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ICE written submission to the National Infrastructure Assessment Call for Evidence

Dear Lord Adonis,

Please find below the Institution of Civil Engineers' submission to the National Infrastructure Commission's call for evidence on the National Infrastructure Assessment.

This submission draws on the ICE's *National Needs Assessment*, which we shared with the NIC back in October 2016. The report was the product of collaboration and consultation with a wide range of parties – including experts from industry, finance and environmental research - over an 18 month period. It also includes emerging findings from our next *State of the Nation* Policy Report, launching next month. *State of the Nation: Digital Transformation* will look out how best to harness technological advances to produce smarter infrastructure, which in turn, supports more prosperous communities.

As you will know, the ICE is a UK-based international organisation with over 91,000 members ranging from professional civil engineers to students. It is an educational and qualifying body and has charitable status under UK law. Founded in 1818, the ICE has become recognised worldwide for its excellence as a centre of learning, as a qualifying body and as a public voice for the profession.

ICE would like to thank the National Infrastructure Commission for the chance to take part in this consultation. We would welcome any opportunity to provide further insight at subsequent stages.

Yours sincerely,

Andrew Wescott
Head of Policy and Public Affairs

ICE Submission to the NIC's Call for Evidence on the National Infrastructure Assessment

1. What are the highest value infrastructure investments that would support long-term sustainable growth in your city or region? Note: this can apply to national, regional or local infrastructure, where you consider it would best support sustainable growth in your city or region in practice. Considerations of "highest value" should include benefits and costs, as far as possible taking a comprehensive view of both. "Long-term" refers to the horizon to 2050 and should exclude projects that are already in the pipeline.

Modern societies depend on infrastructure to sustain their quality of life and business competitiveness. Our advanced economy increasingly relies on connectivity – bringing people together physically and virtually to innovate and trade. Infrastructure is not a series of stand-alone assets. It delivers benefits through complex networks. We explore the opportunities derived by managing the network interdependently later in this submission.

3. How should infrastructure be designed, planned and delivered to create better places to live and work? How should the interaction between infrastructure and housing be incorporated into this?

Some of the greatest opportunities for innovation are in people's homes and workplaces – working and socialising with ultra-fast digital connectivity that removes a need to travel, smarter use of energy and storage which can be balanced with intermittent renewable energy supplies, energy generation with cheap photovoltaic cells, drastic reductions in demand for heating and cooling through intelligent design and retrofit, re-use of rainwater and sewage, resource recovery from solid waste – these are all opportunities that should be harnessed in new and retrofitted buildings.

Opportunities to reduce demand for water through recycling and reuse are currently not cost effective at a household scale but are being realised at community level.

We must reduce the cost of building and operating infrastructure. Innovation and training will be key. Use of offsite manufacturing and building information modelling (BIM) can reduce construction costs and provide data packages that are shared across multiple projects. Sensor technology will streamline new construction (with significant cost savings) and improve the whole life approach to maintenance and asset management. This technology can cut the cost of maintenance by identifying leaks in water mains and gaps in the thermal insulation of houses, for example. There are many other examples of advances in sensor technology leading to significant cost savings of new construction and of management and maintenance of infrastructure.

4. What is the maximum potential for demand management, recognising behavioural constraints and rebound effects? Note: "demand management" includes smart pricing, energy efficiency, water efficiency and leakage reduction. "Rebound effects" refer to the tendency for demand to increase when measures aimed at reducing or spreading demand also lead to lower prices or reduced congestion, undoing at least some of any demand reduction. For example, if smart meters reduce the cost of electricity in off-peak periods, this could lead to greater energy consumption overall, where a large number of individuals or firms take advantage of these lower prices by increasing their total usage.

Demand management for the UK's economic infrastructure needs can be achieved through strategic decisions concerning the location of new housing delivery and technical measures in building design. Concentrating new housing development in locations offering easy access to public modes of transport serves as a form of demand management in the transportation sector. Increased use of urban and suburban public transportation contributes to an overall reduction in transport congestion and help to decarbonise the national transportation system and reduce environmental impacts such as air pollution.

The design and construction of housing offers potential to contribute to energy, mitigating energy demand and production of waste. Construction methods can be designed to maximise re-use and recycling of materials and minimise waste, contributing to the circular economy agenda. Use of alternative fuels to natural such as biogas and hydrogen, combined with district heating and to the decarbonisation of the energy sector, whilst thermal efficiency measures (e.g. insulation) reduce overall demand for energy.

The need for density in new developments should be balanced with provision of green infrastructure, which acts to reduce the urban heat-island effect and store carbon. 'Whole house solutions' or 'smart homes' – could include power-to-heat systems and stationary battery storage technologies - that enable the consumer to export electricity when it is economically advantageous to do so. The housing sector's potential contribution to energy demand is likely to increase in the future as working patterns shift away from offices to (potentially less efficient) individual homes.

In the long term, new housing development could contribute to mitigating the regional imbalance in UK transport congestion and water demand, if new developments are utilised to create new opportunities in the water rich, less populated north and west. Spatially rebalancing the UK's economy is a multifaceted task requiring significant and varied investment and political commitment - including transport infrastructure - to promote a more even distribution of employment opportunities. Nevertheless, the provision of high quality housing facilitating development of places and communities is integral to the rebalancing agenda.

Housing delivery also presents the opportunity for providers of digital infrastructure to exploit economies of scale, facilitating the deployment of new to market and often very expensive technologies where dense population allows access by a large quantity of early adopters. In order to fully realise cross-sectoral benefits offered by the housing sector, measures must be implemented in the existing housing stock which will form the majority of the UK's housing to 2050. Existing stock can be retrofitted to enhance demand management in energy (insulation, electric heat, smart systems) and flood risk, water and wastewater (sustainable urban drainage systems, dual sewer networks, rain water harvesting, etc.), albeit frequently requiring large-scale investment.

5. How should the maintenance and repair of existing assets be most effectively balanced with the construction of new assets?

We should adopt a 'whole life' approach to infrastructure. The performance of assets and networks often determines what new capacity we require. We cannot afford to spend our way out of infrastructure challenges simply by building new capacity. Nor would that be the smart choice. As set out in the response to the previous question, technology, enabled by the right policies, provides the opportunity to use new and existing infrastructure capabilities much more efficiently. This will enable high quality affordable services. Infrastructure policy should involve a combination of increased capacity (where necessary), optimised by technology.

7. What changes in funding policy could improve the efficiency with which infrastructure services are delivered? Note: by "funding", the Commission means who pays for infrastructure services and how, e.g. user charges, general taxation etc.

Technological innovation means that people are paying for infrastructure services in different ways – from Uber taxi car rides to bundled telecoms packages. Car tax and duty on fuel will become obsolete as vehicles become powered by electricity (a low tax fuel) and car ownership diminishes. This will have an impact on revenue generation and so Government needs to quickly look into new ways for raising revenue from roads. Charging per trip with smart metering provides a more flexible way of paying for roads while enabling smarter management of demand.

Some innovative schemes are being put in place. For example, Greater Manchester Combined Authority has negotiated a model, which allows it to 'earn back' tax from the growth it creates. Such schemes are welcomed as ways of increasing areas' control over investment streams. However, they are complicated, resource intensive to set up and, therefore, unlikely to be suitable for all combined authorities.

Allowing such flexibility will enable investment to widen the currently narrow focus on economic development and support truly transformative change. Furthermore, facilitating greater financial autonomy should establish the necessary conditions for further devolution of power.

9. How can we most effectively ensure that our infrastructure system is resilient to the risks arising from increasing interdependence across sectors? Note: this includes resilience against external risks and/or problems that arise in one or more parts of the system.

Many interdependencies occur because of the demands that one infrastructure network places on others. Interdependence also occurs because increasing demand from households and businesses, due to economic and population growth tends to be correlated across all sectors. There are technological changes that mean that these interdependencies are becoming more significant. The response to this question sets out cross sector opportunities.

Water and wastewater solutions
Demand in the water sector has a direct impact on the wastewater sector as most of the national per capita daily consumption of water (150p/c/d) is returned as wastewater. Accordingly, demand management in the water sector translates directly into demand management for the wastewater sector, reducing the need for investment in new capacity of wastewater treatment and reducing this infrastructure sector's contribution to carbon emissions.

The Infrastructure Transitions Research Consortium (ITRC) has modelled the future demand for wastewater services based on the projected future population and the national per capita daily consumption of water and tested two demand reduction strategies (medium and high) with lower per capita water use, respectively 127 and 117 p/c/d, based on the demand management interventions in the water sector. Total volume of wastewater in 2050 is over 1m ML lower in a high demand reduction strategy, saving £18bn compared with a scenario in which demand is unconstrained. It also results in a reduction in cumulative emissions of almost 3 Mt by 2050.

Flood risk management and wastewater solutions
Measures to mitigate flood risk frequently also act as a form of demand management for wastewater. 'Green infrastructure' solutions involve naturally removing pollutants from watercourses and adding additional buffering capacity to reduce the impacts of flood events, whilst sustainable urban drainage systems (SuDS) reduce the amount of storm water discharged into sewers and hence directed to treatment plants for processing. It is not possible to quantify savings from SuDS at this stage since the relevant data are unavailable.

Housing and multi-sectoral solutions
The interdependencies of housing delivery and demand for economic infrastructure, while adding complexity to decision making also present opportunities for demand management and cross-sectoral enhancement. To seize the opportunities presented by housing delivery, integration of the

decision making framework for infrastructure with planning (such as coupling land use planning with the identification associated off-site infrastructure requirements), regulation and demand management, and that a spatial approach be taken.

Digital communications and multi-sectoral solutions
The increasing pervasiveness of digital and 'smart' technology, enabling collection and analysis of big data, is to have a profound impact on infrastructure needs, demands and delivery across all sectors – only likely to increase with future innovation. Projected contributions of digital communications to infrastructure sectors include:

- Energy: smart grids, meters and 'smart house' solutions for demand management;
- Transport: telecommunications and teleworking reduce the need to travel and aids demand management for transport, smart highway and journey planner systems and autonomous vehicles to manage congestion and peak demand;
- improved transport network availability and increased capacity through condition and usage monitoring and condition based maintenance; and
- Water, wastewater and solid waste: smart metering to manage demand.

Big data requires significant electricity to power it. The US National Resource Defense Council reports that in 2013 US data centres consumed energy equivalent to 34, 500MW coal fired power stations. Managing the storage and sharing of the huge quantities of data requires policy action if data demand and ultimately energy to support are not to grow beyond sustainable levels.

Housing delivery to increase economic infrastructure capacity
Effective housing delivery is dependent upon supporting infrastructure. As such, delivery of housing in locations lacking in sufficient infrastructural capacity can act as a stimulus to investment in capacity increase. Moreover, housing delivery can contribute towards the funding of investment in infrastructure via section 106 obligations or Community Infrastructure Levy (CIL). For example, the Northern Line extension has secured over £200m from the developers of Battersea Power Station housing development in this way.

10. What changes could be made to the planning system and infrastructure governance arrangements to ensure infrastructure is delivered as efficiently as possible and on time?

The scope of the National Needs Assessment (NNA) did not cover planning; however, ICE received anecdotal evidence regarding public engagement for infrastructure projects. The general view is that local communities are not engaged effectively in the proposal and planning process. This can lead to NIMBYISM and add to time and cost delays for infrastructure delivery.

ICE believes that the NIC has a role in addressing this public engagement challenge. Through the NIA, the NIC could set out a series of desired outcomes for the economy and society. In order to achieve these outcomes, the NIC could propose a series of demand and supply infrastructure interventions that could be debated by local communities. This would involve early engagement in multiple options, rather than consultation over a single option.

Transport:

13. How will travel patterns change between now and 2050? What will be the impact of the adoption of new technologies? Note: "travel patterns" include both the frequency and distance of trips taken, as well as the mode of transport used. This covers both personal and commercial travel, including freight.

The UK's population has grown from just over 50 million in the early 1960s to just over 65 million at the present time[1]. During this period, the demand for transport across all key modes (with the exception of bus patronage) has also risen[2]. Factored against the ONS central scenario for the UK's population to reach 75 million by 2050[3], it is almost inevitable that the demand for transport infrastructure and services will continue to grow in the coming decades.

Growth will occur in both intercity and urban transport operations. Emerging centres of economic growth in the Midlands and North of England will create new opportunities for the movement of people and goods to access new markets. In London and other high-wage urban centres, economic and population growth will increase the mobility of people and goods.

Greater demand placed on urban transport systems – overcrowded inner city roads, metro systems and orbital routes – may lead to policy interventions to encourage modal shift. This means new bus rapid transit, light rail and tram systems, alongside higher rates of active travel such as walking and cycling. Road user charging to alleviate congestion on key urban and intercity routes may also emerge as a more viable option for managing traffic flows.

Demand drivers impact use of infrastructure in different ways. Technological advancements in communications and IT are already creating new opportunities for many office based employees to work from remote locations. At scale, remote working could reduce peak travel demand and therefore cut congestion across transport networks during the busiest times. Conversely, demographic changes such as ageing population are likely to increase travel demand in peripatetic sectors such as health and social care, pushing up travel demand rather than reducing it.

Mobility as a service (MaaS) and the introduction of connected and autonomous vehicles (CAVs) have the greatest potential to disrupt travel patterns between now and 2050.

MaaS providers are already common place in the UK's transport system. On demand services like Uber and vehicle sharing schemes like Lift Share are challenging traditional network planning and delivery models. MaaS solutions mean transport services are increasingly based around an index of consumer preferences; journey planning and management, personalised service and flexible payment[4]. As our comprehension of mobile technologies and applications grow, MaaS will challenge conventional attitudes towards travel and create wider opportunities for the personalisation of services. This will present both challenges and opportunities for transport planning.

CAVs will result in a host of efficiency, safety, environmental and public benefits. On efficiency, this includes extracting greater capacity out of existing road networks through closer lane running. With regards to safety, sophisticated sensory and communication technology could result in less road traffic incidents. Potential environmental and public benefits include the reduced need for car parks and on street parking, therefore creating cleaner spaces for walking and cycling.

The 'connected' aspect of CAVs could revolutionise the management of road networks. Connectivity and information sharing between vehicles – and the wider network infrastructure – would enable smoother traffic flows, through the detection of traffic hotspots and real time rerouting capability. CAVs may even be sophisticated enough to carry out routine network maintenance operations, feeding back diagnostic information to asset operators.

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[1] ONS (2016) Overview of the UK population
[2] ITRC (2016) in ICE (2016) National Needs Assessment
[3] ITRC (2016) in ICE (2016) National Needs Assessment
[4] Transport Systems Catapult (2016) Mobility as a Service: Exploring the opportunity for mobility as a service in the UK

As a cheaper form of mobility, CAVS are likely to lead to a significant decline in private vehicle ownership. This in turn paves the way for the wider adoption of MaaS, as service users seek to travel in the most efficient and cost effective way.

14. What are the highest value transport investments to allow people and freight to get into, out of and around major urban areas? Note: "high value transport investments" in this context include those that enable 'agglomeration economies' – the increase in productivity in firms locating close to one another.

There are a variety of high value transport investments that can be made to reduce congestion for people and freight in major urban areas.

Road user charging can be an effective tool for reducing congestion in urban traffic hotspots, improving local environments and freeing up space for more active forms of transport, such as cycling and walking. However, as such charges become accepted as a cost of business, the impact of such interventions as a deterrent for avoiding heavily congested areas can become less significant[5]. Shifting to a usage charge based on the time spent within a congestion charging zone or on distance covered could be a more effective way of reducing traffic levels.

Greater infrastructure provision for active forms of transport will lead to higher levels of modal shift, which in turn will help to alleviate congestion in major urban areas. Active modes of transport, like cycling and walking, also reduce greenhouse gas emissions, improve air quality and reduce noise levels. There is also an economic case to be made – payback on £1millon of investment in cycling infrastructure requires only 109 people a year to become regular cyclists when considering the benefits to health, congestion and pollution[6].

Reducing the number of heavy goods vehicles by consolidating freight operations in urban areas can help to reduce congestion. This will require investment in new consolidation centres close to the UK's major urban areas. Consolidation can be incentivised by providing congestion charging discounts for freight vehicles registered to consolidation centres. There are also opportunities to take advantage of cycling as an effective means of transporting goods around large urban areas.

Technology also has a key role to play in helping to smooth traffic flows into and out of major urban areas. Live traffic and travel information, made available via mobile applications, provides both passengers and freight operators with the necessary information to make intelligent decisions on travel in real time. This requires investment in the digital infrastructure underpinning the UK's largest cities in order to improve mobile internet connectivity and data sharing[7].

As outlined above, CAVs could improve traffic flows within major urban areas in a number of ways. This includes creating additional capacity in existing road networks by allowing vehicles to travel closer together and via the sharing of traffic information between CAVs to enable in travel route management. Investment in MaaS and interventions to promote the potential of shared ownership models for CAVs could also have a significant impact on reducing congestion by reducing the number of privately owned vehicles in operation[8].

Improvements in technology can also help improve the attractiveness and capacity of rail-borne freight. One of the current problems is the mix of freight and passenger traffic on key rail lines such as the East Coast Main Line, which has the impact of limiting the capacity of the route and the

[5] ICE London (2016) Response to the London Assembly consultation on traffic congestion in London
[6] SQW (2008) Planning for Cycling – Report to Cycling England
[7] NIC (2016) Connected Future
[8] WSP I Parsons Brinckerhoff (2016) Making Better Places: Autonomous vehicles and future opportunities

availability of rail freight paths. The introduction of the Digital Railway programme[9], much like CAVs, can help achieve a better balance between freight and passenger traffic by optimising the pathing distances, thereby making better use of existing infrastructure and opening up additional freight paths.

15. What are the highest value transport investments that can be used to connect people and places, as well as transport goods, outside of a single urban area? Note: this includes travel in and between rural areas, as well as between urban areas and international travel.

The demand placed on the UK's transport network continues to grow. Road travel reached 317bn miles in 2015[10], while trips across the rail network in England and Wales reached approximately 65bn passenger km[11]. The UK's largest airports are fast approaching runway limits, with Heathrow at 95% and Gatwick at 80% operational capacity[12].

There are a number of high value investments that will improve the connectivity of people and freight between single urban areas in the UK. Schemes earmarked for the Government's second Road Investment Strategy, include the Oxford to Cambridge expressway and better Trans-Pennine connections across the A66.

Improving connectivity between high-performing economic areas can significantly reduce business costs and enable economies of scale and agglomeration[13]. Other potential schemes included in the strategy development, like Trans-Pennine Tunnel, will enhance connectivity between northern cities like Manchester and Sheffield.

In rail, the successful delivery of HS2 will mean eight of the UK's ten largest cities will be directly linked[14]. Journey times between key cities in the North and the Midlands will be significantly reduced, providing access to new jobs markets, with HS2 expected to create 400,000 new jobs[15]. Taking forward the emerging preferences for the Northern Powerhouse Rail scheme, as well as enhanced connectivity at HS2 stations and touch points will only widen the benefits from HS2 and increase its agglomeration benefits.

The Davies Commission has been clear that building a third runway at Heathrow will deliver the greatest benefits to UK trade globally via better connections to emerging markets in Asia and South America. Expansion will also mean an extra 16 million passenger seats by 2040, while 6 new regional routes – providing 14 in total – will improve accessibility throughout the UK for both business and leisure purposes[16].

But improving connectivity between single urban areas isn't simply achieved through building new capacity into existing networks. The introduction of smart motorways – the management of traffic flows in real time – to certain parts of the strategic road network has already resulted in a number of improvements to journey reliability and a reduction in accidents[17]. There is a clear case for the wider rollout of this technology, including: effective use of gantry signs for communicating roads hazards, variable speed limit management and all lane running.

[9] Digital Railway (2016) A Digital Railway for a Modern Britain
[10] DfT (2016) Transport Statistics Great Britain 2016
[11] Ibid
[12] ITRC (2016) in ICE (2016) National Needs Assessment
[13] DfT (2016) Oxford to Cambridge Expressway Strategic Study
[14] DfT (2013) High Speed Two: an engine for growth
[15] Ibid
[16] DfT (2016) Government decides on new runway at Heathrow
[17] Highways England (2016) Smart motorways programme

Similarly, there is a need for greater investment in mobile data sharing networks to enable road users to more effectively share information about traffic conditions in travel. Greater access to reliable information on road works or incidents enables road users to take avoiding action, which in turn reduces the build-up of unnecessary congestion[18].

Some progress has already been made in integrating new technologies into the rail network to improve reliability. It is estimated that 12,000 rail infrastructure assets are now connected to an intelligent infrastructure system of points, track circuits and signal power supplies which has meant 153,000 minutes saved in delays[19].

Progressing with the Digital Railway programme is fundamental to transforming the passenger network and delivering a modern railway that can accommodate more trains, enable more and faster connections, and greater reliability. The successful delivery of the programme will also mean more efficient rail freight operations through timetable flexibility, the greater availability of paths and optimised running. ICE welcomes plans set out in the Government's Industrial Strategy for priority investment in digital signalling[20].

Delivering these benefits will require investment in traffic management software and driver advisory systems, alongside the rollout of reliable mobile network technology across the network that will enable industry to better communicate real time journey information to passengers and freight operators alike.

16. What opportunities does 'mobility as a service' create for road user charging? How would this affect road usage?

Road user charging already exists in London through the Congestion Charge. Individuals entering the zone have a choice between paying the daily charge to enter in their own vehicle or to use an alternative mode of transport. Such alternatives include public and active transport or private hire. There is a legal requirement for monies raised from the charge to be spent on improving transport provision across London[21].

On demand MaaS providers like Uber– which fall within the private hire category – are therefore exempt from the Congestion Charge. However, there is little available evidence that demonstrates that as a consequence less private vehicles are entering the zone during its operational hours. Only 5.9% of all Uber journeys in London occur in the charging zone during operational hours[22] and this is against the backdrop of an increase in overall congestions levels within the zone[23].

The ability of businesses in London to absorb the cost of the Congestion Charge is evident. Trialling road user charging with exemptions for MaaS providers in other towns and cities will provide an alternative context for measuring its impact on road usage more widely. Including schemes that provide shared mobility solutions like car and cycle clubs could also provide useful data for the rollout of more sophisticated MaaS platforms in the future.

Digital Communications:

[18] NIC (2016) Connected Future
[19] ICE (2016) National Needs Assessment
[20] BEIS (2016) Building our Industrial Strategy: green paper
[21] TfL (2016) Congestion Charge
[22] Inrix (2016) London Congestion Trends
[23] Ibid

17. What are the highest value infrastructure investments to secure digital connectivity across the country (taking into consideration the inherent uncertainty in predicting long-term technology trends)? When would decisions need to be made?

The UK currently has a very advanced digital communication infrastructure system comprising communication (fixed and mobile telephony, broadband, television and navigation systems) and computation (data and processing hubs). Due to rapid innovation, increasing demand and a changing economic landscape, it is challenging to forecast the future of the digital communications infrastructure system to meet our future connectivity needs. There will almost certainly be a mix of fixed, mobile, wireless and satellite connectivity.

It is anticipated that 5G technology will mean seamless connectivity, ultra-fast and ultra-reliable, transmitting massive amounts of data at super low latency[24]. By 2050, the main access points to data services will be through mobile devices and the internet of things grounded on widespread coverage of 5G (or other) mobile broadband[25]. Delivery will require significant infrastructure densification. To date there has been strong political ambition for the UK to be a world leader in 5G technology deployment, reflected in Ofcom Strategic Review of Digital Communications 2016. ICE welcomes the Government R&D funding commitments in the 2016 Autumn Statement.

However, the desire for expediency in delivery must be balanced with the need to ensure implementation of a system that can meet long-term economic, social and environmental needs.

In determining when decisions would need to be made, it is important to consider the interdependencies with other infrastructure systems, as highlighted in ICE's *National Needs Assessment – A Vision for UK Infrastructure.* 5G technology – or other future wireless broadband services - has the potential to enable a number of high-value use-cases, including autonomous vehicles, Internet of Things, smart cities, and real-time infrastructure operational data. As with existing digital connectivity, efforts must be made to ensure comprehensive coverage in order to maximise opportunities from these technologies. However, consideration should be given to the impacts on other infrastructure, like transport and particularly electricity generation.

The increasing pervasiveness of digital and 'smart' technology, enabling collection and analysis of big data, is to have a profound impact on infrastructure needs, demands and delivery across all sectors – and is only likely to increase with future innovation. This will be enabled by increasing 'always on' connectivity – both fixed and wireless. Big data requires significant electricity to power it. The National Resource Defense Council reports that in 2013 US data centres consumed energy equivalent to 34 500MW coal fired power stations, managing the storage and sharing of the huge quantities of data requires policy action if data demand and ultimately energy to support are not to grow beyond sustainable levels. More recently it was estimated that the 416.2 terawatt hours of electricity the world's data centres used last year was significantly higher than the UK's total consumption of about 300 terawatt hours[26].

However, it is also worth noting that increased connectivity can also help to balance energy consumption and generation through use of smart grid and smart meter technologies, benefiting both consumers and generators. Swift decisions on how best to meet the resultant increased energy demand in a sustainable way are required.

[24] NIC (2016) Connected Future
[25] ICE (2016) National Needs Assessment
[26] The Independent (23 January 2017) Global warming: Data centres to consume three times as much energy in next decade, experts warn

18. Is the existing digital communications regime going to deliver what is needed, when it is needed, in the areas that require it, if digital connectivity is becoming a utility? If not, how can we facilitate this?

Due to rapid innovation, increasing demand and a changing economic landscape, it is challenging to forecast the future of the digital communications infrastructure system to meet our future connectivity needs. There will almost certainly be a mix of fixed, mobile, wireless and satellite connectivity.

A key current challenge for the digital sector is a persistent digital divide between those who have access to the latest technologies and those who do not, with resulting social and economic exclusion, particularly as dependence on e-services and digital communications increases. 8% of all UK premises cannot access a broadband speed of 10Mbit/s[27], while around 3% of premises in the UK fall below the government's current minimum target download speed of 2 Mbit/s[28]. While all four mobile network operators (O2, Three, Vodafone and EE) enable you to make a call in 99% of urban areas, this proportion falls to 72% in rural areas, 41% on UK roads, and 31% inside buildings in rural areas[29]. Universal digital connectivity would serve as an equaliser of economic opportunity in that it enables participation in a modern digital economy. The recommendations from the National Infrastructure Commission's Connected Future report should be supported and will help to address the digital divide.

The UK currently performs well in digital communications. Internet penetration is at around 90%, and in 2014, on average 76% of adults in the UK accessed the internet every day. OfCom has obligated 98% population 4G coverage by 2017[30], and provide superfast broadband coverage to 95% of UK premises by the end of 2017.[31]

Estimates of projected bandwidth demand for 2023 show that peak technical demand for a single person household with standard definition television could be satisfied with 10Mbit/s[32] whereas a household with four intensive users and a 4k television would require 25Mbit/s. The top 1% of households would demand in excess of 35Mbit/s. Demand is likely to increase further with the introduction of novel technologies.

By 2050, the main access points to data services will likely be through mobile devices and the internet of things grounded on widespread coverage of 5G (or other) mobile broadband. To date there has been strong political ambition for the UK to be a world leader in 5G technology deployment, reflected in Ofcom Strategic Review of Digital Communications 2016 and the NIC Connected Future report. However, the desire for expediency in delivery must be balanced with the need to ensure implementation of a system that can meet long-term economic, social and environmental needs. As with existing digital connectivity, efforts must be made to ensure comprehensive coverage. This will require increased densification of supporting infrastructure, and changes to planning frameworks should be made with this in mind. The UK Government's commitment at the 2016 Autumn Statement of £1bn for improved connectivity, including 5G, is a welcome step.

Government has a role in establishing standards, opening up networks and ensuring that high quality access is available even where it is less financially viable for commercial providers. In the Autumn Statement in 2016, the Government pledged to support the broadband delivery programme to

[27] OfCom (2016) Connected Nations
[28] ITRC (2016) in ICE (2016) National Needs Assessment
[29] OfCom (2016) Connected Nations
[30] House of Commons Library (2016) Briefing Paper, Number CBP-07069: Mobile Coverage in the UK: Government plans to tackle 'mobile not-spots'
[31] House of Commons Library (2016) Briefing Paper, Number CBP06643: Superfast Broadband Coverage in the UK
[32] Broadband Stakeholder Group (2013) Domestic demands for bandwidth: An approach to forecasting requirements for the period 2013-2023

provide fibre broadband to reach 95% of the UK by the end of 2017, and 97 – 98% by 2020. Government should provide the private sector with incentives to roll out 'ultrafast' broadband coverage. Where the market fails to respond to those incentives, the Government should intervene to require that coverage is provided. The outcomes of the Government's recent consultation on the extension of full-fibre networks will reflect a range of potential approaches.

Energy:

19. What is the highest value solution for decarbonising heat, for both commercial and domestic consumers? When would decisions need to be made?

Shifting to alternative types of gas holds the potential to decarbonise heat without the need to disrupt millions of people's homes and businesses or overhaul our (electricity and gas) distribution and transmission networks.

Around 50% of UK energy use is for heating and around 84% of domestic and commercial heat (space and water) is from fossil fuels – mostly natural gas[33]. Due to its diffuse nature (around 27 million homes and 2 million commercial premises), comparatively little has been done to decarbonise heat: overall, there has been an 8% *increase* in emissions from heat between 1990 and 2015[34].

The electrification of heat through adoption of heat pumps alongside district heating, as set out in DECC's Future of Heating strategy (2013)[35] remains the current policy. It suggests heat pumps/district heating could supply 80% of domestic properties by 2050. The forthcoming Emissions Reduction Plan -expected to be published in end of February 2017[36] - is anticipated to include detail on the decarbonisation of heat. At present, there has been little further published Government work in the area.

Much of the difficulty in the electrification of heat is that it depends on individual property owners and landlords making decisions to change their heating systems, which typically involves installation of radiators and insulation as well as the pumps themselves. This not only costs considerably more than replacing gas boilers (around £8,000 compared to around £2,000 for gas), but it also results in far greater disruption during installation and requires different heating practices and supply chains that currently have very limited capacity.

As a result, despite funding being available through the Renewable Heat Incentive[37], there has been little progress: gas heating remains far more popular with 1.6 million gas condensing boilers sold in 2014 compared to only 50,000 heat pump installations[38].

From an infrastructure point of view, switching to heat pumps would involve serious challenges (and associated costs). For example, it would require significant additional electricity generation[39] and reinforcement of the grid. At present, there is no storage in the electricity system able to manage

[33] UKERC (2014) The Future Role of Thermal Energy Storage in the UK Energy System: An Assessment of the Technical Feasibility and Factors Influencing Adoption
[34] Policy Exchange (2016) Too Hot to Handle? How to decarbonise domestic heating
[35] DECC (2013) The Future of Heating
[36] Royal Geographical Society (2016) Looking Ahead to 2017: The Emissions Reduction Plan

[38] Policy Exchange (2016) Too Hot to Handle? How to decarbonise domestic heating
[39] Ibid. A recent estimate of switching 80% of homes to heat pumps would require an additional 105 GW of electricity generation capacity - an increase of 175% above current peak power demand

the equivalent seasonal variations in heating demand[40]. Such capacity will likely be under-utilised during summer seasons but still carry significant economic cost[41].

Moreover, if electrification and district heating progress at the rate needed to reach around 80% penetration it is likely to outstrip at least in the short-term the decarbonisation of the electricity grid, leading to an increase in emissions. Electrification may also result in stranded gas assets including storage units, distribution and transmission networks, much of which is currently being upgraded through the Iron Mains Replacement Programme due to be completed in the early 2030s.

It is necessary to consider alternative strategies to provide heat services that may be more efficient with respect to cost and non-cost factors. An optimal strategy for energy needs to include a mixture of supply technologies to balance their strengths and weaknesses[42]. The choice of technology will depend partly on the population density and types of properties in the area served.

A more effective approach could be at the macro level: instead of replacing millions of boilers with heat pumps, the type of fuel could be changed. Alternatives including biogas, bio-methane[43] and power to gas fuels such as hydrogen and synthetic natural gas (SNG) have significantly lower emissions than natural gas and can be injected directly into the gas grid. This is not to discount heat pumps completely – they are likely to have a role for the 20% of homes not connected to the gas grid, which in the main currently use either solid fuel or heating oil.

It is unlikely that any one of the alternatives to natural gas could on their own provide a complete replacement. For example, the amount of raw material for the production of biogas from AD facilities would limit it to a maximum of around 10%[44]. For power to gas, the amount of hydrogen that can be used without needing to modify gas boilers and cookers is around 7-10% of total delivered gas[45] but could potentially be used in total conversion of sections of the distribution network[46]. SNG offers more potential. It can be conditioned to meet the quality requirements of the GB gas network and the amount that can be produced is (theoretically) unlimited and but with a lower conversion factor than hydrogen, requires more electricity for its production.

Whether power to gas technologies can provide low carbon heat depends on the source of electricity generation they use. An ideal situation would be for the electrolysers to be powered by dedicated renewables facilities, therefore providing 100% renewable heat. Due to renewables intermittent nature, this is unlikely but it is estimated that up to 58 TWh (approximately 15% of annual electricity demand) of wind power will be curtailed each year once wind penetration has reached 55%[47]. Therefore, introducing power to gas reduces the amount of wind curtailment, providing both cost and balancing benefits.

Power to gas could utilise the existing storage capacity of the gas network to store large amounts of renewable electrical energy. For SNG in particular, as it combines hydrogen with carbon dioxide to produce methane there is potential for it to be utilised in CCS facilities. It could, therefore, create a bi-directional link between the electricity and gas sectors, which could offer an efficient management of energy resources at each point in time.

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[40] Winter gas peak demand for heat can be 12 times higher than in the summer, and is five times the current electricity peak demand (Maclean et al. 2016). See ICE (2016) National Needs Assessment

[41] Eyre and Baruah (2015) have estimated the cost of additional generation capacity at £3,000 per household not including the price of the heat pump, which is currently £8,000 per household (to decrease to £5,000 by 2030). See ICE (2016) National Needs Assessment

[42] Eyre and Baruah (2015), Maclean et al. (2016): see ICE (2016) National Needs Assessment

[43] The recently announced increase in support under the non-domestic RHI is welcome (BEIS (2017) The Renewable Heat Incentive: A Revised Scheme, and we would encourage Government to look at similar systems for power to gas technologies

[44] ENA / Labour Party Energy and Climate Change Committee (2016) The Green Gas Book

[45] Dodds and McDowall (2013) The Future of the UK gas network' and ENA / Labour Party Energy and Climate Change Committee (2016) The Green Gas Book

[46] Northern Gas Networks (2016) H21 Leeds Citygate

[47] Imperial College (2012) Understanding the Balancing Challenge

Furthermore, the by-products heat and oxygen can be recycled in industrial processes and directly as an energy source for domestic and industrial customers. It can also be used as a fuel in the transportation sector, especially in mobility applications that are difficult to electrify (e.g. heavy goods and public service vehicles).

20. What does the most effective zero carbon power sector look like in 2050? How would this be achieved? Note: the "zero carbon power sector" includes the generation, transmission and distribution processes.

As all renewables involve the production of carbon and/or other greenhouse gases at some point in their life-cycle[48], this question is taken specifically to refer to zero carbon from power generation.

A zero carbon power network is not an end in itself - it is part of the infrastructure that allows customers to use their appliances while limiting environmental impacts. However, it has key features that contribute to the security of supplies of energy and is likely to be hugely important for decades to come.

There is significant historic investment in network assets and they are long lived. A substantial portion of the electricity networks that exist now will still be in service in 2050 and beyond. This means that zero carbon power sector will be similar to our current networks.

To achieve a zero carbon network, it is not just systems being zero carbon in their own right. It is also about being able to enable / accommodate low carbon and widely dispersed sources of generation on the system. This will require smart systems for consumption, generation and network management.

The transition to a secure, affordable and zero carbon power sector is feasible but requires a clear vision from Government and policy makers, with cross-party support to maintain the necessary policy stability.

The question rightly identifies that a zero carbon power sector includes generation, transmission and distribution. However, added to this should be consumption: reducing demand through energy efficiency and behavioural changes could significantly reduce demand from domestic and commercial consumers, reversing or at least mitigating expected increase in demand for example from population increase and electrification on transport (see question 21, below).

Efficiency improvements across buildings, appliances and lighting can produce the following outcomes:

- 5% reduction in leakage rate in buildings (increasing thermal efficiency);
- 10% efficiency improvements in residential and service sector lighting;
- 10% efficiency improvements in residential and service sector appliances;
- 20% in industrial sector appliances; and
- 20% in industrial sector lighting [49].

In addition, behavioural change can be promoted through education encouraging conservation of energy or technological measures such as pricing, which acts as a deterrent, as well as monitoring technology that enables users to track and moderate their own consumption.

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[48] For example, a recent study of onshore wind generation found a range of 5 CO2eq/kWh to 106 CO2eq/kWh, depending on a range of factors including capacity, design lifespan and turbine location. See Climate Exchange (2015) Life Cycle Costs and Carbon Emissions of Onshore Wind Power

[49] ITRC (2012) in ICE (2016) National Needs Assessment

For electricity infrastructure itself, such as generation, distribution and transmission, a key limitation is that it is set up to transmit power from a small number of large generators to demand centers. While the infrastructure generally works well at present, to get more renewables on the system means accommodating more distributed generation at the same time as managing increasing demand. Balancing and maintaining the system will become increasingly complex. These limitations are likely to manifest at the distribution level.

There are several potential ways to address these limitations:

- Deployment of electricity storage across networks;
- Greater use of demand side management;
- Further installation of interconnectors; and
- Line upgrades.

The key point is not to look at individual technologies or responses in isolation but rather consider the electricity system as a whole. As such, there is a need for systems-of-systems engineering and a 'system architect' to ensure integration of design, implementation and operation of energy networks to address the energy trilemma[50]. Analysing the national infrastructure as a system-of-systems allows these important interdependencies to be captured and quantified and measures to maximise efficiency to be identified[51].

21. What are the implications of low carbon vehicles for energy production, transmission, distribution, storage and new infrastructure requirements?

Managing the connection of an ever-increasing share of distributed generation combined with the electrification of transport, plus increasing numbers of customers actively taking part in the market will be a challenge, particularly for Distribution Network Operators (DNOs). With multiple, intermittent sources with the potential to alternate between demand and supply, networks will no longer be just from transmission to customers, but rather multifaceted networks with two-way flows.

DNOs will feel pressure to operate new services, such as storage and ancillary services, to actively manage their networks. However, at present DNOs' (and the Transmission System Operator's) licences prevent them from operating generation in the market and, therefore, they cannot control storage facilities, nor participate in demand side management or smart metering.

There is a strong case to examine the licensing of regulated activities with a view to freeing up this red tape to reflect the changing nature of maintaining balance in the system.

While the future of low carbon vehicles is likely to be dominated by battery electric vehicles, other fuel types, such as hydrogen and SNG should not be discounted. As outlined above in the response to Question 19, power to gas offers the possibility of low carbon fuel for both heat and transport via the existing gas grid. Advantages of utilising gas are the relatively straightforward conversion of existing petrol/diesel vehicles, are suitable for use with HGVs and greater range.

Water and wastewater (drainage and sewerage):

[50] See IET (2013) Handling a Shock to the System for more detail.
[51] ICE (2016) National Needs Assessment

22. What are most effective interventions to ensure the difference between supply and demand for water is addressed, particularly in those parts of the country where the difference will become most acute? Note: "demand" includes domestic, commercial, power generation and other major sources of demand.

Although the UK climate is generally wet and mild compared to much of the world, less rainfall and high population density in the South and East means that water availability per person in these regions is low. Regional rainfall differs significantly. The Southeast is the driest part of the country (London is drier than Istanbul) and already water stressed. By contrast, the North and West and much of Wales and Scotland receive the majority of UK rainfall but are more sparsely populated.

The challenge for future water supply in the UK is to meet the demands of socio-economic growth and climate change –without compromising the environment and other users of water, or placing an excessive financial burden on consumers. Recent work by water companies and particularly by Water UK (2016) has assessed the resilience of supplies to key drivers (drought, environment, growth and climate change) over the next 50 years. This shows that significant and growing risk of severe drought arises from climate change, population growth and environmental drivers. Some risks (drought and environmental demand) are immediate and will require a prompt response. The most cost-effective approach to increasing resilience is likely to drive action in the current round of water resource management plans (WRMPs).

The investment needed to increase resilience to drought is relatively modest. Building on the existing water resources planning framework, Water UK concludes that a 'twin track' approach that includes supply enhancement, with associated transfers, as well as demand management, remains the most appropriate strategic mix to meet supply demand pressures now and into the future.

There is a case for considering more extensive measures to manage demand than are in place today to provide a greater level of resilience to more extreme future shocks. However, such levels of demand management are ambitious and will require significant behavioural change, innovation and potential regulatory change.

Inter-regional transfers, new storage capacity and re-use of water may represent key components of a more resilient system, through a combination of localised and strategic schemes. For example, using the River Severn and River Trent to transfer water to the South and East. However, connecting major supply systems has implications for river regulation, water quality, and environmental risk (both the natural environment and carbon costs of moving water over large distances). In some cases, the nature of drought risk within the supplying water resources systems may also increase as a result. The transfer and trading of water, as well as innovation across all other aspects of supply and demand of water are a key focus of ongoing regulatory reform.

There is a case for a national level 'adaptive plan' that supports on-going WRMPs and balances risks against opportunities to defer costs. Such a plan would identify the key 'trigger points' that will determine which set of investments and policy interventions would be needed for the 2040 and 2065 horizons, depending on how risks materialise in the future.

Demand management is expected to play an important role in future water security for the UK. Water companies plan to increase metering coverage from 48% in 2011 to 61% in 2020. A key advantage of metering is the ability to provide complete coverage within a short time frame and its increasing sophistication, with digital transformation and smart technologies, enables more effective monitoring to determine pricing and can provide the basis for block tariffs to manage variation in demand.

Furthermore, technology that enables users to track their own consumption of infrastructure can induce behavioural change. A potential blocker to the success of consumer behaviour change is price inelasticity of demand for services. Other demand reduction measures include technologies such as grey water re-use and policy measures such as tariffs, water efficiency audits, pay- as –you- save schemes and educational programmes. A less hi-tech method involves designing for reduced point of use consumption - one-cup kettles and half-flush toilets.

Education has a particularly important role for technological roll-outs as it can ensure that the benefits of technologies are fully exploited. Demand management in the delivery of water services is incentivised by mechanisms such as outcome delivery incentives within the 2015-20 period, with additional mechanisms for upstream water trading and sludge management being considered as part of the price control methodology by Ofwat.

23. What are the most effective interventions to ensure that drainage and sewerage capacity is sufficient to meet future demand? Note: this can include, but is not necessarily limited to, governance frameworks across the country.

The UK enjoys high levels of sewage connectivity compared to the rest of Europe. However, meeting increasing environmental standards together with improved understanding of the fate of contaminants and better detection have driven more challenging wastewater treatment standards and significant investment in new infrastructure, often requiring increased energy and chemical consumption, resulting in higher tariffs for customers.

The energy intensity of wastewater treatment infrastructure also makes it a target for policies to reduce greenhouse gas emissions, such as the 2008 Climate Change Act. The wastewater industry consumes approximately 0.4% of the national energy budget (Ofwat, 2011).

Wastewater management will also be improved by approaches to flood risk management which increase systemic resilience, including sustainable urban drainage schemes (SuDS) and other 'green infrastructure' solutions which provide buffering capacity.

However, total volume of wastewater is still likely to increase, requiring new treatment capacity and acting to increase emissions. In delivery of new wastewater capacity, adoption of new technologies could decrease or retain net energy consumption for wastewater treatment. More energy could be recovered from waste in future. Targeted 'green infrastructure' solutions can be implemented to naturally remove pollutants from watercourses.

Increased centralisation of services could alleviate increasing costs through economies of scale. Wastewater plays an important role in maintaining river flows – smaller sewage works, which might benefit most from centralisation, can be the sole contributor to river flow during dry periods – so there is an environmental cost. This would require planning reforms and an estimated cumulative capital investment of £17.5bn (ITRC 2016). For the time being, decentralised technologies do not achieve the same economic advantages, levels of reliability or purity of effluent.

Further regulatory reform could ensure the implementation of building-level efficiency measures (including demand management). Many new housing developments are being connected through dual wastewater and storm water networks which could contribute to lower per capita costs and lower susceptibility to water quality problems during extreme rainfall events. There is potential – albeit requiring major new investment – to retrofit dual sewer systems. Depending on demographic trends, projected cumulative expenditure on new sewers to 2050 ranges between £20 - 120bn (ITRC 2016).

Flood risk management:

25. What level of flood resilience should the UK aim to achieve, balancing costs, development pressure and the long-term risks posed by climate change?

Flood resilience is divided into three aspects: resistance, preparation and response, and recovery.

Resistance to flooding may be provided by flood defences at a regional or local level, or by local resistance measures at the level of the individual development plot or property. Flood protection and resistance measures should be implemented where the risk of flooding is high – either because the likely frequency of flooding is high or because the consequence of flooding is high (e.g. critical infrastructure). The level of protection or resistance to flooding should be based on the cost of implementation balanced against the consequential impact of flooding. However, as a general rule, high consequence flooding should be exceptional, that is it should not occur more frequently than once in 200 years on average.

The Environment Agency's long term investment scenarios highlight the cost-beneficial nature of flood risk management solutions. It recommends a programme of investment over the next century to reduce risks where benefits are greater than costs. Modelling shows that a cost-beneficial investment programme will require between £750m and £920m per year on average to maintain a climate-adjusted current level of risk for expected annual damage reduction of 4%-24% in the next 50 years[52].

There has been good progress through the combined efforts of the Met Office and the Environment Agency on flood forecasting. This now needs to be matched by effective preparation and response to limit the consequences of flooding. Although Fire and Rescue are usually a primary responder to floods they have no statutory duty to do so. This anomaly should be rectified, but only if Fire and Rescue are adequately resourced to undertake a more effective and proactive role in helping communities to prepare for floods.

Evidence from recent floods shows that flood recovery is poor. Recovery is often hampered by the breakdown of other infrastructure whose availability has been unduly affected by flooding. The inter-dependency of infrastructure is still not well understood. In particular redundancy has been stripped out of infrastructure in the pursuit of efficiency without a full understanding of its impact on resilience. Resilience is not simply about prevention – it is about recovery as well.

In the longer term, flood risk will be affected by two key pressures – development of the built environment and climate change. It is unlikely that England can meet its development needs without new construction in flood risk areas. Such development must meet two conditions. It should not make flood risk worse in other areas, and secondly it should not expose future occupiers of the development to high levels of flood risk. As stated in the recent Environment, Food and Rural Affairs Select Committee report[53], these conditions are not met by the current planning process and we believe they should be adopted as standard practice.

The second pressure arises from climate change which is likely to result in more intense summer storms and more prolonged winter storms. There is sufficient information available from climate models to predict at least the scale of the change if not the precise timescale. A more holistic approach to managing flood risk is needed to counteract this threat, treating flood risk management on a catchment scale and engaging the multiple stakeholders that have a part to play. It would be

[52] Environment Agency (2014) Flood and coastal erosion risk management – long-term investment scenarios
[53] Efra Select Committee (2016) Future Flood Prevention

wrong to look at climate change in the context of flood risk only, since it is likely to have an even greater impact on water resource availability, especially in the South East of England. It would be a mistake to address long term flood risk management in the absence of the management of drought, since potential solutions may well prove to be complementary.

26. What are the merits and limitations of natural flood management schemes and innovative technologies and practices in reducing flood risk? Note: "innovative technologies and practices" can include, but is not necessarily limited to, property level resistance and resilience, temporary defences, advances in predictive asset maintenance and innovative construction materials.

Natural flood management measures are being promoted as a fresh approach to managing flood risk. Such measures would make use of farm land and other areas to temporarily store water during flood events. They have been shown to be effective on a small scale but so far there appears to be no conclusive evidence to show that they work cost-effectively on a large scale.

The principle of managing flood risk through the provision of additional storage within a catchment is however well established. There a numerous examples of on-line and off-line flood storage schemes along our major rivers and smaller watercourses. The difference with the natural measures proposal is that it distributes such storage over a wide number of sites. If it is to be effective, these sites would need to provide the necessary flood storage volume if they are to be effective.

There is however significant scope for innovation. Moving to a whole catchment approach to flood risk management involving all the necessary stakeholders would be a good first step. As mentioned above, combining the needs of drought management with flood risk management is recommended.

Buildings should be both flood resilient and resistant. Currently many of our buildings suffer unnecessary flood damage due the materials used and the way housing are designed. For example, timber and gypsum take longer to dry out than other materials and plug sockets positioned too close to the floor are unusable post flooding due to damage. Through the Government's property flood resilience action plan[54], ICE believes all new buildings should be resilient and resistant to flooding and previously flooded buildings should be restored to flood resilient and resistant standards.

In a similar vein, key energy and transport infrastructure assets are inappropriately located in areas prone to flooding without any sensible measures to protect them from the consequence. This is not helped by our approach to mapping the extreme flood outline. It is not simply the area that is flooded but the velocity and depth of flood water that matters.

Solid waste:

27. Are financial and regulatory incentives correctly aligned to provide sufficient long-term treatment capacity, to finance innovation, to meet landfill and recycling objectives and to assign responsibility for waste?

The main financial incentive in the solid waste sector in the UK is the Landfill Tax. Since January 1998, the Treasury has received £14bn in tax receipts – with just under £1bn in 2015 alone. The tax had its annual escalator of £8/tonne suspended in 2014 to allow for a consultation on the level that should apply to waste processed at mechanical treatment plants. This concluded in 2015 but the escalator remains suspended with the landfill tax rate only increasing at RPi.

[54] Defra (2016) The property flood resilience action plan

The Landfill Tax has been successful in the primary driver of increasing diverting waste from landfill and consequently increasing recycling rates[55]. Therefore, ICE agrees with organisations such as the Resource Association[56] and CIWM[57] that the escalator should be reinstated.

There also remains a need to intervene directly in recycling itself to offset effects of market fluctuations. This is because collection and recovery processes and maintenance of recyclate quality, is at least partly market driven and as such it is often more economic to instead of recycling send materials to energy from waste plants either in the UK or increasingly, abroad.

Municipal Solid Waste (MSW) recycling rates in England had been increasing steadily from 11% in 2000 to over 40% by 2010 but the rates have plateaued over the past five years and actually fell back from 45% in 2014 to 44% in 2015[58]. In the same time period, Scotland saw an increase in recycling of only 1% to 43%[59]. In comparison, Wales increased from 57% to 61% for the 12 months to the end of June 2016[60].

Unlike the rest of the UK, Wales not only has a comprehensive long-term waste strategy, it has also set statutory waste and recycling targets. To avoid financial penalty, every local authority in Wales must meet recycling and landfill targets that rise gradually to 70% by 2025[61]. With Wales leading the way in recycling in the UK, it suggested that Government in England examines and learns from its experience and focus on creating a policy, regulatory and commercial environment that encourages maximisation of waste prevention and recycling through specific, legislative action.

Material recovery could be enhanced by a re-use and recycling strategy to make better use of existing capacity to recovery – with a potential increase from 18 Mt in 2015 to 21.4 Mt by 2050[62]. The UK recycling system should be realigned to include manufacturers, re-processers and recyclers[63]. A step in this direction would be to increase packaging recycling and reuse targets in line with the Circular Economy Package recycling targets for 2025[64].

In addition to the MSW sector, there is a high potential for recycling and reuse of both Commercial and Industrial (C&I) construction and demolition (C&D) waste, not least because the amount produced in these sectors far outstrips that managed by local authorities[65].

The construction sector is currently outperforming many other sectors for recovery of materials. The UK generated an estimated 46 Mt of construction waste in 2012. Some 45 Mt of this was non-hazardous, 39 Mt of which was recovered – a rate of 87%.

The UK has made significant progress in this over the past decade: concepts such as design for manufacture and assembly, building information modelling, and the circular economy are all having a positive impact, but there should be more focus on the whole lifespan of a development.

As outlined in Defra's Waste Management Plan for England[66], in managing waste to support the economy and protect the environment, much has been done but much remains to be done:

[55] HMRC (2016) Landfill Tax: Increase in Rates
[56] Resource Association (2014) Response to Budget 2014
[57] CIWM (2014) Survey Finds Respondents In Favour Of Landfill Tax Rise
[58] DEFRA (2016) Statistics on waste managed by local authorities in England in 2015/16
[59] SEPA (2016) Household waste – Summary data 2015
[60] Welsh Government (2016: 1) Local authority municipal waste management, April – June 2016 (provisional)
[61] WLGA-CILC (unknown date) Waste
[62] ITRC (2016) in ICE (2016) National Needs Assessment: A Vision for UK Infrastructure
[63] ICE (2016) National Needs Assessment: A Vision for UK Infrastructure
[64] Option 2 in DEFRA (2016) Consultation on changes to packaging recycling business targets for paper, steel, aluminium, wood and overall recovery and recycling for 2018-20
[65] Data for C&I waste arisings in England are not regularly collected. The most recent data is from the 2009 'Commercial and Industrial Waste Generation and Management Survey'. In the 2009 survey, arisings were 48Mt compared to 24 Mt of MSW. See DEFRA (2013) Forecasting 2020 Waste Arisings and Treatment Capacity

population increase, rising consumption, climate change and raw material supply risks are combining to increase pressure on resources resulting in rising - but volatile - prices and supply risks.

Waste minimisation is the most straightforward strategy to reduce the cost and environmental impact of waste management. It should be deployed alongside strategies for re-use and recovery. An ambitious strategy could reduce total waste produced to 22 Mt in 2050[67] and significantly decrease carbon dioxide emissions and costs associated with waste collection and treatment. Measures including designing in recyclability, designing out waste, light-weighting and eco-packaging will result in a reduction in overall volume of waste.

28. What are the barriers to achieving a more circular economy? What would the costs and benefits (private and social) be? Note: A "circular economy" is an alternative to a traditional 'linear economy' (i.e. make, use, dispose) in which products are designed and packaged to minimise waste, and resources are kept in use for as long as possible, e.g. through re-use, recycling and greater recovery of materials through the waste management process

A circular economy where opportunities for recycling are maximised and all residual waste may be sent for energy recovery rather than landfill is estimated by the Environmental Services Association to require a further £5bn investment[68]. An aggregated services model, such as that proposed by Viridor[69], can contribute to the development of progressive policies in recycling and resources and realising economic benefits (productivity, employment and business growth) of a circular economy.

The establishment of a circular economy will require leadership from policymakers, embedding the idea across government, for example through broadening the ban on sending materials to either landfill and developing minimum reuse/recycling targets as set out as 'Option 2' in DEFRA's recent packaging recycling consultation.[70]

At present, the market process fails to emphasise the total first lifetime costs of a product and structure such as purchase, running costs and repairs, or identify the value remaining at the end of a product's first life. For example, capital and running costs may not be borne by the same party, thereby driving lower initial costs at the expense of full life costs.

As such, there is little incentive for designers and constructers to design and build in minimised total first lifetime costs, or to maximise the value and reusability of the product/structure at the end of that lifetime use, for example through design for disassembly in the construction sector[71]. Broadening the use of leasing or pay-per-use would address this but has failed to find traction, especially in the domestic market

While data for MSW is reasonably well recorded, in the C&I sector – estimated to produce around double the annual tonnage of MSW[72] – the available figures are outdated and often inaccurate. Without rigorous data, resource management (and, it follows, a circular economy) becomes difficult to implement. This not only affects investment in the waste sector but also has negative effects on other sectors, for example by creating uncertainty for EfW and associated combined heat and power operators.

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[66] Defra (2013)'Waste Management Plan for England
[67] ICE (2016) National Needs Assessment: A Vision for UK Infrastructure
[68] Ibid.
[69] Ibid.
[70] DEFRA (2016) Consultation on changes to packaging recycling business targets for paper, steel, aluminium, wood and overall recovery and recycling for 2018-20
[71] Rios et al (2015) Design for Disassembly and Deconstruction - Challenges and Opportunities
[72] DEFRA (2013) Forecasting 2020 Waste Arisings and Treatment Capacity

The availability of accurate information is crucial for effective public policy and the operation of markets. Material flows are largely unmonitored compared to the financial flows they accompany. This results in sub-optimal decisions about materials management at every economic stage. Without good data it is impossible to determine the right facilities to invest in and their optimum location – or indeed, if in one type of technology is seeing over-investment.

The lack of C&I waste data is mirrored in the dearth of strategic direction in the sector. While MSW operators have benefitted from government leadership, C&I management has been left largely to the private sector; ministers have provided no clear direction, targets or support. In England, this is due to a lack of government co-ordination with responsibility dispersed across at least nine government departments including Defra, DCLG, BEIS and the Treasury.

Only Government can set policy frameworks, act as a facilitator for action and provide support for innovation where market conditions - both on the supply and the on demand side - are difficult.

Government's role in shaping the 'information infrastructure' needs explicit attention. Until we have high quality data and statistical information, it will be very difficult for policymakers to understand the UK's resource needs and vulnerabilities, let alone how materials contribute to the economy or remain in productive service for longer.

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