy and embodied carbon) at 170 $MtCO_2e$. Allocating this footprint (including the embodied carbon) to the USA and Europe gives a carbon footprint of about 40 $MtCO_2e$, which when compared to the carbon abatement calculated, gives the ratio of nearly 5:1.

A more detailed explanation of this calculation can be found in Appendix 1.

A significant proportion of the carbon abatement quantified by the research is a result of human behavioural changes. It has been possible to quantify this using the results from the consumer research commissioned for this report (see Appendix 5), together with other data and research. The consumer research identified that there is already a significant propensity for consumers to use their smartphones to access services and engage in mobile enabled activities. This has a direct impact on lower carbon emissions associated with certain behaviours. The consumer research also showed that there is an even higher percentage of people who would be prepared to adopt these behaviours in the future.

There are some limitations to the research that should be noted. The bottom-up methodology that has been used in this report is effective for quantifying the carbon emissions abatement that can be attributed specifically to mobile today, as it is based on current available technology. Applying it to future scenarios does not consider progress of technology and business model innovation nor the additional impact gained through increased adoption of mobile enabled services.

Previous work, completed by GeSI and others, has tried to understand the positive effect that ICT as a whole – including mobile – can have on future carbon emissions reduction and sustainable development. Therefore, this report does not provide a more detailed projection of future carbon emissions abatement from mobile. Nonetheless, areas of opportunity are discussed more broadly.

Predicting the future

The focus of this report is on calculating the current carbon abatement that mobile communications technologies are enabling today. However, it is possible to use the analysis to also create a broad estimate for what this abatement might be in 2020. This has been done by using predictions for the number of M2M connections in 2020 and applying these to the same factors used for the 2015 analysis. This results in a prediction of about 500 $MtCO_2e$ annual carbon abatement in 2020, nearly three times the figure for 2015.

This is likely to be an underestimate, as it only accounts for the growth in M2M connections, and has not considered any increase in carbon abatement from further behavioural changes in use of mobile phone technology. Additionally different emission factors have not been applied (for grid electricity and transport), which are likely to reduce as the economy begins to decarbonise in the next 5 years.

11 GSMA (2012), *Mobile's Green Manifesto 2012.*

12 Fehske et al. (2011), *Global Footprint of Mobile Communications: The Ecological and Economic Perspective.* IEEE Communications Magazine, August 2011, pp 55-62.

It is also highly likely that access to mobile communications has improved absolute economic productivity, which can lead to an increase in overall economic activity. This has its own associated additional emissions impacts,[13] commonly known as rebound effects. There is a growing field of literature that has attempted to determine where some of these rebound effects may be taking place, as well as the extent to which they are having an impact on energy use and carbon emissions.[14]

Some examples of rebound effects include: providing real time data on parking spaces, which would reduce driving emissions from driving around to find a space, but may encourage greater levels of car use as a transport mode; distant family and friends can keep in touch with video calls, which in some cases can reduce travel, but in others may maintain stronger relationships that would encourage more visits than would have happened otherwise; and mobile shopping may reduce travel to the shops, but may encourage more overall shopping resulting in increased consumption.

Due to the high levels of uncertainty and complexity in calculating or quantifying the rebound effect for each of the enablement mechanisms considered in this report, potential rebound effects from mobile have not been assessed. There is further discussion of rebound effects in Appendix 6.

13 This is commonly referred to as the Jevons paradox, following the economist William Stanley Jevons who identified in 1885 that technology enabling greater efficiency in the use of a resource (in that case coal) actually resulted in a greater total use of that resource.

14 Gossart, C. (2015) *Rebound Effects and ICT: A Review of the Literature,* pp. 435–448 in: Hilty, L.M. & Aebischer, B. (eds.) *ICT Innovations for Sustainability. Advances in Intelligent Systems and Computing.* Springer International Publishing. Cham.

Findings from research

Analysis has been completed across ten categories to understand the current impact of mobile communications technology to enable reductions in national greenhouse gas emissions in Germany, France, Spain, the UK and the USA, as well as across the entirety of Europe.[15]

The full methodology for the quantification is contained in detail in Appendix 1, with the data sources and assumptions listed in Appendix 3.

Analysis indicates that the greatest impacts are currently in the buildings, transportation and energy sectors, as well as those arising from changing working patterns and enabling lower carbon lifestyles. The other areas assessed are currently showing comparatively limited contributions to greenhouse gas reductions, although in some cases significant potential exists for future contributions.

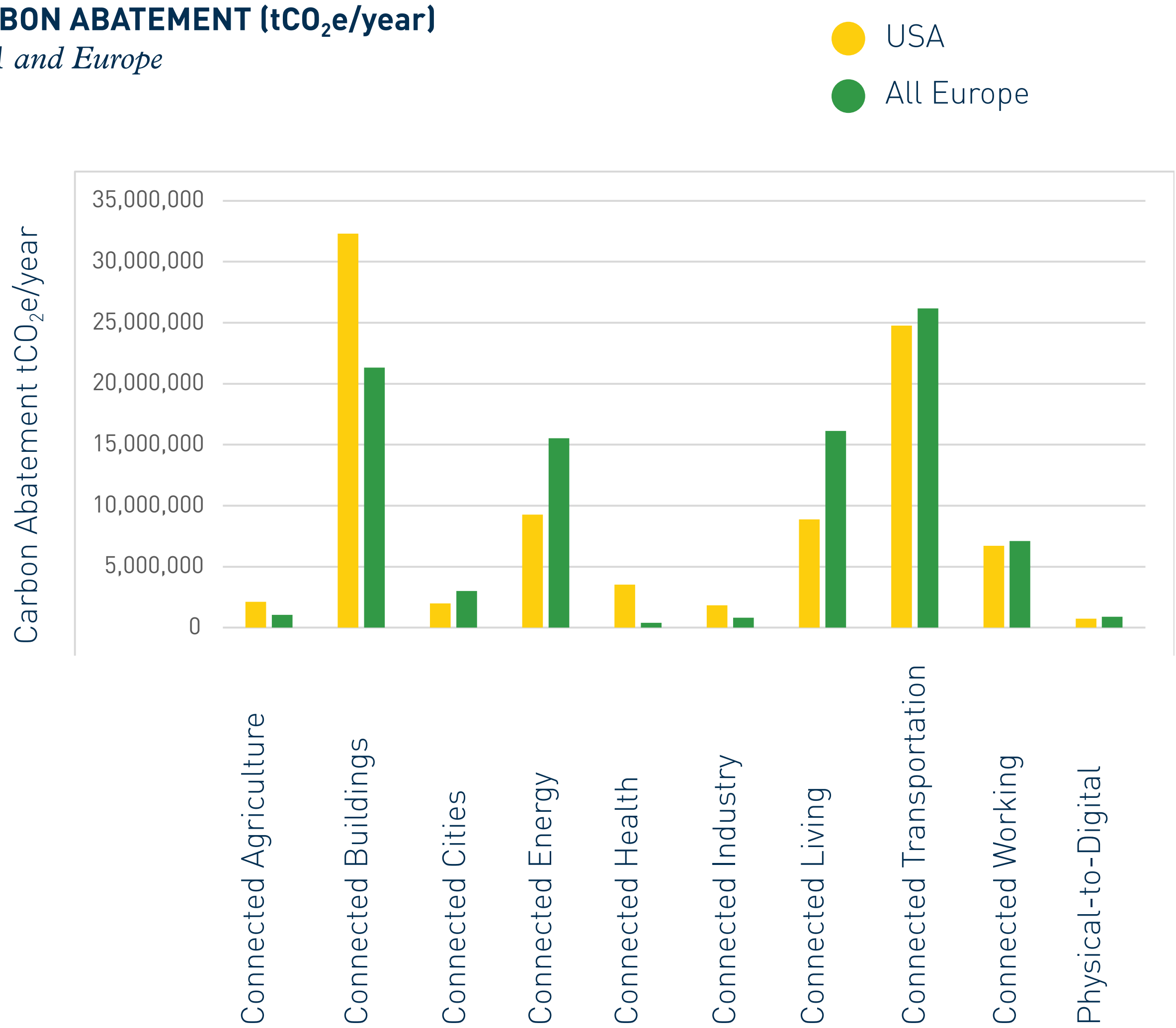
CARBON EMISSIONS ABATEMENT BY CATEGORY AND GEOGRAPHY (tCO_2e/year)

Category	UK	Germany	Spain	France	USA	Europe
Connected Agriculture	53,000	125,000	28,000	170,000	2,125,000	1,043,000
Connected Buildings	2,916,000	1,148,000	2,120,000	754,000	32,300,000	21,333,000
Connected Cities	435,000	498,000	226,000	383,000	1,990,000	3,018,000
Connected Energy	1,536,000	5,255,000	939,000	221,000	9,265,000	15,523,000
Connected Health	47,000	89,000	29,000	51,000	3,540,000	406,000
Connected Industry	88,000	196,000	65,000	32,000	1,837,000	808,000
Connected Living	1,259,000	1,412,000	1,079,000	1,163,000	8,889,000	16,123,000
Connected Transportation	2,340,000	4,255,000	1,197,000	2,709,000	24,756,000	26,173,000
Connected Working	810,000	1,340,000	759,000	1,084,000	6,714,000	7,096,000
Physical-to-Digital	90,000	109,000	72,000	63,000	743,000	891,000
Total	**9,574,000**	**14,427,000**	**6,514,000**	**6,630,000**	**92,159,000**	**92,414,000**
Per capita abatement ($kgCO_2e$):	*149*	*179*	*140*	*101*	*292*	*124*

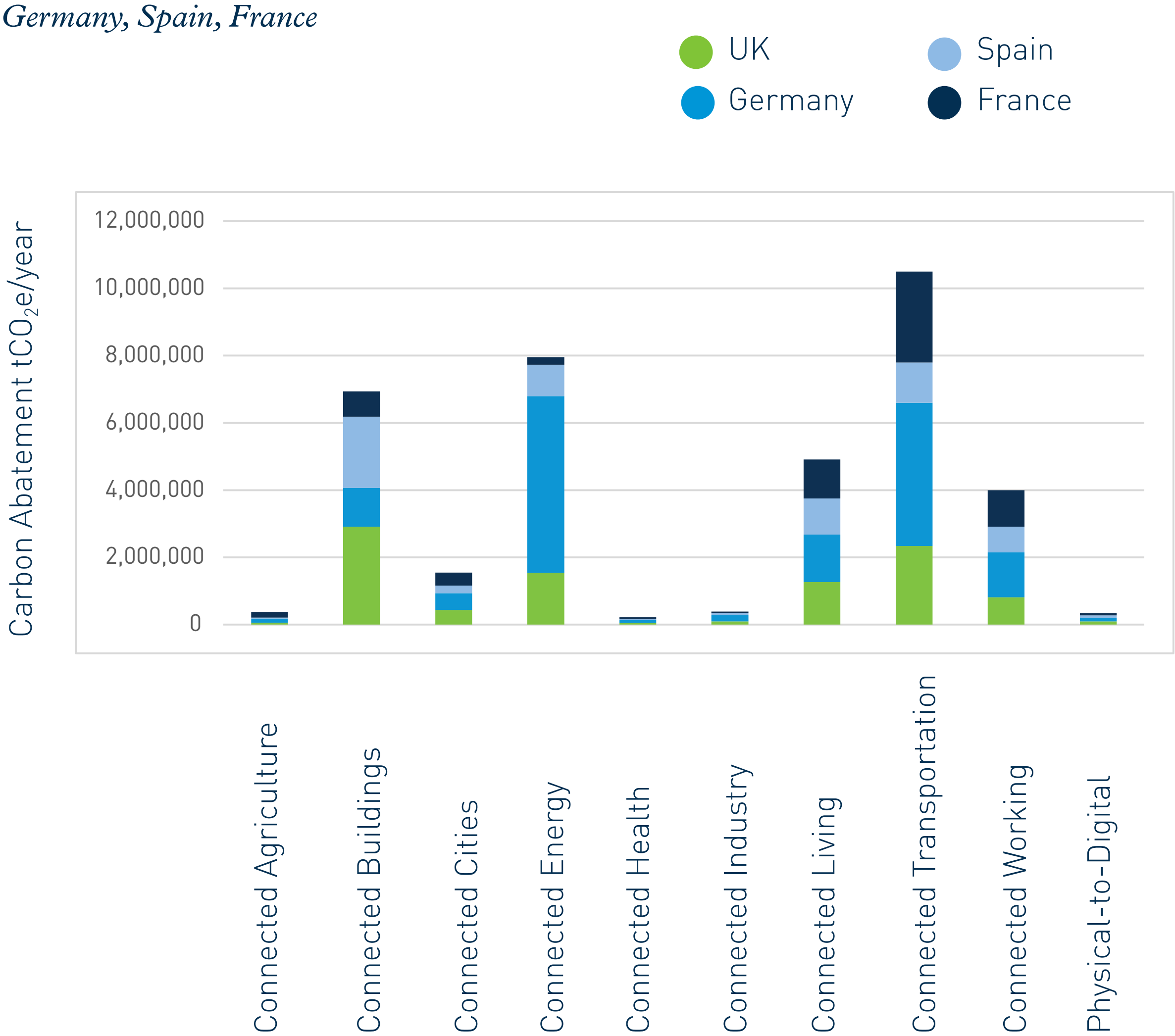
15 The definition of Europe used includes all countries in Europe, including Russia and the Caucasus republics, Turkey, Greenland and Iceland.

The per capita abatement figures provide some context to understand and compare the numbers. However, they also reflect the individual circumstances of the different countries. Thus France has the lowest carbon abatement per capita which reflects the fact that France has a low grid electricity emission factor (due to the high proportion of nuclear electricity generation). Germany has a high carbon abatement per capita largely due to the high amount of renewable microgeneration because of the very successful feed in tariff programme that was supported by the German government. The USA figure is large partly reflecting the relatively high grid electricity emission factor, and partly because the baseline emissions are greater than in Europe, so the same percentage saving equates to a higher absolute carbon emissions reduction.

CARBON ABATEMENT (tCO_2e/year)
USA and Europe



CARBON ABATEMENT (tCO_2e/year)
UK, Germany, Spain, France



The following sections in this report provide more detail on the various categories of carbon emissions abatement enabled by mobile communications technology that have been assessed. This includes a more detailed explanation of the practical mechanisms used to quantify carbon emissions reduction. Where certain mechanisms overlap between multiple categories, these have been allocated to the most appropriate, in order to avoid double counting.
The following sections also incorporate a broader discussion of current activities and opportunities within each category. Selected case studies and findings from consumer research have been included, where appropriate, to illustrate some of the more promising areas where mobile can contribute to carbon emissions reduction, and have a positive impact on other areas of sustainable development.

Connected Agriculture

Agriculture and the use of mobile

Connected Agriculture refers to the use of mobile communications technologies to help improve the efficiency of farming and forestry. These range from the simple dissemination of general information related to weather or good farming practices, through to providing highly granular data allowing for advanced decision-making.

The key technologies enabling emissions savings today are the use of positioning systems such as Global Navigation Satellite Systems (GNSS), auto-guiding systems for farm machinery and technologies which enable a variable application rate to optimise fertiliser and pesticide use. These technologies have been widely used across arable farms with large field sizes in the main growing areas of developed countries, with the aim of maximising profitability.

The combination of monitoring crops with satellites, airborne thermal imaging and ground-level sensors is commonly referred to as precision agriculture. Data that is collected can help to inform decisions to optimise yields with a minimum of resource input in areas such as fertiliser and pesticide use, as well as improving water efficiency in irrigation. This allows a farmer to respond precisely to variability between fields, and within fields, instead of taking a uniform approach, particularly when data is analysed through advanced Decision Support Systems (DSS).

The main areas of emissions savings from use of mobile today are in yield increase which can result in a lower demand for agricultural soil, decrease in fertiliser use and lower water consumption used for irrigation. Indirectly, variable fertiliser application can also lead to reducing nitrate leaching and groundwater contamination. More efficient farming techniques and improved operation of machinery also results in less use of energy, typically diesel fuel.

The reduction in fertiliser use is key, as this is a major source of agricultural greenhouse gas emissions. Where manure is used this results in methane and nitrous oxide from aerobic and anaerobic decomposition. Synthetic fertilisers tend to require substantial amounts of fossil fuels in their manufacture, and can result in nitrous oxide emissions from their use on soil.

Abatement mechanisms

There are two specific mechanisms for which material carbon emissions abatement from mobile have been quantified. These are:

- **Enhanced agricultural equipment logistics:** *more efficient operational use of farm machinery such as tractors, harvesters and compactors results in a reduction in fuel use through automatic machine setting, autonomous guidance, steering systems and telemetry.*
- **Improved crop management:** *providing information to farmers, controlling irrigation remotely and monitoring soil conditions to allow for less use of fertiliser, which can result in an overall increase in productivity and yields alongside reduced wastage.*

CARBON EMISSIONS FROM CONNECTED AGRICULTURE ABATEMENT[16] (tCO_2e/year)

	UK	Germany	Spain	France	USA	Europe
Connected Agriculture	**53,000**	**125,000**	**28,000**	**170,000**	**2,125,000**	**1,043,000**
Agricultural equipment logistics	5,000	12,000	7,000	22,000	235,000	121,000
Crop management	48,000	113,000	21,000	149,000	1,890,000	923,000

Future opportunities

Agriculture, forestry and other land use accounts for around 24 percent of all global anthropogenic greenhouse gas emissions.[17] Mobile has significant potential to help reduce these emissions through mechanisms that have been identified but that are not quantified here. This is because either the impact today is not material or there is insufficient available data. But many of these advances will have a role to play in enhancing food security and resilience to climate change, as well as meeting other serious sustainability challenges such as freshwater availability, biodiversity loss and nutrient pollution.

For example, mobile is already being used at some scale to: support more efficient livestock farming;[18] track illegal deforestation; provide best practice guidance to smallholder farmers in the developing world; manage pests more effectively to minimise the impact of pesticide on biodiversity; and use sensors to accurately measure carbon sequestration.

16 Note: Due to rounding, totals may not sum exactly. (Figures above 1,000 have been rounded to the nearest 1,000 and below 1,000 rounded to the nearest 10). This also applies to all carbon abatement figures in the report.

17 IPCC (2014) *Summary for Policymakers. In: Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.* Cambridge University Press. Cambridge, United Kingdom and New York, NY, USA.34

18 Gerber, P.J. et al. (2013) Tackling climate change through livestock: a global assessment of emissions and mitigation opportunities. Food and Agriculture Organization of the United Nations. Rome.

However, in practice levels of success vary significantly by land and crop type, as well as between farmers. Large differences between the actual and potential yields can be attributed to suboptimal management, inappropriate technology and a lack of training. It is expected that as these technologies become more commonplace, intuitive and user-friendly, that best practice will be adopted and emissions reductions will increase.

Despite being a major source of global emissions, agriculture is also a key sector for reducing emissions, as forests, crops and grassland all act as sinks to sequester atmospheric carbon dioxide. But it is also one of the areas of the greatest uncertainty within scientific knowledge of climate change. Emissions uncertainty for agriculture, forestry and other land use ranges from 10 to 150 percent, which is a significantly greater margin than for fossil fuels which range from 10 to 15 percent.[19] Greater use of sensors, enabled by mobile, would provide valuable scientific data which could help to increase sequestration rates.

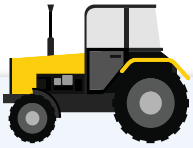
One of the greatest barriers to reaching mobile's potential in the sector has been identified as a lack of common standards and limits on the exchange of data between systems. This is compounded by the fragmentary nature of agriculture, suggesting that standardised solutions are not always appropriate. There is significant variability between farming methods and land types, which means that development costs are high for new mobile solutions and may face long sales cycles before becoming commercially viable.

In developing countries, the major barrier to the adoption of precision agriculture technology is the relative cost of labour and scale of individual farms. In low wage rural economies, people are seen as a cheaper solution than capital investment into technology, which in any event could result in the loss of valuable employment opportunities. Availability of independent advice, better quantification of environmental benefits and improved knowledge on the determinants of yields have been identified as ways to overcome these barriers. But investment in solutions is likely to be determined by commodity price fluctuations, labour prices, energy prices and environmental regulation. It may also only occur in circumstances where replacement is required.

Significant future opportunities exist to reduce emissions from cities, healthcare and agriculture.

through the use of mobile communications technology, although the impact of these areas today is relatively small.

19 Tubellio, F.N. et al. (2014) *Agriculture, Forestry and Other Land Use Emissions by Sources and Removals by Sinks.* Food and Agriculture Organization of the United Nations. Rome.



Smarter farming

Mobile phone penetration is now reaching some of the least developed areas in the world, many of which rely on agriculture both for subsistence and as their main economic activity. Access to mobile is helping to improve sustainability by providing these rural communities with improved information on agricultural methods, more accurate weather forecasts and information about market prices for agricultural commodities. This is helping to improve yields, reduce environmental impact, prevent food wastage through post-harvest losses and support economic development.

Innovative platforms such as WeFarm are helping to connect farmers without internet access in rural areas of Africa and Latin America, enabling peer-to-peer sharing of knowledge and best practice through SMS messages.

Similarly, the Vodafone Farmers Club in Turkey provides farmers with SMS alerts about weather forecasts, crop prices and other information that is tailored to their local area and crop types. They also get access to a mobile marketplace that enables them to sell their produce directly to buyers. Since its launch in 2009, the service has benefitted more than 1.25 million farmers in Turkey. To date, more than 700 million SMS alerts have been sent to members.

Another example is the SMS-based iCow app, delivered by Safaricom, which is helping 500,000 farmers in Kenya increase yields, income and productivity by sharing best practice tips and providing support for efficient farm management.

Connected cows

Livestock production is one of the most significant contributions to greenhouse gas emissions, accounting for around 14.5 percent of the total, which is more than the direct emissions from the entire transportation sector. With global demand expected to continue increasing, mobile has an important role to play in helping to minimise supply-side emissions.

The use of precision techniques are less well established in livestock farming when compared with arable crops, but there is a growing trend of mobile technology being used to increase farm profitability and reduce environmental impact. Mobile is used for automatic monitoring of individual animals through sensors. This is helpful to improve the efficiency of meat, dairy and egg production by monitoring overall animal productivity, behaviour and health.

For example, Deutsche Telekom and NTT DOCOMO use connected sensors to monitor pregnant cows and ensure the safe delivery of calves. The service has been deployed for 30,000 cows, alerting farmers to changes in temperature as an indication that delivery is about to begin. This has helped to reduce calf mortality rates from 10 percent to less than 1 percent.

A number of app-based solutions for farmers are now reaching the market. The Silent Herdsman app provides wirelessly connected collars to monitor a cow's temperature and behaviour. This is used to alert farmers to the best time for insemination, as well as providing details on milk yields and alerting the early onset of illnesses. Similarly, a company called Vital Herd uses an electronic pill that is swallowed by the cows, while another called Quantified Ag uses biometric ear tags.

Smartphones and sensors are also used in more general herd management, where the Brazilian company Bovcontrol has created an app that makes use of RFID chips to track location, provide vaccine management and assist with pasture rotation. Good pasture management can have a positive impact on land degradation and deforestation.

Connected Buildings

Buildings and the use of mobile

Connected Buildings refers to the use of a variety of technologies to optimise energy use within buildings, such as building management systems, advanced lighting and thermal controls. It is also the area where the greatest impact is being realised today in terms of carbon emissions reduction from mobile communications technology.

The main areas of carbon emissions abatement are from reduced gas and electricity use. This is being achieved through the installation of intelligent systems that either automatically control settings, or allow for more effective human monitoring and control of energy use through wall-mounted panels or touchscreen devices.

M2M connectivity is of particular importance in this area, as it allows for the automation and monitoring of various systems remotely. This enables communication between systems to provide intelligent responses in one system to changes detected in another, which do not rely on the active involvement of users. For example, it allows for systems to be switched on and off depending on occupancy or temperature. It can also apply analytical tools for predictive maintenance and more sophisticated building control policies, such as adjusting heating in line with the weather forecast and historical comfort data.

Abatement mechanisms

There are three groups of mechanisms for which material carbon emissions abatement from mobile have been quantified. These are:

- **Advanced building energy management systems:** *automated energy management systems using smart meters, which track energy use and provide information that allows optimised use of electricity and heating, resulting in energy savings.*
- **Improved HVAC (heating, ventilation and air conditioning) controls:** *more effective monitoring and control of HVAC systems using connected sensors, including automatic response to occupancy levels of areas within buildings, leading to overall reductions in building energy consumption.*
- **Smart meter installation:** *providing greater visibility through detailed monitoring of energy and water use raises awareness of where savings can be achieved, helping to positively encourage energy saving behaviour.*

CARBON EMISSIONS ABATEMENT FROM CONNECTED BUILDINGS (tCO_2e/year)

	UK	Germany	Spain	France	USA	Europe
Connected Buildings	**2,916,000**	**1,148,000**	**2,120,000**	**754,000**	**32,300,000**	**21,333,000**
Building energy management systems (electricity commercial)	470,000	78,000	1,079,000	19,000	7,716,000	5,347,000
Building energy management systems (gas commercial)	1,001,000	22,000	39,000	22,000	1,421,000	4,281,000
HVAC control - commercial buildings	1,211,000	971,000	670,000	685,000	12,724,000	8,722,000
HVAC control - residential buildings	29,000	31,000	7,000	11,000	395,000	146,000
Smart meters - water commercial	50	250	1,000	230	9,000	6,000
Smart meters - water residential	30	80	470	110	9,000	2,000
Smart meters (electricity residential)	109,000	44,000	318,000	15,000	9,849,000	2,557,000
Smart meters (gas residential)	95,000	2,000	5,000	2,000	175,000	273,000

Future opportunities

Buildings are responsible for 19 percent of all anthropogenic greenhouse gas emissions. And most of these emissions come from energy demand for heating, ventilation and air conditioning (HVAC) and electricity in those buildings.[20]

Automated control over HVAC and lighting systems using connected systems appears to offer the greatest immediate potential for energy saving. Automation improves reliability and efficiency, versus manual control, and it lowers personnel costs and does not depend on individual users´ commitment to change.

Increasing levels of building automation are driven by a desire to reduce energy costs, which is supported by government regulation, building standards or energy efficiency incentives that aim to reduce carbon emissions on a national level. Energy utilities have been key to supporting the roll out of smart meters, particularly in the USA, which has allowed them to introduce dynamic pricing and shift loads away from periods of peak demand.

In some markets further impetus has been provided on a local government level as part of a wider effort to develop connected smart cities, with intelligent buildings as a key element. There is also a trend, especially in new builds, towards fully integrated building automation systems that go beyond just managing energy use to also control security, access, communications and safety systems.

Retrofit of these technologies into existing buildings will also have a key role to play in tackling climate change. This is particularly the case in developed countries, as it is likely that a large proportion of buildings in existence today will be around for decades to come. Using mobile rather than fixed-line communications for this retrofit should be attractive, as it can reduce the overall costs of installation by not requiring disruption from installing additional wiring.

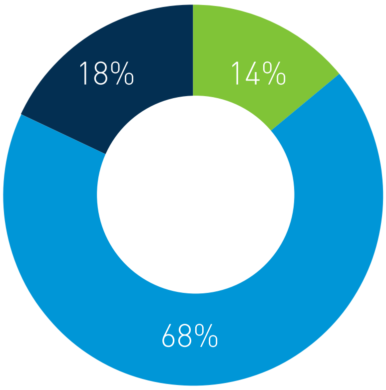
Future potential for savings will arise when data from sensors can use advanced data analytics to provide deep insight into energy underperformance in buildings. This could be used to provide tailored, actionable advice to non-domestic customers without the need for site audits.

In the longer term, connected buildings will allow for rapid demand response to shifts in energy demand, allowing more intermittent renewable energy generation to be effectively integrated into the electricity grid. By reducing levels of peak demand this will also reduce the overall requirements for backup generation infrastructure, which will help countries to deal with rising electricity demand, particularly in the developing world.

Some of the major barriers to deployment include the initial installation costs for connected technology, as well as the long replacement cycles for building infrastructure, which can be measured in decades in some cases. Other barriers include the lack of effective governmental support in some countries, as well as the existence of multiple standards for building automation and smart meters. There are also concerns about cybersecurity, with the risk of connected building systems being disrupted.

The consumer research found a significant willingness for people to use their smartphone to control their energy use at home, which indicates that the potential for carbon savings exists as the technology becomes more widely adopted.

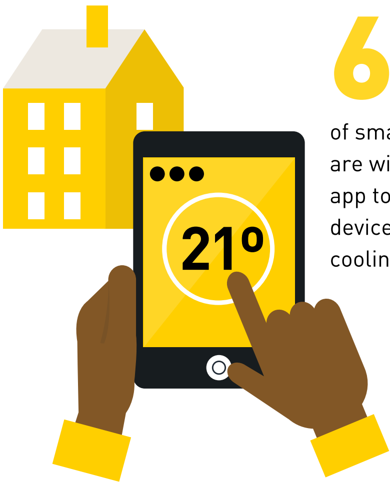
20 IPCC (2014) *op.cit.*



Are you, or would you be willing in future, to use a mobile device to control your electrical appliances and heating/cooling at home?

- Already do this
- Willing to do this
- Not willing to do this

Base: *All respondents* (4,000)



68%

of smartphone users are willing to use an app to control electrical devices and heating or cooling at home.

Homes of the future

The Weissenhoff Estate in Stuttgart, Germany is home to the B10 Aktivhaus, designed for the Stuttgart Institute of Sustainability. This house was built to demonstrate the potential for modern technology to create an extremely sustainable living space, and to go beyond even the renowned Passivhaus concept in terms of energy performance. It is designed to produce up to twice the energy that it needs and can use the excess to power electric cars, bikes and the house next door, or return it to the grid.

The house is operated by a predictive, self-learning energy management system that is connected to the internet and controlled by a mobile app. This system is able to track occupancy. When the house is empty then all systems are put into energy management mode. The system also tracks electric cars by GPS, so it can prepare for the occupants' return home by turning on the heating, lighting and raising or lowering the blinds.

The mobile app connects by Wi-Fi when the occupier is inside the house and by mobile signal when they are away from the house. The app interface changes depending on the time of the day or year, to put an emphasis on the most likely features to be used. For example lighting controls become prominent when it gets dark. This allows the resident to monitor energy performance and manually control features.

While the B10 Aktivhaus pushes the boundaries of what is possible, home automation technology is a growing market, with an increasing number of systems available to allow for remote control of energy and electric appliances. These include Nest, Hive and Loxone. However, questions still exist over the levels of consumer demand for connected home functionality beyond the early adopters. More support may be required to explain the benefits and encourage the uptake of these systems.

Smarter workplaces

ASB Bank, one of New Zealand's largest banks, worked with Vodafone to install over 200 M2M smart meters across its branches, offices and data centre. These meters collect data from power sources at 15 minute intervals, continuously feeding back to a central server every 30 minutes.

Thanks to the smart meters the bank was quickly able to discover that the remote monitoring controls they had been using were not working as expected, leading to lights, display signage and air conditioning units being left switched on out of hours. This helped them to immediately make significant energy savings and set new benchmark targets for different types of branches.

Using the smart meters, engineers are now able to monitor real-time performance and make changes at short notice, helping to maintain optimum performance. An employee intranet portal also allows staff to monitor their own workplace.

The smart meters have been used to track the actual impact of energy saving technologies that have been trialled, such as insulation, occupancy sensors, delay timers and higher performance window films. This allows the bank to get a clear picture of the actual return on investment if these technologies were rolled out across their entire estate.

After one year the smart meters had helped to save approximately NZ$675,000, with total cumulative savings after three years of NZ$2,650,000. Like-for-like energy consumption was reduced by 23 percent, resulting in saving more than 1,000 tonnes of carbon emissions a year.

Connected Cities

Cities and the use of mobile

Connected Cities refers to embedding smart M2M technology into city infrastructures, which allows a central control system to remotely monitor, analyse and act upon data from multiple different sources and utilities. However, it does not include some mechanisms related to energy generation and transportation infrastructure, which are covered elsewhere in the report. Currently cities bring together a lot of separate infrastructure projects and services, each of which have to be controlled and managed separately by local or national government. This often involves a great deal of manual intervention.

The main areas of carbon emissions abatement enabled by mobile communications technology today are in reducing fuel use from vehicles and electricity use from street lighting. Reducing fuel use includes avoiding traffic congestion, where vehicles are not moving but continuing to expend fuel, as well as managing speed, which can be particularly effective as it strongly influences the level of fuel consumption per journey. It also includes helping drivers to find a parking space, preventing unnecessary additional fuel use at the end of journeys. Additional environmental and social benefits include improving air quality and reducing noise pollution, as well as increased productivity.

Intelligent Transportation Systems (ITS) make use of sensors with M2M connectivity. These can be used to monitor traffic volumes, provide information to drivers and adjust traffic signals to optimise traffic flow. In some more advanced scenarios it is also possible to simulate traffic outcomes to make predictions and plan what to do in the event of road improvements, congestion or an accident. It also enables the implementation and enforcement of a number of traffic control measures, such as congestion charging or road tolls, or specific lanes for vehicles with multiple occupancy.

Abatement mechanisms

There are four mechanisms for which it has been possible to quantify carbon emissions abatement from mobile. These are:

- **Parking space monitoring:** *tracking car parking space availability can provide information or feedback to vehicles helping to route them towards available spaces, which saves fuel use from driving around looking for spaces.*
- **On-demand refuse connection (smart bins):** *using smart bins that are able to report when they are in need of emptying can help to make refuse collection more efficient, allowing for the optimisation of routes used and avoiding fuel use from unnecessary collections.*
- **Intelligent street lighting:** *energy demand for street lighting is being reduced thanks to new lamps that contain sensors and can be controlled remotely in order to switch off or dim lighting when it is not required, saving electricity use.*
- **Smart traffic management:** *with remote monitoring of traffic conditions, mobile technology can be used to dynamically change road signs or traffic signals in order to avoid congestion or curb excessive speed, give preference to public transportation, or to enforce a congestion charging policy, helping to avoid additional fuel use from vehicles.*

CARBON EMISSIONS ABATEMENT FROM CONNECTED CITIES[21] (tCO_2e/year)

	UK	Germany	Spain	France	USA	Europe
Connected Cities	**435,000**	**498,000**	**226,000**	**383,000**	**1,990,000**	**3,018,000**
Parking space monitoring	9,000	12,000	6,000	12,000	260,000	74,000
Smart bins	20	20	10	10	70	100
Street lighting	108,000	42,000	8,000	5,000	31,000	202,000
Traffic congestion management	38,000	61,000	40,000	45,000	212,000	403,000
Traffic congestion monitoring (road signs)	149,000	204,000	92,000	170,000	372,000	1,281,000
Traffic congestion monitoring (traffic lights)	131,000	179,000	81,000	150,000	1,116,000	1,057,000

21 The quantification for reduced carbon emissions from traffic are not solely confined to urban environments, as the data used includes the national networks of highways and motorways which link cities.

Future opportunities

Over half of the global population now live in urban areas, up from a third in 1960. And by 2050 two-thirds of humans are expected to live in urban areas.[22] As such, addressing the carbon emissions from cities will be an absolutely crucial part in tackling climate change.

One of the greatest challenges for cities will be to put in place adequate infrastructure and services at a pace that can meet the demands of a rapidly growing urban population, making more efficient use of limited resources while reducing carbon emissions. There are also challenges in balancing the needs of multiple stakeholder groups with potentially divergent interests. This will be particularly problematic when retrofitting existing cities with smarter infrastructure, which will require long term planning and considerable amounts of finance.

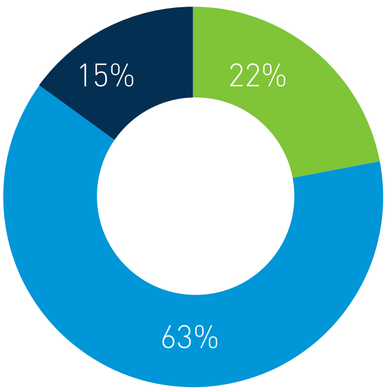
High smartphone penetration rates could create a big role for citizens to directly participate and collaborate in smart city initiatives. This may involve providing feedback either automatically or manually, related to their location, which could provide valuable data for the city to use.

A key barrier to adoption is effectively integrating old or legacy infrastructure within new connected cities projects. In order to overcome this, open standards and solutions may be of assistance, although these may be difficult to implement universally given the fragmentation between city environments.

There are also issues with governance, as fully integrated projects may cut across multiple independent areas of authority, so ownership of projects may not always be clear and transparent. This lack of control could result in delays in rolling out upgrades, or in other circumstances it could mean that services will suffer long delays or be implemented in a suboptimal manner. It also raises concerns about data security and privacy.

A small but interesting example of public services being provided through mobile technology is 'Smart Justice', where minor court cases such as motoring offences can be handled online, reducing travel, paper work and bureaucracy.[23] A more controversial example is using M2M technology for monitoring convicted offenders, allowing them to remain in society rather than being held in prison. This reduces the prison population and therefore reduces the carbon emissions of prisons, however this needs to be offset against the carbon emissions from the offender living at home and travelling in the community.

The consumer research found a significant willingness for people to use their smartphone to access public services, which indicates that the potential for carbon savings exists as the technology becomes more widely adopted.

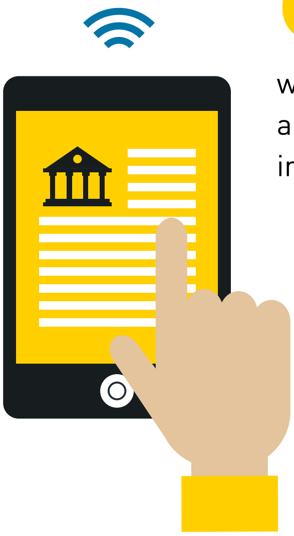


Are you, or would you be willing in future, to use a mobile device to access public services (e.g. voting, obtaining parking permits, paying fines, renewing driving license)?

- Already do this
- Willing to do this
- Not willing to do this

Base: *All respondents* (4,000)

22 United Nations Department of Economic and Social Affairs, Population Division (2014) *World Urbanization Prospects: The 2014 Revision.*
23 Coleman, C. (2015) *Online motoring service launched.* BBC News. [Available at: http://www.bbc.co.uk/news/uk-31653760]



63%

would use mobile to access public services in the future.

Smart parking

Milton Keynes Council in the UK worked with BT and the Open University to pilot a smart parking initiative that could help to reduce fuel use and vehicle emissions across the whole city. There are approximately 25,000 parking spaces in Milton Keynes, with forecasts that a further 12,000 may be required by 2020 to meet the city's growth. But currently around 7,000 parking bays are empty at any one time, mostly because people don't know where to find them. The cost of creating a new parking bay is around £15,000.

The pilot made use of sensors at the city's railway station that could tell when a bay was occupied. These sensors wirelessly beam data to solar-powered receivers on lampposts, which are then relayed to a central data hub for analysis. This analysis is then displayed on a public information dashboard, as well as being available as an overlay to Google maps on a web browser, colour coding bays to show when they are free.

Seeing the impact of the pilot, the Council is now planning to extend the network to a further section of the city with 250 sensors. Full deployment across all of the city could result in a capital saving of £105 million for the city, as well as resulting in meaningful reductions in fuel use and vehicle emissions.

Intelligent street lighting

Smart street lighting is being rolled out in a number of cities around the world, helping to reduce local government electricity costs through greater connectivity. This allows the brightness of lights to be adjusted based on current conditions and need, for example they can be dimmed during a bright dawn or turned up for dealing with an emergency situation.

The city of San Diego in the USA is estimated to be saving more than $250,000 a year thanks to the implementation of an intelligent LED lighting system by GE Lighting, replacing bulbs within 3,000 decorative historical street lights around the city, which are now embedded with wireless control technology. These lights use innovative GPS location features to allow an accurate measurement of energy use by each individual street light.

As well as allowing for customisable levels of brightness, accurate energy metering means that the municipality will only pay for the energy they actually use. The connection also provides immediate notification for when maintenance is required. The lights are tied into GE Lighting's 'Intelligent Cities' system, which is a software platform that can support advanced lighting control, optimising traffic management and parking, and environmental monitoring and analysis.

Connected Energy

Energy and the use of mobile

Connected Energy currently refers to the use of ICT, including mobile, in order to enable the creation of a low carbon energy generation and transmission infrastructure. This newly emerging, cleaner system is proving to be more decentralised, distributed and intermittent than what has previously existed.

It is here that mobile is also playing a key role, enabling the creation of smart grids that use advanced technology to actively manage and monitor the transport of electricity to meet varying levels of demand. This is helping to coordinate the needs of generators, grid operators, end users and electricity market stakeholders to minimise cost and environmental impact, while maximising system reliability, resilience and stability.

The most material impacts being made mobile on carbon emissions today are in M2M connections accommodating smaller scale electricity generation within the wider system. This is enabling individuals and smaller players to participate economically, creating new markets for greener, local energy. Short-range wireless technologies allow owners to access installation diagnostics, performance monitoring and the collection of environmental metrics. Finally, mobile connections are being integrated into the nascent infrastructure that will allow for the electrification of transportation. Electric vehicle users are able to access and pay for the growing networks of charging points thanks to these connections, which allow those points to be activated by use of smartphone apps, swipe cards or cards containing RFID chips.

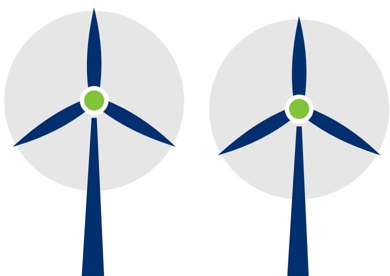
Abatement mechanisms

There are three mechanisms for which it has been possible to quantify carbon emissions abatement from mobile. These are:

- **Electric vehicle infrastructure:** *mobile has an important role to play in supporting the use of electric vehicles, enabling charging point connection to electricity grids, and helping to facilitate the transition to low carbon transportation.*
- **Connection of decentralised energy generation (microgeneration):** *enabling low carbon microgeneration of energy by individuals and businesses to be exported to the grid by communicating capacity and pricing, as well as facilitating payment. Technologies assessed include combined heat and power (CHP), solar photovoltaics and wind turbines.*
- **Managed smart grids:** *by monitoring the distribution of an electricity or gas network, utilities can identify points of loss and improve efficiency.*

CARBON EMISSIONS ABATEMENT FROM CONNECTED ENERGY (tCO_2e/year)

	UK	Germany	Spain	France	USA	Europe
Connected Energy	**1,536,000**	**5,255,000**	**939,000**	**221,000**	**9,265,000**	**15,523,000**
Electric vehicle connection	840	1,000	650	3,000	1,000	11,000
Micro-generation (CHP business)	40	80	9	5	180	180
Micro-generation (CHP residential)	7	10	2	1	50	40
Micro-generation (solar business)	458,000	3,340,000	517,000	125,000	1,817,000	8,711,000
Micro-generation (solar residential)	426,000	1,441,000	210,000	51,000	747,000	3,797,000
Micro-generation (wind business)	470,000	286,000	82,000	6,000	3,623,000	1,445,000
Micro-generation (wind residential)	58,000	45,000	8,000	990	347,000	165,000
Smart Grids - electric network management	98,000	114,000	102,000	19,000	2,434,000	1,117,000
Smart Grids - gas network management	25,000	28,000	19,000	15,000	296,000	277,000



Future opportunities

The existing electricity system in most parts of the world has been designed for scale and centralisation. Universal grids provide energy from a small number of nodes in a network, with infrastructure built to meet peak levels of demand. This is well suited to fossil fuel and nuclear energy generation, where the economies of scale possible at larger sizes have shaped the utility business models that deliver current electricity supply.

This model is not well suited, however, to the development of a decentralised low carbon energy system. The need to take action on climate change has spurred significant investment into renewables and other technologies that can reduce greenhouse gas emissions by providing cleaner energy, greater efficiency or lower peak demand.

The creation of a sustainable, low carbon energy system is no easy challenge. Global demand for electricity continues to rise and this is mostly still being provided by ageing infrastructure built for an era of abundant fossil fuels. Connectivity is key to creating a resilient, low carbon electricity system at the lowest possible cost, which accommodates a range of generation and storage options.

Within the utility sector, mobile communications technologies are starting to be deployed to optimise the use and operating efficiency of generation and transmission assets, constantly monitoring for when things are not working as they should be, allowing for remote control and pre-emptive maintenance. These assets are typically expensive and have a significant cost associated with their failure, often far greater than the cost of M2M modules, which should lead to a far greater use of mobile in future. Mobile also allows utilities to aggregate multiple distributed sources of renewable energy and CHP into single virtual power plants, controlled from a central location.

Mobile is starting to enable a higher level of economic participation in electricity systems outside the utility sector, from the household with solar panels on the roof to the data centre powered by its own wind farm. Governments have been key to facilitating this transition, particularly through the introduction of feed-in tariffs. In developing countries, mobile is also supporting more affordable off-grid access to clean energy, helping address fuel poverty and improve health outcomes.

Taking a whole-system perspective, mobile is helping to reduce energy demand through smart grids. Currently energy infrastructure is designed to meet the highest level of simultaneous demand. This means that most of the time, the system is underutilised. Mobile connections provide the ability to reduce peak loads by dynamically responding to demand, increasing prices or automatically switching off non-critical systems for a short time. This can negate the need to build larger amounts of infrastructure, which is a particular benefit in the developing world where demand growth is very high, as well as in countries with existing, ageing systems that need to be maintained and taken off line while integrating new technologies.

The ability to collect and act on almost real time data thanks to mobile will allow better overall system planning, increasing options for integrating new loads such as electricity storage (including electric vehicles) and intermittent renewable generation. Increasing the geographic distribution of the electricity system, as well as the range of energy technologies used, also provides a greater resilience to disturbances, attacks and natural disasters.

As with any major changes to an incumbent system, the transition to a low carbon energy system and smart grids will face a number of serious barriers. The size of the challenge is magnified in this case by the physical and institutional complexity of the existing electricity system, the high capital costs of deployment, long development and replacement cycles for infrastructure, consumer privacy issues and other political sensitivities.

These issues are compounded by an inertia in decision-making, as rapid innovation and cost-reduction curves across a variety of technologies risk making a major project look out-of-date or overly expensive by the time it reaches fruition. Within developing countries there are further issues related to lack of technical skills or availability of capital, as well as high installation costs that cannot be justified economically in the absence of subsidies.

These barriers are gradually being overcome as small and large scale pilot projects are demonstrating the successful use of mobile communications technology to enable low carbon energy. This is helping to empirically prove the extent to which smart grid technology can provide equal or improved levels of power quality and reliability.

In most cases government intervention is required to drive the transition to create the market conditions for a lower carbon energy system, through regulations, subsidies or grants. However, some innovative business models are demonstrating that mobile communications technology can directly enable savings in areas such as demand response. For example, in the UK companies such as Open Energi and KIWI Power act as aggregators, managing the load of multiple large electricity users in order to temporarily turn down energy consumption to balance the grid and reduce peak demand.

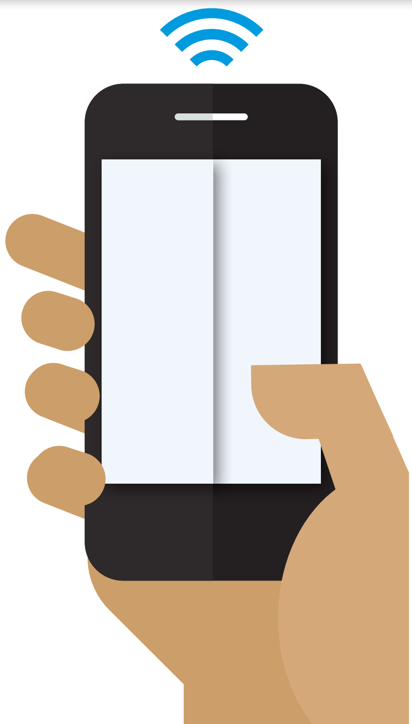
Mobile business models

BBOX is a company founded by three former students of Imperial College London, with the ambition of helping to provide off-grid renewable energy in the developing world. Mobile connectivity is a fundamental element that helps to run the company's business model effectively, by allowing solar panels to be monitored, managed and controlled remotely.

Solar panels are provided on credit finance, with users commonly providing monthly payments to match what they would have previously paid for kerosene, batteries and phone charging services. This allows them to access clean renewable energy while working towards eventual ownership of the solar panels, for no additional energy cost.

Working with Vodafone, BBOX is able to remotely connect its units distributed in rural areas across Kenya, Uganda and Rwanda by using M2M SIMs. Each panel can then be activated, updated and managed from the company's London headquarters, with access to real-time data on customer usage, payments and hardware faults. In order to maintain repayment schedules panels can be turned off when required.

The model has already proved to be successful in helping hundreds of thousands of people in the developing world to leapfrog the need for conventional grid connection and access low carbon renewable energy. BBOX currently distributes products to over 40 countries and aims to have 100,000 units in the market by the end of 2016.



Connected Health

Health and the use of mobile

Connected Health explores the impact that mobile is having on human health and access to healthcare. These have been substantially improved in many ways through the use of ICT and access to mobile communications technology. But much of what has been made possible is new or additional to what was previously available, meaning that it has not resulted in readily quantifiable direct reductions to greenhouse gas emissions.

The major abatement mechanism that has been quantified has been the avoidance of carbon emissions from transport thanks to the remote delivery of healthcare. As quantification has only taken place in the USA and Europe – regions with comparatively developed healthcare infrastructure – in many cases those avoided journeys are of a comparatively short distance. However, in developing or geographically remote regions of the world, where greater distances need to be travelled to access services, the abatement potential may be considerably larger.

It has also been possible to recognise benefits from reduced stays in hospital, which can be more resource intensive than remaining at home. Reductions in carbon emissions are attributed to reducing journeys to and from the hospital by visitors, as well as the fact energy use per person is higher hospitals than in the home.

Abatement mechanisms

There are two mechanisms for which it has been possible to quantify carbon emissions abatement from mobile. These are:

- **Smart home care:** *monitoring chronic or high risk patients at home with mobile technology can avoid repeated car journeys to hospital by the patient, or by health professionals to the patient's home, as well as provide better pre-emptive medical intervention to reduce the total number of days spent in hospital.*

- **Connected out of hospital care:** *remote monitoring and assisted living for patients out of hospital (compared to no remote monitoring) helps to reduce the number of days needed to be spent by patients in hospital and can help to avoid additional journeys and reduce resource consumption per patient.*

CARBON EMISSIONS ABATEMENT FROM CONNECTED HEALTH (tCO_2e/year)

	UK	Germany	Spain	France	USA	Europe
Connected Health	47,000	89,000	29,000	51,000	3,540,000	406,000
Smart Health - home care	43,000	82,000	26,000	46,000	3,361,000	372,000
Smart Health - out of hospital care	4,000	7,000	3,000	4,000	179,000	33,000

Future opportunities

There are already a number of nascent technologies being developed that are allowing healthcare to be provided remotely, thanks to the use of mobile. These include sensors that can be attached to smartphones to test blood, DNA and urine. This is allowing care to be provided in increasingly remote locations, which is particularly beneficial in developing countries and remote areas.

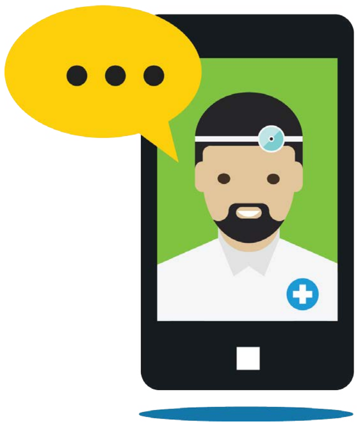
However, it would appear that the greatest future opportunities for mobile to have an impact on greenhouse gas emissions in healthcare is through its potential to stop medical conditions from arising in the first place. Smartphones and other smart devices, such as watches, are now being used to track fitness and diet, encouraging more healthy lifestyles and helping prevent non-communicable diseases such as obesity or diabetes. According to a report from the McKinsey Global Institute the global cost of obesity is around $2 trillion, accounting for between two and seven percent of healthcare spending in developed economies and rising to as much as 20 percent when accounting for associated diseases.[24]

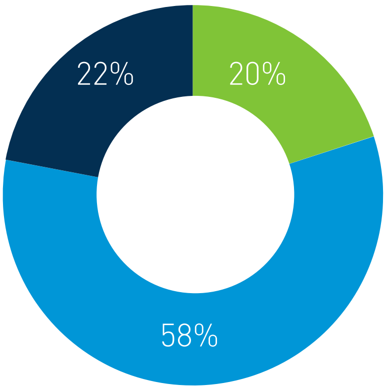
It is also worth mentioning that mobile is helping to reduce the direct and indirect impacts of providing healthcare through its use of buildings, transport and manufactured products. Although it has not been possible to separate out and quantify that impact within this section, it forms a significant part of the quantification in other categories.

24 Dobbs et al (2014) *How the world could better fight obesity.* McKinsey Global Institute.

For example, the National Health Service (NHS) in the UK measured its end-to-end carbon footprint for 2012 and found that it was 25 million tonnes, which is approximately one third of the annual emissions from heating every home in the UK. This was composed of the goods and services it procured (61%), building energy use (17%), travel (13%) and commissioned health services from outside the NHS (9%).

The consumer research found a significant willingness for people to use their smartphone to access health remotely, saving time and travel for visits to a doctor.

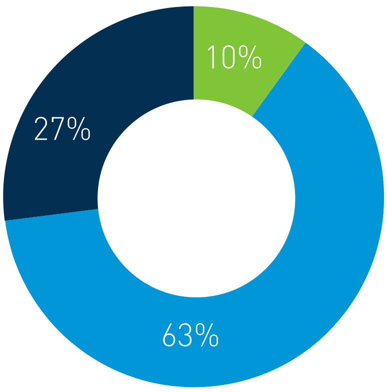




Are you, or would you be willing in future, to replace a non-emergency visit to the doctor by making a phone call?

- Already do this
- Willing to do this
- Not willing to do this

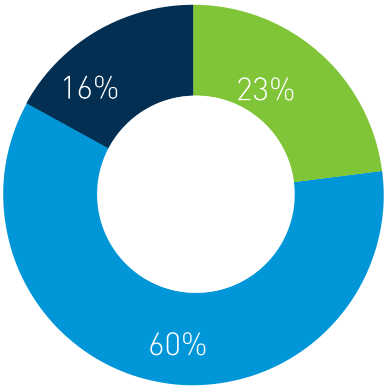
Base: *All respondents* (4,000)



Are you, or would you be willing in future, to replace a non-emergency visit to the doctor by making a video call?

- Already do this
- Willing to do this
- Not willing to do this

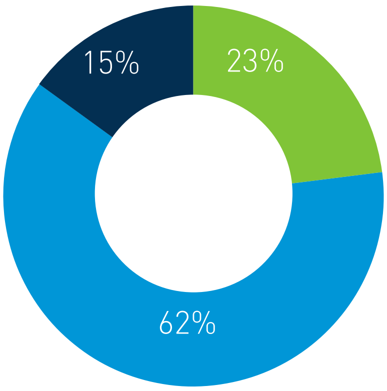
Base: *All respondents* (4,000)



Are you, or would you be willing in future, to use a mobile device to seek health advice?

- Already do this
- Willing to do this
- Not willing to do this

Base: *All respondents* (4,000)



Are you, or would you be willing in future, to use a mobile device to monitor your fitness and health?

- Already do this
- Willing to do this
- Not willing to do this

Base: *All respondents* (4,000)

Remotely improving patient outcomes

Telehealth is the rapidly growing field of providing medical services through communications technology. This ranges from video consultations with general practitioners, through to actively tracking chronic conditions and alerting risks.

For example, it is possible to wirelessly track blood pressure and heart rate, allowing patients to monitor and manage conditions from their own home, or have readings relayed to a monitoring centre. In Bangalore, India, Vodafone has supported the company Diabetacare to complete a successful pilot to remotely monitor the blood-sugar levels of 800 individuals with diabetes using M2M connections.

BT has also been a pioneer in this area, helping to enable telehealth services within the UK. The company currently provides services for Cornwall Council in the sparsely populated southwest of the country. This is helping to substantially reduce the number of visits to the doctor from certain patient groups, as well as reducing emergency visits to hospital and ambulance call-outs. Trials by the Department of Health in the UK have found that use of telehealth services helped to materially reduce mortality rates and overall costs per patient.

Connected Industry

Industry and the use of mobile

Connected Industry refers to the use of mobile communications technologies, particularly M2M connections, to support economic activity concerned with the extraction and processing of raw materials into finished products or services. In addition to the manufacturing industry, this includes the construction and utilities sectors, as well as the supply chain management activities for the transportation and storage of raw materials, intermediates and products.

In industry there have been a wide variety of ICT innovations enabling faster, more efficient and more flexible processes to produce higher-quality goods at reduced costs, reducing resource consumption and lowering carbon emissions. These include: improved energy monitoring and management systems with better data capture and analysis tools; new wireless sensors that send information to a central system for analysis; virtual process testing and simulation; improved automation and synchronisation of processes, resulting in less waste; improved detection of machine wear and maintenance requirements; more effective implementation of produce-to-demand strategies; improved quality control; and less off-specification production.

Abatement mechanisms

There are five main mechanisms for which it has been possible to quantify material carbon emissions abatement from mobile. These are:

- **Automating industrial processes:** *the use of M2M connections helps to improve the efficiency and productivity of industrial processes, helping to reduce energy consumption.*
- **Field force automation:** *improved connectivity helps to increase productivity and reduce travel by mobile work teams, reducing overall vehicle fuel use.*
- **Improved supply chain and inventory management:** *mobile can be used to monitor goods and equipment helping to improve efficiency in logistics and reduce wastage, particularly for perishable goods. This includes connected vending machines that can be remotely monitored, improving the logistics for restocking.*
- **Enabling cashless payment (point of sale):** *mobile is used to facilitate payment at point of sale, helping the economy to use less physical cash and to avoid fuel use from its production and transportation.*
- **Enhanced detection of inefficiency (water grid):** *sensors can help to identify areas of loss and enable rapid repairs, preventing unnecessary resource use, for example where utilities are able to use mobile to detect leaks in the water grid.*[25]

CARBON EMISSIONS ABATEMENT FROM CONNECTED INDUSTRY (tCO_2e/year)

	UK	Germany	Spain	France	USA	Europe
Connected Industry	**88,000**	**196,000**	**65,000**	**32,000**	**1,837,000**	**808,000**
Automation in industrial processes	37,000	92,000	20,000	7,000	324,000	319,000
Field force automation	5,000	5,000	5,000	7,000	101,000	30,000
Supply chain management	4,000	5,000	3,000	4,000	23,000	44,000
Inventory management	37,000	85,000	32,000	8,000	1,309,000	364,000
Vending machines	6,000	9,000	5,000	6,000	79,000	47,000
Point of sale	290	170	270	310	2,000	3,000
Water grid - leak detection	1	10	3	3	50	40

25 Construction equipment monitoring and construction materials monitoring have not been quantified in the report, due to the relatively low contribution to carbon emissions reduction.

Future opportunities

The future potential for mobile enabled improvements in emissions here is considered to be very large. This is because the technology has a range of applications, from supplier to customer, as well as vertically, across different company functions and value chains.

ICT solutions can enable increases in productivity and efficiency, as well as a significant simplification of processes. As such, many traditional industrial sectors are experiencing an era of innovation thanks to the power of advanced computing, improved analytics, low-cost sensor technology and new levels of connectivity between products, value chains and business models. Many of these solutions can be delivered either through fixed connections or mobile, with the latter increasingly becoming the preferred option.

This new era of connectivity is commonly referred to as the fourth industrial revolution or Industry 4.0, which was originally the name of a programme under the German government's High-Tech Strategy, focusing on the use of ICT in manufacturing industry to improve efficiency.

However, there are some significant barriers to opportunities being fully exploited. As might be expected in sometimes highly competitive industries, data is closely guarded and access is limited. This lack of data availability and transparency makes it difficult for comparisons to be made, which could otherwise highlight inefficiencies.

In some parts of the world there are counterproductive policies, which prevent technologies being adopted. For example, if an industry has energy costs heavily subsidised then there are lower incentives for taking action to improve efficiency.

Adoption rates for available technologies are slowed in some industries by the high capital costs of plant and machinery, which are expected to operate over long lifecycles. This creates an inertia that holds back process change or upgrade cycles in some areas.

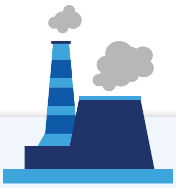
Governments and industry associations have a role to play in driving change, which can be accelerated by regulations or standards encouraging greater levels of energy efficiency or emissions reductions. Ultimately, businesses will be driven by the strength of the business case to act to improve efficiency. As technology becomes cheaper and more easily integrated, or solutions are demonstrated and deployed at scale, this will increase the use of mobile-enabled technology that can reduce emissions.

Industrial internet

A 2014 report from Strategy& and PwC based on a survey of 235 German industrial companies investigating the potential of the industrial internet, found that businesses were particularly optimistic about the opportunities for increased productivity and resource efficiency. The survey revealed that over the next five years these companies were expecting to spend an average of 3.3 percent of their annual revenues on industrial internet solutions.

Although only one fifth of companies surveyed had already digitised key processes along the value chain, in five years' time 85 percent expect to have done so across all important business divisions. This is associated with an average increase in productivity of 18 percent over the five years, leading to growing revenues by two to three percent a year.

Out of the benefits listed by companies, better planning and control in production and logistics, as well as improved quality, can be directly linked to a reduction in energy use. These two categories together make up 34 percent of the total ICT-enabled improvements expected. This is likely to involve significant use of mobile, particularly in logistics where RFID and NFC technologies are commonly used.



Smart factories

Increasing levels of digitisation and connectivity in manufacturing are helping to deliver unprecedented levels of efficiency. For example, Polibol, a flexible packaging manufacturer in Zaragoza, Spain makes use of Microsoft's Azure cloud platform connected to sensors made by Libelium.

These sensors monitor the temperature of critical processes, environmental variables and other parameters to track quality and working conditions. This helps to minimise the monitoring and management costs to effectively optimise the manufacturing process and increase product quality.

The scale of the potential for improvement in product quality using ICT, including mobile connections, can be seen in one of the world's most advanced factories operated by Siemens. An electronics plant in Amberg, Germany has been created as a Digital Factory, designed in such a way that products communicate with machines, and processes are integrated, controlled and optimised using IT.

Using advanced tools for planning and managing production processes in this plant has helped to improve overall production quality to unprecedented levels of 99.99885 percent. This helps to avoid the waste, inefficiency and emissions associated with producing defective or low-quality products.

Connected Living

Living and the use of mobile

Connected Living refers to consumer use of certain apps or online services which can result in a reduction in their personal carbon footprint. This category includes the use of smartphones with smart home control apps and satnav apps. The availability of mobile communications technologies is contributing to both major and minor changes in people's behaviour in their everyday lives.

The greatest impact today that is being made in this area is making certain journeys redundant thanks to enhanced connectivity, reducing emissions from fuel use. The largest element of this is avoiding travel to visit family and friends, where in some circumstances this can be replaced with phone or video calls using mobile connections. There is also avoided travel through availability of online services, such as mobile banking or shopping.

Further reductions in transport emissions are being enabled by satnav apps which allow for better planning of routes or avoiding traffic, as well as through eco-driving apps that promote more efficient use of fuel, and ride sharing services that avoid additional journeys. It is worth noting that this refers just to use of apps on smartphones. Overlap has been avoided between mechanisms in the *Connected Transportation* section, where standalone or integrated satnav devices are included.

Another area where emissions are being avoided include remotely controlling heating, cooling and appliance electricity use in homes. This refers specifically to the use of smartphone apps in domestic buildings, so that overlap is avoided with mechanisms in the *Connected Buildings* section, which includes similar mechanisms for non-domestic buildings and the use of automated controls.

Many of the abatement mechanisms can be used with fixed-line or mobile connections. For example, internet banking could be used on a laptop plugged into a router as well as on a mobile phone, but both can avoid physical journeys to the bank. Where this is the case then assumptions have been made in quantifications of what percentage of the impact should be allocated to mobile.

Finally, mobile is helping to enable peer-to-peer economic (as well as non-economic) activities. Unwanted goods can be sold, rented or freely given away, helping to reduce waste and avoid production of additional goods. And the provision of services can also be enabled. For example, the renting out of unused space for accommodation can help avoid carbon emissions when compared to the emissions associated with a stay in a hotel.

Abatement mechanisms

Mechanisms for which it has been possible to quantify carbon emissions abatement from mobile fall within five main areas. These are:

- **Enabling the sharing economy:** *mobile apps are helping to overcome barriers which were preventing direct peer-to-peer sharing or exchange, for example by renting goods, finding new owners for unwanted goods, sharing car journeys or offering unused space for accommodation.*
- **Keeping in touch virtually (friends and family):** *the use of mobile devices to connect with family and friends through voice and video calling can help to reduce the frequency of travel to visit them, avoiding the associated transportation emissions.*
- **Remote access to goods and services (mobile banking and shopping):** *mobile access can avoid journeys to retail locations in order to shop for goods or access services such as banking.*
- **Smart home control:** *smartphones can be used to remotely operate appliances, heating and cooling within the home, helping to reduce electricity and gas demand.*
- **Improving route planning and eco-driving:** *map or satnav apps on smartphones can be used to plan journeys more efficiently, minimising the distance to travel and avoiding traffic. Similarly, eco-driving apps can minimise fuel use by providing guidance and supporting behaviour change.*

CARBON EMISSIONS ABATEMENT FROM CONNECTED LIVING (tCO_2e/year)

	UK	Germany	Spain	France	USA	Europe
Connected Living	**1,259,000**	**1,412,000**	**1,079,000**	**1,163,000**	**8,889,000**	**16,123,000**
Accommodation sharing	262,000	276,000	274,000	240,000	928,000	3,583,000
Ride sharing	47,000	47,000	39,000	41,000	219,000	586,000
Sharing economy (goods sharing)	96,000	74,000	56,000	64,000	398,000	955,000
Avoiding social journeys (friends & family)	410,000	571,000	459,000	496,000	2,748,000	6,625,000
Mobile banking	178,000	225,000	130,000	184,000	1,733,000	2,067,000
Mobile shopping	37,000	31,000	3,000	12,000	347,000	153,000
Smart homes	104,000	54,000	21,000	19,000	1,562,000	599,000
Use of mobile as a satnav	101,000	116,000	81,000	90,000	848,000	1,304,000
Eco-driving	24,000	19,000	16,000	17,000	108,000	252,000

Future opportunities

Many of the technologies or platforms that enable the mechanisms for emissions reductions quantified within this category have only been widely available for a comparatively short time. Even in areas where digital services – such as online banking or shopping – are quite frequently used, the majority of use in developed countries is still through fixed-line connections rather than mobile. As such there has been relatively limited impact to date due to low user numbers.

However, recent experience in a number of technology areas has shown that when the user experience is of sufficient quality, the use is normalised, and a critical mass of users is established, then digital services can rapidly increase levels of public acceptance and adoption. This can be seen, for example, with a number of video and messaging apps, as well as social media networks.

Similarly, new products such as smart systems that enable remote control of home energy use are only just beginning to be adopted at scale. A number of businesses have been investing in bringing these technologies to the mass market, with products such as Tado, Honeywell's Lyric and Evohome, Google's Nest and Hive all supporting smartphone control. As with eco-driving or ride sharing apps, the opportunities for cost saving provide economic incentives to adopt these technologies, which can deliver environmental benefits at the same time. However, the strength of those incentives would be diminished if the cost of energy falls significantly.

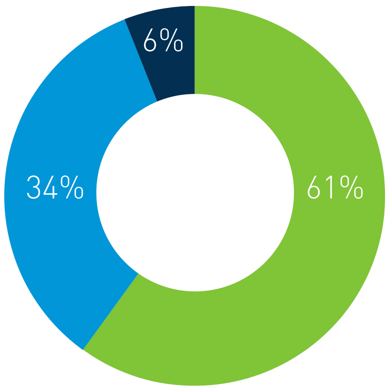
The sharing economy and other digital services promise to disrupt a number of existing markets, by offering new levels of convenience, or by allowing individuals to access marketplaces and create economic value where previously the barriers to entry or risks were too high. It should be noted that these services tend to be of greatest application in dense clusters of population, such as cities, where there is better connectivity.

Currently a number of businesses and entrepreneurs are exploring how ICT connectivity, including the use of mobile, can be effectively used to introduce the use of products as services, or to disrupt existing business models and value paradigms across a range of sectors. In most of these cases the business opportunity comes from increasing levels of efficiency and convenience, which are frequently associated with reductions in environmental impact. This may not be the case every time and further analysis would be needed for individual circumstances, to investigate the actual impact on carbon emissions, including rebound effects.

There are, therefore, ample reasons to expect the positive growth in abatement effect to be rapid and significant for most of the mechanisms outlined above. These should be joined by new mechanisms as ICT disrupts other sectors. This is likely to parallel the expected growth in user numbers of the mobile technologies or platforms, which in many cases has already been exponential. For example accommodation sharing service, Airbnb was only founded in 2008, but at the time of publication, claims to have supported over 40 million guests to book stays across 1.5 million listings in more than 190 countries.

These opportunities for reducing personal carbon footprints require changes in behaviour. In order to facilitate these changes, the new behaviours need to be made easier or more attractive than the incumbent alternatives. To achieve this it will be important to give individuals confidence in the trustworthiness or security of the services they are using. High quality user experience, as well as industry regulation and minimum standards, will be helpful in increasing the rates of adoption.

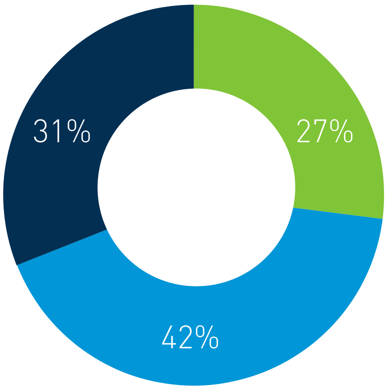
The consumer research found that over 50 percent of people already, or would be willing to, adopt a number of behaviours using their smartphones that have carbon saving benefits. In some cases, such as mobile banking and influencing travel plans, the number of people already doing this is over 50 percent.



Are you, or would you be willing in future, to use your mobile device to make or influence travel plans (e.g. mapping routes, checking traffic, checking public transport times)?

- Already do this
- Willing to do this
- Not willing to do this

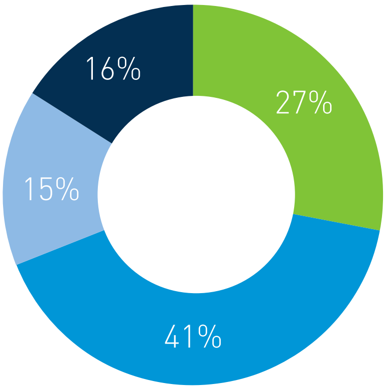
Base: *All respondents* (4,000)



Are you, or would you be willing in future, to replace a visit to friends or family by making a video call using a mobile device?

- Already do this
- Willing to do this
- Not willing to do this

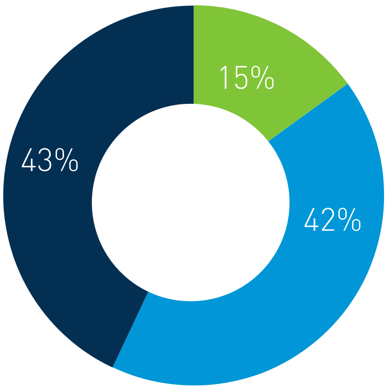
Base: *All respondents* (4,000)



Do you use satnav for planning routes, following routes, and avoiding traffic congestion on a mobile device such as a smartphone?

- All of the time
- Some of the time
- Rarely
- Never

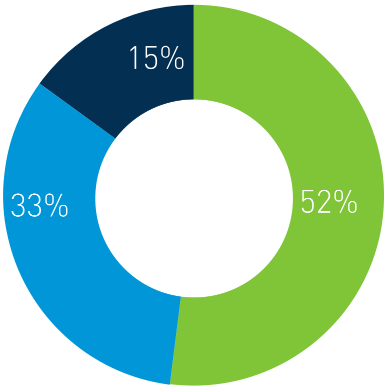
Base: *All drivers* (3,220)



Are you, or would you be willing in future, to use your mobile device to find someone to share a car journey with?

- Already do this
- Willing to do this
- Not willing to do this

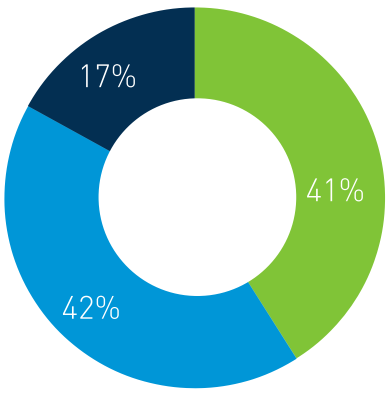
Base: *All respondents* (4,000)



Are you, or would you be willing in future, to replace a visit to the bank by using a mobile device?

- Already do this
- Willing to do this
- Not willing to do this

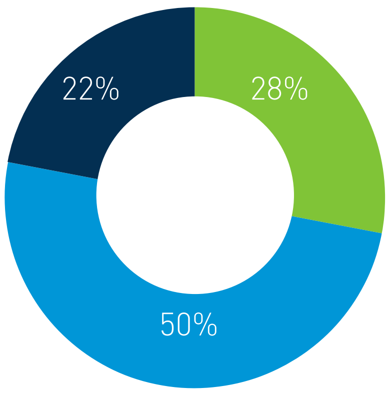
Base: *All respondents* (4,000)



Are you, or would you be willing in future, to replace a visit to the shops by using a mobile device?

- Already do this
- Willing to do this
- Not willing to do this

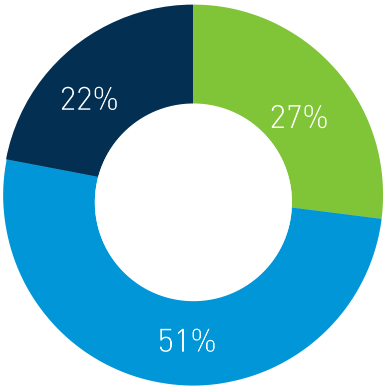
Base: *All respondents* (4,000)



Are you, or would you be willing in future, to use a mobile device to sell, rent, share items that you own?

- Already do this
- Willing to do this
- Not willing to do this

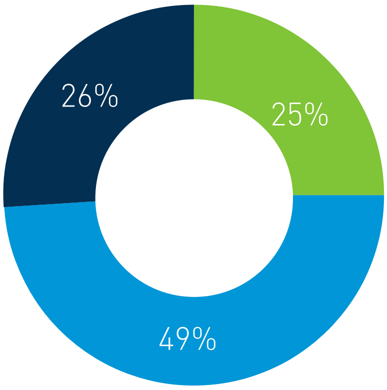
Base: *All respondents* (4,000)



Are you, or would you be willing in future, to use a mobile device to buy or rent items from others?

- Already do this
- Willing to do this
- Not willing to do this

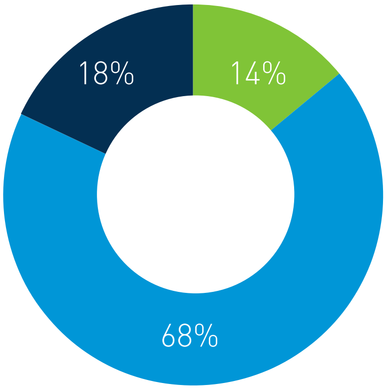
Base: *All respondents* (4,000)



Are you, or would you be willing in future, to use a mobile device to find and book accommodation in someone's home instead of using a hotel?

- Already do this
- Willing to do this
- Not willing to do this

Base: *All respondents* (4,000)



Are you, or would you be willing in future, to use a mobile device to control your electrical appliances and heating/cooling at home?

- Already do this
- Willing to do this
- Not willing to do this

Base: *All respondents* (4,000)

49%

would replace the use of their debit or credit card and cash with their smartphone.

50%

would be willing to use their smartphone to sell, rent or share items that they own with others.

49%

would be willing to replace a visit to a hotel with staying in someone's home.

Connected Transportation

Transportation and the use of mobile

Connected Transportation refers to the use of mobile connections to optimise the route planning and increase the efficiency of use for various modes of transport. Improving efficiency includes fleet management, speed management, loading optimisation and improvement of driver behaviour. Route optimisation can include optimisation of single mode transport as well as optimising transportation between different modes (e.g. overall optimisation of train and truck transport). Transport across land, sea and air is responsible for approximately 14 percent of global greenhouse gas emissions.[26]

The main method of carbon emissions reduction is through decreasing fossil fuel use by shortening journeys and improving vehicle efficiency. The greatest impact is currently being had through improving driver behaviour, through monitoring and providing advice on driving technique, or enabling usage-based insurance that economically incentivises more efficient driving.

It should be noted that the quantifications in this category have explicitly excluded the personal use of satnav on smartphones for improved route planning, as well as the use of smartphone apps to increase the efficiency of driving technique in personal vehicles. This is to avoid overlap with the Connected Living category, where these mechanisms have been included. However, this category does include the impact from integrated or standalone satnav devices in personal vehicles, reductions in fleet vehicle emissions, and mechanisms where mobile enables a modal shift to public transport.

26 IPCC (2014) *Summary for Policymakers. In: Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.*

Electric vehicles have been included in the Connected Energy category, as they are enabled through smart grid connections and metering.

Significant reductions in emissions are currently being made from encouraging modal shift to public transport, by improving its usability through the provision of real time information via mobile connections, allowing users to plan journeys more effectively. This is done through a vehicle tracking system or Automatic Vehicle Location (AVL) technology. Mobile is also used in smart payment systems, making ticketing systems simpler and more user-friendly.

Other savings are being achieved through improved logistics, where the use of satellite navigation is important for route planning and fleet management. Smaller impacts are also being realised due to the use of mobile connections for managing fleet vehicle loads, pre-empting maintenance issues and providing access to car clubs that allow multiple users to access shared vehicles.

Abatement mechanisms

There are three groups of mechanisms for which it has been possible to quantify carbon emissions abatement from mobile. These are:

- **Enabling smarter logistics:** *mobile technology can optimise multi-modal land and sea fleets so that they operate more efficiently through better routing, avoiding areas of travel, optimising vehicle loads and improving the fuel efficiency of road vehicles.*
  (Includes: Fleet vehicle driver behaviour improvement, Smart Logistics - efficient routing & fleet management, Smart Logistics - loading optimisation, Sea fleet)

- **Reducing the impact of breakdowns:** *mobile technology can optimise multi-modal land and sea fleets so that they operate more efficiently through better routing, avoiding areas of travel, optimising vehicle loads and improving the fuel efficiency of road vehicles.*
  (Includes: Fleet vehicle driver behaviour improvement, Smart Logistics - efficient routing & fleet management, Smart Logistics - loading optimisation, Sea fleet)

- **Changing individual transport choices and driving behaviour:** *mobile connectivity can help individuals to make lower carbon transport decisions in various ways, such as: improved route guidance using satellite navigation; supporting access to on-demand car sharing services through car clubs; helping improve public transport user experience with mobile ticketing and better journey planning; and enabling insurance policies that actively monitor driving to reduce premium costs for safer, more fuel efficient driving.*
  (Includes: Satellite navigation, Car sharing (car clubs), Usability of public transport, Usage based car insurance)

CARBON EMISSIONS ABATEMENT FROM CONNECTED TRANSPORTATION (tCO_2e/year)

	UK	Germany	Spain	France	USA	Europe
Connected Transportation	**2,340,000**	**4,255,000**	**1,197,000**	**2,709,000**	**24,756,000**	**26,173,000**
Fleet vehicle driver behaviour improvement	803,000	1,060,000	203,000	1,314,000	10,059,000	5,800,000
Smart Logistics - efficient routing & fleet management	293,000	315,000	65,000	495,000	3,259,000	1,973,000
Smart Logistics - loading optimisation	117,000	126,000	26,000	198,000	1,303,000	789,000
Sea fleet	309,000	1,803,000	116,000	109,000	517,000	8,183,000
Remote vehicle condition monitoring	100	150	50	120	990	900
Roadside assistance	20	40	20	30	140	240
Satellite navigation	23,000	23,000	6,000	31,000	27,000	184,000
Car sharing (car clubs)	86,000	309,000	86,000	86,000	341,000	589,000
Usability of public transport	536,000	466,000	567,000	364,000	8,075,000	6,556,000
Usage based car insurance	173,000	154,000	127,000	111,000	1,174,000	2,097,000

Future opportunities

The most critical element in enabling a full transition to a low carbon transportation system is the development of engine technologies that harness clean energy, such as electricity, hydrogen or biofuels. But it is likely that the development and deployment of clean engine technologies across all forms of transportation will take several decades. The use of fossil fuels in this sector is currently expected to continue well into the latter half of the twenty-first century. And mobile is already helping to ensure that this impact is minimised, by improving the efficiency of vehicles and sea fleets.

As the software for satnav technology continues to improve, there is the opportunity for it to be integrated with data from other sources, such as traffic cameras. This can provide drivers with constant updates on the most efficient routes. Software that proactively supports better driver behaviour has not yet been widely adopted, although where it is being used it is delivering very good results. But it is reasonable to expect that, as the technology advances and becomes more readily available on smartphones, more and more fleets and individuals will begin using this in order to save money on fuel costs.

In the longer term mobile will have an important role to play in supporting the transition away from personal vehicle ownership, encouraging a shift towards the use of less carbon intensive modes of transport. For example, real-time transport planning apps or digital services that support a modal shift to public transport have only become common in larger cities comparatively recently.

Greater penetration of smartphones and the availability of mobile data should increase the reduction in carbon emissions through this mechanism in the future. But modal shift will not be particularly effective where public transport systems are inadequate. However, it is expected that there will be substantial future investment in public transport systems in response to the need to address climate change, meaning that use will become more commonplace.

Mobile is also enabling business models for on-demand vehicle sharing, such as the Autolib' electric vehicle hire system operated by the city of Paris, or the company Zipcar which now operates more than 10,000 vehicles in the USA, Canada, the UK, Spain, France, Austria and Turkey. These have been enabled by the ready availability of mobile data or Wi-Fi, which can be accessed through smartphones, to allow for locating the nearest vehicle, gaining access and proving payment.

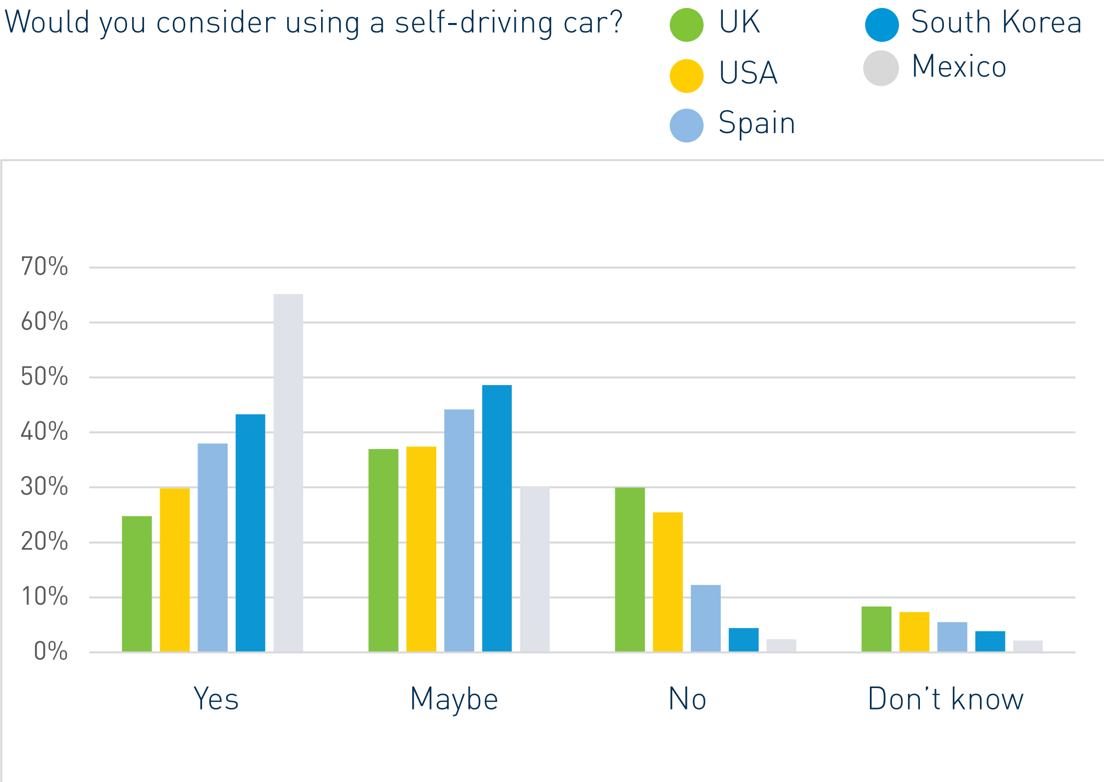
The adoption of usage-based insurance systems for vehicles allows for incentivising safer, more fuel efficient driving. Unsurprisingly a number of insurers are interested in this in order to more accurately manage risk and assess premiums based on granular individual data. Its adoption in Europe has been boosted following a recent ruling by the European Court of Justice preventing insurers from taking into account the sex of the applicant when setting premiums. This has meant that insurers have had to raise costs for younger female drivers, grouping them with typically riskier younger male drivers. However, there are some privacy concerns with the use of this system.

Finally, mobile communications technology has a role to play in enabling the emerging technology of self-driving cars. This will involve not just satellite connections for route planning, but also some measure of vehicle-to-vehicle (V2V) communications. As self-driving cars take human decision making out of the driving experience, these can be automated to be used at an optimised efficiency. Self-driving cars could potentially be used in some form of on-demand taxi or public transportation system, where smartphones are used in order to access the service.

Research conducted for this report has found that there is fairly broad support for this technology in principle around the world, particularly in Mexico where almost two-thirds are positive about it. Even in the country with the highest levels of opposition, the UK, just three in ten are completely opposed to using the technology. However, the actual rate of adoption will depend upon convincing the public of its improved safety and convenience.

People are embracing the use of mobile technology in key areas such as transportation, helping to reduce energy and fuel use.

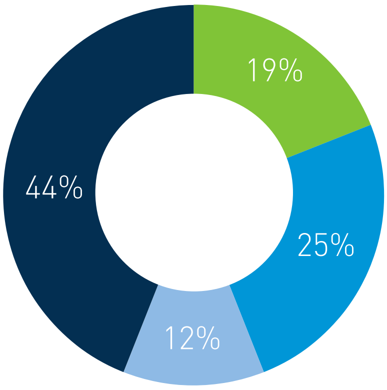
Would you consider using a self-driving car?



In general, the consumer research found that a majority of respondents were prepared to adopt new behaviours and new technologies that could help them to reduce their personal carbon emissions from driving cars, or by using mobile technology to help them switch to public transport more often.

4 in 10

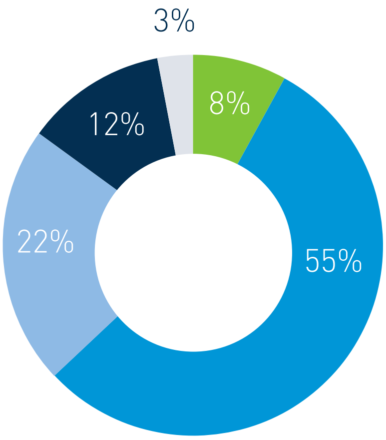
drivers would consider using a self-driving car in future.



Do you use satnav for planning routes, following routes, and avoiding traffic congestion on a fixed satnav in your vehicle?

- All of the time
- Some of the time
- Rarely
- Never

Base: *All drivers* (3,220)



Would you be willing to have a device fitted to your vehicle which records the way you drive, if driving in a safer and more environmentally-friendly way reduced your car insurance?

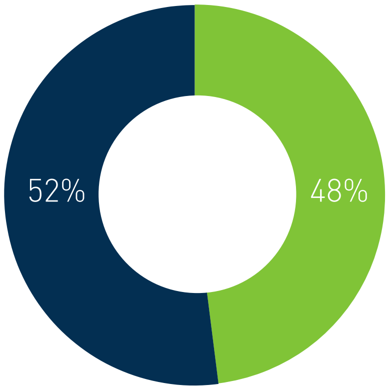
- Yes, I already use one
- Yes, I would consider it
- Maybe
- No
- Don't know

Base: *All drivers* (3,220)

55%

of the car drivers surveyed would consider having a device fitted that would reduce car insurance

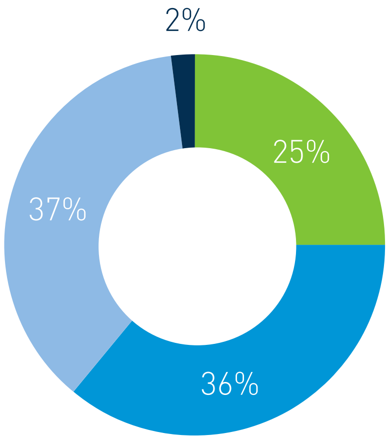
if they drove in a safer, more environmentally friendly way.



In some regions, you can use a mobile device and/or an app when using public transport (e.g. bus, train) to find out precisely when the next service arrives. Is this something you have ever used?

- Yes
- No

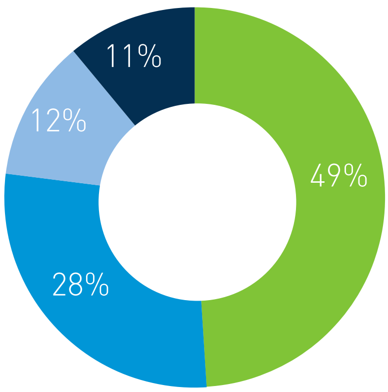
Base: *All respondents* (4,000)



Do you use public transport more often as a result of this information being available on your mobile device?

- Much more often
- Slightly more often
- Makes no difference
- Don't know

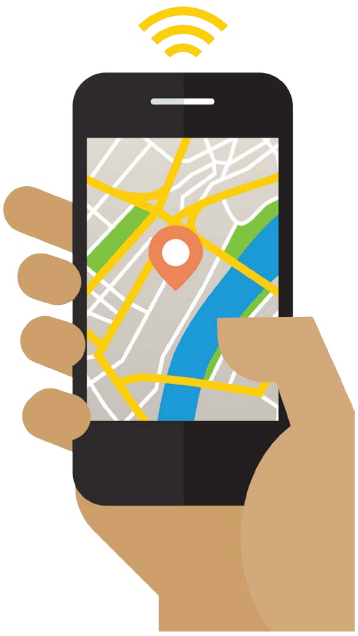
Base: *Respondents using live travel info* (1,907)



Would you be more likely to use public transport (e.g. bus, train) if by using your mobile device and/or an app you could find out precisely when the next service would arrive?

- More likely
- Unlikely
- Definitely not
- Don't know

Base: *Respondents not using live travel info* (2,093)

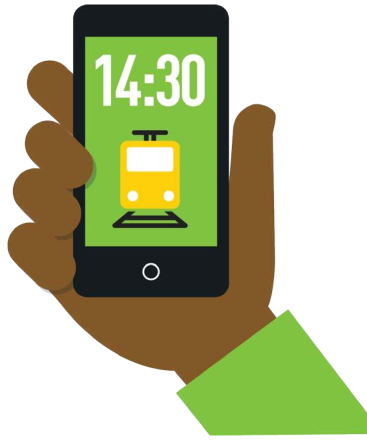


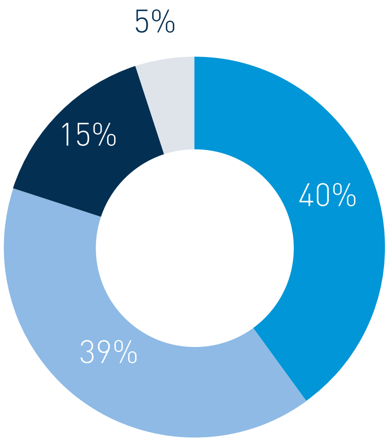
84%

of drivers who own smartphones make use of satnav apps to plan more efficient travel routes or avoid traffic.

48%

would be more likely to use public transport if they had an app to see precisely when the next service would arrive.





Self-driving cars are being developed. These high-tech vehicles would know their surroundings and the position of other cars and would effectively drive themselves. If they were fully developed and legal, would you consider using a self-driving car?

- Yes, I would consider
- Maybe
- No
- Don't know

Base: *All drivers* (3,220)

Improving driver behaviour

The HGV (heavy goods vehicle) sector accounts for 21 percent of all the UK's carbon emissions from transport. Fuel efficiency is central to reducing this. As one of the UK's largest haulage companies, Turners of Soham uses substantial amounts of fuel in more than 1,200 trucks. This fuel use represents one of the most significant overheads for the business, as well as accounting for the majority of the company's carbon emissions.

In order to reduce fuel use and carbon emissions the company made use of an award-winning smartphone app, Driver Assist, as part of its innovative fleet management strategy. The app, developed in conjunction with BT and transport consultancy Dartt, was designed to assist HGV drivers with route-planning and improved driving behaviour. It operates on a standard smartphone, without the need for any specialist hardware.

The Driver Assist app informs drivers of the most appropriate location to start good coasting, where the HGV is in gear, with zero throttle and no cruise control. Using terrain data, road layout information, vehicle speed and other sensor data, the optimum driving technique is identified to maximise fuel efficiency, reducing emissions. Safety has also been taken into account, with the app using a voice interface designed to reduce driver distraction.

Connected Working

Working and the use of mobile

Connected Working refers to the use of ICT, including mobile, in order to allow productive remote working from outside of the traditional workspace. Within this category 'work' has been defined broadly, to include not just paid employment but also education.

Practically, the enablement of remote working involves a combination of several technologies including home broadband internet access, smartphones, mobile data, productivity software and cloud computing. Because mobile communications is a part of this mix, appropriate allocations have been made for the impact of the technology within quantifications for different mechanisms, which are detailed in the methodology in Appendix 3.

The most significant carbon reductions achieved within this category are through reducing fuel use and the associated emissions from traveling back and forth from a workplace or educational establishment, or through replacing business travel to meetings thanks to audio or video connectivity. Further savings are made through reducing building energy consumption, by rationalising office space or reducing occupancy levels.

Abatement mechanisms

There are two mechanisms for which it has been possible to quantify carbon emissions abatement from mobile. These are:

- **Reducing business travel (audio conferencing):** *it is possible to reduce fuel use from business travel with audio and video connectivity through mobile, as well as access to collaborative working software.*
- **Enabling home working:** *improved connectivity helps to increase productivity and reduce travel by mobile work teams, reducing overall vehicle fuel use.*

CARBON EMISSIONS ABATEMENT FROM CONNECTED WORKING (tCO_2e/year)

	UK	Germany	Spain	France	USA	Europe
Connected Working	**810,000**	**1,340,000**	**759,000**	**1,084,000**	**6,714,000**	**7,096,000**
Audio conferencing	207,000	55,000	6,000	66,000	1,680,000	404,000
Working from home	603,000	1,284,000	754,000	1,018,000	5,034,000	6,692,000

Future opportunities

The opportunities for working outside of a traditional office environment have been discussed for a long time. The potential was first recognised in the late 1940s, as the installation of home telephones became more common. Interest was revived during the oil crisis of the 1970s and alongside the rise of affordable personal computing in the 1980s.

However, it has only been recently that many large enterprises have been seriously considering home working and the implementation of flexible working practices at scale. This shift has been driven by a number of factors, not least the availability of a range of communications technologies to allow remote collaboration and interaction. It is also likely that shifts in management techniques and a focus on the need to reduce environmental impact have played a key role in this transition.

There is a strong likelihood that the adoption of remote working practice will accelerate. For many employers it can deliver both financial and environmental benefits, which are becoming more readily accessible as the costs of the enabling technologies fall. Some of the uncertainty around the value of remote working will also be overcome by increasing awareness of the benefits, as well as examples of successful implementation.

One of the greatest barriers to the future adoption of connected working practices is a nervousness from employers and educational establishments that individuals will not perform to the same level outside of the traditional work environment. Concern has also been expressed for the wellbeing of employees, who may be encouraged to be constantly contactable outside of working hours thanks to mobile communications technology.

New approaches to supervision or management can be adopted to overcome these issues, such as monitoring practical outcomes rather than supervising process and attendance. A number of studies have found that concerns related to losses in productivity or quality did not actually occur when homeworking systems were implemented.[27,28]

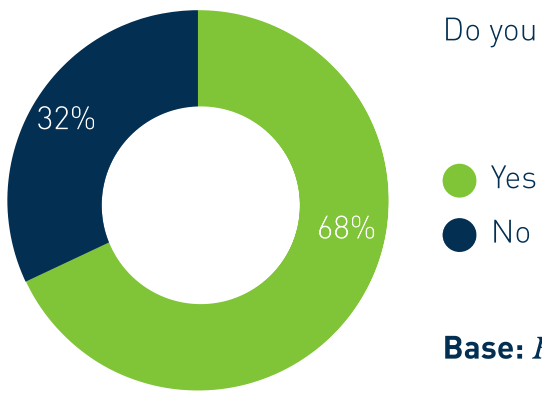
There is a strong financial and environmental case for increasing levels of working outside traditional workplaces. Previous research by the Carbon Trust found that increasing the numbers of UK employees working from home could cut annual costs for employers and employees by £3 billion and save over 3 million tonnes of carbon emissions.[29]

One company that has made use of homeworking is Cisco, where the average employee telecommutes two days a week, or three days a week if using Cisco Virtual Office technology. This has helped avoid 35 million miles of commuting a year, as well as reducing Cisco's emissions by 17,000 tonnes and providing estimated productivity savings of $333 million.

However, it is worth noting that there are some circumstances where there would not be positive savings from increased homeworking. Take for example an already energy efficient office within a big city, such as New York, in the winter. In this circumstance most of the employees would be likely to commute by public transportation, or other low carbon methods such as cycling.

Most of the typical savings in this category come from reducing emissions from transport and office energy use. But in these circumstances commuting emissions are comparatively low and increased office energy use is likely to be lower than the combination of heating multiple homes, which may not be as efficient as the office. It is therefore important that opportunities are considered on a case-by-case basis to evaluate the likely impact.

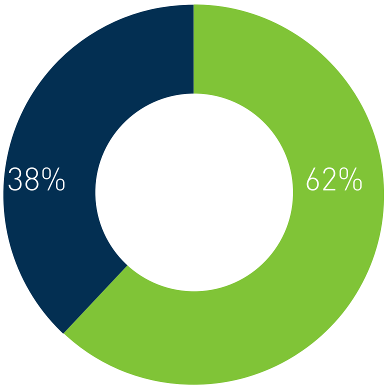
The consumer research found that of the people who use a mobile device as part of their work or studies, over 80 percent said that this enabled them to either work from home or work more flexibly. This increasing trend of flexible and home working is a great opportunity for saving on travel emissions.



Do you use a mobile device as part of your work/studies?

Base: *Respondents in work or studying* (2,946)

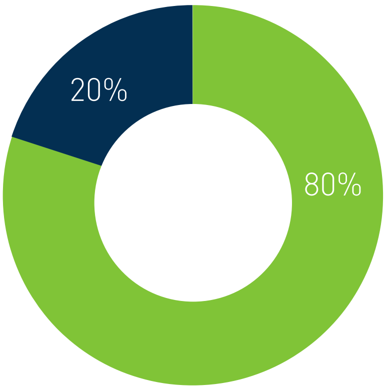
27 BT (2007) *Flexible working – Can your company compete without it?*
28 Bentley, T., McLeod, L. et al. (2013) *Future of Work Programme – The Trans-Tasman Telework Survey.* New Zealand Work Research Institute
29 Carbon Trust (2014) *Homeworking: helping businesses cut costs and reduce their carbon footprint*



Could you do your job/studies without your mobile device?

Yes
No

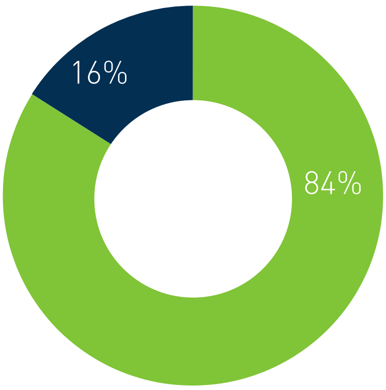
Base: *Respondents using mobile device for work or study* (1,993)



Does having a mobile device enable you to work/study from home?

Yes
No

Base: *Respondents using mobile device for work or study* (1,993)



Does having a mobile device enable you to work/study outside your normal workplace/educational establishment?

Yes
No

Base: *Respondents using mobile device for work or study* (1,993)

Flexible working practices

O2 UK, a part of Telefónica Europe, has demonstrated how mobile communications technology can be used to help a business reduce its carbon emissions. This was done through a project known as OurSpace, which took place alongside the company's move into new headquarters in the town of Slough in 2010. This location serves as the base for around 2,000 employees.

The project was designed to create a more sustainable workplace, using energy management, smart technology and flexible working patterns to reduce the company's environmental impact, save money and improve productivity.

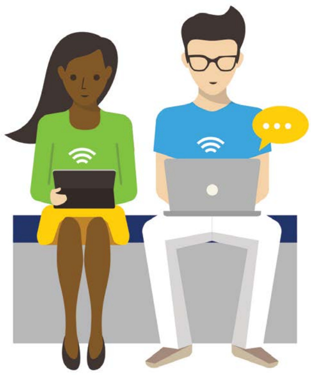
A crucial element to enable this transition was making communication flexible, whether employees were working from home or other remote locations. This involved providing all employees with smartphones with anytime, anywhere plans, allowing them to make voice or video calls, send messages or access email. Outside the office employees were also able to use low definition visual communication, through webcams and Microsoft Communicator software.

The overall results were highly impressive, with O2 achieving a 53 percent overall reduction in total emissions in its premises, as well as removing 500 desks, leading to a 36 percent reduction in average annual emissions per desk.

20%

of current abatement comes from the use of

mobile devices to enable behavioural changes in lifestyle and working patterns.



Physical to Digital

Replacing physical items with the use of mobile

Physical-to-digital refers to a broad range of applications where digital services are replacing physical goods and services. This includes certain physical devices that provide a user with the functionality to do multiple tasks which would previously have required multiple standalone devices. For example a smartphone or a tablet computer can replace the need to own a separate camera, satnav device (or a map), music player, portable video player, home telephone, calculator, alarm clock and so on. The effect in this category is commonly referred to as dematerialisation.

The main mechanism for reducing emissions is preventing the emissions associated with the production of physical goods or the delivery of services, which would otherwise have been produced or delivered if mobile communications technology was not widely available today. This includes, for example, the emissions associated with extracting raw materials, processing those materials, manufacturing items, logistics and other transportation emissions, the use of items and the final disposal of items at the end of their useful life.

Overall, the largest current reductions in this category are being made in the replacement of physical media, such as newspapers, magazines, CDs and DVDs, with digital media. This reflects the major shift that is taking place within the media industry, where new formats, digital distribution and streaming services are disrupting incumbent players. However, there are currently some significant differences between countries in the findings. This may in part be down to data availability, but it also reflects the varying pace of change in consumer behaviour within different markets for comparatively recent trends.

Abatement mechanisms

There are two grouped mechanisms for which it has been possible to quantify carbon emissions abatement from mobile. These are:

- **Increasingly multifunctional devices:** *smartphones are replacing multiple devices that were separately produced in the past, such as cameras, calculators, music players, alarm clocks and satnavs, avoiding embodied emissions from their continued production.*

- **Access to digital media:** *mobile devices are being used to provide access to digital media such as images, news, music and video, avoiding emissions from the production and transportation of photographs, newspapers and magazines, CDs and DVDs.*

CARBON EMISSIONS ABATEMENT FROM PHYSICAL-TO-DIGITAL (tCO_2e/year)

	UK	Germany	Spain	France	USA	Europe
Physical-to-Digital	**90,000**	**109,000**	**72,000**	**63,000**	**743,000**	**891,000**
Multi-functional device	9,000	41,000	66,000	36,000	132,000	556,000
Newspapers, music, DVD, storage.	81,000	68,000	7,000	27,000	611,000	335,000

Future opportunities

There is every reason to expect that the process of dematerialisation will continue in a number of areas of consumer spending. The most prominent impact to date has been seen in the media. The publishing, music, film and television industries have already gone through seismic shifts over the past decade.

This has involved major disruptions to incumbent business models alongside the growth of digital distribution methods, creating both winners and losers. Businesses focusing on devices or digital content, such as Amazon, Apple and Netflix have thrived. Companies that relied on physical media have done rather less well. For example Blockbuster had 9,000 stores and 60,000 employees at its peak in 2004 and almost ceased to exist by 2014.[30]

The consistent pattern has been the rapid increase in the digital consumption of media, a transition which shows no sign of slowing globally. This has no doubt been spurred on by the growing availability of mobile devices and data services that allow easy access. As marketing increases for digital content services, supported by a focus on digital business models by content producers and improvements in the quality of user experience, this should accelerate the decline of physical media.

But although there are clear and readily quantifiable emissions reductions associated with the decline of physical media, it should be noted that there are also less readily quantifiable rebound effects from the emissions associated with the consumption of digital media.

30 Harress, C. (2014) *The Sad End Of Blockbuster Video: The Onetime $5 Billion Company Is Being Liquidated As Competition From Online Giants Netflix And Hulu Prove All Too Much For The Iconic Brand.* International Business Times. [Available at: http://www.ibtimes.com/sad-end-blockbuster-video-onetime-5-billion-company-being-liquidated-competition-online-giants]

The network infrastructure to support the dissemination of digital media – in particular streaming services – has a high electricity demand. Improving the availability of media may also be increasing the total consumption levels. There is therefore a need to ensure that as services are digitised, the network infrastructure providing this is powered by low carbon electricity and run as efficiently as possible, in order to keep emissions down.

The use of multiple functions on single devices is also becoming far more normal and is likely to continue to accelerate. As the adoption rates of smartphones have increased, there has been a corresponding decline in the sales of standalone devices where the functionality has been replicated on a smartphone. In 2010 the USA imported almost 24 million electrically powered alarm clocks, but by 2014 this had dropped to just over 16 million.[31]

Indeed, adding new functionality to smartphones can have a hugely disruptive effect and very quickly make an impact on the production of certain categories of goods. For example, group revenues at the leading manufacturer of standalone GPS devices, TomTom, plummeted after satnav was introduced as a free feature on Android smartphones through the Google Maps app: from €634 million in the last quarter of 2007 to €213 million in the first quarter of 2009.[32]

However, even though multifunctional devices do act to reduce the total emissions, they also have associated emissions from their own production. There is therefore still an issue related to the emissions and electronic waste attributable to multifunctional devices.

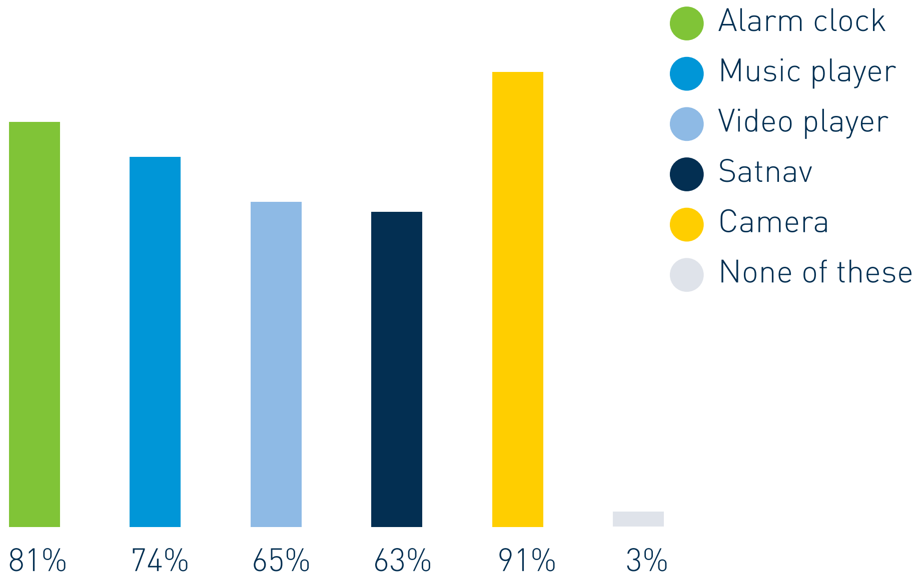
The current obsolescence of smartphones just a few years after they are produced is potentially a serious source of emissions likely to continue into the future, particularly given the growing number being produced now that market penetration is rapidly increasing in both the developed and developing world. Further work on looking at what happens to smart devices at the end of their useful life will be required, such as exploring the potential for recycling or remanufacturing. Some promising approaches are currently being developed to address this issue of obsolescence, with new modular smartphones such as Phonebloks and Google's Project Ara being developed.

The consumer research found that a very significant percentage of people already use their smartphone as a multifunctional device, and that significant numbers of people already do or would be willing to use their smartphone functionality to replace the use of physical products.

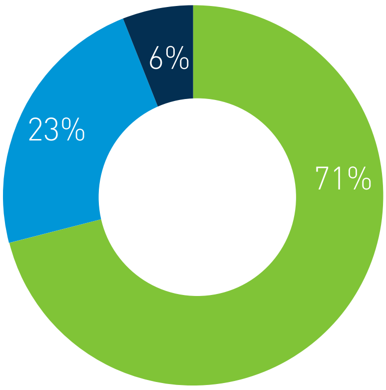
31 UN Trade Statistics available at: http://comtrade.un.org/data/.

32 Arthur, C. (2015) *Navigating decline: what happened to the TomTom?*. The Guardian. [Available at: http://www.theguardian.com/business/2015/jul/21/navigating-decline-what-happened-to-tomtom-satnav]

Do you currently use any of the following functions on a mobile device (smartphone/mobile)? Choose all that apply.



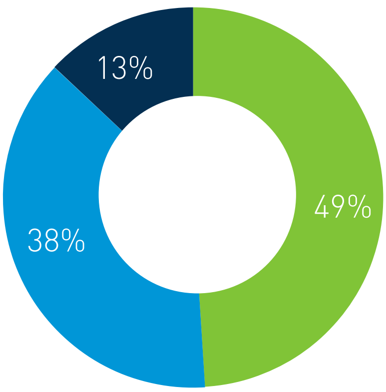
Base: *All respondents* (4,000)



Are you, or would you be willing in future, to replace the use of other devices with a smartphone (e.g. camera, alarm clock, music player, satnav)?

- Already do this
- Willing to do this
- Not willing to do this

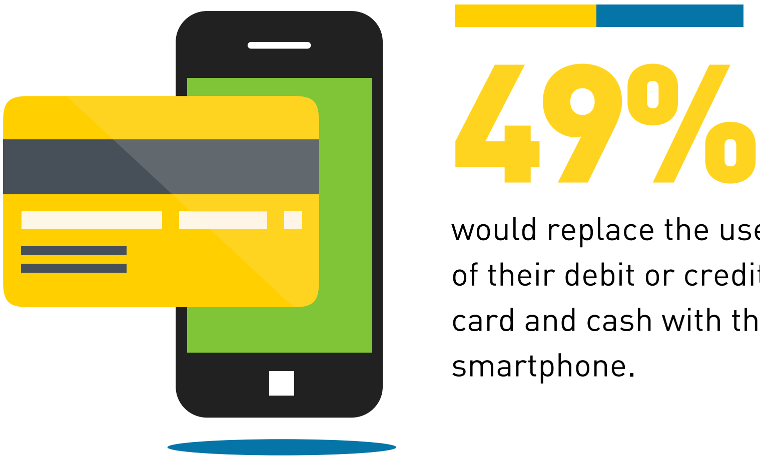
Base: *All respondents* (4,000)



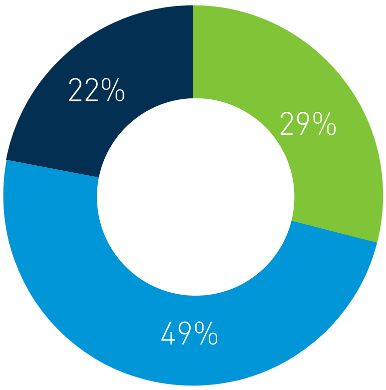
Are you, or would you be willing in future, to use a mobile device to replace the purchase of physical products with digital products (e.g. newspapers, books, music)?

- Already do this
- Willing to do this
- Not willing to do this

Base: *All respondents* (4,000)



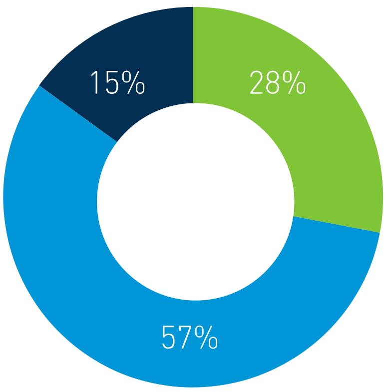
would replace the use of their debit or credit card and cash with their smartphone.



Are you, or would you be willing in future, to use a mobile device for payments to replace your credit/debit card or cash use?

- Already do this
- Willing to do this
- Not willing to do this

Base: *All respondents* (4,000)



Are you, or would you be willing in future, to use a mobile device to replace the use of tickets for travel or events?

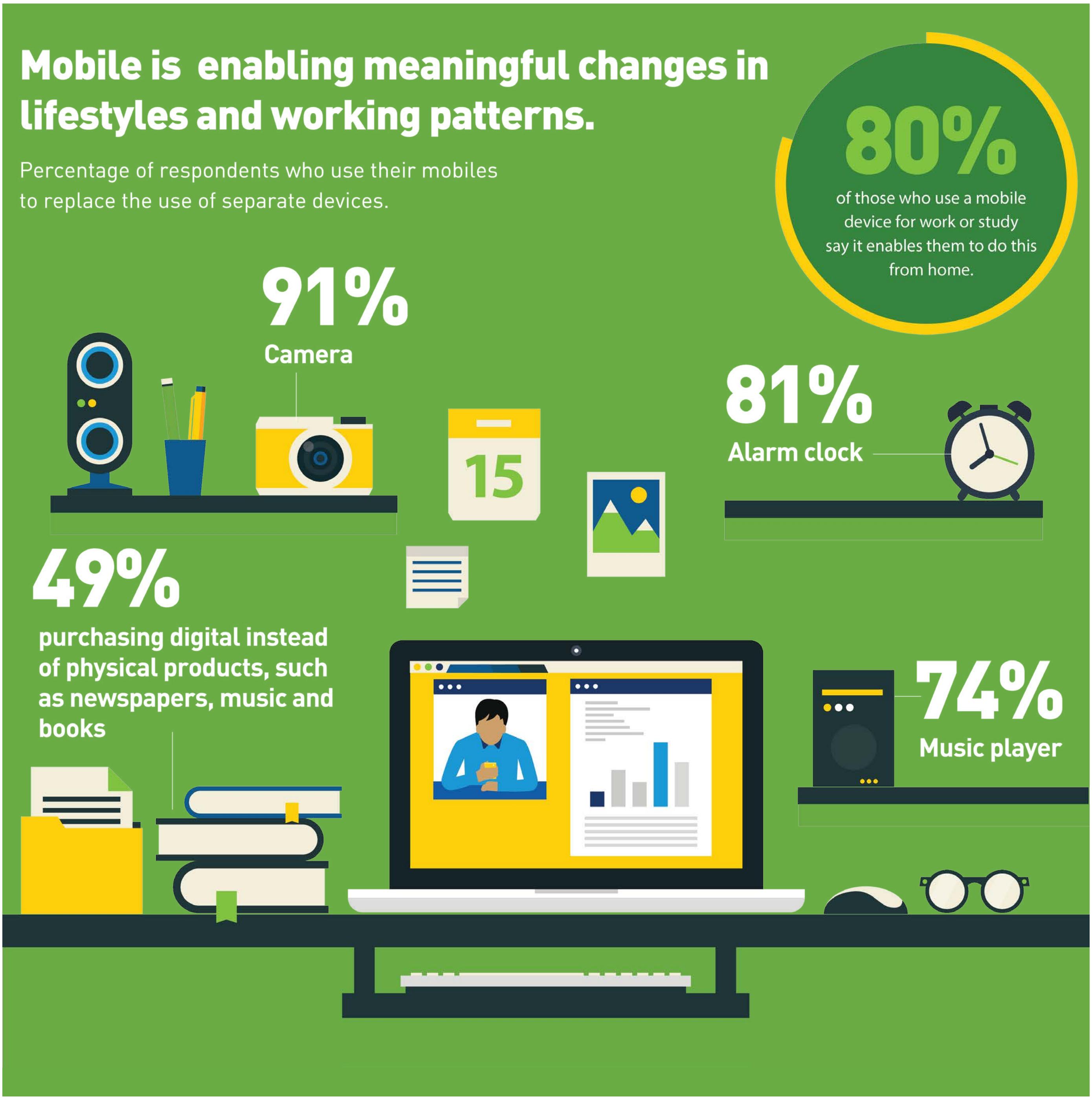
- Already do this
- Willing to do this
- Not willing to do this

Base: *All respondents* (4,000)

Multifunctional devices

Independently reviewed industry data shows that the carbon emissions from manufacturing a high end smartphone are significantly lower than the total of production emissions from devices it can replace.

Analysis conducted by Fraunhofer IZM in 2014 found that smartphone manufacturing emissions were less than half that of separately producing five common single-function devices: an MP3 player, compact digital camera, feature phone, portable games console and navigation system. This calculation did not factor in other devices that are often replaced by smartphones, such as alarm clocks, timers or ebook readers.



Conclusion and discussion

Following the completion of the Carbon Trust's assessment into the influence of mobile communications technology on reducing global carbon emissions across a wide range of applications, it is clear that it is already having a substantial impact. This outstrips the total direct emissions[33] associated with the provision of mobile today by a factor of five. It is having a net positive impact.

The total quantified abatement of carbon emissions from mobile communications technology today in the USA and Europe is the equivalent of a reduction of 180 million tonnes of CO_2e a year. This is not insubstantial. It is greater than the entire direct annual emissions of many large national economies, such as the Netherlands or Pakistan.

M2M technologies are responsible for the greatest part of these emissions reductions, with around 70 percent of the total quantified abatement accounted for by their use in the buildings, transport and energy sectors. In many ways this is an unsurprising conclusion, although the scale of the savings enabled is impressive given the relative novelty of the technologies.

Between them, the energy, transportation and buildings sectors represent almost half of global emissions. And M2M technologies are already being widely used to enable efficiencies that simultaneously deliver both commercial and environmental benefits, which can be achieved without the need for substantial behaviour change. There is therefore a strong business case driving their adoption and this is only likely to increase with further demonstrations of success, falling costs and improvements in technologies.

One of the barriers to unlocking future opportunities in sectors where M2M technologies could be widely used – such as buildings, energy, transport, cities and industry – is that substantial capital investment can be required to unlock the benefits. It is rarely a quick and cheap process to retrofit large numbers of buildings, replace commercial fleets, build new energy grids, upgrade city infrastructure or buy new industrial plant equipment.

But climate change remains a key driver that means that a lot of things will need to be changed around the world to help reduce carbon emissions. This will mobilise the capital required for change. Mobile communications technology can help to enable this and there is every reason to expect it will be integrated as a core element.

Key Findings

- The carbon emissions abatement enabled by mobile communications technology today is approximately five times greater than the carbon emissions from mobile networks.
- Use of mobile communications technology is currently enabling a total reduction of **180 million tonnes of CO_2e** a year across the USA and Europe. This amount is greater than the annual carbon emissions from the Netherlands and equivalent to **1.5 percent** of all greenhouse gas emissions from the USA and Europe.
- **70 percent** of current abatement comes from the use of machine-to-machine (M2M) technologies in the buildings, transport and energy sectors, where devices are able to communicate automatically with each other without requiring human intervention.
- **20 percent** of current abatement comes from use of smartphones to enable behavioural changes in lifestyles and working patterns.
- Significant future opportunities exist to reduce emissions from cities, healthcare and agriculture through the use of mobile communications technology, although the impact of these areas today is relatively small.
- The total carbon emissions abatement from mobile communications technology is expected to grow at least three times larger over the next five years (to about **500 million tonnes** of carbon emissions abatement per year across the USA and Europe), given current projections of the increase in deployment of M2M technologies.
- International consumer research shows high levels of willingness for smartphone users to adopt behaviours that will result in reduced personal carbon emissions, enabled by functions or apps on their mobile devices. The greatest impact today is through connecting with family and friends using voice or video calls, replacing physical journeys.

33 Total emissions of networks as calculated by other studies. See Appendix 1 ('Emissions of mobile networks') for further explanation.

In other sectors, the quantified impact on emissions reduction today is very small because technologies are not fully mature, although they are being rapidly developed. In categories such as healthcare and agriculture, significant emerging opportunities exist. The speed with which they are adopted will depend on the willingness of practitioners to adopt new technologies. This will require some measure of behaviour change alongside the development and demonstration of innovative technologies.

Currently a smaller percentage of the overall quantified carbon emissions abatement in this report comes from use of smartphones and other communications technologies to enable behavioural changes in lifestyles and working patterns. Human behavioural change is often a slower and more complicated process than changing technology.

Fortunately, the consumer research conducted for this report shows high levels of willingness for individuals to adopt behaviours in their lives that will result in reduced personal carbon emissions. These will commonly be enabled by functions or apps on their mobile devices, many of which are currently being developed and marketed to make them more attractive to users.

While the impact today is promising, it is only a fraction of the identified potential that has been identified. Although there has been some early progress on opportunities in categories such as buildings and transportation, most of the benefits have yet to be unlocked.

This is likely to change rapidly. Based solely on projections of growth in M2M connections within the USA and Europe, without factoring in any possible changes in behaviour or increased efficiencies, the annual carbon emissions abatement calculated in this report should more than triple over the next five years.

There are good reasons to expect that the real impact is likely to be more substantial than this. Research suggests that there are numerous additional efficiencies and innovations, however it has not been possible to quantify these due to lack of data availability.

Recent estimates produced by Accenture in GeSI's SMARTer 2030 report indicate that the ICT sector as a whole, including but not limited to mobile, could enable an annual global saving of 12 billion tonnes of carbon emissions by 2030. The SMARTer 2030 report estimates that this would be equivalent to a 20 percent reduction in global emissions at that time and is approximately 65 times greater than the abatement calculated within this report for the USA and Europe.

Mobile communications technology represents a substantial part of the expected future growth of the ICT sector, particularly in the developing world where it can obviate the need for fixed line infrastructure. But to ensure that sustainability benefits are fully realised alongside that growth it will be necessary to put in place conditions that will promote success.

To unlock the full potential of mobile communications technology to enable carbon emissions reduction, consumer and business behaviour will need to change, current solutions will need to be deployed at scale, technology innovations will be required, and regulatory obstacles across a wide range of sectors will need to be overcome.

The analysis completed for this report has highlighted four levers that can be used to accelerate the benefits of mobile communications technologies on carbon emissions abatement. These are:

- **Enabling technology:** *there is a need to invest in innovative or disruptive new technologies that enable better, low energy access to mobile communications, as well as creating the enabling network infrastructure for connections around the world.*
- **Implementing solutions:** *businesses and governments need to adopt and scale up the mechanisms that are effective in reducing carbon emissions today, as well as exploring novel uses for mobile communications technology that can achieve further reductions.*

- **Policy landscape:** *governments can accelerate progress by supporting common standards and developing appropriate regulatory oversight, as well as advancing deployment by the use of incentives and disincentives, such as support for improved connectivity or putting a strong price on carbon emissions through cap-and-trade schemes and taxes.*
- **Changing behaviour:** *there is a significant opportunity to use mobile to support organisations and individuals by developing simple, useful tools that offer lower carbon options and services.*

Further work will be required to better understand how practical progress can be made in each of these four areas in order to unlock the full potential of the carbon abatement from mobile. More detailed discussion of some of the change-levers and significant barriers, categorised by sector and geography, can be found in GeSI's SMARTer 2020 report written by the Boston Consulting Group.[34]

There are promising early indications that things are moving in the right direction. There is already strong consumer adoption of mobile devices, as well as high levels of apparent willingness to use apps that can enable low carbon behaviour. Mobile enabled business models have already disrupted the status quo in a number of industries, experiencing rapid growth in some cases, which suggests that the commercial case for action is strong. And governments are working with the ICT industry to increase coverage and connectivity, recognising this is now a critical part of a modern national infrastructure.

The climate change occurring as a result of increasing global carbon emissions is one of the greatest challenges ever faced by human civilization. There are very few easy answers on how to increase prosperity at the same time as minimising long term risks of harm to the environment and people. But greater deployment of mobile communications technology appears to be an effective tool to do both, providing a rare win-win opportunity.

Given the clear potential for mobile communications technology to be used as an effective tool in mitigating climate change, serious thought ought to be given by both government and industry into how to magnify its impact today. This will help ensure that the greatest possible benefits can be realised without undue delay, to help meet this urgent global challenge.

34 Boston Consulting Group (2012) *SMARTer 2020: The Role of ICT in Driving a Sustainable Future. Global e-Sustainability Initiative.* Brussels.

Appendix 1: Methodology for assessing carbon abatement

Overview of methodology

The objective of the methodology is to calculate the current carbon abatement from mobile communications technologies at a country-by-country level for 2015.

A number of distinct mechanisms were identified that could reduce carbon emissions, and for each mechanism a calculation methodology was defined. Using data from specific studies or assumptions, a carbon abatement factor was derived. The carbon abatement factor is relevant to a volume factor that represents the quantity for the mechanism. This volume factor can be the number of relevant M2M (Machine-to-Machine) connections or could be the number of smartphones or the proportion of people using a specific application.

Carbon abatement = volume x carbon abatement factor

Scope

Definition of mobile

The scope includes any carbon abatement enabled by mobile communications technology.

This primarily includes both use of mobile phones and use of M2M technology.

Additionally, usage of Wi-Fi is included, where this is itself connected using mobile communications, or where public Wi-Fi is provided. Also other wireless frequency bands (e.g. license-free ISM) bands are included where these are then connected using mobile communications; this includes LPWA (low power wide area) networks. The future growth area for mobile communication including communication via drones, satellites and balloons is also included within the scope of the report (although of these only satellite has any significant impact at present).

Geography

The scope of this report is to calculate the carbon abatement from mobile for the USA and Europe. The carbon abatement for Europe is calculated using UK, Germany, France, and Spain as a sample of representative countries. An average of the carbon abatement factors for these four countries is then multiplied by the relevant volume factors for Europe.

The definition for Europe follows that used by Machina Research, *"All of Europe including Russia, the Caucasus republics and Turkey and all points west, including Greenland and Iceland."*

Scope of abatement

Carbon abatement is included from mechanisms where mobile has a fundamental role in providing the enabling effect (in other words the outcome would not happen without the existence of the mobile technology). Where the abatement mechanism is shared between fixed and mobile telecommunications networks, an allocation factor was used (see below section on 'Allocation to Mobile'). For some mechanisms, the ICT or mobile technology may only be partly responsible for the carbon abatement (e.g. for example other technologies such as laptop computers, or other infrastructure may be required). No attempt was made to allocate the abatement between different technologies.

Exclusions

Mechanisms were only included where there was a clearly defined carbon abatement mechanism, which was supported by credible data or reasonable assumptions. Therefore there were a number of mechanisms that were identified but could not be included in the final analysis.

The analysis for each mechanism calculated the carbon savings from the mechanism, but did not include the emissions of the ICT technology enabling the mechanism. However, an overall comparison of the carbon abatement compared with the carbon footprint of mobile networks is provided (see 'Emissions of mobile networks' below in Appendix 1).

Rebound effects have not been included in the calculation of the carbon abatement, except for home working where the effects of home energy consumption and increased personal errands were included in the calculation, as these can be identified and quantified relatively easily. For further discussion of rebound effects see Appendix 6.

List of mechanisms

The following ten categories were identified as the key areas where mobile has the opportunity to deliver carbon abatement:

Connected Agriculture
Connected Buildings
Connected Cities
Connected Energy
Connected Health
Connected Industry
Connected Living
Connected Transportation
Connected Working
Physical to Digital

Over one hundred mechanisms were identified within these ten categories. This was reduced to about sixty mechanisms that had a clear abatement mechanism with credible data to support the calculations. The mechanisms with calculation methodologies and key assumptions are listed in Appendix 3.

Therefore the overall result is likely to be an underestimate of the benefit. A conservative approach has been taken so the total does not include some categories which have been excluded either because of lack of suitable data, or because they were assumed to have a minimal impact. Additionally, there are areas where ICT is so integrated into everyday activities that it is difficult to separate out the effects of ICT, and no systematic statistical data will exist.

Calculation, data and assumptions

For each mechanism, a carbon abatement factor is calculated based on a combination of studies, case studies, data points, national statistics, and reasonable assumptions. Wherever possible, academic or industry studies were used to provide key data points. Again, where possible, multiple sources have been used to allow cross-checking and provide confidence in the data. Where multiple sources show different percentage savings, then either an average, or lower than average value has been used. In some cases where the studies provide an unlikely high percentage saving, then there has been an arbitrary reduction to the saving to err on the side of caution. This is considered to be reasonable if the studies have been undertaken in a trial or idealised situation, and cannot be extrapolated to a wider, more generic situation.

Where there was a lack of credible data points, or to support the existing data, then reasonable assumptions have been used (see Appendix 3 for details).

For a number of the mechanisms, the carbon savings are based on consumer behaviour changes. This is particularly so for these three categories: Connected Living, Connected Working and Physical-to-Digital. In some of these cases the results from the consumer survey data commissioned by the Carbon Trust were used to support the calculations. For further details of the consumer survey see Appendix 5.

In the consumer survey, respondents were asked if they sometimes or frequently undertook certain behaviours; in these cases it was assumed that '*sometimes*' equates to 10% use, and '*frequently*' equates to 30% use.

Volume factors

To calculate the carbon abatement for each mechanism the carbon abatement factor is multiplied by the volume factor. For the majority of the mechanisms the volume factor is the number of M2M connections. Data on the number of M2M connections was provided by Machina Research. The categorisation of the M2M connections is described on page 81. For 15 of the categories the volume factor used is related to the number of people effecting the mechanism (e.g. number of smartphones, number of mobile phones, or population).

Carbon savings - emission factors and embodied carbon

The carbon abatement savings come primarily from savings in energy (gas or electricity) or reductions in transport. Carbon emission factors for gas, electricity and different forms of transport are used to convert the savings into CO_2e figures. The emission factors used are those provided by Defra, and are full life cycle factors (i.e. electricity factors include upstream supply chain emissions and downstream distribution losses; fuel factors include upstream 'well-to-tank' emissions). Electricity factors are used for the different countries (UK, Germany, France, Spain and USA). Electricity emission factors are from Defra (2015), and transport emission factors are from Defra (2014).

Carbon savings due to reductions in embodied carbon have not been included except for the two 'Physical-to-Digital' mechanisms, where the savings are predominantly from reductions in physical devices or physical media.

Transparency

The intention of this report is to be completely transparent in how the calculations of the carbon abatement have been made, and the underlying data and assumptions. If additional information or further clarification is required regarding the calculations, the data used and the assumptions, then this can be provided by the Carbon Trust on request.

Example calculations

To help illustrate the calculations, the following two examples are explained:

Building energy management systems for commercial buildings using smart meters

The carbon abatement is from the reduction in energy use in commercial buildings from energy management systems. This is enabled through the provision of smart meters to collect energy data. The smart meters are connected using M2M technology, the assumption being that each M2M connection represents one smart meter.

Volume factor: number of smart meters used for such systems today = number of M2M connections

Data source: number of business smart meter M2M connections from Machina Research (these are factored to only include the connections related to mobile).

Carbon abatement factor: carbon reduction per smart meter. This is derived from case studies (e.g. Vodafone ASB bank case study,[35] and case studies in the Better Buildings Partnership "Better Metering Toolkit"[36]). These give energy savings of between 7.5% and 25%. A mid-range value of 14% has been assumed. Combined with the typical number of smart meters per floor area, and typical energy consumption per floor area, an energy saving and therefore carbon saving per smart meter can be derived.

Fleet vehicle driver behaviour improvement

The carbon abatement is from the reduction in fuel use due to improved driver behaviour. This is the result of both feedback on driving performance (e.g. speed, acceleration, braking, cornering) from telematics enabled through M2M technology, and management intervention to encourage better driving techniques (e.g. training, incentives, scorecards).

Volume factor: number of connected vehicles = number of M2M connections

Data source: number of fleet management M2M connections from Machina Research.

Carbon abatement factor: carbon reduction per vehicle. This is derived from various studies that give a range of 5% to 20% for the fuel saving factor, depending on the level of intervention. A mid-range value of 10% as typical has been assumed. This is combined with average vehicle emissions per km (from Defra emission factors), and typical annual distance for vehicles (available from national statistics). A mix of vehicle types is assumed (20% car, 60% LGV, 20% HGV) based on typical split of M2M connections for fleet management, which is from Carbon Trust analysis of source data.

Detail of methodologies

Appendix 2 lists the carbon abatement factors calculated for each mechanism.

Appendix 3 lists the calculation methodologies, key assumptions and reference sources for each of the mechanisms.

All sources and references are listed in Appendix 4.

35 Vodafone (2012). *ASB Bank Case Study*

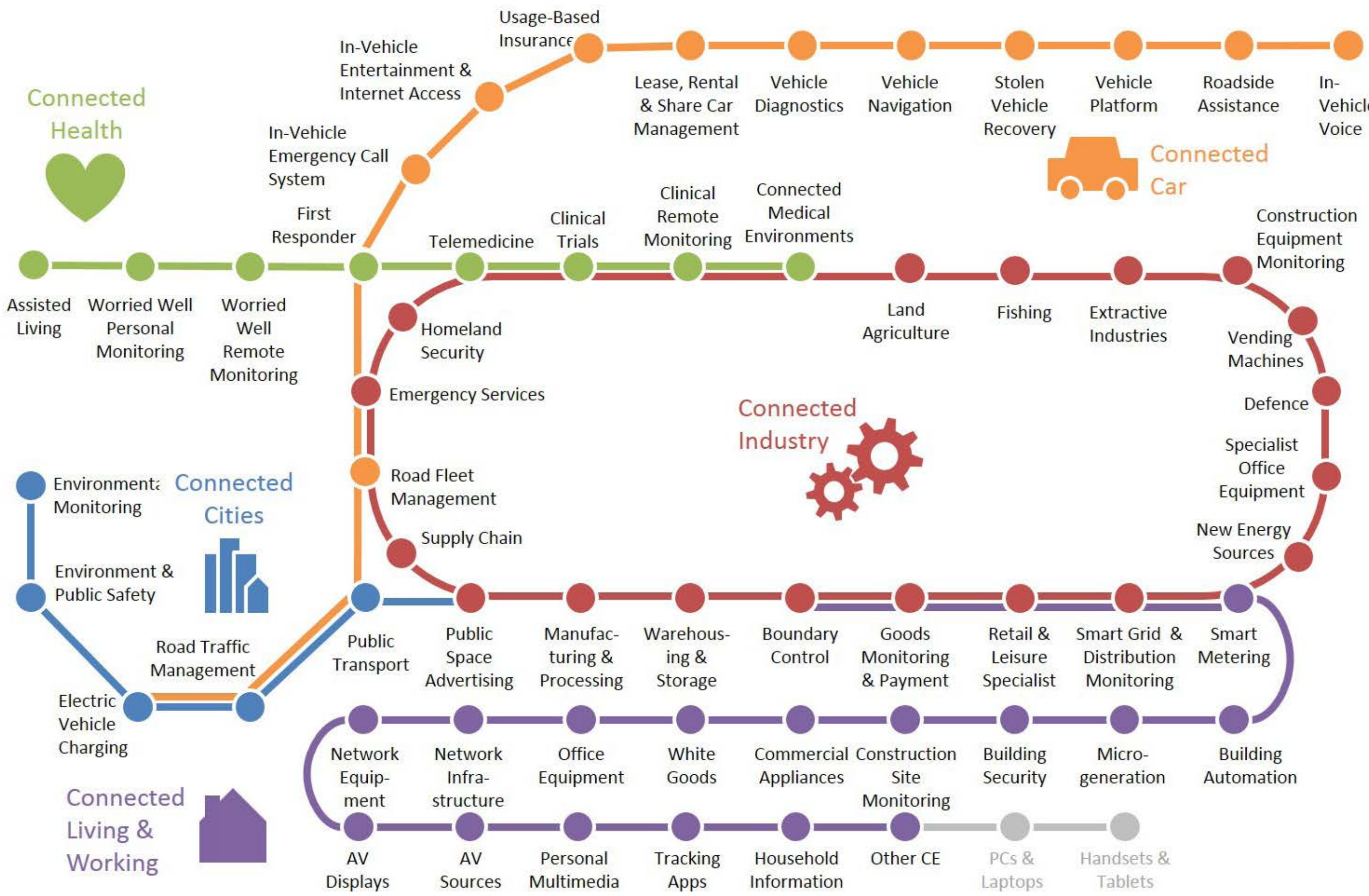
36 Better Buildings Partnership (2011). *Better Metering Toolkit. A guide to improved energy management through better energy metering*

M2M connections data

Mapping to M2M categories

For categories that have a carbon abatement related to the number of M2M connections, data has been used on the number of M2M connections provided by Machina Research. Machina Research categorise the M2M connections into the following five sectors: Car, Health, Cities, Industry, and Living & Working. Each of those sectors breaks down into a number of 'application groups', as illustrated in the diagram below.

Usually the relationship of M2M connections to the number of services was one-to-one. However, in some case additional conversions were applied (for example, number of connected smart meters per commercial office unit of floor area). These are explained in the assumptions listed in the table in Appendix 3.



In total there are 60 application groups. Each of those application groups break down into a number of separate applications. For instance 'Smart Metering' splits between gas, electricity and water for both business and residential. In total across all 6 sectors and 60 application groups, there are around 200 separate applications.

Carbon abatement mechanisms have been matched to the relevant M2M categories confirming the mapping in collaboration with Machina Research. For some mechanisms there may be multiple M2M applications that relate to the same mechanism.

The categorisation of the M2M applications is quite detailed, and each application is unique, thus there is not double counting due to overlapping M2M categories. However, there may be some M2M applications where the carbon abatement is only relevant to a sub-set of the M2M connections; in these cases there may have been an overestimation of the savings (although in selecting carbon abatement factors the approach has been conservative or used averages, which should balance out any overestimation of the applicable M2M connections).

Allocation to mobile

For each application Machina Research provides the number of M2M connections for the following technologies: Cellular (2G, 3G, 4G); Low power wide area (LPWA); Metropolitan Area Networks (MAN); Satellite; Short range; Wide area fixed. It is considered that all cellular, LPWA and satellite connections are mobile. A percentage of MAN and short range connections are also allocated to mobile (the percentage value was provided by Machina Research). Wide area fixed were not included, as these relate only to fixed (non-mobile) connections.

Sources and references

In choosing studies for data points, the Carbon Trust has aimed to select reliable sources such as academic or industry studies. The references used are listed in Appendix 4.

For national data primarily national government statisticshave been used, including data from Defra,[37] Eurostat,[38] World Bank[39] and UNECE.[40]

Review process

All the calculations were subject to internal cross-checking and review by the Carbon Trust. The methodologies, calculations, assumptions and data were all critically reviewed. The results and calculations were also reviewed by the GeSI Steering Committee.

Comparisons and cross-checks

In addition to the review process, a number of sense checks and comparisons with other studies were made.

Carbon abatement factors and methodologies were compared with other pzrojects where data has been published (these being primarily those of mobile telecommunications operators).

Total carbon abatement figures were compared with other published studies, these included studies published by mobile operators and reports such as the Mobile's Green Manifesto,[41] Carbon Connections[42] Connected Agriculture,[43] Spain 20.20[44] and the SMARTer2030[45] reports. Direct comparisons were not possible as these studies were looking at different time periods or had slightly different scopes in terms of geography or categories, however useful checks were able to confirm that the results were comparable in broad terms of magnitude. Other comparisons between studies have also been undertaken and some of these are summarised in a paper by Ericsson Research.[46] It is fair to say that this analysis is at a more detailed and comprehensive level than most of the other reports which have tended to take a more macro approach, and therefore direct comparisons are not necessarily helpful.

37 Department for Environment, Food and Rural Affairs (DEFRA), Greenhouse Gas Conversion Factor Repository, available at: http://www.ukconversionfactorscarbonsmart.co.uk/

38 Statistical office of the European Union, Eurostat database, available at: http://ec.europa.eu/eurostat/data/database

39 The World Bank, World Bank Open Data, available at: http://data.worldbank.org/

40 United Nations Economic Commission for Europe (UNECE), on-line statistics, available at: http://w3.unece.org/PXWeb/en

41 GSMA (2012), *Mobile's Green Manifesto 2012*.

42 Vodafone (2009), *Carbon Connections: Quantifying mobile's role in tackling climate change.*

43 Vodafone (2011), *Connected Agriculture: The role of mobile in driving efficiency and sustainability in the food and agriculture value chain*

44 Club de Excelencia en Sostenibilidad (2012), *Spain 20.20 : ICT and Sustainability*

45 Accenture Strategy (2015) *SMARTer2030: ICT Solutions for 21st Century Challenges*. Global e-Sustainability Initiative. Brussels.

46 Malmodin et al, (2014), *Considerations for macro-level studies of ICT's enabling potential.*

The number of M2M connections was compared with the same studies as used for the comparison of the carbon abatement figures.

Additionally a number of "sense checks" were made with other published data, for example the number of households in a country should be greater than the number of M2M connections for households (assuming that not all households are connected).

Where anomalies were identified, then there was a re-checking of the data and assumptions used, and in some cases either additional data sources were used or the assumptions were modified.

Considerations and limitations to methodology

Uncertainty

Uncertainty describes how accurate results are or how close to the 'true' value a result is. Typically the uncertainty will relate to a statistical or probability assessment of the results. The calculation of the carbon abatement figures uses various data sources including the volume data (e.g. number of M2M connections, number of smartphone users, population number), and other factors to calculate the carbon savings. However, the result is highly dependent on percentage saving factors and assumptions. While the volume factors could be analysed on a statistical basis to assess their impact on the uncertainty of the result, the saving factors have insufficient data points to be analysed statistically. Therefore, in order to avoid optimistic results,conservative factors were selected from data where a range of factors were available to choose from.

Overlaps / double counting

Some of the carbon abatement mechanisms cover similar or related areas. As a result of this the Carbon Trust's team has been careful to avoid any overlaps or double counting. For example, the mechanisms for smart meters and HVAC control both relate to energy savings in buildings. However, the mechanism for smart meters assumes behavioural changes to reduce energy consumption, while HVAC control is assuming automatic control changes. Also, the volume metrics for the two mechanisms are separate M2M categories and do not overlap.

Emissions of mobile networks

In calculating carbon abatement figures the Carbon Trust has calculated the savings in carbon emissions from the mechanisms supported by mobile communications technology. This has not included a subtraction of the emissions related to the use of the mobile technology. In practice this is likely to be small compared to the abatement for each mechanism. It is possible to put this into context by comparing the total abatement on a regional basis with the total emissions from mobile networks.

The energy used by mobile networks has been estimated by various studies, with GSMA having conducted one of the more detailed analysis. The unique difference in this study is that it is based on actual energy data provided by mobile operators, with gaps in data being interpolated and analysis has accounted for variation in key factors in population density, average ambient temperature, and data volumes. The GSMA data includes both energy consumption from grid electricity and energy consumption from diesel used to power generators for base stations.

The GSMA Mobile's Green Manifesto 2012[47] gives a total annual global figure for mobile networks of 120TWh energy consumption for the year 2010.

Other studies broadly corroborate these figures of energy consumption for mobile networks, however it is not straightforward to compare these directly. As mentioned, the GSMA figures include energy from diesel generation, which can be significant in certain countries, while most other studies only calculate the electricity consumption. A number of studies are primarily looking at forecasts of energy consumption, rather than the current measured consumption and use estimation factors to project the total energy, as opposed to the GSMA figures based on data from a variety of network operators. Also, differences in definition of what is included in the "network" will have an impact on the resulting energy figure for different studies – for example, the following may or may not be included: the network operator's own offices, retail stores and data centers; as well as core switching sites and transmission.

After removing the energy due to diesel generation and efficiency losses, the GSMA figure is about 80TWh purely for electricity consumption. This compares closely with the figure quoted by Fehske et al[48] of 77 TWh projected for the year 2013.

Other studies have also used estimation techniques based on average energy consumption: for example, Andrae and Edler[49], Lambert et al[50], Scheck[51].

However, the energy consumption of the mobile networks is only responsible for part of the total carbon emissions from the use of the network. Other emissions are due to the embodied emissions of both the network and of the mobile devices. Fehske et al[52] estimate the global carbon footprint of mobile communications for 2014 as 170 $MtCO_2e$, attributing 38% (64.5 $MtCO_2e$) to the operation of the mobile network. This is also similar to the figures presented in Ericsson's Energy and Carbon Report November 2014[53].

The GSMA Mobile's Green Manifesto 2012[54] figure of total annual global energy consumption for mobile networks of 120TWh is equivalent to 70 $MtCO_2e$ (this is for the year 2010). This includes 7.4 $MtCO_2e$ for Europe and 8.2 $MtCO_2e$ for North America.

These figures are compared in the following table and chart.

47 GSMA (2012), *Mobile's Green Manifesto 2012.*

48 Fehske et al (2011), *The Global Footprint of Mobile Communications: The Ecological and Economic Perspective*

49 Andrea, A. and Edler, T. (2015), *On Global Electricity Usage of Communication Technology: Trends to 2030*

50 Lambert, S. et al (2012), *Worldwide electricity consumption of communication networks*. Opt. Express 2012, 20, B513–B524.

51 Scheck, H. (2013), *User equipment receiver sensitivity: The forgotten mobile network efficiency factor*. European Telecommunication Standards Institute

52 Fehske et al (2011), *op. cit.*

53 Ericsson (2014), *Ericsson Energy and Carbon Report*

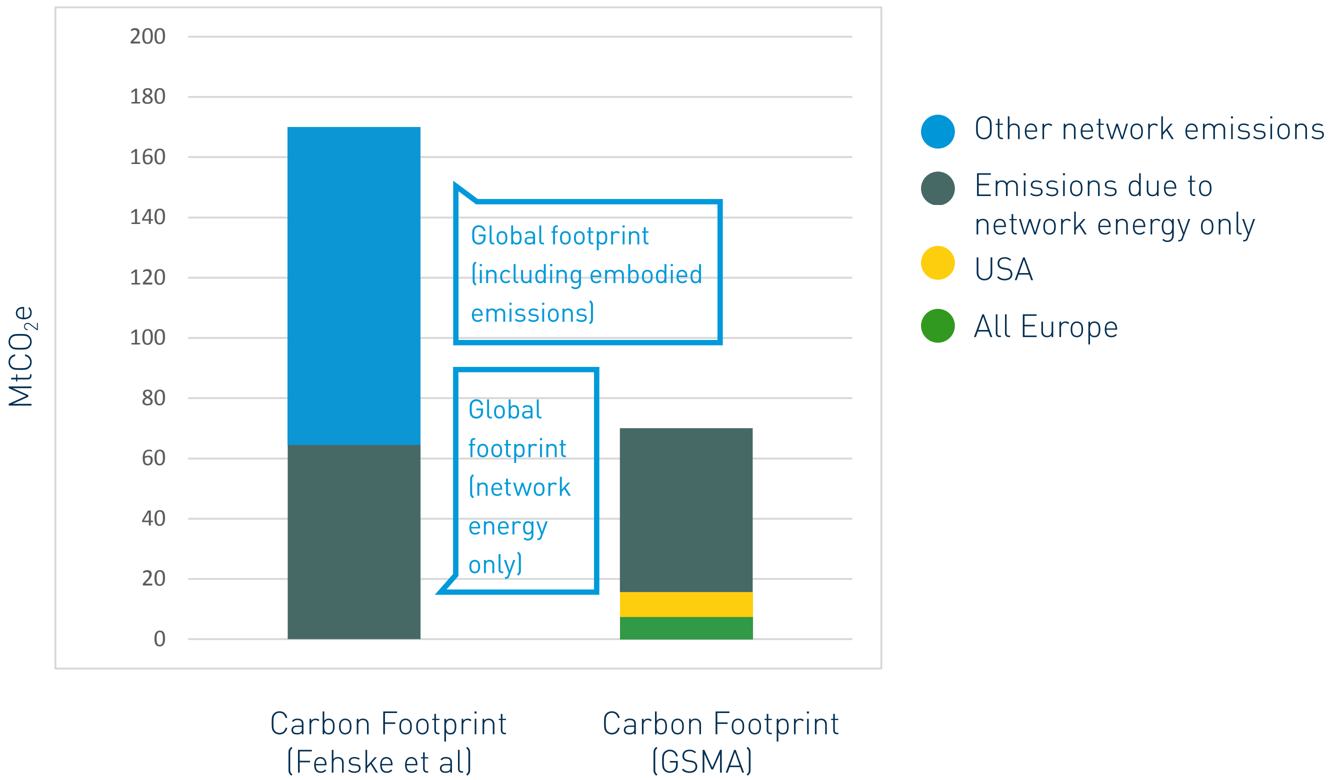
54 GSMA (2012), *op. cit.*

CARBON FOOTPRINT OF MOBILE NETWORKS (PER YEAR)

Source	Scope (see notes below)	Date of Study	Year data refers to	Global carbon footprint $MtCO_2e$	Carbon footprint Europe $MtCO_2e$	Carbon footprint N America $MtCO_2e$
GSMA	Network energy only (see note 1)	2012	2010	70	7.4	8.2
Fehske et al	Network energy only (see note 1)	2011	2014	64.5		
Fehske et al	Total life cycle (see note 2)	2011	2014	170		

Notes

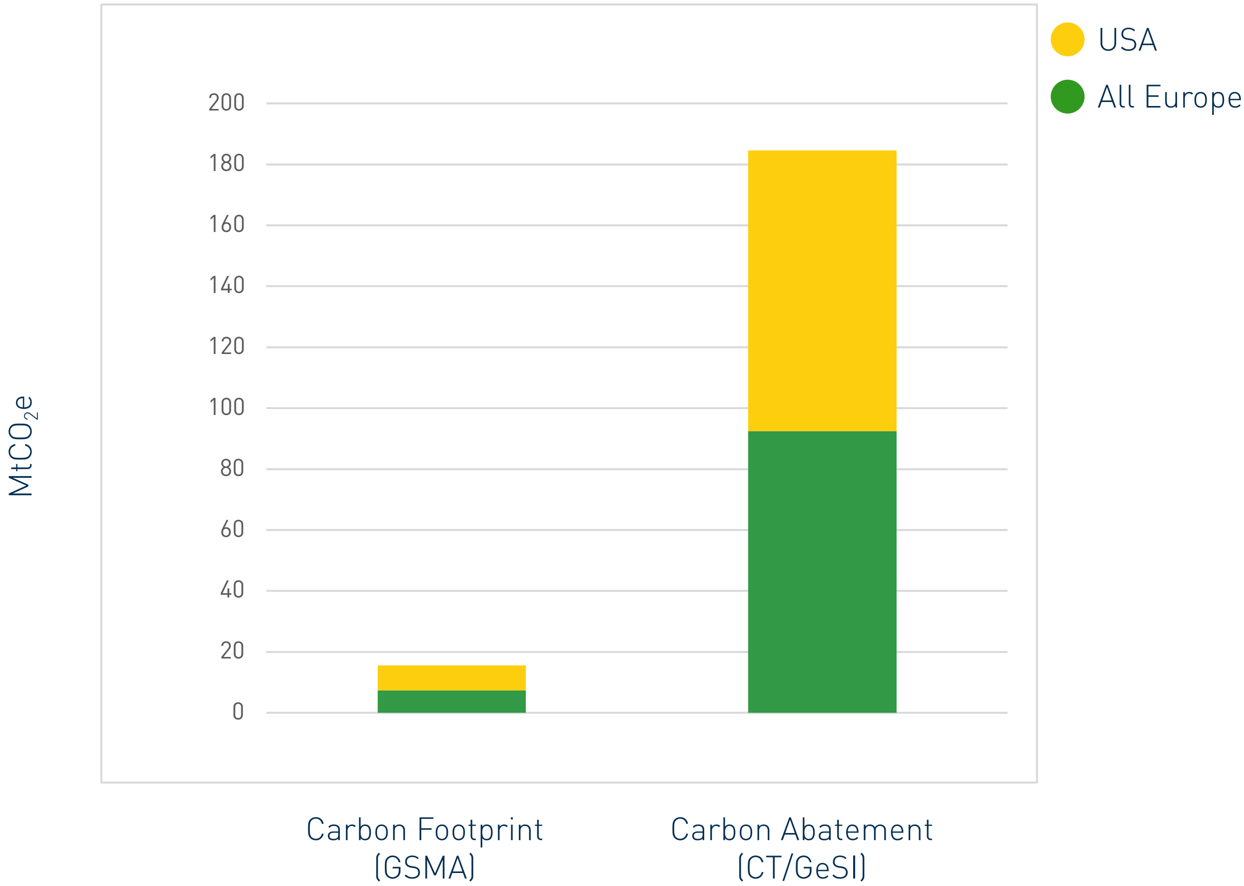
1. Due to energy use of the network only.
2. Total life cycle footprint including energy use of the network, operation of mobile devices, embodied carbon of network and mobile devices, operator activities and data centres.



COMPARISON OF GLOBAL MOBILE NETWORK EMISSIONS

It is then possible to compare the carbon footprint of the network with the carbon abatement that has been calculated for Europe and USA. The GSMA[55] gives the carbon footprint of the mobile network for Europe and North America as 7.4 and 8.2 MtCO2e respectively, compared to the carbon abatement that has been calculated of just over 90 $MtCO_2e$ for each region. (See chart below).

COMPARISON OF MOBILE NETWORK EMISSIONS (NETWORK ENERGY ONLY) AND CARBON ABATEMENT



Thus for USA and Europe, there is a carbon footprint for the network energy of 15.6 $MtCO_2e$, compared to a carbon abatement of 185 $MtCO_2e$. If the embodied emissions of the network are included (by factoring based on the study by Fehske et al[56] then this gives a carbon footprint of about 40 $MtCO_2e$. Thus by including the embodied emissions of the network this means that the carbon abatement is nearly five times the carbon emissions from the mobile network.

Note that this is a useful way to contextualise the carbon abatement that has been calculated in this report. However, this ratio is dependent on the carbon footprint of mobile derived from other studies. Caution should be used if trying to draw comparisons with other similar ratios, which may have used different boundaries and different assumptions.

55 GSMA (2012), *op. cit.*

56 Fehske et al (2011), *op. cit.*

The following assumptions have also implicitly been included in calculating this ratio, and provide additional caveats when using the simplistic ratio metric:

- In the carbon abatement this has included satellite and public Wi-Fi, whereas these are not included in the carbon footprint of mobile networks.
- The carbon footprint data from the GSMA[57] is the latest published data and refers to 2010. The emissions from mobile networks is likely to be larger in 2015, as mobile network emissions have generally been increasing.
- In applying the embodied emissions of mobile networks, there has been an implicit assumption that the global embodied emissions are applicable in the same ratio for the USA and Europe.
- Increased smartphone penetration since 2011 will have increased the embodied emissions (as smartphones have a higher carbon footprint than feature phones).

Applying the methodology at a company level

Many telecommunications companies are already measuring the carbon abatement for their products and services, using a methodology similar to that used for this report. These include: BT, EE, Elisa, KPN, Swisscom, Telefonica-O2, Telstra, Verizon, and Vodafone.

When applying this methodology at a company level rather than at a country level, although the approach and the factors used will be similar, there will be some differences:

- The main difference is that a telecommunications operator should be able to be much more precise over the number of M2M connections and the categorisation of these. This will depend on how detailed and accessible the sales data is.
- A mobile telecommunications operator is likely to only include the carbon abatement directly related to the products and services that they sell (rather than the range of mechanisms that have been included in this report).
- A mobile telecommunications operator will typically consider the M2M connections that they sell directly, rather than the wider definition of mobile adopted in this report which includes a proportion of connections from short range and Metropolitan Area Networks that are supported by mobile cellular networks.
- Generally telecommunications operators have not included the carbon abatement from the use of mobile phone apps (i.e. primarily those mechanisms in the "Connected Living" category of this report). This is largely because of uncertainty in quantifying the number of people using the apps and the behaviour changes which deliver the carbon savings. (The calculations in this report for this category rely heavily on the new consumer research commissioned specifically for this report).

As a companion to this report, the Carbon Trust have also prepared a 'Carbon Abatement Calculation Handbook' to provide data and factors to support practitioners who are carrying out carbon abatement assessments of ICT products and services.

57 GSMA (2012), *op. cit.*

Appendix 2: Table of carbon abatement factors

This table presents the carbon abatement factors calculated for each mechanism for each country. These are provided to allow for validation and comparison.

The assumptions and sources used to calculate the carbon abatement factors for each mechanism are presented in Appendix 3.

The factors are provided to 2 decimal places. Although this overstates the accuracy of the figures, it allows others to use these factors as they are. The Carbon Trust has rounded the resulting carbon abatement figures, and would recommend that this is done for any other use of these factors.

	UK	Germany	Spain	France	USA	units
Connected Agriculture						
Agricultural equipment logistics	110.92	125.00	97.18	127.11	297.76	$kgCO_2e$ / tractor
Crop management	18,881.52	18,587.70	3,646.38	14,352.69	44,058.52	$kgCO_2e$ / farm
Connected Buildings						
Building energy management systems (electricity commercial)	528.63	312.39	554.19	54.98	837.23	$kgCO_2e$ / smart meter
Building energy management systems (gas commercial)	3,967.95	2,593.98	579.12	1,961.62	2,320.50	$kgCO_2e$ / smart meter
HVAC control - commercial buildings	9,042.50	5,527.13	7,257.54	5,577.09	11,993.49	$kgCO_2e$ / average office
HVAC control - residential buildings	398.87	271.07	168.60	133.71	716.25	$kgCO_2e$ / household
Smart meters - water commercial	15.24	15.24	15.24	15.24	20.79	$kgCO_2e$ / smart meter
Smart meters - water residential	1.21	0.83	1.20	1.22	3.57	$kgCO_2e$ / smart meter
Smart meters (electricity residential)	64.00	56.02	45.13	12.34	197.03	$kgCO_2e$ / smart meter
Smart meters (gas residential)	56.56	29.49	11.00	25.47	42.92	$kgCO_2e$ / smart meter
Connected Cities						
Parking space monitoring	2,666.66	2,666.66	2,666.66	2,666.66	2,666.66	$kgCO_2e$ / parking space
Smart bins	5.00	5.00	5.00	5.00	5.00	$kgCO_2e$ / smart bin
Street lighting	122.11	126.90	80.23	16.57	162.68	$kgCO_2e$ / street light
Traffic congestion management	12,943.04	15,227.10	22,079.30	13,704.39	28,724.41	$kgCO_2e$ / traffic monitoring device
Traffic congestion monitoring (road signs)	17,999.96	17,999.96	17,999.96	17,999.96	17,999.96	$kgCO_2e$ / road sign
Traffic congestion monitoring (traffic lights)	17,999.96	17,999.96	17,999.96	17,999.96	17,999.96	$kgCO_2e$ / traffic light

	UK	Germany	Spain	France	USA	units
Connected Energy						
Electric vehicle connection	129.76	122.88	173.91	245.95	112.35	$kgCO_2e$ / charging point
Microgeneration (CHP Business)	1,125.72	1,882.94	667.66	152.71	1,384.70	$kgCO_2e$ / installation
Microgeneration (CHP Residential)	1,125.72	1,882.94	667.66	152.71	1,384.70	$kgCO_2e$ / installation
Microgeneration (solar business)	3,752.40	6,276.48	2,225.52	509.04	4,615.68	$kgCO_2e$ / installation
Microgeneration (solar residential)	1,196.08	2,000.63	709.38	162.26	1,471.25	$kgCO_2e$ / installation
Microgeneration (wind business)	32,833.50	54,919.20	19,473.30	4,454.10	40,387.20	$kgCO_2e$ / installation
Microgeneration (wind residential)	5,378.44	8,996.29	3,189.91	729.62	6,615.81	$kgCO_2e$ / installation
Smart Grids - electric network management	4,390.61	4,517.83	3,696.58	920.35	13,155.13	$kgCO_2e$ / connection
Smart Grids - gas network management	3,741.85	6,254.86	8,886.45	5,242.18	14,326.22	$kgCO_2e$ / connection
Connected Health						
Smart Health - home care	441.03	440.61	440.87	440.99	440.87	$kgCO_2e$ / patient
Smart Health - out of hospital care	360.56	282.17	341.13	285.27	313.62	$kgCO_2e$ / patient
Connected Industry						
Automation in industrial processes	942.33	990.43	633.38	129.31	1,064.12	$kgCO_2e$ / smart motor
Field force automation	4,736.21	4,736.21	4,736.21	4,736.21	4,736.21	$kgCO_2e$ / connection
Inventory management	7,379.93	7,756.65	4,960.40	1,012.70	22,701.14	$kgCO_2e$ / warehouse
Point of sale	13.53	13.53	13.53	13.53	13.53	$kgCO_2e$ / POS terminal
Supply chain management	71.50	71.50	71.50	71.50	71.50	$kgCO_2e$ / pallet of goods
Vending machines	31.93	37.56	54.47	33.81	70.86	$kgCO_2e$ / vending machine
Water grid - leak detection	0.89	4.70	2.72	1.68	6.50	$kgCO_2e$ / connection
Connected Living						
Accommodation sharing	6.58	8.60	10.63	8.60	5.20	$kgCO_2e$ / smartphone user
Eco-driving	0.60	0.60	0.60	0.60	0.60	$kgCO_2e$ / smartphone user
Avoiding social journeys (friends & family)	10.27	17.78	17.78	17.78	15.41	$kgCO_2e$ / smartphone user
Mobile banking	2.78	2.78	2.78	2.78	5.48	$kgCO_2e$ / average person
Mobile shopping	0.58	0.38	0.06	0.19	1.10	$kgCO_2e$ / average person
Ride sharing	1.17	1.47	1.52	1.47	1.23	$kgCO_2e$ / smartphone user

	UK	Germany	Spain	France	USA	units
Sharing economy (goods sharing)	2.41	2.29	2.17	2.29	2.23	$kgCO_2e$ / smartphone user
Smart homes	2.61	1.67	0.80	0.67	8.76	$kgCO_2e$ / smartphone user
Use of mobile as a satnav	2.52	3.62	3.14	3.24	4.75	$kgCO_2e$ / smartphone user
Connected Transportation						
Car sharing (car clubs)	26,966.72	34,321.28	26,966.72	26,966.72	26,966.72	$kgCO_2e$ / car club vehicle
Fleet vehicle driver behaviour improvement	1,643.85	1,888.40	980.35	1,667.94	1,381.04	$kgCO_2e$ / vehicle
Remote vehicle condition monitoring	0.93	0.93	0.93	0.93	0.93	$kgCO_2e$ / vehicle
Roadside assistance	1.65	1.65	1.65	1.65	1.65	$kgCO_2e$ / vehicle
Satellite navigation	15.17	15.64	10.20	13.98	15.96	$kgCO_2e$ / connected satnav
Sea fleet	354,117.71	354,117.71	354,117.71	354,117.71	354,117.71	$kgCO_2e$ / ship
Smart logistics - efficient routing & fleet management	600.07	560.46	313.90	628.26	447.39	$kgCO_2e$ / vehicle
Smart logistics - loading optimisation	240.03	224.18	125.56	251.30	178.96	$kgCO_2e$ / vehicle
Usability of public transport	13.43	14.51	21.96	13.06	45.29	$kgCO_2e$ / smartphone user
Usage based car insurance	203.66	208.39	154.01	191.84	211.57	$kgCO_2e$ / connected car
Connected Working						
Audio conferencing	2.63	0.55	0.12	1.05	5.49	$kgCO_2e$ / mobile phone
Working from home	14.48	24.13	24.13	24.13	24.13	$kgCO_2e$ / employee
Physical to Digital						
Multi-functional device	0.23	1.29	2.54	1.29	0.74	$kgCO_2e$ / smartphone user
Newspapers, music, DVD, storage	1.26	0.84	0.14	0.41	1.93	$kgCO_2e$ / average person

Notes on country factors

It is noticeable that there is significant variability for some of the carbon abatement factors between countries. There can be a variety of reasons to explain why these differences exist.

Where the carbon abatement results from a reduction in the use of electricity, then the national electricity grid factor has a significant impact. For such cases the carbon abatement factor for France is significantly smaller. This is due to high level of nuclear power in France, which results in its grid emission factor being about 8 times smaller than UK and Germany.

For other cases, there are specific country characteristics that have an impact. These could be to do with the geography and average distances travelled, or typical energy consumption per square meter for buildings. For example, the average energy consumption for buildings is much higher in USA than in other countries, average farm size is smaller in Spain.

In a few cases, where specific data for the different countries were unavailable, the same assumptions were made for all countries, explaining why the carbon abatement factor does not vary between countries.

Appendix 3: Data sources and assumptions

The following table provides a short description, the calculation methodology and key assumptions for each mechanism. (A complete list of references used in this section is in Appendix 4.)

Label	Text	Reference
Category	Connected Agriculture	
Sub-category	Agricultural equipment logistics	
Mechanism	Better utilisation of farm equipment resulting in reduction in diesel consumed by farm machinery such as tractors, harvesters, compactors.	
Methodology	Tracking systems enable better routing, which reduces the fuel consumed during harvesting, tillage, irrigation and harvesting. Average fuel consumption by machinery per year is based on average consumption per machinery and density of such machinery per hectare. Based on this, together with the average fuel saving, and the emission factor associated to the fuel used, a total saving per machinery is calculated.	
Assumptions	Actual fuel savings arising from the use of GPS guiding systems on farm equipment. This includes four main processes (i.e., tillage, planting, spraying and harvesting), which were equally weighted. An average saving for all processes of 6.315% was used.	(Bora et al. 2012)
	Average fuel consumption for wheat cultivations is 55.6 l/ha. This figure was used as representative of fuel consumption for all agricultural machinery.	(Schenck, R.; Huizenga 2014)
	Emission factor for fuel used is 2.299 kgCO_2e/l.	
Category	Connected Agriculture	
Sub-category	Crop management	
Mechanism	Better use of resources (human, fuel and water) and increase in productivity can lead to increased yield and reduced wastage. It can also lead to a reduction in fertiliser required as it can be allocated to the appropriate areas as well as reduced irrigation (e.g., plants tweeting when they need to be watered.)	
Methodology	Fertiliser reduction: estimation based on the amount of fertiliser used per farm per year, and the country specific emission factor of fertilisers used. Previous studies give an estimation on the reduction of fertiliser used as a result of mobile enabled soil and water sensors.	
Assumptions	Smart technology can reduce expenditure on chemical inputs by 40% per hectare. This figure was used and assuming that a reduction in expenditure is directly equivalent to a reduction in product quantity used.	(GSMA Intelligence 2015)
	Smart technology has led to improvements on nitrogen efficiency in Germany between 10-15%.	(Joint Research Centre (JRC) of the European Commission 2014)

Label	Text	Reference
Category	Connected Buildings	
Sub-category	Building energy management systems (electricity commercial)	
Mechanism	Energy management systems lead to optimised energy and heating demand resulting in energy savings.	
Methodology	Estimate percentage saving of average office electricity consumption due to smart meters. Assume more than one M2M connections per office. An average electricity saving per m² is calculated based on the national electricity consumption per business and the assumed saving percentage from smart meter use. Considering the number of meters per m² and the national electricity emission factor, a CO_2e abatement factor per country can be calculated.	
Assumptions	14% electricity saving from smart meter use in commercial buildings. This is an average value based on the following two studies:	
	• 12% electricity saving from a controlled trial involving 538 SMEs.	(Carbon Trust 2007)
	• GE case study results: 16% electricity saving.	(Ross et al. 2011)
	Other case studies have energy savings from 5% to 25%, one example being the ASB Bank case study which has a 23% energy saving.	(Vodafone 2012a)
	Estimated 0.02 electricity meters per m².	Carbon Trust analysis of Low Carbon Workplace (LCW) data
Category	Connected Buildings	
Sub-category	Building energy management systems (gas commercial)	
Mechanism	Energy management systems lead to optimised energy and heating demand resulting in energy savings.	
Methodology	Estimate percentage saving of average office gas consumption due to smart meters. Assume more than one M2M connections per office. An average gas saving per m² is calculated based on the national gas consumption per business and the assumed saving percentage from smart meter use. Considering the number of meters per m² and the gas emission factor, a CO_2e abatement factor per country can be calculated.	
Assumptions	12% gas savings from smart meter use in commercial buildings. This is based on the following three studies (the 7% figure is based on a reasonable large sample, but only considered SMEs, therefore it is reasonable to assume a higher saving):	
	• 42% saving from GE case study.	(Ross et al. 2011)
	• 4.5% gas consumption reduction in the non-domestic sector.	(DECC 2014)
	• 7% gas saving from a controlled trial involving 538 SMEs. (Non-SMEs are likely to have higher savings).	(Carbon Trust 2007)
	Assume 0.001 gas meters per m².	Carbon Trust analysis of Low Carbon Workplace (LCW) data

Label	Text	Reference
Category	Connected Buildings	
Sub-category	HVAC control - commercial buildings	
Mechanism	Monitoring and control of HVAC systems, including automatic reaction based on occupancy, leading to reduction in energy consumption.	
Methodology	Estimate average energy consumed by HVAC system in an average office building by multiplying the energy per m^2 by the average floor space and the percentage of energy consumed by HVAC system. Multiply by the percentage reduction in energy consumption caused by HVAC control systems and by the energy emission factor to calculate an average abatement factor.	
Assumptions	27.5% energy saving from HVAC controls for the USA. This is based on the PNNL study, which suggests HVAC controls will offer energy savings of 24%-35% in commercial buildings.	(Wang et al. 2013)
	20% Energy savings from HVAC controls for Europe. This is from the Carbon Trust study, which suggests HVAC controls will offer energy savings of 20% in commercial buildings.	(Carbon Trust 2012)
	Average energy emission factor of 0.381 (for combined gas and electricity consumption), which assumes that the energy mix is 63% electricity and 37% gas.	(Department of the Environment Transport and the Regions (DETR) 2000)
	The CIBSE Journal article quotes that cooling & ventilation accounts for 21% and heating for 20% of the average electricity consumption in UK office buildings, so it was assumed that 41% of energy is consumed by HVAC systems in commercial buildings.	(Dwyer 2015)
	The sample mean of workplace density is $10.9m^2$, so it was assumed that is the average floor space per worker in m^2.	(Bedford et al. 2013)
	Machina Research data used is based on an average office size (donated as 'Revenue Generating Units' or RGU). Machina Research assumes an average RGU is 100 people in 2013, straight-line falling to 40 in 2024, hence by interpolating between these figures the average number of employees per RGU unit in 2015 is 90, which is the figure used to calculate average office floor area.	
Category	Connected Buildings	
Sub-category	HVAC control - residential buildings	
Mechanism	Monitoring and control of HVAC systems, including integration of domestic systems based on personal presence, leading to reduction in energy consumption.	
Methodology	Estimate average emissions from an average residential building. Considering the percentage of energy consumed by HVAC and the percentage reduction in energy consumption caused by HVAC control systems, an average abatement factor can be calculated.	
Assumptions	The reference study found that on average the HVAC system consumes around 39% of total energy consumption of a household. This figure was used in the calculations.	(Center for Climate and Energy Solutions n.d.)

Label	Text	Reference
	• For the energy reduction from HVAC control systems a value of 20% was assumed. This was based on the following two studies that both indicated a potential reduction of about 28%. This figure was adjusted downwards to reflect the situation in typical residential accommodation.	
	• This study found that universities can reduce the energy use from HVAC systems in residential halls by 25%-32% by introducing HVAC controls, which gives a mid-point value of 28.5% reduction.	(Anderson 2011)
	• The results of this study indicate that the smart thermostat can provide larger energy savings and more comfort than existing baseline solutions. This approach has a very low initial cost of less than $25 per home, and can save 28% of residential HVAC energy consumption on average, without sacrificing comfort.	(Lu et al. 2010)
Category	Connected Buildings	
Sub-category	Smart meters - water commercial	
Mechanism	Use of smart meters to monitor water usage, raises awareness, highlights wastage of water and leads to behaviour change reducing water consumption.	
Methodology	Estimate average CO_2e abatement factor based on the average water consumption per business, the average water emission factor, and the reduction in water consumption from smart meter use.	
Assumptions	The Business stream reference suggests that the right water monitoring solution for businesses could cut consumption and costs by up to 5%. A value of 5% water saving was used in the calculation.	(Business Stream n.d.)
	Machina Research data used is based on an average office size (denoted as 'Revenue Generating Units' or RGU). Machina Research assumes an average RGU is 100 people in 2013, straight-line falling to 40 in 2024, hence by interpolating between these figures the average number of employees per RGU unit in 2015 is 90, which is the figure used to calculate average water consumption per business.	
Category	Connected Buildings	
Sub-category	Smart meters - water residential	
Mechanism	Use of smart meters to monitor water usage, raises awareness, and leads to behaviour change reducing water consumption.	
Methodology	Estimate average CO_2e abatement factor based on the average water consumption per household, the average water emission factor, and the reduction in water consumption from smart meter use.	
Assumptions	Anglian Water has trialled smart water meters with IHDs in the homes of over 11,000 customers. Results suggest that customers reduced their water usage by 3-4%. An average water saving of 3.5% was assumed from smart meters in residential buildings.	(Houses of Parliament 2014)

Label	Text	Reference
Category	Connected Buildings	
Sub-category	Smart meters (electricity residential)	
Mechanism	Use of Smart meters enables monitoring of energy used, raises awareness, and leads to behaviour change reducing energy consumption.	
Methodology	Estimate average CO_2e abatement factor based on the average electricity consumption per household, the average electricity emission factor per country, and the reduction in electricity consumption from smart meter use in residential buildings. Assume one M2M connection per household.	
Assumptions	An electricity saving from smart meter use of 2.8% was assumed. This is based on the following three references, where a lower figure from the range provided by these studies has been selected.	
	• Electricity saving from smart meter use found to be 2.8%.	(DECC 2010)
	• Electricity saving from smart meters 5-15%.	(Lu 2010)
	• Electricity saving from smart meters 2-3%.	(Commission for Energy Regulation (CER) 2011)
Category	Connected Buildings	
Sub-category	Smart meters (gas residential)	
Mechanism	Use of Smart meters enables monitoring of energy used, raises awareness, and leads to behaviour change reducing energy consumption.	
Methodology	Estimate average CO_2e abatement factor based on the average gas consumption per household, the average gas emission factor, and the reduction in gas consumption from smart meter use in residential buildings. Assume one M2M connection per household.	
Assumptions	Gas saving from smart meter use found to be 2% for gas credit and 0.5% for pre-payment meter. A figure of 2% gas saving from use of smart meter per household was used.	(DECC 2010)
Category	Connected Cities	
Sub-category	Parking space monitoring	
Mechanism	Smart sensors monitor car park space availability in cities. This information is fed back to vehicles and drivers are able to reserve and be directed to the appropriate parking space. This greatly reduces the time spent driving around looking for available parking.	
Methodology	The average parking space is used approximately 16 times per day. If each time it is used the driver is able to avoid the need to drive around looking for a space, then there will be a total reduction in time spent driving, thus emissions are avoided. This overall reduction is the saving per parking space.	
Assumptions	An average of 10 minutes spent looking for a parking space was assumed (Streetline data is an average time of 6-14mins).	(Steetline 2013)
	• Supporting study: In Barcelona a million drivers spend on average 20 minutes a day looking for parking.	(Bielsa 2013)

Label	Text	Reference
	Supporting study: Smart Parking in Milton Keynes the sensors revealed that an average stay in the station drop-off zone is 16 minutes, enabling the Council to adjust the wait limit upwards to 20 minutes.	(British Telecommunications plc 2014)
	An assumption was made that the average stay in a parking space is 30mins, which equates to 16 uses per day over an 8 hour period.	
	It was assumed that the average speed when looking for parking spot is 15km/h.	
	It was assumed that the use of technology reduces the time searching for a parking space from 10 minutes to 2 minutes.	
Category	Connected Cities	
Sub-category	Smart bins	
Mechanism	Smart bins monitor their capacity as they collect waste. This is used to notify collection units when bins need emptying, thus optimising the routes taken by refuse vehicles.	
Methodology	Using the findings from a Mic-O-Data study, the annual carbon saving from a sample of smart bins is 30,000kgCO_2e. This was based on a study of 6,000 connected bins, thus giving an abatement per bin of 5kgCO_2e. This is the emission factor to be used.	
Assumptions	Vodafone Mic-O-Data case study. 30,000kgCO_2 for 6000 smart bins gives an abatement factor of 5kgCO_2/smart bin.	(Vodafone 2012b)
Category	Connected Cities	
Sub-category	Street lighting	
Mechanism	Connected street lights will adjust light output to suit variations in demand. By not having to be at full power all the time, the energy consumption of each light will be reduced. Energy consumption per light obtained from a range of independent sources. Carbon saving from the implementation of smart light output, not switching to more efficient LED bulbs.	
Methodology	A study carried out by Telensa estimated that smart street lighting reduces carbon emissions by 20%. This saving is applied to the average carbon emissions from one street light. This is calculated through the average annual energy consumption of one light, multiplied by the emission factor of the local grid.	
Assumptions	Smart street lighting reduces carbon emissions by 20%.	(Telensa 2015)
Category	Connected Cities	
Sub-category	Traffic congestion management	
Mechanism	Traffic congestion management through signs and signals control, resulting in reduced traffic congestion, and therefore reduced fuel consumption.	
Methodology	The percentage reduction in the number of vehicles is multiplied by the average journey distance. This is then multiplied by an emission factor for an average car.	

Label	Text	Reference
Assumptions	Transport for London data shows a 14% reduction in vehicles entering the London congestion zone compared to pre-congestion charging. This percentage was used together with the number of monitoring devices to calculate a vehicle reduction per device.	(Transport for London (TfL) 2008)
	Supporting data showing that road pricing results in 16% less carbon emissions.	(Joint Expert Group on Transport and Environment 2010)
	Annual abatement is based on 260 working days per year (week days). This is multiplied by the average weekday driving distance to get an annual figure.	
	Average weekday trip driving distance data for Europe is from the European Commission JRC report.	(Pasaoglu et al. 2012)
	Average weekday trip driving distance for USA is from US Department of Transportation data.	(US Department of Transportation Federal Highways Administration (FHWA) 2011)
Category	Connected Cities	
Sub-category	Traffic congestion monitoring (road signs)	
Mechanism	Smart monitoring of traffic congestion and traffic hotspots. Connected road signs direct traffic away from these areas to avoid further congestion and optimise routing.	
Methodology	Smart traffic signals' emissions savings arise from being able to maintain a more consistent speed while driving, this is as a result of avoiding congestion areas. Attribute the associated carbon reduction to the distance travelled by an average car while 'affected' by the sign as it passes. Each year an estimated number of vehicles will pass each sign.	
Assumptions	A 5% reduction in emissions from synchronised traffic signals was assumed.	(Accenture and Vodafone 2009)
	It was assumed that one car arrives at a sign every 4 seconds during peak periods (7am-7pm).	
	It was assumed that the sign impacts journey for 400m.	
Category	Connected Cities	
Sub-category	Traffic congestion monitoring (traffic lights)	
Mechanism	Smart monitoring of traffic flow to communicate between lights and optimise wait times at junctions. This will prevent traffic delays and allow drivers to maintain a more consistent speed.	
Methodology	Smart traffic lights will result in emissions savings from being able to maintain a more consistent speed while passing through the traffic light. Attribute the carbon reduction to the distance travelled while 'affected' by the light for an average car passing the traffic light.	
Assumptions	A 5% reduction in emissions from synchronised traffic signals was assumed.	(Accenture and Vodafone 2009)
	It was assumed that one car arrives at a sign every 4 seconds during peak periods (7am-7pm).	
	It was assumed that the sign impacts journey for 400m.	

Label	Text	Reference
Category	Connected Energy	
Sub-category	Electric vehicle connection	
Mechanism	Smart grids enabling connection of electric vehicles, therefore increasing shift from petrol and diesel cars to electric cars.	
Methodology	Estimate the total kilometres driven per charging point using the total kWh charged divided by the total number of charging points and multiply by the kilometres driven per kWh. Calculate the difference in emissions when total kilometres are driven by an average car compared to an electric car.	
Assumptions	It was assumed that total kWh charged per charging point over a year is 244.4 kWh, based on the reference below.	
	• Total kWh used over a 3 month period: 51,957 (Sep 2013); 86,266 (June 2014)	(Transport for London 2014)
	• Current number of Charge Points Installed in London: 1,392 (Sep 2013); 1,412 (June 2014)	(Transport for London 2014)
	Electric vehicle wall-to-wheels energy use is 211 Wh/km, based on the Nissan Leaf, so the distance driven by an electric car per kWh is 4.74 km/kWh	(Wilson 2013)
Category	Connected Energy	
Sub-category	Microgeneration (CHP business)	
Mechanism	Enabling electricity to be exported to the grid through decentralized low carbon energy generation. Communication of electricity capacity, pricing and payment is enabled through smart meters and M2M connection.	
Methodology	Estimate the typical electricity generation of a commercial CHP installation per year and multiply by the residual grid factor. Assume one connection per installation.	
Assumptions	Micro CHP unit can generate 2400 kWh per year.	(University of Strathclyde 2015)
	The average residual mix emission factor in the US is calculated as an average of the residual mix emission factors for the different NERC regions. (For Europe RE-DISS II data was used).	(Center for Resource Solutions (CRS) 2015)
Category	Connected Energy	
Sub-category	Microgeneration (CHP residential)	
Mechanism	Enabling electricity to be exported to the grid through decentralized low carbon energy generation. Communication of electricity capacity, pricing and payment is enabled through smart meters and M2M connection.	
Methodology	Estimate the typical electricity generation of a residential CHP installation per year and multiply by the residual grid factor. Assume one connection per installation.	
Assumptions	Micro CHP unit for domestic use can generate 2400 kWh per year.	(University of Strathclyde 2015)

Label	Text	Reference
Category	Connected Energy	
Sub-category	Microgeneration (solar business)	
Mechanism	Enabling electricity to be exported to the grid through decentralized low carbon energy generation. Communication of electricity capacity, pricing and payment is enabled through smart meters and M2M connection.	
Methodology	Estimate the typical electricity generation of a commercial solar installation per year and multiply by the residual grid factor. Assume one connection per installation.	
Assumptions	10 kWp commercial Solar PV system could generate around 8,000 kWh per year, a 20kWp around 16,000kWh and a 50kWp around 40,000kWh. An average energy generation of 8,000 kWh per year for a commercial Solar PV was assumed.	(Clean Energy Installations 2015)
	A 50 kW array will produce an average of around 43,800 kWh of energy per year.	(RegenSW 2015)
Category	Connected Energy	
Sub-category	Microgeneration (solar residential)	
Mechanism	Enabling electricity to be exported to the grid through decentralized low carbon energy generation. Communication of electricity capacity, pricing and payment is enabled through smart meters and M2M connection.	
Methodology	Estimate the typical electricity generation of a residential solar installation per year and multiply by the residual grid factor. Assume one connection per installation.	
Assumptions	It was assumed that an average domestic Solar PV installation will be 3kW, based on the below reference.	
	• A typical system size of 3kW will give an estimated annual output of 2550 kWh.	(Vasili 2015)
Category	Connected Energy	
Sub-category	Microgeneration (wind business)	
Mechanism	Enabling electricity to be exported to the grid through decentralized low carbon energy generation. Communication of electricity capacity, pricing and payment is enabled through smart meters and M2M connection.	
Methodology	Estimate the typical electricity generation of a commercial wind installation per year and multiply by the residual grid factor. Assume one connection per installation.	
Assumptions	An average electricity generation of 70,000 kWh per year for a commercial wind installation was assumed, based on the references below.	
	• Gazelle 20kW Wind Turbine produces around 60,000kWh per year.	(Gazelle Wind Turbines 2015)
	• The Enertech 40 kW turbine will produce 75,000-80,000 kWh per year with 12 mph avg. wind speeds.	(Solar Windtek 2015)

Label	Text	Reference
Category	Connected Energy	
Sub-category	Microgeneration (wind residential)	
Mechanism	Enabling electricity to be exported to the grid through decentralized low carbon energy generation. Communication of electricity capacity, pricing and payment is enabled through smart meters and M2M connection.	
Methodology	Estimate the typical electricity generation of a residential wind installation per year and multiply by the residual grid factor. Assume one connection per installation.	
Assumptions	It was assumed that domestic wind installations are around 2.5kW to 10kW in size, based on the reference below, so the average electricity generated by a domestic wind microgeneration installation assumed is 11,467 kWh.	
	A domestic 2.5kW wind turbine can produce around 4,000kWh per year, 5kW around 8,900 and a 10kW around 21,500kWh per year.	(The Renewable Energy Hub 2015)
Category	Connected Energy	
Sub-category	Sub-category Smart Grids - electric network management	
Mechanism	By monitoring the transmission and distribution (T&D) elements of the network, utilities can identify points of loss. This leads to more efficient distribution network, resulting in reduced T&D losses.	
Methodology	Estimate the percentage of the grid that is smart by assuming 100% of the grid is smart in 2050 and calculate emissions caused from the proportion of the grid that is smart. Calculate the reduction in T&D losses possible with a smart grid and apply reductions to the proportion of smart grid emissions. Divide by the number of M2M connections to get carbon abatement per connection.	
Assumptions	An average figure of 7% for T&D losses was used, as a percentage of total electricity generation.	(International Energy Agency (IEA) 2005)
	Using the two references below, it was assumed that reduction in T&D losses from smart grids are 7.5%. (The US DOE study has been taken as more representative).	
	• The SMART 2020 report estimates potential reduction in T&D losses from use of smart grids to be 30%.	(Global e-Sustainability Initiative (GeSI) 2008)
	• US DOE smart grid study estimates potential reduction in T&D losses from use of smart grids to be 5-10%.	(U.S. Department of Energy (DOE) 2012)
	It is assumed that in 2050, 100% of the grid is smart. Hence, the percentage of grid estimated to be smart currently is measured by the ratio of connections in 2015 over connections in 2050. The connections in 2050 were derived by assuming a linear increase in connections from 2030 onwards based on the figures from 2025-2030. (Data on number of M2M connections is from Machina Research data).	

Label	Text	Reference
Category	Connected Energy	
Sub-category	Smart grids - gas network management	
Mechanism	By monitoring the gas network, utilities can identify points of loss. This leads to more efficient distribution network, resulting in reduced losses due to leaks.	
Methodology	Estimate the percentage of the grid that is smart by assuming 100% of the grid is smart in 2050 and calculate the carbon emissions caused from the proportion of the grid that is smart. Calculate the reduction in gas leaks possible with a smart grid and apply reductions to proportion of smart grid emissions. Divide by the number of M2M connections to get carbon abatement per connection.	
Assumptions	It is assumed that in 2050, 100% of the grid is smart. Hence, the percentage of grid estimated to be smart currently is measured by the ratio of connections in 2015 over connections in 2050. The connections in 2050 were derived by assuming a linear increase in connections from 2030 onwards based on the figures from 2025-2030. (Data on number of M2M connections is from Machina Research data).	
	It was assumed that 0.24% of the natural gas that is produced escapes from delivery systems operated by local natural gas utilities, and that this leakage can be avoided by use of smart grid monitoring.	(National Grid (US) 2014)
Category	Connected Health	
Sub-category	Smart Health - home care	
Mechanism	Monitoring of chronic or high risk patients at home and thus avoiding car journeys to hospital. Reduction in number of days needed at the hospital. Reduction in travel for health professionals to visit patients at home.	
Methodology	Estimation based on an emission factor for a hospital stay, and a round trip to hospital multiplied by the average annual reduction in hospital visits per patient.	
Assumptions	Telehealth interventions reduce hospitalisation by 55% and reduce A&E admissions by 29%. It was assumed that there was an average figure of 42% reductions in hospital admissions.	(PwC 2013)
	15,624,000 hospital admissions in the UK annually - this is divided by the UK population to give an average of 0.24 hospital admissions per person per year. It was assumed that this is representative of people with health monitors - in practice they will likely have a higher admission rate.	(NHS Confederation 2015)
	Hospital stay emission factor (440 kgCO_2e per hospital stay) is from Carbon Trust research, based on NHS data.	
	Assumed travel to hospital in a large car, as likely to be a range of cars and ambulances.	
	Average distances to hospital are from OECD data for different countries.	

Label	Text	Reference
Category	Connected Health	
Sub-category	Smart Health - out of hospital care	
Mechanism	Monitoring of chronic or high risk patients at home reducing the number of days needed at the hospital.	
Methodology	Estimation based on an emission factor for a night spent in hospital, multiplied by the average annual reduction in nights spent in hospital per patient.	
Assumptions	Hospital stay emission factor (440 kgCO_2e per hospital stay) is from Carbon Trust research, based on NHS data.	
	Mobile Health (mHealth) trials have shown a 50-60% reduction in hospital nights.	(PwC 2013)
	Average annual nights spent in hospital for those with chronic condition is 12.5 for men and 11.3 for women, an average of 11.8 nights was assumed.	(Hernandez et al. 2009)
	Average length of hospital stay from Eurostat data for different countries.	
Category	Connected Industry	
Sub-category	Automation in industrial processes	
Mechanism	Increased efficiency and productivity through the automation of industrial processes connected through M2M connections.	
Methodology	Assuming remote diagnostics enable energy savings in industrial motors.	
Assumptions	A medium size motor, with median output power of 9.5W was assumed, operating at load factor of 60%, for 3000 hours per year. Data from IEA report, Table 15 - Characteristics of general purpose medium-size industrial electric motors: used in pumps, fans, compressors, conveyors, industrial handling and processing.	(International Energy Agency (IEA) 2005)
	Studies by the Carbon Trust and others show that metering, monitoring and targeting (MM&T) can typically deliver energy use savings of between 5% and 15%. An assumption was made of a 10% electricity saving for a typical industrial motor when connected with a remote monitoring, diagnostic, control system.	(Carbon Trust 2011)
Category	Connected Industry	
Sub-category	Field force automation	
Mechanism	Reduction in travel from productivity improvements for mobile work teams (field force).	
Methodology	Case studies giving a typical saving in fuel per vehicle used by field force. Assume one M2M connection per vehicle.	
Assumptions	Typical fuel savings per vehicle derived from BT Northumbrian Water case study.	(British Telecommunications plc 2013)
Category	Connected Industry	
Sub-category	Inventory management	
Mechanism	Inventory management systems reduce the overall level of inventory needed. As a result, less warehouse storage space is required. Smaller storage space requires less energy for lighting and cooling.	

Label	Text	Reference
Methodology	SMARTer 2020 report identifies inventory savings of 24%, this increased efficiency is applied to the electricity consumption of a typical warehouse.	
Assumptions	Assume the average medium sized warehouse is 20,000ft².	(EIA 2006)
	ICT enabled inventory management reduces inventory levels by up to 24%. It was assumed that this reduces the electricity consumption per warehouse by 24%.	(Global e-Sustainability Initiative (GeSI) and The Boston Consulting Group (BCG) 2012)
Category	Connected Industry	
Sub-category	Point of sale	
Mechanism	Use of mobile connections for payment transactions leading to less use of cash, and reduced cash transportation. Carbon emissions savings are from reduced use of security vehicles for cash drops.	
Methodology	Estimation based on a carbon abatement factor per £ transferred, multiplied by the total amount transferred per point of sale.	
Assumptions	1,179,175 point of sales in the UK (in 2009).	(Payments Council 2010)
	£114 billion is transferred annually by POS, from Carbon Trust Analysis.	
	140 $kgCO_2e$ is the carbon abatement factor per £1 million transferred by POS, from Carbon Trust analysis.	
Category	Connected Industry	
Sub-category	Supply chain management	
Mechanism	Improved monitoring of goods and equipment throughout the supply chain to ensure efficiency and reduction of waste of perishable goods	
Methodology	Calculate the embodied emissions of an average pallet's worth of goods. Each pallet represents one M2M connection. By improved management, the amount of wastage per pallet is reduced. The carbon abatement is the embodied emissions of the associated reduction in waste.	
Assumptions	Perishable goods range from 4.5-11.4% wastage, non-perishable goods will have a much lower wastage rate. This used a conservative assumptions that the overall inventory wastage rate is 5%.	(Buzby et al. 2009)
	Assume ICT prevents half of all wastage (i.e. 2.5% avoided wastage).	
	Average embodied emissions for goods assumed to be 2.86 $kgCO_2e/kg$. This was averaged from product carbon footprints for 250 different products (primarily food products). Emission factors were sourced from the Carbon Trust Footprint Expert database.	
	Assume pallet loading is 1000kg. Maximum load capacity of European pallets is 1000kg, dimensions 120cmx80cmx180cm.	(TNT 2011)
Category	Connected Industry	
Sub-category	Vending machines	
Mechanism	Remote monitoring of vending machines, enabling improved logistics for restocking of vending machines.	

Label	Text	Reference
Methodology	Estimates the emissions from the average number of trips per year to vending machines and multiply by the potential fuel savings from remotely controlling vending machines.	
Assumptions	Assume vending machines are replenished on average once per week.	(Snack'ums 2015)
	It was assumed that online management of vending machines can save 25% of fuel costs.	(Vendon 2015)
Category	Connected Industry	
Sub-category	Water grid - leak detection	
Mechanism	Leak detection in water mains, as part of the water distribution network, leading to reduction in water leakage, with resultant reduction in carbon emissions.	
Methodology	1. Estimate the percentage of the water grid that is smart by assuming 100% of the grid is smart in 2050 and calculate the amount of carbon emissions caused from the proportion of the grid that is smart. 2. Calculate the reduction in water leaks possible with a smart grid and apply reductions to the proportion of smart grid emissions. 3. Divide by the number of M2M connections to get carbon abatement per connection	
Assumptions	It was assumed that 20% of water is lost annually in distribution system, due to leakage. This is based on the following three studies:	
	• 15-30% leakage in developed world.	(Bridges & MacDonald 1994)
	• 15-25% leakage in UK.	(ABB 2011)
	• 25-30% in older cities, and 3-8% in newer cities.	(Mutchek & Williams 2014)
	It is assumed that in 2050, 100% of the grid is smart. Hence, the percentage of grid estimated to be smart currently is measured by the ratio of connections in 2015 over connections in 2050. The connections in 2050 were derived by assuming a linear increase in connections from 2030 onwards based on the figures from 2025-2030.	
Category	Connected Living	
Sub-category	Accommodation sharing	
Mechanism	Use of mobile technology facilitates booking accommodation in shared or unused houses, as oppose to in hotels (such as Airbnb). The average carbon impact of a night in a hotel is much greater than that of a residential house.	
Methodology	Airbnb report suggests 61-89% reduction in emissions when using an Airbnb room compared to a hotel stay. Apply this to the average number of annual holiday nights per person. Future thinking survey suggests 25% of people use accommodation functionality, but a frequency factor needs to be applied to this.	
Assumptions	61% and 89% lower emissions in Airbnb accommodation than a hotel stay for the US and EU respectively. Average stay is 4.6 nights.	(Airbnb 2015)

Label	Text	Reference
	Average emissions per guest per night for a hotel = 20.6kgCO_2e.	(United Nations Environment Programme (UNEP) and World Tourism Organization (UN-WTO) 2012)
	The average (UK) person has 3.0 holidays a year.	(ABTA 2014)
	On average 16-28% of those surveyed use their phone to book accommodation in homes instead of hotels. This is divided into those that do this "frequently", and those that do this "sometimes".	Consumer survey – see Appendix 5
	Of those that use mobile technology to book shared accommodation, it was assumed that those that do this "sometimes" do so for 10% of holidays, and those that do this "frequently" do so for 30% of holidays.	
Category	Connected Living	
Sub-category	Eco-driving	
Mechanism	Eco-driving apps for personal vehicles - leading to better driving behaviour, and reduced fuel consumption.	
Methodology	Estimation based on an assumed fuel saving from using eco-driving apps multiplied by the average distance driven using an emission factor for an average car.	
Assumptions	6548 miles (10,596 km) is the average distance driven annually.	(Department for Transport (DfT) 2014b)
	It was assumed that 0.5% of smartphone users use an eco-driving app.	
	Using an eco-driving app leads to a 5% reduction in fuel consumption.	
Category	Connected Living	
Sub-category	Avoiding social journeys (friends & family)	
Mechanism	Use of mobile device for video calls to friends and family, thus reducing need for travel.	
Methodology	Apply the percentage of people replacing a trip to family or friends with video calling to the average annual distance travelled by car to family or friends and multiply by the average car emission factor. The volume factor is the number of people with a smartphone.	
Assumptions	It was assumed that average annual distance travelled was 6,983 miles (11,238 km) and 77% of that distance travelled was by car.	(Department for Transport (DfT) 2014a)
	It was assumed that visiting friends accounts for 20% of distance travelled.	(Department for Transport (DfT) 2014a)
	This gives an average distance of 1731 km travelled by car for visiting friends in a year.	
	It was assumed that 30% visits to family or friends are being replaced by video conferences of those who "frequently" do this.	
	It was assumed that 10% of visits to family or friends are being replaced by video conferences of those who do this "sometimes".	
	Percentages of how many people already replace visiting friends by video calling are taken from the Future Thinking survey for each country (average 18%). For Germany and France the average of other countries was used.	Consumer survey – see Appendix 5
Category	Connected Living	

Label	Text	Reference
Sub-category	Mobile banking	
Mechanism	Use of mobile phone for banking transactions, resulting in a reduction in physical trips to a bank.	
Methodology	The calculation methodology builds on the Monte Carlo simulation developed by the Yankee Group for the report 'Measuring the Energy Reduction Impact of Selected Broadband-Enabled Activities within Households' (2012). The main saving mechanism is from travel avoidance. The Yankee Group model is used to derive an abatement factor per person in the average population. This is then multiplied by the ratio of mobile logins to PC logins to give a mobile abatement per person.	
Assumptions	Methodology and assumptions from Yankee Group Study.	(Yankee Group Research Inc. and the American Council for an Energy-Efficient Economy (ACEEE) 2012)
	Mobile banking logins as a percentage of total online banking logins (52%).	(BBA 2015)
Category	Connected Living	
Sub-category	Mobile shopping	
Mechanism	Reduced travel to shops, from on-line shopping from a mobile device.	
Methodology	The calculation methodology builds on the Monte Carlo simulation developed by the Yankee Group for the report 'Measuring the Energy Reduction Impact of Selected Broadband-Enabled Activities within Households' (2012). The model has been adjusted to assume that everybody moves to online shopping to get a saving per average person. This figure is then multiplied by the online market share of the entire retail industry. This figure is then multiplied by the mobile market share of the total online market to give an effective mobile saving per person. This abatement factor is then multiplied by the population in each country/region.	
Assumptions	Methodology and assumptions from Yankee Group Study.	(Yankee Group Research Inc. and the American Council for an Energy-Efficient Economy (ACEEE) 2012)
	Online market share as a percentage of retail sales for different countries, is taken from the Centre for Retail Research (2014 data used, ranges from 3% to 13.5% for different countries). The mobile percentage share of the online retail market is also taken from the Centre for Retail Research (2014 data used, ranges from 9.4% to 18.7% for different countries).	(Centre for Retail Research 2015)
Category	Connected Living	
Sub-category	Ride sharing	

Label	Text	Reference
Mechanism	Smartphone Apps that help people who are already driving long journeys to share rides with others, thus avoiding the need for alternative travel modes. e.g. blablacar.com, liftshare.com	
Methodology	Estimation is based on the proportion of those using ride sharing apps, and the frequency of journeys, multiplied by the emissions of a passenger travelling an equivalent journey on a coach.	
Assumptions	Ride sharing replaces coach travel.	
	Assumed that an average ride share journey is 200km.	
	Carbon Trust consumer research data was used for the number of smartphone users that use their phones to find lifts. Where possible, country specific figures were used. The average figures were 5% do this "frequently", and 10% do this "sometimes". It was assumed that frequent use was 3 ride share journeys per year, and sometimes was equivalent to 1 ride share journey per year.	Consumer survey – see Appendix 5
Category	Connected Living	
Sub-category	Sharing economy (goods sharing)	
Mechanism	Mobile technology facilitates a market for second-hand goods. Renting equipment avoids the purchase and manufacture of new goods.	
Methodology	Results of the Future Thinking survey were used to estimate the use of the technology. Assuming each person rents/shares a set number of indicative products a year, the avoided embodied emissions of purchasing a new product are equal to the carbon abatement.	
Assumptions	Assume embodied emissions of a standard 'annual bundle' of rented/shared goods is 60 $kgCO_2e$. The bundle of goods includes: lawnmower, drill, shoes, CD, books. Carbon footprint values are from appropriate sources. Lifetime replacement factors were assumed, and typical number of rentals/shares per year.	
	Carbon Trust consumer research data was used for the number of smartphone users that use their phones for goods sharing. Where possible, country specific figures were used. The average figures were 9% do this "frequently", and 18% do this "sometimes". It was assumed that 'sometimes' equates to 10% of rentals/shares are made by smartphone, and 'frequently' equates to 30%.	Consumer survey – see Appendix 5
Category	Connected Living	
Sub-category	Smart homes	
Mechanism	Use of smartphone to remotely control devices in the home, thus reducing energy use.	

Label	Text	Reference
Methodology	The average annual emissions per person (for household gas and electricity emissions) were estimated and then multiplied by the percentage of reduction in energy consumption due to remotely controlling devices through services such as Nest or Hive. This emissions reduction was then multiplied by the percentage of people who control devices in the home using a smartphone. This gives the carbon abatement per person for those who already control their devices remotely. The volume factor is the number of people with a smartphone.	
Assumptions	Guardian article (by Gordon Kelly) tested four smart thermostats and concluded that smarter control of your heating and remote access can offer energy savings of 20-30%.	(Kelly 2015)
	The Guardian figure is a combination of different estimates from industry and is likely to be estimated based on perfect conditions. Therefore, this percentage was lowered and a 12.5% energy saving was assumed when remote controlling a home.	
	Number of Homes with smart thermostats in 2014 were 2.5 million in the US. As a percentage of households, this means that approximately 2% of smartphone users in the USA have smart thermostats. It was assumed that these people will remotely control their devices.	(The NEWS Magazine 2015)
	More than 200,000 people are already using the British Gas Hive system to wield greater control over their home energy use. This is 0.8% of UK households. This percentage was assumed for the rest of Europe. As it only includes Hive for the UK, this percentage was adjusted to include other systems such as Nest to 1% for the UK.	(Business Green 2015)
Category	Connected Living	
Sub-category	Use of mobile as a satnav	
Mechanism	Reduced distance travelled due to use of smartphone as a satnav.	
Methodology	Estimation is based on the proportion of smartphone users using their phones as satnav, multiplied by a fuel saving factor for satnav, distance driven, an average car emission factor, and proportion of miles driven with a satnav.	
Assumptions	The SWOV Study gives a fuel saving factor of 16% for use of satnav in unfamiliar areas. As this was deemed very high, a conservative factor of 5% saving was used.	(SWOV (Institute for Road Safety Research) 2010)
	The percentage of smartphone users that drive cars is taken from the Carbon Trust Future Thinking Survey. Figures range between 68% for UK and 94% for USA. Country specific figures were used.	Consumer survey – see Appendix 5
	Average vehicle annual distances for cars were sourced from national government statistics data.	
	It was assumed that 10% of total journeys made are in unfamiliar areas that would require satnav.	
	The frequency of use of a smartphone as a satnav comes from Carbon Trust Future Thinking Survey.	Consumer survey – see Appendix 5

Label	Text	Reference
Category	Connected Transportation	
Sub-category	Car sharing (car clubs)	
Mechanism	Car sharing car clubs allow the shared use of a car by multiple users. Each vehicle owned by a car club operator is equivalent to one M2M connection. Smartphones are used to book, locate and unlock car club vehicles. Resulting reductions in carbon emissions are due to car club members reducing their annual distance travelled by car, and improved fuel efficiency of car club cars compared to private cars.	
Methodology	Being in a car club reduces individual travel as non-essential journeys are no longer made by car. Savings per member are calculated by multiplying the average distance reduced by an average car emission factor. This is then multiplied by the average number of members per car to calculate the carbon abatement per car. The savings from more efficient cars is calculated by multiplying the average car club annual distance by the difference in emission factors for car club car compared to a typical average private car.	
Assumptions	Average Zipcar emissions are 110gCO_2e/km.	(Zipcar 2014)
	33 members per car club car in England and Wales (outside of London), and average net reduction in mileage is 1910 miles (3074 km) per member. Total average mileage is 3500 per member.	(Carplus 2015)
	9000 car sharing vehicles and 380,000 members. Equates to 42 members per car club car in Germany. This figure was used for Germany and 33 for all other countries.	(Bundesverband CarSharing e.V 2015)
	It was assumed that the average club car travels 20,000 miles per year (32,186km), this equates to 606miles (975km) per member.	
Category	Connected Transportation	
Sub-category	Fleet vehicle driver behaviour improvement	
Mechanism	Improvement of driver behaviour through telematics - leading to reduced fuel consumption.	
Methodology	Calculate average emissions per vehicle for cars, LGVs and HGVs, using national data on total distance, number of vehicles, and standard emission factors. Calculate weighted average vehicle emissions assuming mix of car/LGV/HGV for M2M connections. Multiply average emissions per vehicle by percentage fuel saving (based on various studies).	
Assumptions	A 10% fuel saving was assumed due to improved driver behaviour. Various published and unpublished studies indicate savings from 5-15%, dependant on level of intervention. Examples of some published sources:	
	• 2-10% fuel saving, Jürgen Hase, VP of M2M Competence Centre at Deutsche Telekom.	(O'Flaherty 2013)
	• 9% saving in all fleet	(FleetNews 2011)
	• 10-15% savings	(Energy Saving Trust 2011)
	• up to 20% saving	(Fleet industry advisory group 2014)

Label	Text	Reference
	• 10%-15% saving, Jari Salminen, Vodafone head of business development, M2M	(O'Flaherty 2013)
	• an average of 5-10% savings on fuel costs - in many cases, this saving reaches 15%	(Mix Telematics 2015)
	• 14% saving	(FleetNews 2011)
	• 20% saving	(Het nieu Rijden 2015)
	• 10% saving	(ANWB 2015)
	• 15% saving	(EcoDrive 2015)
	• 11.5% - 18.3% saving	(Sycada-Green 2010)
	Average annual distances for cars/LGVs/HGVs were used based on national statistics and emission factors.	
	A mix of vehicle types were assumed (20% car, 60% LGV, 20% HGV) based on typical split of M2M connections for Fleet Management. (Carbon Trust analysis).	
Category	Connected Transportation	
Sub-category	Remote vehicle condition monitoring	
Mechanism	Remote vehicle condition monitoring, allowing advance maintenance planning that reduces breakdowns and reduced call-out journeys by breakdown vans.	
Methodology	Estimation is based on a reduction in average call outs, multiplied by the average distance of a call out using a van emission factor.	
Assumptions	Assumed average distance of a call out is 15km.	
	Assumed that people call out breakdown vans on average 0.5 times a year.	
	Clever Devices suggest that Automatic Vehicle Monitoring reduces call outs by 25-40%. A figure of 25% reduction in call outs was assumed.	(Clever Devices 2015)
Category	Connected Transportation	
Sub-category	Roadside assistance	
Mechanism	Vehicle condition monitoring, allowing breakdown companies to plan better call out trips. Resulting reduction in carbon emissions is from using motorbikes instead of vans to fix flat batteries.	
Methodology	Estimation is based on the average call outs for battery related issues multiplied by the emissions of an average call out on a motorbike, subtracted from the emissions of an average call out using a van.	
Assumptions	Average annual battery related calls is assumed to be 0.3 call outs per member.	
	Average distance of a call out is assumed to be 15km.	
Category	Connected Transportation	
Sub-category	Satellite navigation	
Mechanism	Use of satellite navigation (satnav) in cars, reducing distance travelled, incorporating traffic information.	
Methodology	Estimation is based on a fuel saving factor for satnav, annual distance driven, an average car emission factor, and proportion of miles driven with a satnav.	

Label	Text	Reference
Assumptions	The SWOV Study gives a fuel saving factor of 16% for use of satnav in unfamiliar areas. As this was deemed very high, a conservative factor of 5% saving was used.	(SWOV (Institute for Road Safety Research) 2010)
	It was assumed that 10% of total journeys made are in unfamiliar areas that would require satnav.	
Category	Connected Transportation	
Sub-category	Sea fleet	
Mechanism	Tracking of Sea fleets and real-time information updates, allowing for optimised routings, direction of ships to most appropriate port, reducing waiting and loading times at docks. Resulting in overall savings in transport fuel used.	
Methodology	SEMAFORS optimised ship routing estimates fuel savings of up to 5%. Using this information and taking a conservative estimate of real savings of 2%, apply this to the average emissions of a commercial ship. The average is calculated from the overall global shipping emissions divided by the number of vessels. This information is obtained from the IMO (International Maritime Organization).	
Assumptions	Total annual emissions from the global shipping fleet were 972,000,000tCO_2e. This is based on 54,897 vessels.	(International Maritime Organisation (IMO) 2014)
	Assume a conservative estimate of 2% savings.	(Semafors 2013)
Category	Connected Transportation	
Sub-category	Smart logistics - efficient routing & fleet management	
Mechanism	Better routing and coordination of vehicle fleets, resulting in reduction of total distance travelled, avoiding areas of high congestion and optimising fuel usage.	
Methodology	Calculate average emissions per vehicle for cars, LGVs and HGVs, using national data on total distance, number of vehicles, and standard emission factors. Calculate weighted average vehicle emissions assuming mix of car/LGV/HGV for M2M connections. Multiply average emissions per vehicle by percentage fuel saving (based on various studies).	
Assumptions	A 5% fuel saving was assumed (various sources suggest 2-15% savings) - e.g.	
	• 2-10% fuel saving	(O'Flaherty 2013)
	• 9% saving in all fleet	(FleetNews 2011)
	• 10-15% savings	(Energy Saving Trust 2011)
	• up to 20% saving	(Fleet industry advisory group 2014)
	• 10%-15% saving, Jari Salminen, Vodafone head of business development, M2M	(O'Flaherty 2013)
	Average annual distances for cars/LGVs/HGVs were assumed based on national statistics and emission factors.	
	A mix of vehicle types was assumed (20% car/60% LGV/20% HGV) based on typical split of M2M connections for Fleet Management. (Carbon Trust analysis).	
	It was assumed that routing savings are only applicable to goods vehicles.	

Label	Text	Reference
Category	Connected Transportation	
Sub-category	Smart logistics - loading optimisation	
Mechanism	Remote monitoring of vehicle loading, allowing better utilisation of vehicles and hence reduced overall journey distances.	
Methodology	Calculate average emissions per vehicle for cars, LGVs and HGVs, using national data on total distance, number of vehicles, and standard emission factors. Calculate weighted average vehicle emissions assuming mix of car/LGV/HGV for M2M connections. Multiply average emissions per vehicle by percentage fuel saving (based on various studies).	
Assumptions	A 2% fuel saving was assumed for loading optimisation of goods vehicles. Reference indicates that 10% of miles in the USA of leased freight is empty. It was assumed that a fifth of the 10% figure (i.e. 2%) can be saved due to telematics. Various other sources suggest 2-15% savings due generically to telematics in vehicles. - e.g.	(Carbon War Room 2012)
	• 2-10% fuel saving	(O'Flaherty 2013)
	• 9% saving in all fleet	(FleetNews 2011)
	• 10-15% savings	(Energy Saving Trust 2011)
	• up to 20% saving	(Fleet industry advisory group 2014)
	• 10%-15% saving, Jari Salminen, Vodafone head of business development, M2M	(O'Flaherty 2013)
	Average annual distances were used for cars/LGVs/HGVs based on national statistics and emission factors.	
	A mix of vehicle types were assumed (20% car/60% LGV/20% HGV) based on typical split of M2M connections for Fleet Management. (Carbon Trust analysis).	
	It was assumed that loading optimisation savings are only applicable to goods vehicles.	
Category	Connected Transportation	
Sub-category	Usability of public transport	
Mechanism	Use of real time user access to information on public transport services on a mobile device encourages greater use of public transport. This results in a modal shift from car to public transport.	
Methodology	Consideration was made of the percentage of typical smartphone users that drive to work and their average commuting distance by car. Taking the results from the consumer research survey, this is multiplied by the percentage of people who say that they use public transport more often. It was assumed that for those that do shift some of their journeys to public transport, that they do this for 10% of their journeys. Savings are applied only to daily commute journeys.	
Assumptions	Average commute distances by car for European countries taken from the European Commission JRC report.	(Pasaoglu et al. 2012)
	Average commute distances by car for USA taken from the US DOT NHTS report.	(US Department of Transportation Federal Highways Administration (FHWA) 2011)

Label	Text	Reference
	It was assumed that using public transport is twice as efficient (in terms of emissions) as transport by personal car, and therefore reduces emissions by 50%.	
	53.6% of people drive to work in UK. It was assumed that this is the same for other European countries.	(Office for National Statistics 2013)
	76.1% of Americans drive to work.	(McKenzie & Rapino 2011)
	Results were taken from the consumer research survey for the percentage of people who use public transport more often as a result of having access to accurate public transport information on their mobile phones (46% to 53% dependant on country). It was assumed that "use public transport more often" means that public transport will be used for 10% of journeys that would otherwise have been done by car.	Consumer survey – see Appendix 5
Category	Connected Transportation	
Sub-category	Usage based car insurance	
Mechanism	Telemetrics (black box) in car collects data on driving behaviour, and rewards safe driving with lower insurance premiums. This leads to improved driving behaviour, reduced fuel consumption and reduced repairs due to accidents.	
Methodology	Estimation is based on a fuel saving factor from eco driving, multiplied by average distance driven using a small car emission factor. This is added to calculated savings from reduced accidents: economic input output data showing the average emissions per £ spent on car repairs, multiplied by the reduction in the average car insurance claim for 17-25 year olds from having a black box installed.	
Assumptions	30% reduction in car insurance claims from black box insurance.	(The Co-operative insurance 2013)
	£600 average size of insurance claim for 17-25 year olds.	(Association of British Insurers 2014)
	0.2889 $kgCO_2e$ per £ spent on car repairs (Carbon Trust analysis derived from EEIO factors).	
	Assumed 5% fuel saving due to improved driver behaviour.	
Category	Connected Working	
Sub-category	Audio conferencing	
Mechanism	Reduction in business travel due to the ability to use audio conferencing facilities, thus avoiding emissions from travelling.	
Methodology	Calculate a total carbon abatement using the avoided emissions per audio conference. The number of audio conference calls made for each country can be calculated by dividing the total number of billable audio conference minutes by the average minutes per conference call. This total carbon abatement is then allocated between mobile and fixed line by multiplying by the percentage of conference calls made by mobile. This is then divided by the total number of mobile phone subscriptions in a country to give a carbon abatement per mobile phone.	

Label	Text	Reference
Assumptions	Avoided emissions from one audioconference call = 28.1kgCO_2e.	(Carbon Trust 2015)
	21.2% of audioconference calls are made from a mobile.	(Collins 2014)
	Market data (by country) on annual billable audioconference minutes provided by BT. Assumed average length of conference call of 55 minutes, with 4.5 participants per call, and that this is the same for all countries.	
Category	Connected Working	
Sub-category	Working from home	
Mechanism	People working from home rather than travelling to an office, resulting in a reduction in commuting transport and reduction in office energy consumption. (Rebound effects of increased home energy consumption and increased personal errands were included in the calculation).	
Methodology	Using as a basis previous Carbon Trust research, and Carbon Trust research for Vodafone Netherlands to calculate average carbon savings per telecommuter. These considered savings from reduced commuting, savings from reduced office energy, and increased home energy use. Apportion this to mobile based on the percentage of telecommuters for whom mobile is important to carry out their work. Convert the 'per telecommuter' figure to a 'per working person' figure by multiplying by the percentage of telecommuters of the total workforce.	
Assumptions	Assumed average telecommuter works 2 days per week from home in UK and 1.4 days per week in Netherlands (based on survey data).	
	Average carbon savings from telecommuting in UK per year: 617 kg CO_2e per telecommuter.	(Carbon Trust 2014)
	Average carbon savings from telecommuting in Netherlands per year: 348 kg CO_2e per telecommuter.	(Vodafone Netherlands 2015)
	The average of the UK and Netherlands figures were used to give a carbon saving of 482.5 kg CO_2e per telecommuter, and applied this to all countries.	
	For the percentage of the total working population that are telecommuters, a 12% figure was used for the UK, and 20% for other countries. (20% being the average of the UK (12%) and Netherlands (28%) figures). Data from national statistics.	
	Results from a survey commissioned by Vodafone Netherlands show that "25% of the working population work from home for either full or part days and consider that either a mobile phone or a dongle is important for them to carry out their work". This figure of 25% was used and it was applied to all countries.	(Vodafone Netherlands 2015)
Category	Physical-to-Digital	
Sub-category	Multi-functional device	
Mechanism	Use of smartphone to replace multiple devices (e.g. camera, calculator, non-smartphone, music player, game console, alarm clock, satnav). Leading to reduced embodied emissions of multiple devices.	

Label	Text	Reference
Methodology	1. Using results from consumer survey gives percentage of smartphone users that say they replace devices with a smartphone. 2. Calculate embodied carbon avoided, by considering the carbon footprint of each device and weighting it by the percentage of people that use that function. 3. Multiply percentage from (1) by embodied carbon avoided (2) and divide by assumed replacement period in years.	
Assumptions	Percentage of smartphone users that say they replace devices with a smartphone is taken from consumer survey. UK: 58%, USA 62%, Spain 70%, Average 64%.	Consumer survey – see Appendix 5
	Embodied carbon footprint for different devices from industry study. Feature phone: 5.4 $kgCO_2e$. MP3 player: 10.3 kg CO_2e. Camera: 19 kg CO_2e. Game console: 31.6 $kgCO_2e$. Satnav device: 18.6 $kgCO_2e$. Smartphone: 41.9 $kgCO_2e$.	
	Percentage of smartphone users that use other functions on their smartphone - figures from consumer research.	Consumer survey – see Appendix 5
	Assume typical replacement period for devices of 2 years.	
Category	Physical-to-Digital	
Sub-category	Newspapers, music, DVD, storage	
Mechanism	Use of mobile devices to replace physical media with digital media for the following: newspapers, music CDs, video DVDs, and photos. The carbon savings are from no longer having the physical media.	
Methodology	The calculation methodology builds on the Monte Carlo simulation developed by the Yankee Group for the report 'Measuring the Energy Reduction Impact of Selected Broadband-Enabled Activities within Households' (2012). The model has been adjusted to calculate the average carbon saving per person if everybody adopted digital to replace physical media. This is calculated for Europe and USA. This figure is then multiplied by the online market share of the entire retail industry, to calculate the carbon savings from on-line activity. The resulting figure is then multiplied by the mobile market share of the total online market, which gives a carbon saving from mobile use per person.	
Assumptions	Methodology and assumptions are taken from the Yankee Group Study.	(Yankee Group Research Inc. and the American Council for an Energy-Efficient Economy (ACEEE) 2012)
	The data for percentage of retail sales, online market share, and mobile percentage share of online market are taken from the Centre for Retail Research for each specific country that is analysed.	(Centre for Retail Research 2015)

Appendix 4: References for data sources and assumptions

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Appendix 5: Findings from consumer research

In April 2015 the Carbon Trust commissioned Future Thinking to carry out research into the ownership and use of smartphones in the UK, USA, Spain, Mexico and South Korea. The research explored smartphone use, smart working and smart travel.

Selected data from the research are presented in the tables below, preceded by the question asked within the survey in English. Korean translation was used in South Korea and local Spanish translations were used in Spain and Mexico.

Device ownership

This question is about smartphones, such as Android, Apple, Blackberry or Windows phones which have smart capabilities including:

- *Accessing the internet*
- *Apps you download*
- *A camera function*
- *GPS location functions*
- *Any other function that your device can do in addition to being a phone.*

Which of the following best applies to you?

	Total	UK	USA	Spain	South Korea	Mexico
Total	4000	800	800	800	800	800
I have access to a smartphone and make use of its smart capabilities	3669	674	736	742	765	752
I have access to a smartphone but do not make use of its smart capabilities	277	115	54	55	18	35
I do not have access to a smartphone now but intend to get one in the near future	54	11	11	3	17	13

Do you have access to a touch-screen tablet computer?

	Total	UK	USA	Spain	South Korea	Mexico
Total	4000	800	800	800	800	800
Yes	2500	510	452	547	355	635
No	1500	290	348	253	445	165

Driving and smart devices

Do you drive a vehicle?

	Total	UK	USA	Spain	South Korea	Mexico
Total	4000	800	800	800	800	800
Yes	3220	541	754	692	568	664
No	780	259	46	108	232	136

Do you use a satnav for planning routes, following routes, and avoiding traffic congestion on a mobile device such as a smartphone?

	Total	UK	USA	Spain	South Korea	Mexico
Total	3220	544	755	692	564	665
All of the time	882	81	160	167	260	214
Some of the time	1330	185	291	308	244	302
Rarely	481	101	146	103	39	91
Never	527	175	156	114	25	57

Do you use a satnav for planning routes, following routes, and avoiding traffic congestion on a fixed satnav in your vehicle?

	Total	UK	USA	Spain	South Korea	Mexico
Total	3220	544	755	692	564	665
All of the time	610	73	71	84	319	63
Some of the time	803	168	153	193	154	134
Rarely	400	72	127	70	33	97
Never	1407	228	402	345	62	371

On average, how many trips per week do you use a satnav?

	Total	UK	USA	Spain	South Korea	Mexico
Total	2898	459	651	614	561	611
less than one a week	1332	303	386	365	97	181
1-2 journeys per week	793	83	151	165	166	228
3-4	435	43	63	52	154	122
5-6	166	20	28	19	59	41
7-8	64	4	9	7	25	18
9-10	29	1	5	3	15	6
Over 10 journeys a week	79	5	8	5	46	15

Would you be willing to have a device fitted to your vehicle which records the way you drive, if driving in a safer and more environmentally-friendly way reduced your car insurance?

	Total	UK	USA	Spain	South Korea	Mexico
Total	3220	541	754	692	568	664
Yes, I already use one	270	37	67	46	61	58
Yes, I would consider it	1762	229	274	388	370	501
Maybe	702	141	190	173	117	82
No	398	114	195	58	13	17
Don’t know	89	20	28	27	7	7

Self-driving cars are being developed. These high-tech vehicles would know their surroundings and the position of other cars and would effectively drive themselves. If they were fully developed and legal, would you consider using a self-driving car?

	Total	UK	USA	Spain	South Korea	Mexico
Total	3220	541	754	692	568	664
Yes, I would consider	1301	134	225	263	246	433
Maybe	1264	200	282	306	276	200
No	481	162	192	85	25	16
Don't know	174	45	55	38	22	14

Public transport

In some regions, you can use a mobile device and/or an app when using public transport (e.g. bus, train) to find out precisely when the next service arrives. Is this something you have ever used?

	Total	UK	USA	Spain	South Korea	Mexico
Total	4000	800	800	800	800	800
Yes	1907	318	206	396	679	308
No	2093	482	594	404	121	492

Do you use public transport more often as a result of this information being available on your mobile device?

	Total	UK	USA	Spain	South Korea	Mexico
Total	1907	318	206	396	679	308
Much more often	477	47	47	71	241	71
Slightly more often	688	92	63	118	273	143
Makes no difference	704	174	93	195	161	82
Don't know	38	5	3	13	5	12

Would you be more likely to use public transport (e.g. bus, train) if by using your mobile device and/or an app you could find out precisely when the next service would arrive?

	Total	UK	USA	Spain	South Korea	Mexico
Total	2093	482	594	404	121	492
Much more likely to use public transport more often	408	33	51	71	20	233
Slightly more likely to use public transport more often	614	121	103	163	48	179
Unlikely to use public transport more often	585	204	185	112	26	58
Would definitely not use public transport more often	260	60	157	24	9	9
Don't know	226	64	97	34	18	14

Reducing travel emissions

Are you, or would you be willing in future, to use your mobile device to make or influence travel plans (e.g. mapping routes, checking traffic, checking public transport times)?

	Total	UK	USA	Spain	South Korea	Mexico
Total	4000	800	800	800	800	800
I already do this frequently	1026	160	172	171	307	215
I already do this sometimes	1396	266	269	311	276	275
I would be willing to do this frequently	556	90	106	111	103	146
I would be willing to do this sometimes	796	203	181	169	96	147
I would not be willing to do this	226	81	72	39	18	17

Are you, or would you be willing in future, to use your mobile device to find someone to share a car journey with?

	Total	UK	USA	Spain	South Korea	Mexico
Total	4000	800	800	800	800	800
I already do this frequently	199	31	34	39	36	60
I already do this sometimes	407	61	73	85	58	130
I would be willing to do this frequently	650	82	89	133	122	224
I would be willing to do this sometimes	1023	152	151	261	232	227
I would not be willing to do this	1722	474	454	282	352	160

Are you, or would you be willing in future, to replace a visit to the bank by using a mobile device?

	Total	UK	USA	Spain	South Korea	Mexico
Total	4000	800	800	800	800	800
I already do this frequently	1171	178	184	211	348	250
I already do this sometimes	889	147	158	211	176	196
I would be willing to do this frequently	712	116	117	138	146	195
I would be willing to do this sometimes	611	140	141	137	83	111
I would not be willing to do this	617	219	200	102	47	49

Are you, or would you be willing in future, to replace a visit to the shops by using a mobile device?

	Total	UK	USA	Spain	South Korea	Mexico
Total	4000	800	800	800	800	800
I already do this frequently	651	103	105	119	209	115
I already do this sometimes	980	160	170	186	259	204
I would be willing to do this frequently	777	120	123	159	160	216
I would be willing to do this sometimes	921	194	221	197	124	186
I would not be willing to do this	671	223	180	139	48	80

Are you, or would you be willing in future, to replace a visit to friends or family by making a video call using a mobile device?

	Total	UK	USA	Spain	South Korea	Mexico
Total	4000	800	800	800	800	800
I already do this frequently	374	35	63	78	97	102
I already do this sometimes	715	112	123	123	196	161
I would be willing to do this frequently	604	101	109	104	169	122
I would be willing to do this sometimes	1066	208	221	200	232	205
I would not be willing to do this	1241	344	285	296	106	210

Remote working

Do you use a mobile device as part of your work/studies?

	Total	UK	USA	Spain	South Korea	Mexico
Total	2946	540	566	538	610	692
Yes	1993	245	275	354	505	616
No	952	295	292	184	105	76

Could you do your job/studies without your mobile device?

	Total	UK	USA	Spain	South Korea	Mexico
Total	1993	245	275	354	505	616
Yes	1233	181	204	217	270	362
No	760	64	70	137	235	254

Does having a mobile device enable you to work/study from home?

	Total	UK	USA	Spain	South Korea	Mexico
Total	1993	245	275	354	505	616
Yes	1602	182	196	276	385	563
No	391	63	78	78	119	53

Does having a mobile device enable you to work/study outside your normal workplace/educational establishment?

	Total	UK	USA	Spain	South Korea	Mexico
Total	1993	245	275	354	505	616
Yes	1669	192	223	288	408	559
No	324	53	51	66	96	57

Smart health

Are you, or would you be willing in future, to replace a non-emergency visit to the doctor by making a phone call?

	Total	UK	USA	Spain	South Korea	Mexico
Total	4000	800	800	800	800	800
I already do this frequently	282	66	56	51	36	73
I already do this sometimes	533	134	82	100	50	168
I would be willing to do this frequently	920	160	209	166	194	192
I would be willing to do this sometimes	1396	296	303	269	324	205
I would not be willing to do this	868	145	150	215	196	162

Are you, or would you be willing in future, to replace a non-emergency visit to the doctor by making a video call?

	Total	UK	USA	Spain	South Korea	Mexico
Total	4000	800	800	800	800	800
I already do this frequently	129	21	34	20	23	31
I already do this sometimes	281	50	48	46	50	88
I would be willing to do this frequently	1041	151	196	206	218	270
I would be willing to do this sometimes	1470	283	304	301	311	272
I would not be willing to do this	1079	296	219	228	198	139

Are you, or would you be willing in future, to use a mobile device to seek health advice?

	Total	UK	USA	Spain	South Korea	Mexico
Total	4000	800	800	800	800	800
I already do this frequently	253	38	54	30	32	99
I already do this sometimes	680	159	153	109	83	176
I would be willing to do this frequently	1136	172	197	233	289	244
I would be willing to do this sometimes	1274	282	258	251	276	206
I would not be willing to do this	657	149	138	176	120	74

Are you, or would you be willing in future, to use a mobile device to monitor your fitness and health?

	Total	UK	USA	Spain	South Korea	Mexico
Total	4000	800	800	800	800	800
I already do this frequently	284	42	73	36	41	92
I already do this sometimes	626	120	133	102	116	155
I would be willing to do this frequently	1304	205	213	283	309	294
I would be willing to do this sometimes	1194	266	251	250	245	182
I would not be willing to do this	592	167	130	129	89	77

Multifunctional devices

Do you currently use any of the following functions on a mobile device (smartphone/mobile)? Choose all that apply.

	Total	UK	USA	Spain	South Korea	Mexico
Total	4000	800	800	800	800	800
Alarm Clock	3244	610	579	662	679	714
Music player	2952	458	476	566	715	737
Video player	2580	351	363	563	624	678
Satnav	2515	368	416	545	576	610
Camera	3638	697	701	740	746	753
None of these	103	40	43	13	6	2

Are you, or would you be willing in future, to replace the use of other devices with a smartphone (e.g. camera, alarm clock, music player, satnav)?

	Total	UK	USA	Spain	South Korea	Mexico
Total	4000	800	800	800	800	800
I already do this frequently	1892	259	278	361	513	481
I already do this sometimes	937	207	220	200	164	145
I would be willing to do this frequently	451	84	86	106	85	89
I would be willing to do this sometimes	477	163	145	87	26	55
I would not be willing to do this	242	87	71	45	11	29

Are you, or would you be willing in future, to use a mobile device to replace the purchase of physical products with digital products (e.g. newspapers, books, music)?

	Total	UK	USA	Spain	South Korea	Mexico
Total	4000	800	800	800	800	800
I already do this frequently	795	130	128	109	275	153
I already do this sometimes	1176	193	217	212	259	295
I would be willing to do this frequently	690	108	128	159	133	162
I would be willing to do this sometimes	813	175	201	204	101	131
I would not be willing to do this	526	194	125	117	32	59

Are you, or would you be willing in future, to use a mobile device to control your electrical appliances and heating/cooling at home?

	Total	UK	USA	Spain	South Korea	Mexico
Total	4000	800	800	800	800	800
I already do this frequently	209	38	49	28	39	55
I already do this sometimes	365	52	78	52	90	93
I would be willing to do this frequently	1491	251	221	344	313	362
I would be willing to do this sometimes	1229	237	268	256	261	207
I would not be willing to do this	706	222	185	120	97	83

Are you, or would you be willing in future, to use a mobile device for payments to replace your credit/debit card or cash use?

	Total	UK	USA	Spain	South Korea	Mexico
Total	4000	800	800	800	800	800
I already do this frequently	495	52	71	37	232	103
I already do this sometimes	661	81	122	66	231	161
I would be willing to do this frequently	1036	163	141	297	159	276
I would be willing to do this sometimes	915	216	188	235	109	167
I would not be willing to do this	893	288	278	165	68	94

Are you, or would you be willing in future, to use a mobile device to replace the use of tickets for travel or events?

	Total	UK	USA	Spain	South Korea	Mexico
Total	4000	800	800	800	800	800
I already do this frequently	372	41	67	55	143	67
I already do this sometimes	757	124	144	124	245	120
I would be willing to do this frequently	1200	210	170	303	209	309
I would be willing to do this sometimes	1092	237	262	220	158	215
I would not be willing to do this	580	188	158	99	46	89

Sharing economy

Are you, or would you be willing in future, to use a mobile device to sell, rent, share items that you own?

	Total	UK	USA	Spain	South Korea	Mexico
Total	4000	800	800	800	800	800
I already do this frequently	409	71	78	66	70	124
I already do this sometimes	707	125	113	131	146	191
I would be willing to do this frequently	843	118	128	211	166	220
I would be willing to do this sometimes	1157	217	247	244	262	187
I would not be willing to do this	884	269	234	148	155	77

Are you, or would you be willing in future, to use a mobile device to buy or rent items from others?

	Total	UK	USA	Spain	South Korea	Mexico
Total	4000	800	800	800	800	800
I already do this frequently	374	64	63	48	87	112
I already do this sometimes	706	128	106	146	152	174
I would be willing to do this frequently	882	119	136	206	179	242
I would be willing to do this sometimes	1149	210	245	246	260	189
I would not be willing to do this	888	279	249	154	122	84

Are you, or would you be willing in future, to use a mobile device to find and book accommodation in someone's home instead of using a hotel?

	Total	UK	USA	Spain	South Korea	Mexico
Total	4000	800	800	800	800	800
I already do this frequently	339	41	58	56	78	105
I already do this sometimes	662	88	75	168	143	188
I would be willing to do this frequently	919	130	137	197	217	238
I would be willing to do this sometimes	1024	152	186	253	244	187
I would not be willing to do this	1056	388	343	125	118	82

Are you, or would you be willing in future, to use a mobile device to access public services (e.g. voting, obtaining parking permits, paying fines, renewing driving license)?

	Total	UK	USA	Spain	South Korea	Mexico
Total	4000	800	800	800	800	800
I already do this frequently	281	50	46	47	68	68
I already do this sometimes	586	117	88	103	149	129
I would be willing to do this frequently	1442	197	243	318	343	341
I would be willing to do this sometimes	1094	244	255	220	195	180
I would not be willing to do this	598	193	168	112	45	81

Appendix 6: Rebound effects

Rebound effects relate to additional emissions caused indirectly by (or as a result of) the same mechanism that is causing the savings. Ideally these rebound effects should be quantified and deducted from the savings.

Rebound effects fall into different categories. There are those where additional activities resulting from the mechanism produce additional emissions. Examples of these for home working are additional emissions from heating the home, and emissions due to additional car journeys from errands such as lunch time trips or school runs.

There are those where the use of the ICT solution increases because of its ease-of-use, convenience or low cost, so that its use is greater than the business as usual case without the ICT solution (and therefore the emissions of the ICT solution increase). This is the so-called Jevons paradox. Examples include mobile phone app based solutions, where the convenience encourages greater use.

There is also the indirect rebound effect of re-allocating resources that have been saved. An example of this is where a household saves money through energy saving measures, and then spends that money on additional holidays incurring extra carbon emissions from flying.

In practice, it is difficult to comprehensively identify rebound effects, and even more difficult to quantify them. Thus, except for home working, the rebound effects have not been included. Home working carbon abatement is a result of reducing the travel from commuting. Immediate rebound effects are additional energy consumption at home, and additional trips for personal errands such as trips to the shops at lunch time and picking up the kids from school. There is also the positive rebound effect of reduced office energy consumption, although this relies on a significant proportion of a company's workforce working from home, and thus allowing for smaller offices or otherwise reduced energy consumption. Home working is unusual in that the carbon benefits have been studied for some time, and the immediate rebound effects are identifiable and quantifiable.

An example of where rebound effects could have an adverse effect is parking space monitoring, where smart sensors provide information on available parking spaces and feed this information to drivers, who then save time and fuel in driving around looking for available parking. However, if it is then easier to find parking spaces this can then encourage more people to drive into cities, when they would otherwise have used public transport. More generally, there may be a number of indirect rebound effects on carbon emissions from effective connected cities. For example, if driving becomes easier and more efficient, this may perversely result in more vehicles on the roads.

Another example is keeping in touch remotely with family and friends using voice and video calls to reduce the number of physical visits. However, there is also the potential that in some cases regular video calls might encourage people to undertake visits, which they otherwise would not have.

Mobile shopping reduces travel to shops, however there are the rebound effects of increased emissions due to delivery, and also the possibility that the convenience of mobile shopping encourages an overall increase in shopping activity. There is also the potential for reduced retail space with consequent reduction in energy consumption.

These cases highlight the need to have better data on actual behaviour to quantify actual reductions in amount of travel. In the analysis for this report assumptions were based on what people said that they did from the consumer survey, which is not always the same as what they actually did.

Glossary

Carbon dioxide
A greenhouse gas with a Global Warming Potential of 1.

Carbon abatement
The measurement of the avoided carbon emissions due to the enablement effect. Usually expressed in $kgCO_2e$.

Carbon emissions (CO_2e)
Within the context of this report carbon emissions is used as a shorthand way refer to a volume of greenhouse gas emissions, including other greenhouse gases than just carbon dioxide, but which can be expressed as carbon dioxide equivalent.

Enablement effect
Any mechanism by which carbon emissions can be avoided thanks to the use of technology.

Europe
The definition of Europe used in the report includes all countries in Europe, including Russia and the Caucasus republics, Turkey, Greenland and Iceland.

Fixed broadband
Fixed broadband provides high speed internet connectivity over physical cables (either copper or fibre or a combination of the two).

GPS
Global Positioning System using satellites for navigation purposes.

GWP
Global Warming Potential, a measurement used by the Intergovernmental Panel on Climate Change to compare the relative impacts of different greenhouse gases.

HVAC
Heating, ventilation and air conditioning.

HVG
Heavy goods vehicle.

ICT
Information and communications technology.

ITU
International Telecommunications Union.

LGV
Light goods vehicle.

LPWAN
Low Power Wide Area network – this includes a range of emerging technologies such as Weightless and Sigfox, that are designed for machine-to-machine (M2M) applications that have low data rates, long battery lives and that operate unattended for long periods of time.

M2M
Machine-to-machine.

MAN
Metropolitan area network is a computer network that covers part of a city or a complete city. It comprises a range of medium-range technologies including powerline and community Wi-Fi.

Methane
A greenhouse gas with a Global Warming Potential 30 times greater than carbon dioxide.

Mobile
Mobile is used in the report to refer to a variety of mobile communications technologies that allow for the transfer of information without fixed lines. These include:
- mobile phone networks;
- public Wi-Fi networks;
- metropolitan area networks;
- Low Power Wide Area networks (LPWAN); and
- satellite networks.

Mobile broadband
Mobile broadband uses the mobile phone network to provide high speed internet connectivity with 3G and 4G services.

Nitrous oxide
A greenhouse gas with a Global Warming Potential 265 times greater than carbon dioxide.

Rebound effect
Rebound effects relate to additional carbon emissions caused indirectly by (or as a result of) the same mechanism that is causing the carbon savings.

Satellite networks
Two-way connectivity between a ground-based device and a satellite providing high speed internet connection. Typically used only for niche applications and/or in remote parts of the world.

Satnav
Satellite navigation systems, which can be integrated within a vehicle, accessed through standalone devices or included as an app on smartphones.

Solar PV
Solar photovoltaic panels that generate renewable energy from sunlight.

Smart grid
A smart grid is an energy distribution system which includes a variety of operational and energy measures including smart meters, smart appliances, renewable energy resources, and energy efficiency resources.

V2V
Vehicle-to-vehicle.

Wi-Fi
Local area wireless networking technology using radio waves to provide high speed network connections based on the Institute of Electrical and Electronics Engineers' (IEEE) 802.11 standards.

The Carbon Trust is an independent company with a mission to accelerate the move to a sustainable, low carbon economy.

The Carbon Trust:

- Advises businesses, governments and the public sector on opportunities in a sustainable, low carbon world.
- Measures and certifies the environmental footprint of organisations, products and services.
- Helps develop and deploy low carbon technologies and solutions, from energy efficiency to renewable power.

www.carbontrust.com
+44 (0)20 7170 7000

The Carbon Trust is a company limited by guarantee and registered in England and Wales under company number 4190230 with its registered office at 4th Floor, Dorset House, Stamford Street, London SE1 9NT.

Published in the UK: December 2015

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