CLOSING THE GAP

Local infrastructure business models
to support inclusive growth

iBUILD Infrastructure Research Centre Final Report

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Foreword

In 2015, the iBUILD Infrastructure Research Centre published a mid-term review, or manifesto, in advance of the UK General Election. The UK has since voted to leave the European Union (EU), held another election, and has a new Prime Minister. We have also seen the formation of the Infrastructure and Projects Authority (IPA) and National Infrastructure Commission (NIC), while devolution entered a new phase as six new Metro Mayors were elected in England. The UK government has an Industrial Strategy, with infrastructure at its heart, and a Clean Growth Strategy that complements the Paris Agreement on Climate Change.

Infrastructure remains the foundation upon which prosperous economies and societies are built and function. Currently £600 billion of public and private investment is planned over the next ten years. However, the collapse of Carillion, early withdrawal of Virgin and Stagecoach from the East Coast Mainline Railway franchise, and the National Audit Office's analysis of the Private Finance Initiative further exposes the poor value of existing business models to the taxpayer, consumer and the many private companies involved in infrastructure delivery. Inaction and the continued use of ineffective infrastructure business models will have further detrimental impacts upon the future of infrastructure services such as sanitation, drinking water, warmth, mobility and communication.

The emergence of the NIC is improving national scale infrastructure planning in the UK, providing a welcome strategic context. However, it is important that national-level arrangements take heed of local infrastructure, and how infrastructure is being funded, financed, planned and governed. It is in cities and towns where infrastructure is most dense and where most people will use services in their everyday lives. The government's aim of creating an economy that 'works for everyone' raises the challenge of balancing inclusive growth across different geographical scales – in communities, cities and regions. To illustrate, a review of a $787bn stimulus programme in the USA, in the aftermath of the Global Financial Crisis, highlighted that investment in local infrastructure generated more jobs, more quickly, than large national capital programmes. The question of how infrastructure should be valued, and in particular its distinct contribution to local, regional and urban development and well-being, was the theme of a major conference held in Leeds in April 2017, which iBUILD hosted with partner infrastructure research centres, alongside public, private and voluntary sector actors.

Set against this backdrop, the UK and other major economies are struggling to improve productivity while overall growth rates and real wages are stagnating. Too many individuals and places are left behind by the current economic model. Three years ago we asked 'Are you being served?', here we distil our research to set out an agenda to improve the quality of infrastructure for all by 'Closing the Gap'.

Richard Dawson iBUILD Principal Investigator

[1] iBUILD (2015) *Are you being served? iBUILD mid-term review and manifesto*, iBUILD, Newcastle University: Newcastle upon Tyne.

[2] IPA (2017) *Analysis of the National Infrastructure and Construction Pipeline*, Infrastructure Projects Authority: London.

[3] NAO (2018) *PFI and PF2*, National Audit Office, London.

[4] Speech by Theresa May, UK Prime Minister, to 2016 Conservative Party Conference, 5 October.

[5] Smart Growth America (2009) *The States and the Stimulus*, Smart Growth America, Washington, DC.

[6] https://conferences.leeds.ac.uk/valuing-infrastructure/

#Key Messages

Research from across the iBUILD Research Centre has identified five priority action areas to help governments and infrastructure policy-makers and practitioners 'Close the Gap' by unlocking better and more sustainable infrastructure business models. If applied to all infrastructure planning and decision-making, these action areas will help to challenge the "*timid, uncoordinated, incremental, wasteful*"[7] way the UK currently plans, builds and manages its infrastructure, and should enable a new approach to be developed that delivers infrastructure systems and services that enhance the health, wealth and security of all UK citizens.

- Adopt a broader, integrated and more holistic appreciation of infrastructure
- Enable greater action at the local scale that reflects the distinctive nature of place but also connects with the national level
- Facilitate and capture all forms of long-term value
- Deliver infrastructure more efficiently and with less waste by aligning organisational capabilities and applying circular economy principles
- Accelerate uptake through practical action and demonstration

Priority Action Area #1: Adopt a broader, integrated and more holistic appreciation of infrastructure

Infrastructure systems are not just tracks, tubes and trunk roads. Failure to take a wider view and consider the resources that flow along these, the services they provide and the people and businesses that depend on them, will result in funding and financing models that do not deliver effectively. At the same time, it is crucial that we understand and appreciate how and why each element of these systems is interconnected. Every infrastructure system manifestly influences the performance of all of the other systems with which it interacts, not just technically, but also economically and socially. The UK's infrastructure is amongst the most mature and interconnected in the world, which means there is a pressing need to adopt a broad, integrated, holistic and sophisticated approach to infrastructure planning that also overcomes some of the problems of infrastructure sunk costs that can inhibit innovation.

Recommendation #1:

Governments, advisors, infrastructure planners, financers, engineers and other stakeholders should use a broad, but appropriately specified, definition of infrastructure to identify and realise the full range of opportunities from alternative business models.

Recommendation #2:

Housing and 'hidden infrastructure', such as efficiency measures, should be considered alongside the large-scale capital investments with which they interconnect, and within infrastructure and spatial planning processes.

Recommendation #3:

Reforms in policy, institutions and regulation are needed to facilitate an integrated approach to local infrastructure that can identify, and exploit, synergies across different infrastructure sectors.

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[7] Infrastructure UK (2010) National Infrastructure Plan 2010, First NIP: October 2010, HM Treasury.

Priority Action Area #2: Enable greater action at the local scale that reflects the distinctive nature of place but also connects with the national level

Too much infrastructure planning and delivery is top-down, and yet all infrastructure has to go somewhere; it is inherently local, and 'place-based'. Top-down, silo-based approaches to infrastructure development and management prevent locally-led and innovative business models from flourishing and discourage innovation. There is also a risk, since the performance of all infrastructure is context-dependent, that the wrong infrastructure is put in the wrong place at the wrong time and in the wrong forms, because of poor local knowledge, weak engagement and inappropriate ownership. These issues hinder the UK from maximising the returns from infrastructure investment. There are two returns – direct returns on infrastructure development and investment and indirect returns created elsewhere in the economy. The UK should invest in infrastructure to support inclusive growth, and accelerate the decentralisation of appropriate forms of infrastructure investment and responsibility to local institutions (including devolved administrations and Metro Mayors in England) so that local and regional infrastructure can better reflect the values and needs of the communities and economies it serves. Equally, local and regional infrastructure strategies need to be aligned with and embedded within overall national strategic frameworks, including the emergent National Infrastructure Assessment (NIA) and Industrial Strategy.

Recommendation #4:

Individuals and communities should have an Infrastructure Service Guarantee, ensuring a minimum level of service that is achieved with an engineering solution and business model appropriate to the local situation.

Recommendation #5:

To maximise the effectiveness of local infrastructure business models greater local autonomy is required in the strategic planning, funding, financing and delivery of infrastructure.

Recommendation #6:

The government must enable a wider range of national and local mechanisms for funding and financing. These include state-backed infrastructure investment banks, tax increment financing, municipal bonds, social impact bonds and crowd-sourced funding approaches. This will be increasingly important in the UK as it withdraws from the European Investment Bank.

Priority Action Area #3: Facilitate and capture all forms of long-term value

Infrastructure is not only about cash returns. Investment in infrastructure provides wider health, economic, cultural and environmental benefits for society; infrastructure has the potential to convert financial value into societal value. A new infrastructure valuation system that moves beyond benefit-cost analysis and recognises long-term, whole-life benefits is essential to maximise the benefits (i.e. infrastructure can be designed to best realise them) and to help build more resilient and inclusive economies and communities. Infrastructure must also be built for minimum whole-life costs. This might mean paying a bit more upfront for something that will last and serve society and economy for longer (generating gross future benefits) without the need for frequent (and expensive) maintenance; a robust and sustainable infrastructure is imperative.

Recommendation #7:

Measures of social and environment value (benefit and cost) must be incorporated into infrastructure appraisal frameworks to achieve the widest possible set of mechanisms to capture revenue and other values.

Recommendation #8:

Develop and implement a quantitative framework within the infrastructure appraisal process that can assess the value of flexibility and resilience across the whole infrastructure system over the long-term.

Recommendation #9:

Resource assessments must become routine to identify the potential for land and infrastructure assets to generate long-term, stable revenue streams and sustainable growth, and not just one-off, short-term windfalls from selling-off capital assets.

Recommendation #10:

Employ a new approach to infrastructure economics that recognises the long-term and system-wide value of infrastructure provision and the alternative forms of investment necessary to realise this value.

Priority Action Area #4: Deliver infrastructure more efficiently and with less waste by aligning organisational capabilities and applying circular economy principles

Approaches to, and decisions on, project financing, funding and delivery should not be chosen for political reasons alone. Mechanisms should be adopted that can best deliver desired economic, social and environmental values, regardless of their political flavour.[8] Many of the methods and tools to enable this already exist: for example, the Project Initiation (Infrastructure) Routemap, Building Information Modelling (BIM) systems, and life-cycle assessment. Although the principles of the circular economy are well reported, their application to infrastructure is something we have pioneered, although much more needs to be done. These approaches support more efficient planning and procurement by public and private sector actors, improve adaptation and mitigation measures, minimise costs and labour, preserve the environment, and maximise the potential to reuse and recycle materials and components in the future.

Recommendation #11:

The Project Initiation Routemap has demonstrated many cost reduction benefits and it should be made standard practise for all public-funded projects.

Recommendation #12:

Infrastructure design should be grounded in circular economy principles to consider the whole life material and resource demands of infrastructure pipelines, to identify opportunities to reduce overall energy consumption and waste.

[8] In a speech to the 2016 Conservative Party Conference, the Chancellor of the Exchequer, Philip Hammond, said that "long-term economics, not short-term politics, would drive Britain's vital infrastructure investment": https://blogs.spectator.co.uk/2016/10/full-text-philip-hammonds-conference-speech/

Priority Action Area #5: Accelerate uptake through practical action and demonstration

Approaches to, and decisions on, project financing, funding and delivery should not be chosen for political reasons alone. Mechanisms should be adopted that can best deliver desired economic, social and environmental values, regardless of their political flavour. Many of the methods and tools to enable this already exist: for example, the Project Initiation (Infrastructure) Routemap, Building Information Modelling (BIM) systems, and life-cycle assessment. Although the principles of the circular economy are well reported, their application to infrastructure is something we have pioneered, although much more needs to be done. These approaches support more efficient planning and procurement by public and private sector actors, improve adaptation and mitigation measures, minimise costs and labour, preserve the environment, and maximise the potential to reuse and recycle materials and components in the future.

Recommendation #13:

Establish full-scale urban demonstrator sites for applied research into integrated infrastructure planning and testing of innovative infrastructure business models.

Recommendation #14:

Develop alternative business models by collaborating with the widest range of stakeholders, and integrating the assessment of a broad range of values with the design of engineering solutions.

#Priority Action Areas

Priority Action Area #1:

Adopt a broader, integrated and more holistic appreciation of infrastructure

Continued underinvestment in national and local infrastructure constrains economic growth and productivity at all geographical levels, and prevents the efficient delivery of local services. By international comparison, the UK has historically under-invested in infrastructure.[9] The framework regulating the National Infrastructure Commission (NIC) requires they outline potential infrastructure projects and programmes within a set fiscal envelope of public investment between 1.0 and 1.2% per annum.

How infrastructure is defined, alters how it is valued. This is crucial as underinvestment often springs from under-valuation because of the `positive externalities' or additional benefits that infrastructure generates. Some definitions focus upon components and networks.[10] Other definitions emphasise societal need and economic growth.[11] A third group stresses the financial value of infrastructure as an alternative asset class.[12] The term `business model' describes the creation, delivery, and capture of value in economic, social, cultural and/or other terms.[13] A sustainable infrastructure business model therefore secures the resources, financial or otherwise, to construct and manage infrastructure over its life cycle.

A narrow view of infrastructure can constrain innovative thinking and limit the development and implementation of alternative business models, some of which can be sourced from other sectors (Box 1). Many local infrastructure business models in the UK have been based upon prudential borrowing from the Public Works Loan Board (PWLB), or the use of Private Finance Initiative (PFI) schemes. To unlock new opportunities for business model innovation, an integrated approach that considers the whole infrastructure system from physical components through to the services it provides (including maintenance) is essential. In addition, it is important to arrive at a careful allocation of costs and benefits over the lifecycle of the infrastructure so that issues of equity can be considered in space (across communities, regions, cities, etc.) and over the longer-term. This can help to identify more opportunities to capture value across the entire infrastructure system and throughout its life cycle.

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[9] TUC (2016) UK languishing near bottom of OECD rankings for investment in vital infrastructure, Trades Union Congress, 16 November: https://www.tuc.org.uk/news/uk-languishing-near-bottom-oecd-rankings-investment-vital-infrastructure

[10] ICE (2009) A National Infrastructure Investment Bank, Institution of Civil Engineers, London.

[11] Collins English Dictionary (2013) Definition of "infrastructure", HarperCollins Publishers.

[12] Inderst, G. (2010) Infrastructure as an asset class, Public and Private Financing of Infrastructure, Luxembourg, European Investment Bank.

[13] Teece, D.J. (2010) Business models, business strategy and innovation, Long range planning, 43(2):172-194.

BOX 1:
Business model lessons from other goods and services sectors

Henry Ford is famous for using the assembly line in his car factories to improve production efficiency, but it was connecting this up with other innovations such as increased wages for his workforce to enhance their buying power and franchise dealerships that enabled rapid growth in sales.

High street video rental store Blockbuster filed for bankruptcy in 2010. Six years earlier it had over 9000 stores globally, but the company was slow to respond and take advantage of new business model opportunities from digital film distribution enabled by ICT.

App users on smartphones will be familiar with the Freemium business model. The basic App is provided for free, drawing in users, but additional features are provided at cost.

Like many other manufacturers, Toyota applied the Just-In-Time principle to their manufacturing processes. However, they were also early adopters of applying these principles across the rest of their system in product development, supplier relations and distribution. Toyota also recognised the important role of people involved in these processes through the principle of "Jidoka" (often referred to as automation with a human touch).

A number of companies are now enabling a 'sharing economy', peer-to-peer sharing usually via an online market place. Airbnb allows people to lease or rent short-term lodging, Vinted supports reuse of clothing items and accessories. The approach and emphasis on profit varies considerably, but they typically improve the use and reuse of existing assets.

A key lesson from these business models is that whilst physical components and services are important so are the processes, people and mechanisms for creating, delivering and capturing value. A key challenge for the iBUILD research team has been to draw upon the existing work on business models in such goods and services activities to understand and explain what they mean for the particular characteristics of infrastructure.

Recommendation #1:

Governments, advisors, infrastructure planners, financers, engineers and other stakeholders should use a broad, but appropriately specified, definition of infrastructure to identify and realise the full range of opportunities from alternative business models.

iBUILD undertook the first objective analysis of the local alternative infrastructure business models. An on-line tool provides free access to anyone interested in exploring or developing local infrastructure business models.[14] The tool is based on an analysis of UK and international infrastructure business models, including current, historical and planned developments. Value – economic, social and environmental – can be generated and captured from across the whole infrastructure system. Lessons from other sectors demonstrate how the services and processes are just as important, if not more so, than the tracks, pipes, cables and other physical components. Infrastructure must be considered, and defined, in terms of a 'whole system' that comprises (Figure 1):

- *physical artefacts* – includes the physical links, nodes and components of infrastructure systems such as roads, bridges, pipes and cables;
- *processes* – includes actors, institutions, management, regulation, protocols and procedures that govern the infrastructure over its lifecycle;
- *resources* – includes people, vehicles, water, electricity and data that are conveyed by the physical artefacts and the materials used in the construction of the artefacts; and,
- *services* – such as warmth, mobility, sanitation, transportation, welfare services and communication that benefit a wide range of users.

Infrastructure is therefore the artefacts and processes of the inter-related systems that enable the movement of resources in order to provide the services that mediate (and ideally enhance) security, health, economic growth and quality of life at a range of scales.[15] Infrastructure plays an important role in modulating both the use of natural environment resources, and mitigating environmental risks. Similarly, infrastructure funding and financing is supported by the economy, whilst also acting as a driver of economic growth.

Moving beyond a narrow or solely economic view and distinct from the world of more conventional goods and services, an infrastructure business model therefore describes how infrastructure systems create, deliver and capture economic, social, cultural and environmental value over the whole infrastructure life cycle.[16] In this regard, universal infrastructure is said by the UK National Infrastructure Commission to be the foundation for helping to achieve more balanced economic growth across the UK.[17]

[14] Bryson, J., Mulhall, R. and Song, M. (2017) Infrastructure Business Models and the iBUILD on-line local infrastructure tool: http://ceg-research.ncl.ac.uk/ibuildDemo/

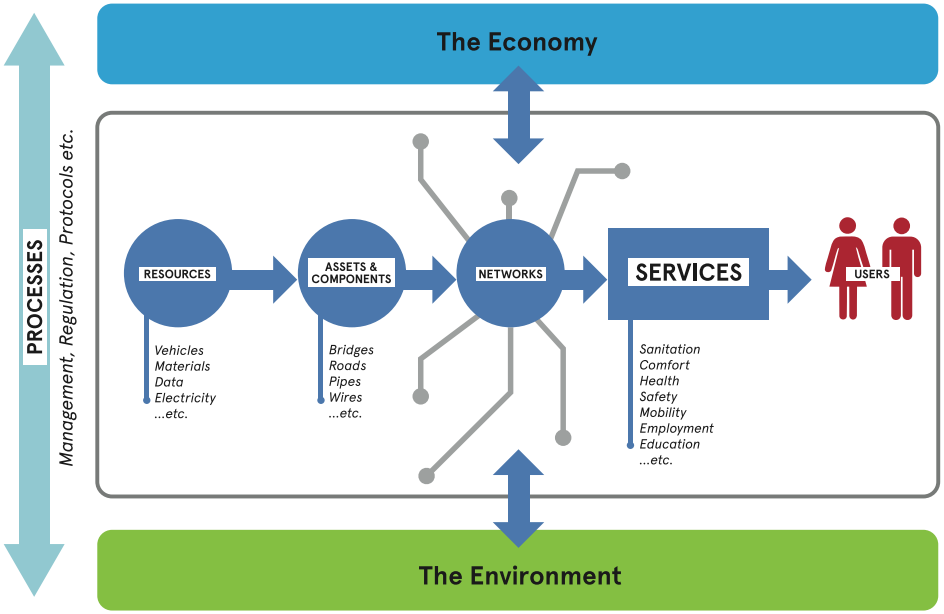
[15] Dawson, R.J. (2013) Bridges n'that: An infrastructure definition for iBUILD, iBUILD Briefing Note 1.

[16] Bryson, J.R., Pike, A., Walsh, C.L., Foxon, T., Bouch, C. and Dawson, R.J. (2014) Infrastructure Business Models, iBUILD Briefing Note 2, Newcastle University: Newcastle upon Tyne.

[17] NIC (2017): www.nic.org.uk/news/adonis-infrastructure-can-be-the-foundation-for-nationwide-economic-growth/

Figure 1:

A systems view of infrastructure.



BOX 2:
The Royal Albert Hall – Not all alternative business models are new

Our review has highlighted that the history of local infrastructure going back to the 17th century is one of continual innovation. The Royal Albert Hall was built between 1867 and 1871. Prince Albert wanted the hall to fulfil two functions – a large music hall, and a conference centre – and was determined that it should be funded privately. Henry Cole, secretary of the Science and Art Department, came up with the idea to circulate a prospectus to raise funds by selling sittings in the hall at £100 each.[18]

This was an early implementation of a debentures business model in which a purchaser or investor pays a one-off fee, which goes towards the upkeep of a facility and in return obtains either free tickets, or the opportunity to buy tickets first at face value, to major events held there. The tickets can also be sold on if the purchaser is not going to use them. Most debentures have a short life of 5-10 years, but the Royal Albert Hall is an exception as the debentures are valid for 999 years.

[18] Sheppard, F.H.W. (1975) Survey of London, Vol. XXXVIII: The Museums Area of South Kensington and Westminster, The Athlone Press/University of London, London.

Recommendation #2:

Housing and 'hidden infrastructure', such as efficiency measures, should be considered alongside the large-scale capital investments with which they interconnect, and within infrastructure and spatial planning processes.

The growing pressures within different parts of the UK housing market are fuelling the growth of housing costs to affordability ratios to such an extent that increasing numbers of people are being priced out of both home ownership and public and private rental accommodation, particularly in London, the greater south east, and some of the UK's other major cities. The housing challenges have profound implications for inclusive growth and infrastructure strategy, planning and development.

The National Infrastructure Plan (NIP)[19] paid limited attention to buildings or property and the important social and economic services they provide. Taking a slightly different approach and recognising the 'housing crisis', the NIC's Interim National Infrastructure Assessment suggests that "housing is the greatest infrastructure capacity challenge of all, and a significant increase in the rate of homebuilding is a key imperative".[20] Many local infrastructure plans, including those for Newcastle and Gateshead[21] and London,[22] recognise the importance of housing efficiency and energy demand reduction measures. The UK has some of the oldest building stock in the EU, and as much as 80% is expected to still be in use by 2050.[23] The majority of the UK's housing stock is not designed for energy efficiency, and this makes it even harder to address the issues of fuel poverty and greenhouse gas emission reductions. In moving forward to increase the number of new homes built in the UK it is important that the quality of housing improves and does not diminish.

Buildings, and spatial planning more generally, play a critical role in configuring and modulating the demands placed upon energy, water and communications networks. Reducing demand for these services through 'hidden infrastructure', such as investment in efficiency measures and demand management strategies, reduces consumer bills, frees up capacity to support growth and regeneration, and defers the need for expensive capital investment in new infrastructure (e.g. for new power stations and water treatment works). The 2014 UK National Infrastructure Plan, for example, outlines a pipeline of £65 billion investment in energy generation and £45 billion investment in energy networks over the coming years. Yet, investing a third of this in energy efficiency measures over the next four decades could free up 12% headroom in generation capacity.[24] These measures are critical to generating long-term and sustainable economic, social and environmental value and must be co-ordinated more effectively.[25]

[19] HM Treasury (2014) National Infrastructure Plan, London, HM Treasury.

[20] NIC (2017) Congestion, Capacity, Carbon – Priorities for National Infrastructure: the Interim National Infrastructure Assessment, National Infrastructure Commission: London: 4.

[21] NCC & GC (2013) Gateshead and Newcastle Infrastructure Delivery Plan, Newcastle City Council & Gateshead Council.

[22] GLA (2015) London Infrastructure Investment Plan, London, Greater London Authority.

[23] Sandberg, Sartori I., Heidrich O., Dawson R.J., Dascalaki E. et al.(2016) Dynamic Building Stock Modelling: Application to 11 European countries to support the energy efficiency and retrofit ambitions of the EU. Energy and Buildings, 132(15):26-38.

[24] Gouldson, A., Kerr, N., Millward-Hopkins, J., Freeman, M.C., Topi, C. and Sullivan, R. (2015) Innovative Financing Models for Low Carbon Transitions: Exploring the case for revolving funds for domestic energy efficiency programmes, Energy Policy, 86: 739-748.

[25] Gouldson, A., Colenbrander, S., McAnulla, F., Sudmant, A., Kerr, N., Sakai, P., Hall, S., Papargyropoulou, E. and Kuylenstierna, J.C.L. (2014) The Economic Case for Low Carbon Cities. New Climate Economy and Stockholm Environment Institute, Stockholm. Available at: http://newclimateeconomy.report.

BOX 3:
Energy Savings Performance Agreement

Efficiency Capital Corporation is a Toronto-based social enterprise which operates a for-profit business model centred on energy retrofitting large commercial buildings. Critical to the business model is the Energy Saving Performance Agreement (ESPA) which has been developed as a non-debt financing tool which enables the installation of energy retrofits and the capture of long-term revenue streams. The instrument works by Efficiency Capital undertaking an energy audit for a consumer, from which financial savings are calculated, followed by which an agreed amount (typically 80-90%) of those financial savings are paid to Efficiency Capital over the term of the agreement (via monthly/quarterly instalments).

Shared financial savings therefore result in no debt or capital outlay required on behalf of the consumer. The performance of the retrofit is monitored throughout the duration of the agreement, and is based on International Performance Measurement and Verification Protocol (IPMVP), with embedded insurance ensuring that the building owner never pays more than the financial savings. Efficiency Capital is part of the Toronto Atmospheric Fund, a body set up and financed by the Provincial Government of Ontario to develop and incubate green businesses and entrepreneurs as part of a long-term campaign to reduce C02 emissions in Toronto.

Recommendation #3:

Reforms in policy, institutions and regulation are needed to facilitate an integrated approach to local infrastructure that can identify, and exploit, synergies across different infrastructure sectors.

Infrastructure systems are increasingly interdependent. These interdependencies can arise through proximity, for example relying upon the same foundation for structural stability or co-location underneath roads. Infrastructures can also often share resources with each other, perhaps energy for power, or information communication technology to enable real-time control. Economic and regulatory frameworks can also create complex, often hidden, interactions as a result of shared similar investment cycles or finance models.[26,27] Whilst users often create interdependencies through demand for shared services; turning a hot water tap calls a water service, heating service and a communication service if the boiler is connected to the Internet of Things. These interdependencies can create risks, but they also present opportunities for managing risks and uncertainties,[28] and for alternative infrastructure business models, particularly at the local level, where these interdependencies are closely related and tightly coupled. These opportunities include sharing physical space for multiple services in multi-utility conduits, use of smart technologies to optimise the efficiency of systems, enabling new technologies such as electric vehicles (Box 4), making better use of spare capacity through sharing (Box 14), and applying circular economy principles to minimise waste.

The current disjointed nature of local infrastructure planning, investment and management is complex, uncertain and produces inefficient outcomes.[29] Enhancing coordination, through alternative local infrastructure business models, of the planning, delivery and management of multiple infrastructure classes enables infrastructure systems to be developed around the principle of providing the highest appropriate level of service at the lowest level of resources used. This would generate additional wider social and environmental benefits, such as tackling fuel poverty, reducing carbon emissions, as well as creating local jobs and reducing costs.[30,31] Local actors need additional capacity and empowerment, including more effective and integrated analytical and decision-making tools, and metrics,[32] alongside national reforms in policy and regulation, to enable places and organisations to integrate local infrastructure provision.[33]

A major appeal of infrastructure to financial investors is the potential for stable returns at relatively low(er) risk over the longer term. Current governance and regulatory arrangements typically foster investment on a sector or project specific basis, which can produce objectives that conflict with those taken by an integrated approach. Bundling the physical, social and economic components of multiple infrastructure services into a single investment package is one option.[19] iBUILD research has been exploring the geographies and potential of other financial instruments that are consistent with an integrated approach, but package investments and returns in different ways that capture value whilst minimising risks for investors, operators, users and tax-payers.[34] There are also broader regulatory changes and labour market (particularly skills) issues within and across different infrastructure sectors that are likely to arise due to Brexit, and which national and local actors will need to consider when planning, building and operating infrastructure assets, services and systems.[35]

[26] Hall, J., Tran, M., Hickford, A. and Nichools, R. (eds.) (2016) The Future of National Infrastructure: A Systems of Systems Approach, Cambridge University Press: Cambridge.

[27] Dawson RJ (2015) Handling Interdependencies in Climate Change Risk Assessment, Climate, 3(4):1079-1096.

[28] Fu G., Dawson, R.J., Khoury, M. and Bullock, S. (2014) Interdependent networks: Vulnerability analysis and strategies to limit cascading failure, European Physical Journal Part B, 87(7):148.

[29] Roelich, K., Knoeri, C., Steinberger, J.K., Varga, L., Blythe, P.T., Butler, D., Gupta, R., Harrison, G.P., Martin, C. and Purnell, P. (2015) Towards resource-efficient and service-oriented integrated infrastructure operation, Technological Forecasting & Social Change, 92(1):40-52.

[30] Roelich, K. and Bale, C.S.E. (2014) Municipal energy companies in the UK; Motivations and barriers, in International Symposium of Next Generation Infrastructure, Vienna, October 2014.

[31] Bouch, C., Rogers, C.D.F., Dawson, R.J., Baker, C.J., Quinn, A. and Walsh, C.L. (2014) A systems-based approach to the identification of enterprise/infrastructure interdependencies, in Proceedings 2nd International Symposium for Next Generation Infrastructure, Vienna.

[32] ICIF & iBUILD (2015) A Critique of Current Infrastructure Performance Indicators: Towards Best Practice, ICIF and iBUILD: London.

[33] Rogers, C.D.F. and Leach, J. (2013) Future Urban Living: Empowering Cities and Citizens, University of Birmingham Policy Commission.

[34] See, for example, Thrower, G. The marketisation of infrastructure: The enmeshment of the qualitative state and variegated capital: http://www.ncl.ac.uk/gps/geography/postgrad/students/studentprofiles/throwergraham.html

[35] Rosewell, B. (2017) Infrastructure, policy, and Brexit, Oxford Review of Economic Policy, 33(S1): S113-S123.

BOX 4:
Charged with potential: The energy-transport nexus

A rapidly emerging interdependence is between electricity and transport infrastructure – most notably through the uptake of electric vehicles (EVs). The UK Government has announced that all new car and van sales should be ultra-low emission vehicles (ULEV) by 2040, as a stepping stone towards decarbonising the UK fleet by 2050, but ULEV adoption in the UK in 2017 was just 0.3% of the vehicle fleet.

iBUILD research has demonstrated that distribution networks could accommodate higher growth in electric vehicles that previously suggested, by exploiting the geographic spread and different timings of EV charging.[36] *However, rapid innovation in technology is seen as a risk by some investors, whilst many consumers are unlikely to adopt ULEV technology until it is perceived as equivalent to, or better than, combustion engines. Rapid Charge Networks offer the necessary convenience but analysis suggests that the financial business case required to achieve the government's ULEV targets would require a threefold mark-up on electricity prices at rapid charging points.*[37]

Distribution network operators should collaborate with new market players, such as charging infrastructure operators, to support the roll out of an extensive charging infrastructure to make both networks more robust. Moreover, due to the risks associated with continuing technological development, consumer acceptance and drivers' willingness to pay the mark-up required, alternative solutions focussing on wider non-financial value should also be investigated.

Picture Courtesy of Go Ultra Low

[36] Neaimeh M, Wardle R, Jenkins A, Hill GA, Lyons P, Yi J, Huebner Y, Blythe PT, Taylor P (2015) A probabilistic approach to combining smart meter and electric vehicle charging data to investigate distribution network impacts, Applied Energy. 157: 688-698.

[37] Serradilla J, Wardle J, Blythe P, Gibbon J. An evidence-based approach for investment in rapid-charging infrastructure. Energy Policy 2017, 106, 514-524.

Priority Action Area #2:

Enable greater action at the local scale that reflects the distinctive nature of place but also connects with the national level

The separation of local infrastructure responsibilities between national government, local authorities, and the private sector creates fragmentation and silos that constrain the development of integrated approaches. Moreover, all engineering is context-dependent – if it is to be effective, it must be designed with its current, and future, context in mind – and thus local infrastructure must be conceived and designed according to the local context.[38]

Local authorities and other actors should be enabled and resourced sufficiently to cultivate alternative ways of developing and managing local infrastructure of all types, but there should also be more effective co-ordination between actors, institutions and strategies across different geographical scales. The emergence of the NIC's Interim National Infrastructure Assessment, and the role identified by the NIC for Mayoral Combined Authorities to support local implementation of the Assessment, including the development of new local infrastructure strategies, illustrates how devolved areas are seen as having an increasingly important role to play in UK infrastructure planning and delivery. At the same time, those areas outside Mayoral Combined Authorities also need infrastructure investment to stimulate and support more inclusive forms of growth.

In advocating greater decentralisation, we should also be mindful not to create new or exacerbate existing spatial disparities. In the aftermath of the vote to leave the European Union, one of the challenges facing policy-makers and researchers is to identify specific interventions and measures to support those places `left behind'[39] and how best to arrest and reverse the UK's productivity decline. For UK national productivity to increase and for spatial disparities to be narrowed requires productivity to go up around the country, not just in London. The UK government accepts that approaches based solely on static analysis can favour investment and re-investment in places where development has already happened, and relatively higher current market values for wages, housing and land in prosperous places generate higher Benefit-Cost Ratios that often overlooks some of the long-term benefits that infrastructure can bring to different places. The Social Mobility Commission has called for government to rebalance the national transport budget to deliver a more equal share of investment per person and contribute towards a more regionally balanced economy.[48] Cost-benefit analysis should be complemented by strategic programme design that makes better use of broad-based and dynamic assessment techniques, if the full potential of infrastructure to support local economies is to be realised.[40] The proposed `Rebalancing Toolkit' is also expected to ensure that the benefits of infrastructure investment are considered more strategically by improving the focus, quality and transparency of `rebalancing' evidence in strategic business cases – and applying it more consistently.[50]

Demands for new infrastructure and maintenance of existing infrastructure are rising, and governments are under pressure, in large part due to austerity, to identify additional new ways of funding and financing infrastructure assets and systems.[41] When there is insufficient investment for maintenance and renewal of existing assets and systems then as illustrated by the example of the New York subway, wide social and economic disruptions can materialise.[42] The network characteristics of most forms of infrastructure also makes its socio-economic contribution difficult to assess but this becomes more important when sourcing funding and finance mechanisms and identifying who should pay and how much.

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[38] Rogers, C.D.F. (2017) The Value of Foresight and Scenarios in Engineering Liveable Future Cities, chapter in Retrofitting Cities for Tomorrow's World, by Eames, M., Dixon, T., Hunt, M. and Lannon, S. (eds.), Wiley Blackwell: Chichester: 139-152.

[39] SMC (2017) Social mobility in Great Britain: fifth state of the nation report, Social Mobility Commission: London.

[40] BEIS (2017) Industrial Strategy: Building a Britain fit for the future, Department for Business, Energy and Industrial Strategy: London.

[41] See for example, municipal bonds and the UK Municipal Bond Agency: https://www.ukmba.org/

Local and sub-national actors, including local authorities and community trusts, have shown they are able to take a lead in developing alternative local infrastructure business models by combining new and different sources of revenue and longer-term capital. For example, UK city regions, such as Tees Valley, have begun to combine local pension fund investment alongside national and local resources, in order to invest in economic infrastructure. Nottingham City Council has also pioneered the use of a workplace parking levy to generate income to help finance new investment in the city's tram system. These approaches are examples of local alternatives in the sense of innovating beyond the current status quo or conventional wisdom. A coordinated local approach to infrastructure planning can be achieved by identifying synergies by bundling infrastructures together into the same business model. Limited local and sub-national institutional autonomy, including the ability to raise and retain local revenue, prevents UK local authorities and other actors from assuming greater responsibility for planning, co-ordinating, implementing public capital and levering in private investment in infrastructure.[43] And yet local governments often have to shoulder the initial risks of infrastructure development in order to create the environment for private finance to then invest in projects that can demonstrate that they are able to generate yields and returns.[44]

BOX 4:
Charged with potential: The energy-transport nexus

In 2011, the UK government set out proposals for how cities and city regions could support economic recovery, rebalanced growth and infrastructure planning and delivery. Between 2011 and 2014, 29 'City Deals' were signed between Local Authorities, Local Enterprise Partnerships (LEPs) and national government. A number of Devolution Deals in England were signed subsequently, followed by the election in May 2017 of new Metro Mayors in six English city regions (Greater Cambridge and Peterborough, Greater Manchester, Liverpool City Region, Tees Valley, West of England and West Midlands). In Scotland and Wales, City (Region) Deals have been developed with all the largest cities in Scotland now being agreed between city-regions, the Scottish government and UK government. The majority of these Deals have been designed to strengthen existing or introduce new forms of infrastructure funding, financing and governance. Many of the significant City Deals and Devolution Deals agreed 'innovative' infrastructure models that promised long-term investment, but at the same time national government has maintained strict fiscal control over their operation and there have been highly uneven outcomes in per capita financial allocations to different places. Whilst the deal-making approach has been an important intervention, when viewed in an international context it does not yet represent radical decentralisation. Instead, iBUILD research has suggested that what is required is a more comprehensive and systemic approach to providing stronger fiscal autonomy and public service integration across all UK cities and local areas, within a stable national framework, to support economic development and infrastructure investment and delivery.[45]

[42] Rosenthal, B., Fitzsimons, E. and LaForgia, M. (2017) How Politics and Bad Decisions Starved New York's Subways, New York Times, 18 November: https://www.nytimes.com/2017/11/18/nyregion/new-york-subway-system-failure-delays.html

[43] O'Brien, P. and Pike, A. (2015) City Deals, decentralisation and the governance of local infrastructure funding and financing in the UK, National Institute Economic Review, No. 233: R14-R26.

[44] Bryson, J.R., Mulhall, R. A. and Song, M. (2017), Urban Assets and the Financialisation Fix: Land Tenure, Renewal and Path Dependency in the city of Birmingham, Cambridge Journal of Regions, Economy and Society: 1-15.

[45] Pike, A., Kempton, L., Marlow, D., O'Brien, P. and Tomaney, J. (2016) Decentralisation: Principles, Policy and Practice, Centre for Urban and Regional Development Studies, Newcastle University: Newcastle upon Tyne. Newcastle University.

Recommendation #4:

Individuals and communities should have an Infrastructure Service Guarantee.

A review of infrastructure business models shows that alternative institutional forms of organisation and modes of operation are evident where infrastructure services are supplied by a range of actors – such as local authorities, social enterprises or community groups – often working together and through new institutional arrangements.[46] These local infrastructure business models could deliver additional and wider benefits, but they face constraints, which limits their growth and transferability.[47] There should be an 'Infrastructure Service Guarantee' for all. This guarantee must not be defined in terms of engineering standards, or be tied to particular technical approach to delivering a service. Rather, it must be defined in terms of service quality, and in terms of delivering the capabilities for economic development, wellbeing and a good quality environment to everybody.

iBUILD research on the energy sector has examined social enterprise, community and municipal energy 'companies' in the UK and internationally. UK energy business models, for example, operate in a privatised and liberalised, but highly regulated, environment. Post-privatisation, energy policy and the regulatory system have evolved around the mainstream mode of operation, which is profit-oriented, throughput-based and large-scale.[48] Current UK regulation views markets and competition as the most effective way of meeting the needs of society, yet local actors are often motivated to achieve goals other than profit generation, such as increased individual and community health and wellbeing through affordable warmth and better air quality. Institutional lock-in is created and reinforced by historical regulatory constraints on the role of local actors, who have traditionally not played a role in energy governance, beyond spatial planning, since the 1940s, thereby limiting innovation. Combined with limited resources and in-house knowledge, there is often insufficient capacity amongst local actors to engage with complex decision processes, which presents a barrier to stakeholders becoming involved in infrastructure planning and development.[49] Within this context a number of local authorities, including Bristol and Nottingham, have created municipal energy companies. Other cities, including London, are pursuing a 'licence lite' approach whereby a local public authority can purchase the output of low and zero carbon electricity generators and supply it to public and commercial electricity users.[50] Research has shown how a not for profit administrator could act as an enabler to better support these and other local energy business models. However, changes to regulation, policy and consumer protection are required to unlock substantial opportunities for energy efficiency in demand reduction, deep retrofit, micro generation and appliance efficiency.[51]

[46] Bryson, J.R., Mulhall, R. and Song, M. (2014) Business Models and Local Infrastructure: Financing, Value Creation and Governance, iBUILD Working Paper No. 12.

[47] Hall, S. and Foxon, T.J. (2014) Values in the Smart Grid: The co-evolving political economy of smart distribution, Energy Policy, 74:600-609.

[48] Mitchell, C. (2010) The political economy of sustainable energy, Palgrave Macmillan.

[49] Bale, C.S.E., Foxon, T.J., Hannon, M.J. and Gale, W.F. (2012) Strategic energy planning within local authorities in the UK: A study of the city of Leeds, Energy Policy, 48:242-251.

[50] https://www.london.gov.uk/decisions/md1663-new-junior-electricity-supply-licence-licence-lite

[51] Hall, S., Roelich, K.E., (2015) Local Electricity Supply: Opportunities, archetypes and outcomes. Ibuild/RTP Independent Report. http://research.ncl.ac.uk/ibuild/outputs/reports/local_electricity_supply_report_WEB.pdf

BOX 6: Citizinvestor

Citizinvestor provides an example of a US-based crowdfunding platform in which people are able to invest in local projects that are likely to provide genuine change and positively shape their surroundings. Investors receive no formal return but donate in the knowledge that their money is being spent to improve their local community. In 2017 Citizinvestor was used by residents of Fort Lauderdale, Florida, to construct a 61,000 sq. ft. dog park.

Supported by Victoria Park Civic Association, a total of $81,670 was raised through the platform which was then spent by the local government to develop the space (build entries, small dog friendly exercise amenities, fences, etc.). The nature of this crowdfunding model means that it is likely to work better in high-income areas and for smaller scale projects where there is active demand for change throughout the local community.[52]

[52] http://www.citizinvestor.com/

Recommendation #5:

To maximise the effectiveness of local infrastructure business models greater local autonomy is required in the strategic planning, funding, financing and delivery of infrastructure.

The UK is a centralised political economy, with a highly concentrated system of taxation and expenditure, in an international context, with the process of fiscal centralisation having increased over recent decades (Figure 2). The UK's 'tax to GDP ratio' is currently 33.2%, according to the Organisation for Economic Cooperation and Development,[53] and local government is responsible for raising 5% of total national tax revenue. In contrast to many other countries, infrastructure decision-making in cities and localities is dominated by centralised mechanisms, which can hinder local innovation and experimentation (including participatory budgeting) as the funding, financing and revenue raising powers are inappropriate for delivering local infrastructure and growth. London, for example, relies more heavily on inter-governmental transfers than locally-raised revenues, compared to global competitor cities, such as New York, Paris and Tokyo.[54]

In a time of austerity, local government budgets have been reduced significantly. Whilst the government has begun to introduce reforms to local authority finance in England, iBUILD research reveals that the ability of localities to reap and reinvest (in infrastructure) more of the proceeds of growth remains constrained,[55] and that local authorities require stronger borrowing powers to invest in housing and associated infrastructure.[56] Private finance has slowed recently, and although there are still high levels of capital, revenue budgets have taken a significant hit, particularly in local level public authorities. In what remains a fiscally-constrained environment, iBUILD research highlights the benefits to the UK economy, in terms of recovery, renewal and rebalancing, of central government adopting a more appropriate, planned and flexible approach to fiscal decentralisation, which enables local areas to retain greater local revenue that is created, and is accompanied by broader devolution of infrastructure planning, regulation and delivery.[57] In return, cities and local areas, individually and collectively, should play a more prominent role within national infrastructure planning, including the new NIC National Infrastructure Assessment and UK Industrial Strategy.

[53] OECD (2017) Revenue Statistics 2017 – the United Kingdom, Organisation for Economic Cooperation and Development: Paris.

[54] Slack, E. & Côté, A. (2014) Comparative Urban Governance, a working paper for the Foresight Future of Cities Project, London, Government Office for Science.

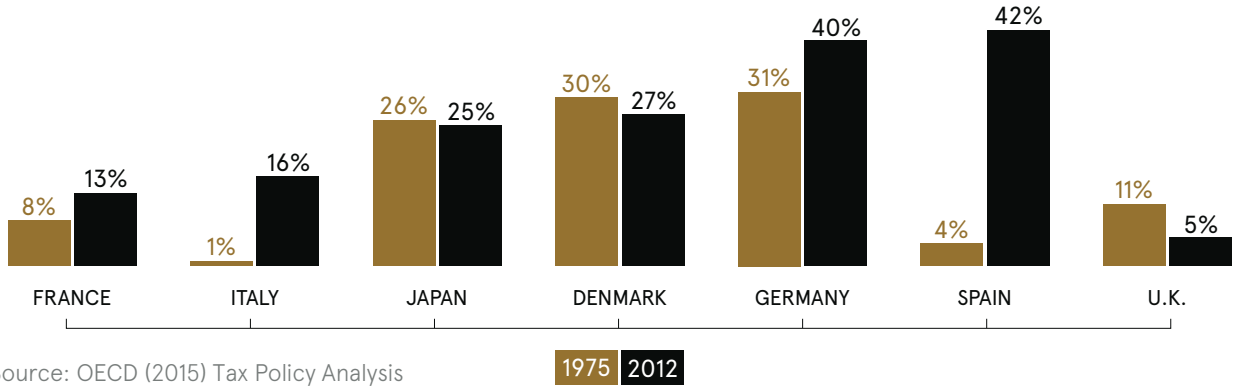
[55] OECD (2015) Tax Policy Analysis, Organisation for Economic Cooperation and Development: Paris.

[56] In the 2017 Budget, the government pledged to lift the borrowing cap for local authorities facing acute housing market pressures. However, the Local Government Association has called for the cap in borrowing to be lifted for all councils.

[57] Pike, A., Kempton, L., Marlow, D., O'Brien, P. and Tomaney, J. (2016) Decentralisation: Principles, Policy and Practice, Centre for Urban and Regional Development Studies, Newcastle University: Newcastle upon Tyne. Newcastle University.

[58] Source: Calculated from OECD Revenue Statistics Comparative tables: http://tinyurl.com/revenuestatistics

Figure 2: **Changes in % of taxes raised locally in 1975 and 2012**[58]



Source: OECD (2015) Tax Policy Analysis

BOX 7: Nottingham City Council Workplace Parking Levy[59]

The Nottingham Workplace Parking Levy (WPL) enables the City Council to levy a charge for parking spaces within certain areas of the city. The WPL is designed to tackle problems associated with traffic congestion, by both providing short-term (ring-fenced) funding for major transport infrastructure initiatives and by acting as an incentive for employers to manage their workplace parking provision. Nottingham has generated an annual income stream of approximately £12m, which has been used to part-finance the Council's contribution towards the extensions to the City's existing tram system, the redevelopment of Nottingham Rail Station and the local bus network. Employers, rather than employees, are responsible for paying any WPL charge, although employers can choose to reclaim part or all of the cost of the WPL from their employees.

[59] https://www.nottinghamcity.gov.uk/transport-parking-and-streets/parking-and-permits/workplace-parking-levy/

Recommendation #6:

The government must enable a wider range of national and local mechanisms for funding and financing. These include state-backed infrastructure investment banks, tax increment financing, municipal bonds, social impact bonds and crowd-sourced funding approaches. This will be increasingly important in the UK as it withdraws from the European Investment Bank.

In response to some of the existing constraints on traditional 'public' sources of infrastructure funding, there has been a shift in emphasis by the UK national and local governments towards attracting private finance and pension and insurance funds to invest in resilient and sustainable infrastructure.[60] Not all infrastructure is of an appropriate size and scale for these forms of finance and not all projects can guarantee sufficient financial returns on investments in the short term. Securing finance that is appropriate to the geographic and temporal nature of projects, and maximises the potential to create local economic and social value, presents significant challenges, particularly in places where markets are less buoyant and investment returns are limited. The potential exists to use alternative forms of local infrastructure funding and finance that are relevant to the scale and outcomes of infrastructure and satisfy restrictions placed on public sector actors. Figure 3 shows a number of these that are technically suitable for adapting infrastructure to climate change, such as bonds, revolving funds and crowd-source funding, but are currently under-used in infrastructure delivery.[61]

As with any financing scheme, care must be taken to ensure the business model is viable and aligned with the desired outcomes. At the opposite end of the spectrum, new approaches to large-scale infrastructure financing, such as those deployed by the European Investment Bank (EIB), which has financed a large number of infrastructure projects in UK cities and regions, will also need to be developed in the run-up to and beyond the UK leaving the EU in March 2019 (Figure 4). The EIB has a requirement for the Bank's investment to reach a 25% threshold in supporting projects that tackle climate change. In addition, there has been a much stronger ethos of social value within the EIB, with a high number of regional deprivation targets. However, the geography of EIB investment in the UK is uneven with certain regions and nations, such as London and Scotland, major recipients of EIB finance over the last two decades (Figure 5). It is important that a similar kind of infrastructure investment vehicle is available in the UK if the EIB is no longer an option to provide finance.

[60] McGrath, J. (2016) 'Local UK Governments Crank up Infrastructure Investments', Institutional Investor, 5 June: https://www.institutionalinvestor.com/article/b1505pfzhw2k4d/local-uk-government-pensions-crank-up-infrastructure-investments

[61] Roelich, K. (2015) Financing infrastructure adaptation to climate change. A report for ClimateXchange and Adaptation Scotland.

Figure 3: **Potential use of alternative funding mechanisms to support climate resilient infrastructure**

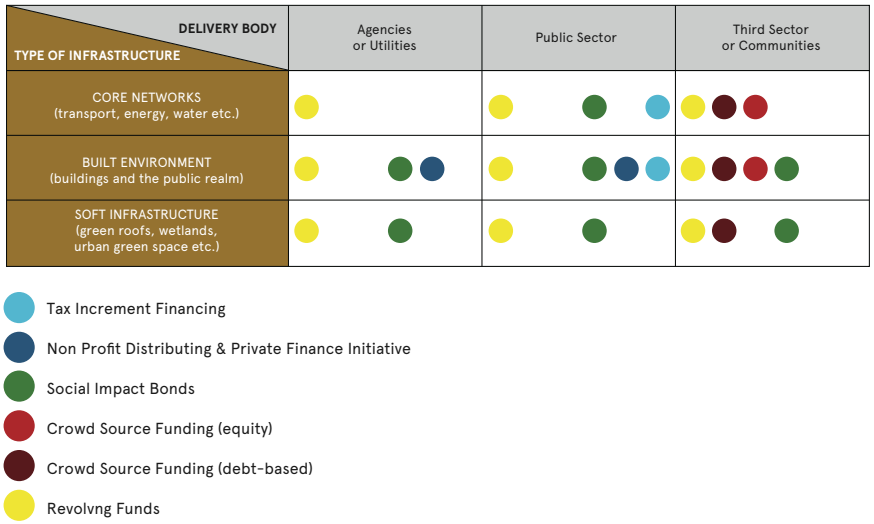
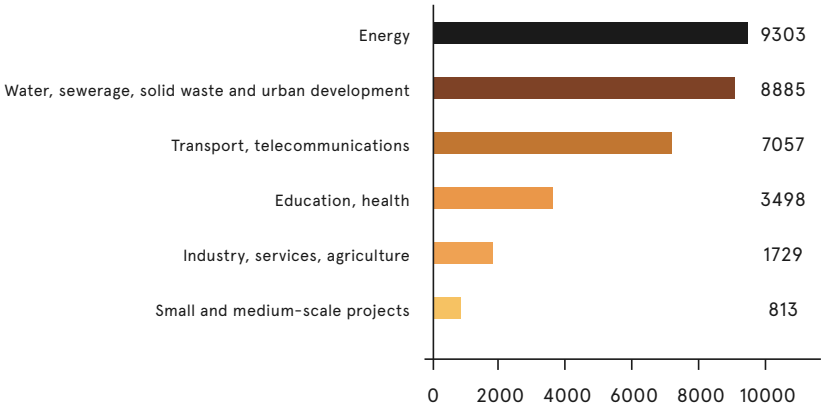
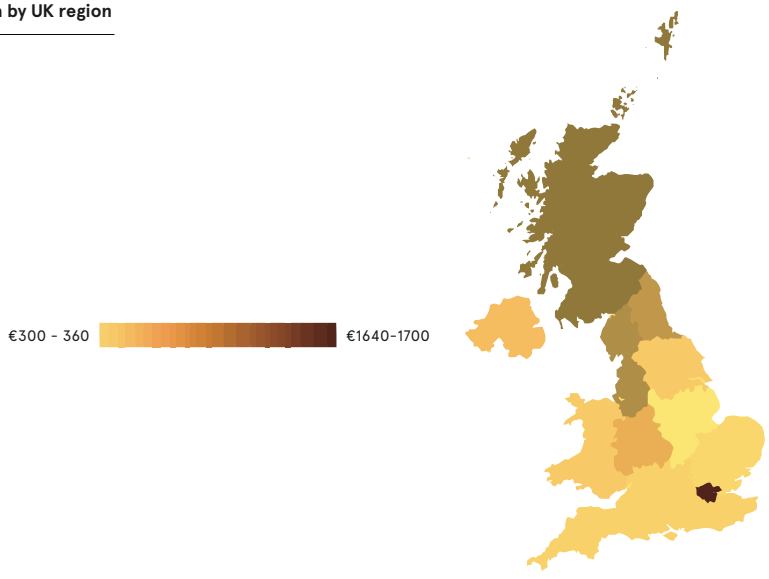


Figure 4: **European Investment Bank lending 2012-2016 (Euro M)**



Source: EIB (2017) The EIB in the United Kingdom, European Investment Bank: Luxembourg: http://www.eib.org/projects/regions/european-union/united-kingdom/index.htm

Figure 5: **Geography of EIB investment per capita by UK region**



Source: Institute for Government analysis of EIB, Annual Reports and Statistical Reports, 2001-2016

Priority Action Area #3:

Facilitate and capture all forms of long-term value

Infrastructure provides many direct benefits, but many more which are diffuse across the whole economy and society, and endure through time. Typically, infrastructure investments are appraised using conventional cost-benefit and multi-criteria analyses. In the UK, this includes the approach set out in HM Treasury's Green Book[62] which is are is elaborated with specific guidance for individual infrastructure sectors, for example by the Department for Transport's Web-based Transport Analysis Guidance[63] and the Environment Agency's Flood and Coastal Defence Project Appraisal Guidance.[64] Standard economic approaches typically assume that individuals are rational, markets behave in an efficient fashion, current market prices of wages, housing and land are the appropriate baseline measures against which to measure the costs and benefits of change, and environmental, demographic and other socio-economic factors are assumed to be static. It is inevitable, therefore, that existing approaches only partially assess the true long-term economic, social and environmental cost and benefits of infrastructure. A key consideration is the purpose of the infrastructure service; is it to maximise revenue, or to provide an affordable service or amenity to citizens and businesses? In line with the iBUILD mid-term report, the NIC's Interim National Infrastructure Assessment recognises the limitations of existing cost-benefit analysis. The NIC has raised concerns that the methods used to inform transport investment decisions do not currently support integrated transport and housing planning and expose the limits of standard cost-benefit analysis when considering particular types of investment.[65] As noted in Priority Action Area #1, iBUILD research has established the importance of such a systems approach to defining infrastructure. Furthermore, research shows how current infrastructure appraisal methods can better reflect issues such the impact of non-marginal changes on valuations.[66]

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[62] HM Treasury (2013) The Green Book: Appraisal and Evaluation in Central Government, London, HM Treasury.

[63] Department for Transport (2014) Transport Analysis Guidance. An Overview of Transport Appraisal, Department for Transport, London.

[64] Environment Agency (2010) Flood and Coastal Erosion Risk Management – Appraisal Guidance, Environment Agency.

[65] NIC (2017) Congestion, Capacity, Carbon, Interim National Infrastructure Assessment, National Infrastructure Commission: London.

[66] Brown, A. and Robertson, M. (Eds.) (2014) Economic evaluation of systems of infrastructure provision: concepts, approaches, methods. iBUILD/Leeds Report, iBUILD: Newcastle upon Tyne.

Recommendation #7:

Measures of social and environment value (benefit and cost) must be incorporated into infrastructure appraisal frameworks to achieve the widest possible set of mechanisms to capture revenue and other values.

Existing guidance for infrastructure appraisal has begun to recognise the importance of labour market participation, resilience, linked networks, and local and regional impacts. The UK Public Services (Social Value) Act 2012[67] enables a commissioning body to consider securing additional economic, social or environmental benefits for their local area. Existing economic approaches to valuing infrastructure are unable to capture all societal dimensions or reflect decision-making at individual, community or political scales.[68] Whilst there are methods to monetise time spent in traffic congestion or the detour associated with a bridge closure, for example, existing approaches do not expose how this would affect an individual, a family, a business or a community. Similarly, cycling and green infrastructures, such as urban parks and wetlands, contribute to social goals such as those related to health and well-being, as well as offering sustainable economic growth and environmental benefits.[69] iBUILD research has highlighted how the social perception and use of infrastructure covers a wide spectrum of perspectives,[70] and that methods for social and environmental accounting and audit or social return on investment provide a richer mechanism for assessing and capturing these wider societal benefits.[71] The benefit of these approaches is well-established in assisting the provision of community services and identifying beneficiaries of these services.[72] The potential to complement these with a form of social infrastructure investment bond – where revenue is tied to the achievement of social outcomes from infrastructure services – could unlock finance and engage new actors.[73] Moreover, research has demonstrated how to balance individual and community aspirations for future urban living (i.e. bottom-up) alongside a city's strategic aspirations (i.e. top-down) in conceiving and designing infrastructure systems, and hence supporting infrastructure.[74]

[67] Legislation.gov.uk (2012) Public Services (Social Value) Act found at www.legislation.gov.uk/ukpga/2012/3/enacted

[68] Wardle, J., Huebner, Y., Blythe, P.T. and Gibbon, J. (2014) The provision of public recharging infrastructure for Electric Vehicles in North East England – is there life after subsidies?, in Proc. ASCE International Conference on Sustainable Infrastructure, Long Beach, California, USA, November 2014.

[69] Demuzere, M., Orru, K., Heidrich, O., Olazabal, E., Geneletti, D., Orru, H., Bhave, A., Mittal, N., Feliu, E. and Faehnle, M. (2014) Mitigating and adapting to climate change: multi-functional and multi-scale assessment of green urban infrastructures, Journal of Environmental Management, 146:107–115.

[70] Tight, M. and Rajé, F. (2015) Walking and cycling – how can we deliver the infrastructure to support Dutch style growth? iBUILD Working Paper No. 11.

[71] Affleck, A. and Gibbon, J. (2015) Valuing the social benefits of local infrastructure in Workington, iBUILD Working Paper No. 9.

[72] Gibbon, J. and Dey, C. (2011) Developments in social impact measurement in the third sector: Scaling up or dumbing down? Social and Environmental Accountability Journal, 31(1): 65–74.

[73] NIA (2016) Potential of social infrastructure investment to enhance social development and economic growth in Northern Ireland', Knowledge Exchange Seminar Series, Northern Ireland Assembly: Belfast.

[74] Rogers, C.D.F. (in press) Using Foresight to Engineer Future Liveable, Resilient, Sustainable Cities, Civil Engineering: Proceedings of the Institution of Civil Engineers.

BOX 8:
DC Water Environmental Impact Bond[75]

Based on the wider principles of Social Impact Bonds, DC Water has developed the first Environmental Impact Bond (EIB) aimed at generating investment for water infrastructure in Washington DC. The EIB allows DC Water to attract investment in green infrastructure through an innovative financing technique whereby the costs of installing the green infrastructure are paid for by DC Water, but the performance risk of the green infrastructure in managing storm water runoff is shared amongst DC Water and the investors. Investors receive payments based on the performance of the infrastructure as measured through specific environmental outcomes. Payment is based on three performance tiers:

- *A runoff reduction of greater than 41.3% will result in DC Water paying investors $3.3m;*
- *A runoff reduction between 18.6% and 41.3% will result in no contingent payment; and,*
- *A runoff reduction of less than 18.3% will result in investors making a risk share payment to DC Water of $3.3m.*

The EIB acts as a risk sharing mechanism whereby successful infrastructure performance generates returns for investors but poor performance results in contingency payments by investors to DC Water, thereby redistributing risk evenly between public and private actors.

[75] https://www.epa.gov/waterfinancecenter/dc-waters-environmental-impact-bond

Recommendation #8:

Develop and implement a quantitative framework within the infrastructure appraisal process that can assess the value of flexibility and resilience across the whole infrastructure system over the long-term.

Infrastructure systems are designed to meet current and perceived future needs. This means that they must be synergistic with both the current, and anticipated future, local contexts as well as those of the wider regional and national systems. However the growing appreciation of the need to embrace sustainability and resilience in engineering designs, and therefore the need to place a value on resilience in the business models, has adjusted the focus on how we deal change and how far into the future we should look. Predictions based on current operating conditions (context) often fail to reflect accurately the situation in the future the farther one projects, and hence that scenario-based approaches have been developed to explore the implications of change for infrastructure design.[76]

A review of international infrastructure business models has highlighted the risks of public and private sectors focusing on short-term financial gain instead of taking a long-term, strategic perspective on infrastructure, spatial planning, urban development and tackling long term drivers such as climate change.[77] To enable infrastructure systems to respond to future uncertainties in environmental, demographic and economic conditions, future flexibility (i.e. to what extent options become closed) must be considered within the appraisal process. Infrastructure's long lifespan means that it is particularly important to consider long-term changes and uncertainties, to understand the true cost of disruption to infrastructure (e.g. in terms of access to employment, productivity, health and wellbeing), the costs of measures to enhance resilience and the opportunity costs of measures that reduce future flexibility.

One of the many examples of the need to be able to operate in, or adapt to, future contexts is climate change. Extreme weather events have tested the UK's ageing infrastructure systems and exposed a limited long-term view over investment and improvements to enhance resilience.[78] Predicted changes in the climate and socio-economic development will, without appropriate action, increase the risk of disruption from extreme weather. However, valuing the benefits of measures to enhance the resilience of infrastructure is challenging because of the long-term – often generational – timeframes involved and the relatively low frequency of extreme events under consideration. For example, flood defence appraisal guidance can bias investment towards the protection of housing and individuals, but this could be to the detriment of economically important infrastructure, such as ports, road networks or food provision. Transport infrastructure appraisal is biased towards benefits that improve system performance under normal operating conditions.[79] This can leave whole regions at the mercy of conventional benefit-cost ratios that lack consideration of wider economic, social and environmental value, strategic importance and interdependencies with other infrastructure services.[80] iBUILD research has developed infrastructure network analytic tools that are able to quantify some of the values associated with infrastructure resilience.[81,82] Crucially, it is important to think about the resilience of the service, which may include the role of measures such as behavioural change and spatial planning can have, and not just reparation or strengthening of assets.

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[76] Rogers, C.D.F. (2017) The Value of Foresight and Scenarios in Engineering Liveable Future Cities, in Retrofitting Cities for Tomorrow's World by Eames, M., Dixon, T., Hunt, M., and Lannon, S. (eds.), Wiley Blackwell: Chichester: 139-152.

[77] Bryson, J. Mulhall, R. and Song, M. (2016) Review of International Infrastructure Business Models, iBUILD Working Paper, University of Birmingham: Birmingham.

[78] DfT (2014) Transport Resilience Review, Department for Transport, London.

[79] Wardman, M., Mackie, P.J. and Gillies-Smith, A. (2014) Valuing systemic transport resilience: methods and evidence, in Brown, A. and Robertson, M. (eds.) Economic evaluation of systems of infrastructure provision: concepts, approaches, methods: iBUILD/Leeds Report.

[80] Dawson, D.A., Shaw, J. and Gehrels, W.R. (in review) Sea-level rise and transport infrastructure: the case of the coastal railway line, at Dawlish, England. Applied Geography.

[81] Pregnolato M, Ford A, Glenis V, Wilkinson S, Dawson RJ (2017). Impact of Climate Change on Disruption to Urban Transport Networks from Pluvial Flooding. ASCE Journal of Infrastructure Systems, 23(4): 04017015.

[82] Fu G, Wilkinson S, Dawson RJ, Fowler HJ, Kilsby C, Panteli M, Mancarella P (2017) Integrated Approach to Assess the Resilience of Future Electricity Infrastructure Networks to Climate Hazards, IEEE Systems Journal. (doi: 10.1109/JSYST.2017.2700791).

However, climate change is not the only driver. Whilst most work in this area has focused on the changing nature of demands on infrastructure, or risks to infrastructure, iBUILD has developed approaches to take into account the issue of resource security and resource scarcity, whether in terms of those supplied by the infrastructure[83] or that are used in its creation.

BOX 9: Flexible options for the London-Penzance railway line

The collapse of the London-Penzance railway line at Dawlish in Devon in 2014 was a high profile infrastructure disruption and left the region without a main railway connection to the rest of the UK for five months. Situated just a few metres above mean sea level, the line has been susceptible to frequent closure during high seas and storms ever since it opened in 1846. The past thirty years have seen the problem worsen, coinciding with rising sea levels, but the current damage is the most severe in its 178 years of service. A few centimetres sea level rise could double disruption on the line.[89] The need for a flexible, integrated and long term strategy is therefore particularly acute. Such approaches have shown great promise for long term planning of flood management in the Thames Estuary and the Netherlands.[85] This must involve, linking short term decisions about the railway with wider social, environmental, development and investment agendas. Strategies that are relatively easy to accelerate or delay, for example in the face of accelerated or slower than expected sea level rise, or facilitate switching between different approaches can be considered flexible.

[83] Rachwal, A., Wharfe, J., Bricker, S., Sharp, E., Leeks, G., Culshaw, F., Roberts, T., Rogers, C.D.F., Butler D., Acreman, M. and Shouler, M. (2014) Future Visions for Water and Cities: a thought piece, UK Foresight Future of Cities Project: www.gov.uk/government/publications/future-of-cities-water-and-cities

[84] Rogers, C.D.F., Hunt, D.V.L., Leach, J.M., Purnell, P. and Roelich, K.E. (2017) Resource Scarcity and Resource Security – A Suppressed Civil Engineering Challenge, Waste & Resources Management: Proceedings of the Institution of Civil Engineers, 166 (2): 49-51.

[85] Delta Commission (2013) Delta Programme 2014, The Ministry for Infrastructure and Environment & The Ministry of Economic Affairs.

Recommendation #9:

Resource assessments must become routine to identify the potential for land and infrastructure assets to generate long-term, stable revenue streams and sustainable growth, and not just one-off, short-term windfalls from selling-off capital assets.[86]

Central government, local authorities, combined authorities, metro-mayors, utility owners and many other stakeholders own land and other physical assets that could be more effectively used to provide new revenue streams.[87] And yet, national regulatory constraints prevent local public authorities individually and collectively from capturing, through taxation, the full market uplift from land and property appreciation, which could be reinvested in local infrastructure. Recent figures from the Office for Statistics have revealed that land is the most valuable asset in the UK, accounting for just over half of the total net national wealth. The value of land has grown rapidly since 1995, increasing by 412% compared with an average increase of 211% in physical assets overlying land.[88]

Ongoing budgetary pressures have also forced local authorities to consider a range of options for raising additional revenue and improving efficiency. This has led, in part, to the sale of property and land, while other measures (or business models) have seen local authorities borrowing at cheap rates from the PWLB to invest in commercial property for the purposes of generating new revenue streams to help fund council services,[89] and/or integrating public sector property through the co-location of public service providers.[90] Local and sub-national government in the UK should have greater fiscal autonomy, which includes greater control over tax revenues, within an over-arching national system of 'redistribution'. This may help to mitigate more speculative, risk-based, financialised models of local government property development, which could present long-term financial challenges to some actors and institutions.

iBUILD research has explored how resource mapping can be used to identify sustainable business models that take a longer-term view to unlock new revenue streams whilst delivering wider social and environmental benefit.[91] Developments in urban energy resource assessment enable potential revenue streams to be calculated using spatial mapping to overlay resource potential and local authority asset locations. For example, in Leeds, a case study analysed the renewable electricity generation potential of over 6,500 sites owned by the City Council.[92] This work was combined with information on generation and export revenues, avoided electricity costs and operational costs to assess net returns. Of the sites analysed, over three-quarters delivered a positive return for all generation options considered, with 334 sites returning a net present value of £100,000 or more for at least one installation option.

Resource potential will inevitably depend upon the asset inventory and geography of each local authority; but iBUILD analysis suggests that there are enormous untapped opportunities across the UK. Work has focused on wind and solar energy generation potential, and has been extended to consider other natural resources, as well as financial schemes to unlock asset capital value.

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[86] Bryson, J.R., Mulhall, R. A. and Song, M. (2017), Urban Assets and the Financialisation Fix: Land Tenure, Renewal and Path Dependency in the city of Birmingham, Cambridge Journal of Regions, Economy and Society: 1-15.

[87] CBRE (2013), Crossrail and the impact on London's property market, London, CBRE; APSE/CLES (2014) Role and Value of Local Authority Assets, Manchester, Association of Public Service Excellence/Centre for Local Economic Strategies.

[88] ONS (2017) The UK national balance sheet: 2017 estimates: https://www.ons.gov.uk/economy/nationalaccounts/uksectoraccounts/bulletins/nationalbalancesheet/2017estimates

[89] Sandford, M. (2017) Local government: commercial property investments, House of Commons Library Briefing Paper 08142, 16 November, House of Commons: London.

[90] See, for example, One Public Estate: https://www.local.gov.uk/topics/housing-planning-and-homelessness/one-public-estate

[91] Bale C, Busch R & Taylor P (2014) Spatial mapping tools for district heating (DH): helping local authorities tackle fuel poverty, Centre for Integrated Energy Research, University of Leeds.

[92] Adam, K., Hoolohan, V., Gooding, J., Knowland, T., Bale, C.S.E. and Tomlin, A.S. (2014) City Scale Studies of Renewable Energy Potential Using High Resolution Data Sets, in Proceedings of Conference on Cities, Energy & Climate Change Mitigation Conference. Leeds, UK.

BOX 10: One Public Estate

One Public Estate (OPE) is a national programme delivered by the Cabinet Office Government Property Unit and the Local Government Association. It provides practical and technical support and funding to councils to deliver property-focused programmes in collaboration with central government and other public sector partners. OPE partnerships across the country have shown the value of working together across the public sector and taking a strategic approach to asset management. At its heart, the programme is about getting more value from collective assets - whether that is in the form of service transformation, such as health and social care integration and benefits reform; unlocking land for new homes and commercial space; or creating new opportunities to reduce running costs or generate income. This is encompassed by the core OPE objectives of creating economic growth (new homes and jobs), delivering more integrated, customer-focused services and generating efficiencies, through capital receipts and reduced running costs.

[75] https://www.epa.gov/waterfinancecenter/dc-waters-environmental-impact-bond

Recommendation #10:

Employ a new approach to infrastructure economics that recognises the long-term and system-wide value of infrastructure provision and the alternative forms of investment necessary to realise this value.

The influence of economics – both economic theory and the economic environment – on infrastructure provision remains significant. Considering the broader dimensions of value is also important, but upfront finance and ongoing funding via realisation of long-term economic value are necessary factors in the continuing viability of infrastructure provision.

Conventional economic theory, including its application in the infrastructure sector, often refers to 'market failures', and is based upon instances when the economic and financial valuation of infrastructure diverges from what is considered socially and economically valuable in the long run. There are three reasons why the traditional assessment and evaluation approach of cost-benefit analysis are sometimes inappropriate as an appraisal tool for infrastructure:

(i) the uncertainty inherent in the long run and system-wide duration and impact of infrastructure;

(ii) the interdependence of attitudes, preferences and behaviours of individuals with the infrastructure systems with which they interact (i.e. infrastructure can shape preferences and values so the latter cannot be used as fixed guides for evaluation); and,

(iii) the system-wide impacts of infrastructure on economic growth and society which require a system-wide analysis beyond the scope of standard cost-benefit analysis.

Just as there is a need for a systems assessment of social and environmental benefits, iBUILD research has shown that a similarly broad view of economic costs and benefits is also crucial. This helps unlock future funding and finance by identifying economic values of the systems of infrastructure provision that include those benefits that are variegated across the economy and society and over long timeframes.[93]

[93] Brown, A., Passarella, M.V. and Robertson, M. (2014) The Economics of Infrastructure, in Brown, A. and Robertson, M. (eds.) Economic evaluation of systems of infrastructure provision: concepts, approaches, methods. iBUILD / Leeds Report.

Priority Action Area #4:

Deliver infrastructure more efficiently and with less waste by aligning organisational capabilities and applying circular economy principles

It is widely recognised that the diversity of infrastructure assets and their supply chains, the interactions between organisations, and the physical scale of the infrastructure itself poses significant challenges for infrastructure planning and delivery.[94,95] The UK faces a particular set of issues in regard to the design and implementation of infrastructure strategy.[96] Furthermore, the nature of these challenges evolves over the infrastructure life cycle, from initiation and design through procurement, delivery, operation to decommissioning or repurposing. Maximising the value from infrastructure will make it a more attractive investment proposition, but in an era of austerity there is equally an imperative to identify opportunities across the whole infrastructure life cycle to deliver greater benefits and efficiencies. These issues are spanning larger spatial scales, such as the city-region and pan-regions, and are posing significant challenges for local infrastructure provision. The NIC has offered to support Mayoral Combined Authorities to plan and deliver local infrastructure strategies. Equally, towns and cities outside such decentralised governance arrangements also need strategic capacity and planning mechanism to underpin infrastructure provision, which may either be situated within existing administrative boundaries or transcend local authorities.

[94] NAO (2011) Initiating successful projects, National Audit Office, London.

[95] Infrastructure UK (2010) Infrastructure Cost Review: Main Report, HM Treasury, London. ISBN 978184532-8160.

[96] Slade, D. and Davies, N. (2017) How to design an infrastructure strategy for the UK, Institute for Government: London.

Recommendation #11:

The Project Initiation Routemap has demonstrated many cost reduction benefits and it should be made standard practise for all public-funded projects.

The IPA's 2017 infrastructure pipeline sets out over £460 billion of planned investment, of which over £240 billion will occur in the next four years. Looking forward, and taking account of the capital programmes of government and private utilities, the IPA outlines a ten-year projection of around £600 billion of public and private investment, covering the period 2017/18 to 2026/27.[97] The government is looking to embed Industrial Strategy objectives within the strategic design stage of major infrastructure investments. Transforming Infrastructure Performance (TIP) is the UK government's plan to increase the effectiveness of investment in infrastructure – including economic infrastructure such as transport and energy networks, and social infrastructure, such as schools and hospitals – by improving productivity in the way assets are designed, built and operated.[98] The Project Initiation Routemap[99] (Infrastructure Routemap) is a set of principles and assessment analytics designed to inform initiation, procurement and delivery strategy over the infrastructure lifecycle, but especially at the early phase of initiation, where decisions on project governance, requirements, risk and procurement can have the greatest impact on outcomes. The Infrastructure Routemap is expected to help the government roll out the principles of TIP.

iBUILD research has highlighted how organisational design, including culture, goals, values, vision and people, is as important as task-oriented aspects, such as: work organisation and practices; procedures and processes; and supply chain capabilities, technology and assets.[100] The Infrastructure Routemap provides an objective assessment of the complexity of the organisation and delivery environment, and also of the capability of the sponsor, client and supply chain. The identification of any misalignment between critical success factors, key risks and opportunities can be identified at an early stage, allowing sponsors and clients to work together to improve delivery. Research by iBUILD has analysed a number of case studies and pilot implementations of the Infrastructure Routemap[101] and revealed a number of significant benefits that include:

(i) Greater stakeholder support for the investment at an early stage through alignment and understanding of objectives, expectations and appropriate incentives;
(ii) More streamlined delivery achieved by systematically matching sponsor, client and supply chain capabilities and requirements; and,
(iii) Reduced delays and costs as a result of planning for transition between different phases of the infrastructure lifecycle.

[97] IPA (2017) Analysis of the National Infrastructure and Construction Pipeline, Infrastructure Projects Authority: London.

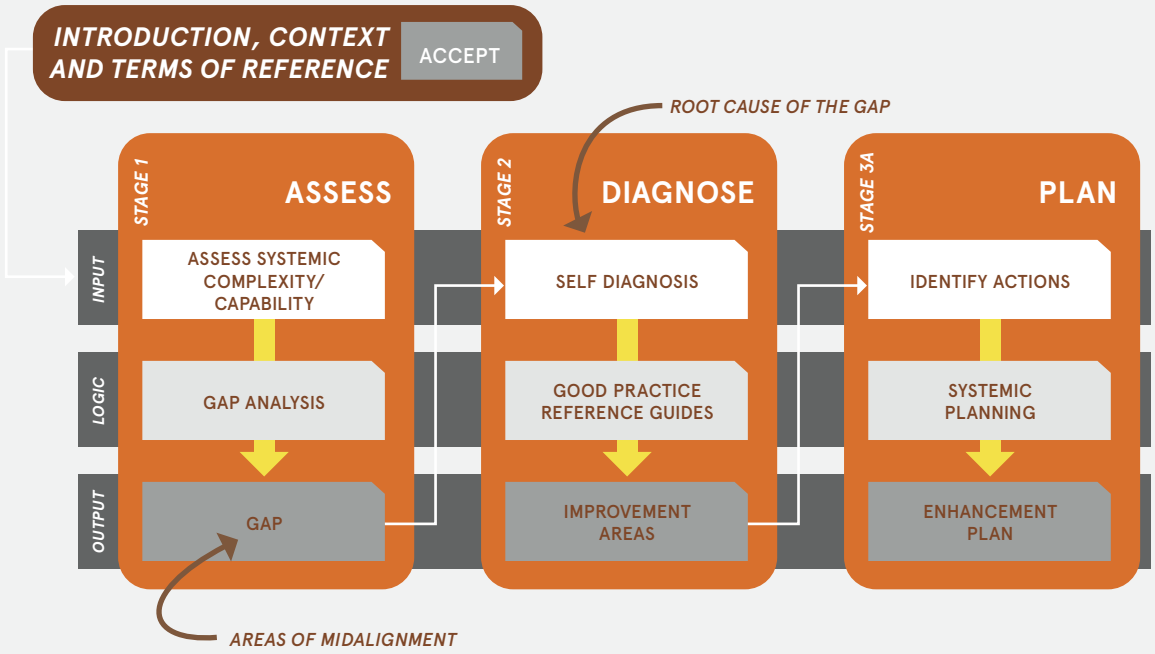
[98] IPA (2017) Transforming Infrastructure Performance, Infrastructure and Projects Authority: London.

[99] Infrastructure UK (2014) Improving Infrastructure Delivery: Project Initiation Routemap Handbook, HM Treasury, London. ISBN 139781910337080.

[100] Aritua, B., Male, S., Bower, D. and Madter, N. (2011) Competencies for the intelligent public sector construction client, Proceedings of Institution of Civil Engineers: Management, Procurement and Law, 164(4): 193-201.

[101] Sandham, R., Bower, D.A. and Madter, N.E. (2014) Infrastructure Routemap: Reflections on the first year, Proceedings of the Institution of Civil Engineers: Infrastructure Asset Management, 1(1): 8-9.

BOX 11:
Upscaling routemapping to the city



iBUILD has collaborated with the RCUK-funded Transformational Routemapping for Urban Environments (TRUE) project to extend the Routemap approach to delivery of social projects. By drawing on the Infrastructure Routemap and adapting it, we are rethinking how local authorities deliver integrated city-wide solutions, aligning complexity with the capabilities required to manage a complex environments and increasing the likelihood of successful outcomes. As a pilot this approach was applied to a selection of priority outcome areas (called Breakthrough Projects) identified by Leeds City Council (LCC) to collaboratively develop a novel, highly applicable and transferable holistic diagnostic tool (see https://www.truetool.org/). It assesses systemic complexity, identifies challenges, and guides the enhancement of capacity amongst city actors to support the delivery of citywide solutions. To date, three Breakthrough Projects have been reviewed, supported by ethnographic studies and extensive surveys of over 20 delivery partners. The senior leadership team at LCC has been fully engaged, positive feedback and constructive criticism of the tool has been received from a wide range of test users at LCC and partners from the private, public and charity sectors. The research is one of many research projects that have drawn heavily on the experience of iBUILD to help embed collaborative creation and ownership of research questions within the operation of this highly interdisciplinary project. It is an excellent example of how the new ways of working across sectors pioneered in iBUILD has led to new consortia, collaborations and research expertise being generated.

Recommendation #12:

Infrastructure design should be grounded in circular economy principles to consider the whole life material and resource demands of infrastructure pipelines, to identify opportunities to reduce overall energy consumption and waste.

Infrastructure requires significant volumes of materials for its construction, maintenance and operation. The physical scale of infrastructure often requires quantities of raw materials that outweigh many other industrial demands, and their extraction has environmental, economic and ultimately social costs.[102] The UK's National Infrastructure Plan[103] and plans for increased low-carbon technologies[104,105] will place increased demands on indigenous materials (e.g. bulk construction materials), and those imported from foreign markets (including rare earth metals). These demands are not unique to the UK and yet the commodities are finite and iBUILD research has shown how movements of such resources are already subject to short-term disruptions and the implications of those for social and economic impacts.[106] Some places, such as Tees Valley, are looking to re-use materials and waste products in new processes as part of a deliberate shift towards trying to build a 'circular economy',[107,108,109] an aspiration repeated at national level in e.g. the National Infrastructure Plan and the Industrial Strategy documents.

In a circular economy, the functional value of products, components and materials is retained as long as possible by designing products to enable their reuse, refurbishment, dismantling and recycling, maximising resource productivity and security.[110] Essential to this is the development of a waste management and resource recovery infrastructure. Joint work by iBUILD and CVORR (a project within the NERC Resource Recovery from Waste Programme)[111] renewed existing and planned infrastructure; it was concluded that our infrastructure is not ready to support a transition to the circular economy and radical changes to regulatory arrangement, data clarity, public investment and business models in the waste management sector will be required.[112]

Over longer timeframes, the planning and design of infrastructure must consider dependence on materials, but iBUILD research highlights how diversity, long recognised as important for resilience in ecological systems, is also an important quality for infrastructure resilience.[113] Moving wholesale to the seemingly 'most efficient' assets and technologies in the short-term can have the unintended consequence of locking systems into modes of operation that are vulnerable to disruptions in supply (including materials and other sources of volatility in the operating environment) but also fixing communities into existing technologies that are expensive to replace or upgrade. For example, renewable energy infrastructure plans may be exposed to a nine-fold increase in materials risk over the next few decades depending on the technologies used.[114] Retaining a suite of technologies to deliver a given infrastructure service will deliver a more sustainable and flexible business model in the longer term.[115] This could be facilitated by development of an infrastructure equivalent of 'Building Information Modelling' systems.

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[102] Leonard, A. (2010) The Story of Stuff: How our obsession with stuff is trashing the planet, our communities, and our health – and a vision for change, Constable and Robinson Ltd: London.

[103] Infrastructure UK (2014) National Infrastructure Plan 2014, HM Treasury, London. ISBN 978-1-910337-41-7

[104] DECC (2011) The Carbon Plan: Delivering our low carbon future. Department for Energy and Climate Change, London.

[105] BEIS (2017) Clean Growth Strategy: Leading the way to a low carbon future, Department for Business, Energy and Industrial Strategy: London.

[106] Brown, S. and Dawson, R.J. (2013) Resilience of resource movements to disruptive events, in Proc. 1st Int. Symposium Next Generation Infrastructure, Wollongong, Australia.

[107] TVCA (2017) Tees Valley Industrial Strategy, Tees Valley Combined Authority: Stockton-on-Tees.

[108] Velenturf, A. and Purnell, P. (2017) Moving beyond waste management towards a circular economy, presentation to Valuing the Infrastructure of Cities, Regions and Nations Conference, Leeds, April.

[109] Sadler, J.P., Grayson, N., Hale, J.D., Locret-Collet, M.G., Hunt, D., Bouch, C.J. and Rogers, C.D.F. (2018) The Little Book of Circular Economy in Cities – A short guide to urban metabolism and resource flows, Imagination: Lancaster.

[110] Iacovidou, E. and Purnell, P. (2016) Mining the physical infrastructure: Opportunities, barriers and interventions in promoting structural components reuse, Science of the Total Environment, 557-558: 791-807.

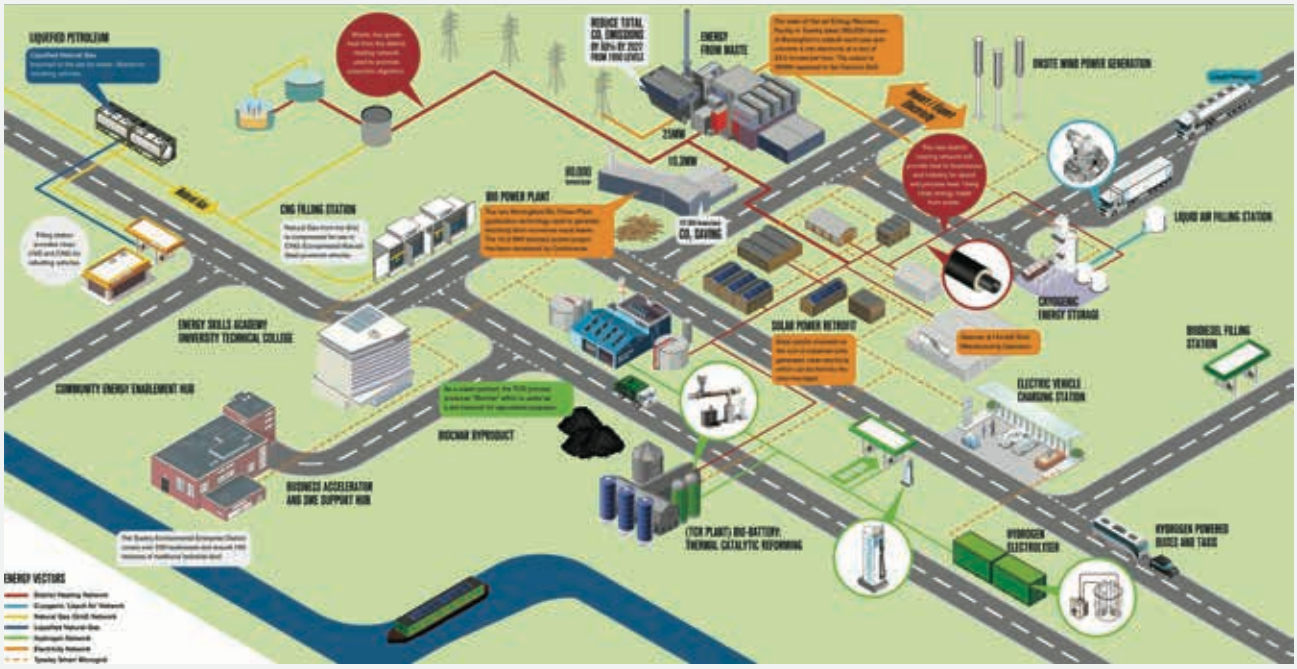
[111] See https://rrfw.org.uk/

[112] Purnell, P. (2017) On a voyage of recovery: a review of the UK's resource recovery from waste infrastructure, Sustainable and Resilient Infrastructure. Published online 8/12/17 http://www.tandfonline.com/doi/full/10.1080/23789689.2017.1405654

[113] Iacovidou, E., Millward-Hopkins, J., Busch, J., Purnell, P., Velis, C.A., Hahladakis, J.N., Zwirner, O. and Brown, A. (2017). A pathway to circular economy: Developing a conceptual framework for complex value assessment of resources recovered from waste. Journal of Cleaner Production, 168:1279-1288.

Whilst digital technologies can help to drive productivity in the delivery of the infrastructure pipeline alongside energy and environmental efficiency, there is currently no investment in the commercialisation of digital solutions for the management of existing infrastructure assets. The privatised nature of the infrastructure sector presents a key challenge for the adoption and dissemination of such technologies, resulting in a focus on short-term benefits. iBUILD research has advocated that digital technologies can help to identify values residing in infrastructure assets (that goes beyond financial benefits), and create an environment where new business models can emerge that are focused on sustainable resource management.[116] If the rapid technological development of digital technologies in promoting resource efficiency can be allied to policy interventions that control and manage its uptake along the supply chain, the circularity of infrastructure assets could be radically enhanced.

BOX 12: Tyseley Energy Park Text



Tyseley Energy Park is situated in Birmingham City Council's Tyseley Environmental Enterprise District, which is one of the principal locations for the city's low carbon economy businesses. Birmingham City Council, West Midlands LEP, West Midlands Combined Authority and the West Midlands Mayor, Andy Street, see the Energy Park and Energy District as key elements of a broader strategy to promote green energy within the city and wider city-region, and create an energy capital, which will also involve the Fraunhofer Institute working with universities in Birmingham. iBUILD researchers have worked with key site owner, the wire manufacturing company Webster and Horsfall, and a number of other stakeholders, to test iBUILD's business model development methodology. As part of a 'decision theatre' exercise, stakeholders were interviewed about their businesses, how they would like to see the Park develop from their perspective, the value that they anticipate could be generated, and the infrastructure that is required to support development. Stakeholders also took part in a workshop that explored the Park's enablers and constraints, and investigated spatial and temporal aspects of value generation. Researchers are synthesising the data and exploring options for an integrated business model to help the Park to thrive, while supporting individual business growth and development.

[114] Roelich, K., Dawson, D.A., Purnell, P., Knoeri, C., Revell, R., Busch, J. and Steinberger, J.K. (2014) Assessing the dynamic material criticality of infrastructure transitions: A case of low carbon electricity, Applied Energy, 123:378-386.

[115] Dawson, D.A., Purnell, P., Roelich, K., Busch, J. and Steinberger, J.K. (2014) Low Carbon Technology Performance vs Infrastructure Vulnerability: Analysis through the Local and Global Properties Space, Environmental Science & Technology, 48(21):12970-12977.

[116] Iacovidou, E., Purnell, P., & Lim, M. K. (2017). The use of smart technologies in enabling construction components reuse: A viable method or a problem creating solution?. Journal of environmental management. DOI 10.1016/j.jenvman.2017.04.093

Priority Action Area #5:

Accelerate uptake through practical action and demonstration

Alternative approaches to infrastructure business models are emerging. However, in order to quickly identify the most successful approaches and encourage their wide uptake locally, nationally and internationally, demonstrator sites can support integrated infrastructure planning and testing of innovative infrastructure business models. Equally, alternative business models can be applied to existing, or proposed, infrastructure developments to establish whether added value might be realised. The uptake of these business models can be accelerated through practical action, demonstration and peer learning, including the increased fostering of city-to-city learning.

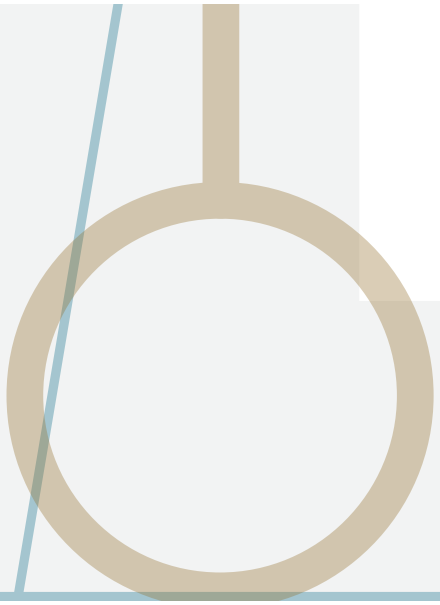
Recommendation #13:

Establish full-scale urban demonstrator sites for applied research into integrated infrastructure planning and testing of innovative infrastructure business models.

There are a number of opportunities to obtain enhanced benefits and savings from infrastructure through the implementation of alternative sustainable business models. In this report, iBUILD has outlined a series of priority actions and policy relevant recommendations.

In line with the fundamental concepts of industrial policy,[117] many infrastructure business models need to adopt a longer-term perspective, balancing capital finance and revenue funding over the full lifecycle to achieve a sustainable and high quality delivery of service. The fragmented and silo-based nature of local infrastructure is currently inefficient; coordinating the delivery of multiple infrastructure sectors across and between scales creates the potential to reduce costs, create wider societal plans and economic benefits and create environmental improvements. An integrated approach to infrastructure delivery, multiple assets and services can be managed as an inter-connected 'bundle' and additions to these infrastructures can be incorporated within the package of business models. However, this will require implementation of more flexible and agile regulation and legislation to facilitate a range of business model structures, combinations of assets and mechanisms for value creation.

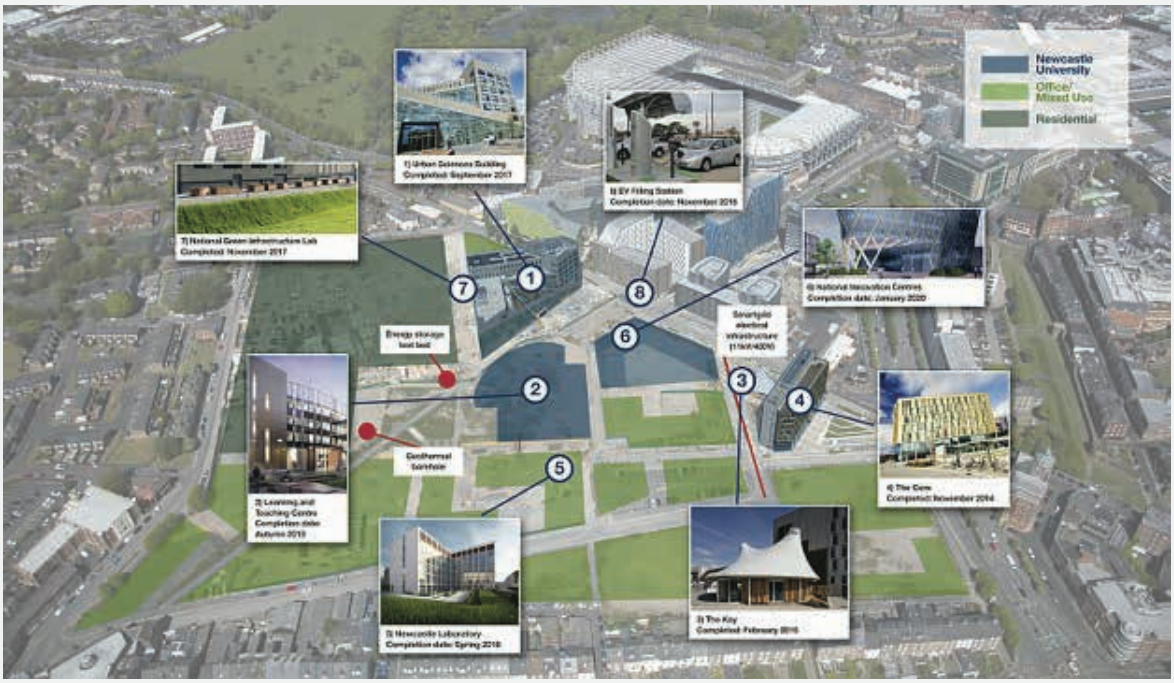
Central to the iBUILD programme has been the development and coordination of place-based case studies – many of which are cited in this document – that have enabled us to integrate multi-disciplinary expertise from across the research team and explore the practicalities of implementing new approaches to applied problems. However, in order to better promote an integrated approach to local infrastructure delivery, more substantial demonstrator initiatives have to be established. The uptake of new business models can be accelerated through practical action, demonstration and peer learning, including the fostering of city-to-city learning. The emergence of SME loan funding to support innovation-based infrastructure demonstrator systems, such as that facilitated by the Humber Local Enterprise Partnership, is a welcome development.[118]



[117] See, for example, Aiginger, K. (2014) Industrial Policy for a Sustainable Growth Plan, Policy Paper 13, https://www.oecd.org/eco/Industrial-Policy-for-a-sustainable-growth-path.pdf

[118] Humber LEP (2017) Innovation loans to demonstrate infrastructure systems, 8 November: http://hub.humberlep.org/2017/11/08/innovation-loans-demonstrate-infrastructure-systems/

BOX 13: Newcastle Science Central



Science Central, a ten hectare development site in the centre of Newcastle, aims to become a world-recognised hub for science and innovation. A distinctive feature of the development is the co-location of 'experimental' infrastructure from different services. This supports not only research at scale into the operation of that infrastructure but, crucially, the interactions between those infrastructures and the users of the services they provide. This research may be more technically focussed in the short-term but will underpin the development of new business models in the future.

EV Rapid Charge Centre: Consists of multiple fully networked multi-standard rapid charge points along with facilities and services. The Rapid Charge Centre will be linked with the Low Carbon Energy Centre and the Energy Storage Test Bed, and charging data will be collected and enriched with data recorded by the Urban Observatory, including smart metering data, travel patterns, socio-economic data and weather data.

Cloud Computing Centre: Analysis through the Cloud Computing Centre will provide deeper understanding of consumer behaviour and usage and drive real behavioural change. Live, online aggregated data analysis will be used for network control through micro-grids, ultimately opening up the opportunity for future implementation of Vehicle-to-Grid (V2G) charging onsite. Live data from the Newcastle Urban Observatory will help understand vehicle usage, and air quality implications, of EV usage.

Sustainable business model for EV charging: Working with Distribution Network Operators (DNOs) and using data from the Urban Observatory and Cloud Computing Centre, a sustainable business model will be created for the development and continued operation of the EV Rapid Charge Centre, which will be adopted as a blueprint for other cities.

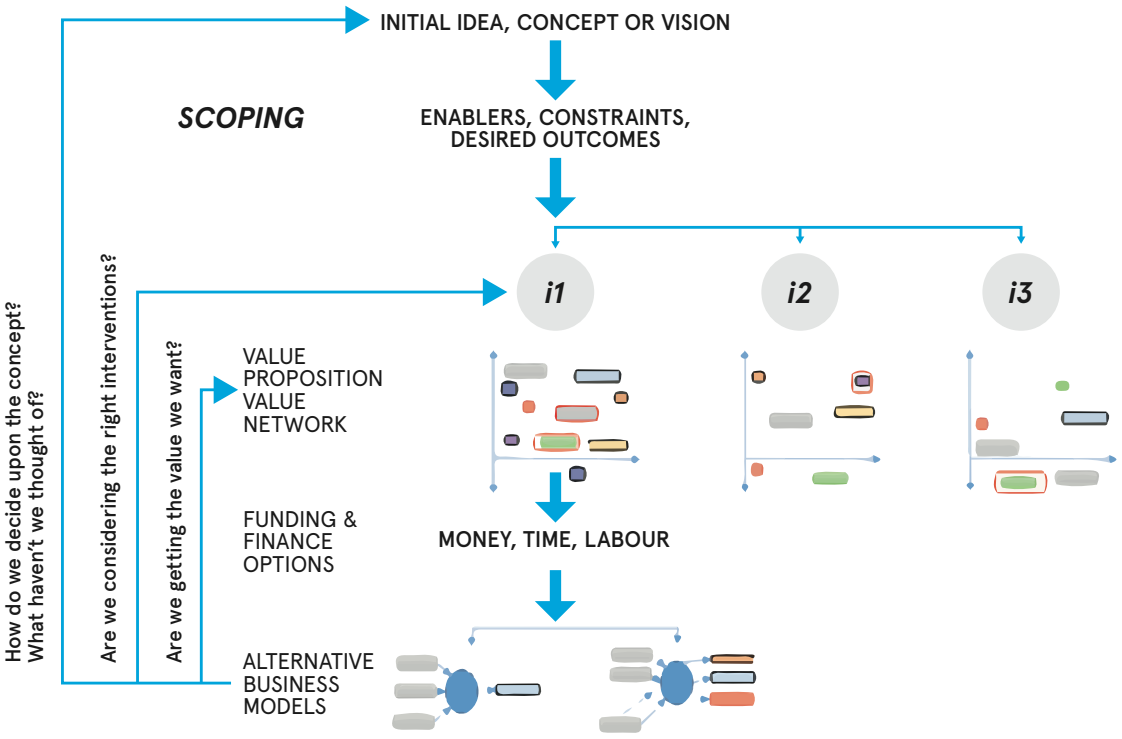
National Green Infrastructure Facility: The UKCRIC-funded National Green Infrastructure Facility, is adjacent to the University's Urban Sciences Building and the site of a new residential development. This location facilitates the study of physical interactions within green infrastructure and its value to building owners (in terms of flood protection), building users (in terms of amenity), and builders (in terms of real, or perceived property price). A deeper understanding of these multiple forms of value and function will underpin improved future design and reveal new opportunities for financing and funding of future schemes.

Recommendation #14:

Develop alternative business models by collaborating with the widest range of stakeholders, and integrating the assessment of a broad range of values with the design of engineering solutions.

Drawing together the many strands of iBUILD research presented in this report, an action framework (Figure 6) has been developed that structures, and helps guide infrastructure stakeholders through, the process of devising alternative infrastructure business models. The framework considers technical and business model interventions in response to an infrastructure service need, and the multiple forms of value that can be created. The actions within the framework below are presented in a logical sequence. However, the nature of the framework means that other sequences are possible, depending on the nature of the need and actors involved.

Figure 6: **Infrastructure value framework**



Initial idea, vision and desired outcomes: An initial need or driver for new infrastructure may emerge for a range of engineering, service provision, political or cultural reasons. Each idea or project will have its own, original, intended desired outcomes i.e. a forward-looking statement (or set of statements) of what that infrastructure is expected to enable; this effectively is the purpose of the infrastructure.[119,120] However, traditional business models are typically bound by a narrow set of desired outcomes; the framework formalises a process to challenge conventional approaches and help deliver a broader set of outcomes and values.

Enablers and constraints: It is important to understand enablers and constraints of potential ideas and outcomes. These include consideration of relevant policies, legislation, regulation, codes and standards (i.e. all the formal and informal rules that constitute governance), societal norms and user behaviours – the full breadth of the infrastructure system.

[119] Dolan, T., Walsh, C.L., Cahart, N. and Bouch, C. (2016) A conceptual approach to strategic performance indicators, Infrastructure Asset Management, 3(4), 132–142.

[120] Cahart, N., Bouch, C., Walsh, C.L. and Dolan, T. (2016) Applying a new concept for strategic performance indicators, Infrastructure Asset Management, 3(4), 143–153.

Possible interventions or solutions: This stage identifies possible interventions that might achieve the desired outcomes. These should not be limited to engineering interventions, but also consider changes in policy or practice. A comprehensive system-wide understanding of the infrastructure under consideration is key to identifying the interdependencies between systems, which offer opportunities for benefits to multiple systems, and help eliminate unintended negative impacts across different infrastructures when viewed in isolation.

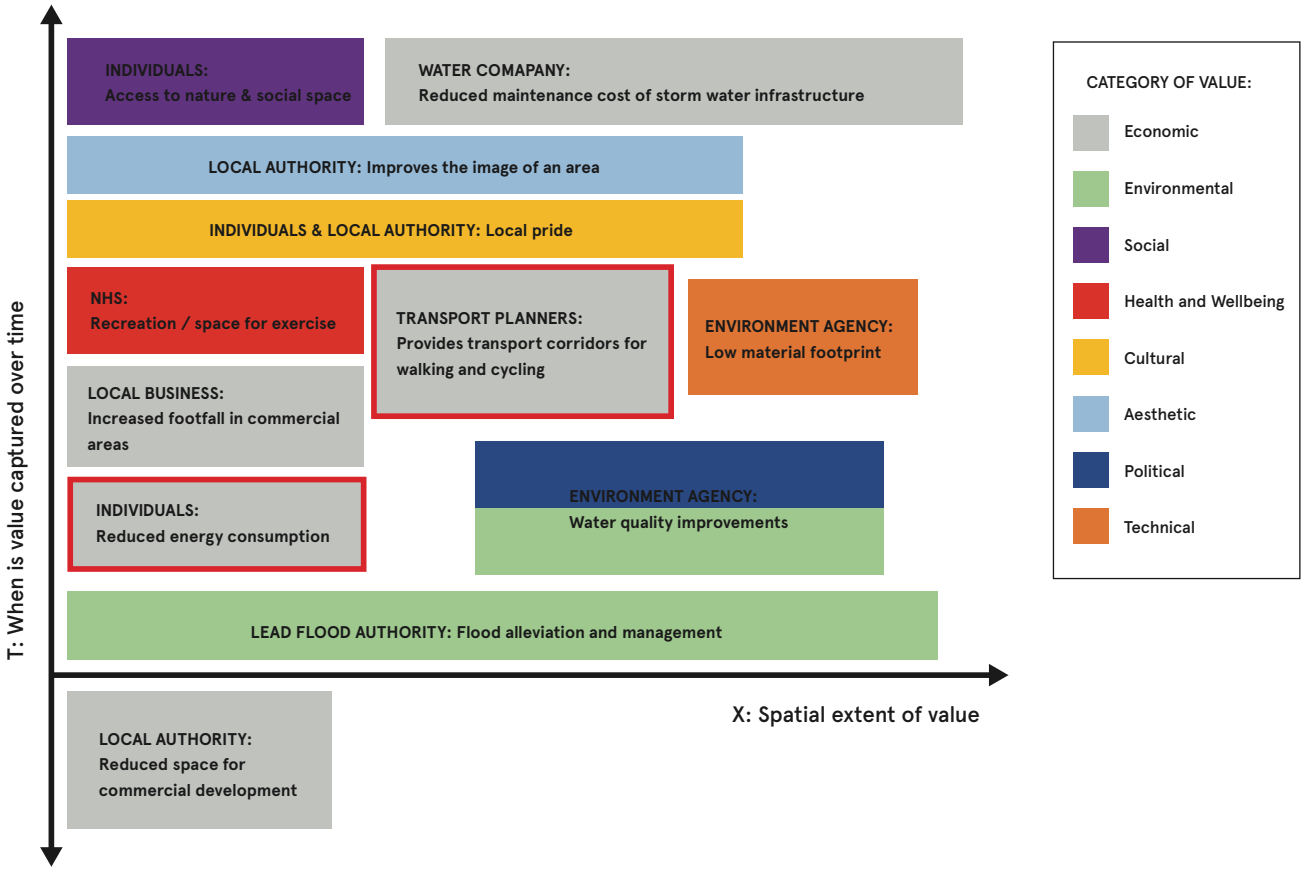
Widening the value network and value proposition: The number of people or organisations (i.e. the value network) that benefit from the value of infrastructure is usually greater than those who invest in it. Different stakeholders derive different, and sometimes multiple, types of value (i.e. the value proposition). The value captured also varies over time and space. For example, the function of a flood defence for its purpose of protecting properties or infrastructure is only realised during a flood event. Whereas the benefit of reduced property insurance premiums catalysed by the flood defence are felt over a longer timescale and over a larger spatial extent. Furthermore, the value of (for example) businesses being protected from flooding is realised across a supply chain that can extend from the local to national and international scales.

BOX 14: Greening Wingrove – from flood management to community orchard

Greening Wingrove is a community-led project focussed on the West End of Newcastle upon Tyne. Its origins were in a small community group who were working together to improve the image of the area through conducting litter picks and planting flowers in abandoned planters. However, the ambition and the group grew which led to them being awarded £1 million through the Big Lottery Fund's Communities Living Sustainably programme. One of the initial priorities for the Greening Wingrove project was to better manage flood risk in the area. However, flood management was not a priority for the local community who shifted the focus towards other values and services. This led to the improvement of existing green spaces, 'greening' back lanes, community orchards and growing food vertically given the lack of outdoor space – many of these improvements also positively contributed to flood management. The work was part funded by the lottery award, but also through donations of time, labour and materials from the community themselves. In addition to increased and enhanced areas of green space, residents were encourage to install water butts to provide a free water source for the food being grown up building facades, which also help attenuate rainfall during storm events. The project highlights the multifunctional benefits of green infrastructure and how these were realised both directly and indirectly by engaging with a wider value network (Figure 7).

Figure 7 presents an extract of a value map (or T-X diagram) for urban green infrastructure. The value mapping considers who or what the benefit is for, the type of value (moving beyond economic value to consider social and environmental benefits and opportunities), and where (X) and when (T) the value is captured are plotted on the orthogonal axes. A particular value proposition may emerge for more than one stakeholder, for example the cultural value of local pride would be felt by both individuals and the Local Authority. Similarly, a value proposition can have more than one type of value, for example, water quality improvements have an environmental value and also a political value for the Environment Agency in meeting water quality standards set by Government. Furthermore, this approach helps to identify interdependencies and opportunity where value is shared between infrastructure sectors, as highlighted in red bold boxes – thermal properties of green infrastructure can help reduce energy demand for cooling from air conditionin, for example. Values can be negative; space given to green infrastructure in the public realm may be at the expense of land that could be developed commercially or for housing, resulting in lost opportunities for increased business rates and council tax for the Local Authority. However, the mapping approach encourages these trade-offs to be considered in a holistic way.

Figure 7: **Value map of urban green infrastructure.**

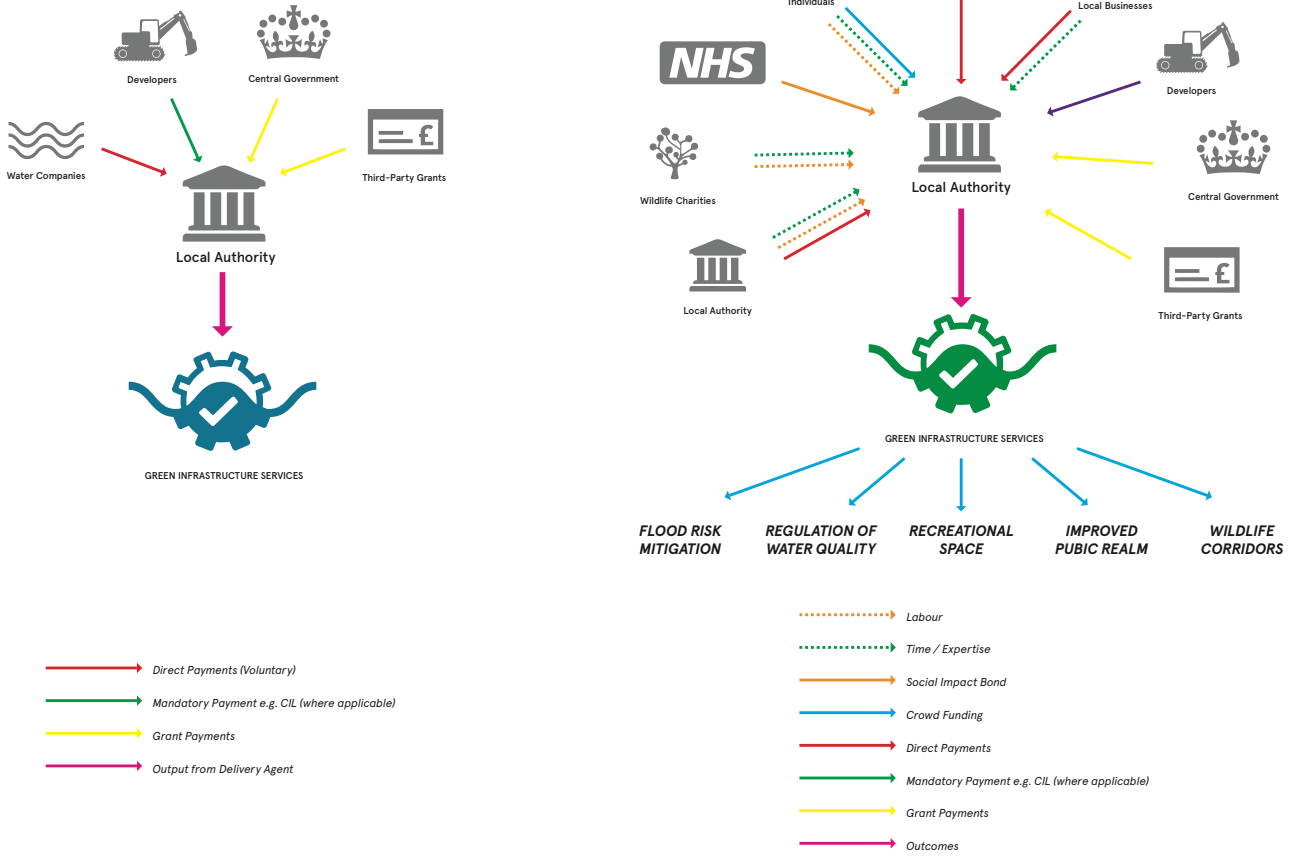


KEY: *The thick red box illustrates interdependencies with other infrastructure systems - energy through the thermal capacity of green infrastructure; transport through the potential multiple use of green infrastructure as walking or cycling routes.*

Funding and Financing Options: A broad assessment of value in space and time is crucial to evaluate and re-assess the desired outcomes. By expanding the value proposition, and hence value network, it becomes possible to unlock new funding and financing options that may not have been considered or been appropriate to the original concept, and to involve individuals and/or organisations who have access to funding and financing not available to others.[121]

Alternative business models: Figure 8a presents the current business model for traditional surface water flood risk management infrastructure i.e. storm water pipes or storage tanks that serve only that purpose; a number of stakeholders contribute to the funding and financing of the infrastructure through direct grant, mandatory and voluntary payments, channelled through one lead organisation. An alternative solution for manging surface water could be green infrastructure. The value mapping of green infrastructure, as illustrated in Figure 7 identified a number of broader non-economic values for a wider network of stakeholders, which and who have access to or could deliver, a wide range of potential monetary and non-monetary transactions. Subsequently the infrastructure would deliver a suite of functions and services. Figure 8b shows one example of an alternative business model that incorporates a broader set of potential transactions.

Figure 8a: **Existing business model for surface water flood risk management.** *(CIL is a Community Infrastructure Levy)*
Figure 8b: **Alternative business model for green infrastructure.**



[121] Bryson, J.R., Mulhall, R. and Song, M. (2014) Business Models and Local Infrastructure: Financing, Value Creation and Governance, iBUILD Working Paper No. 12, iBUILD: Newcastle University.

In addition to opening up different financing and funding routes, widening the value proposition and value network can also reveal alternative governance arrangements to deliver and manage infrastructure. It is by combining the wider non-conventional options for ownership, governance, management, funding and financing that will lead to more innovative business models.

Iteration and learning loops: The framework encourages iteration and learning at several stages.

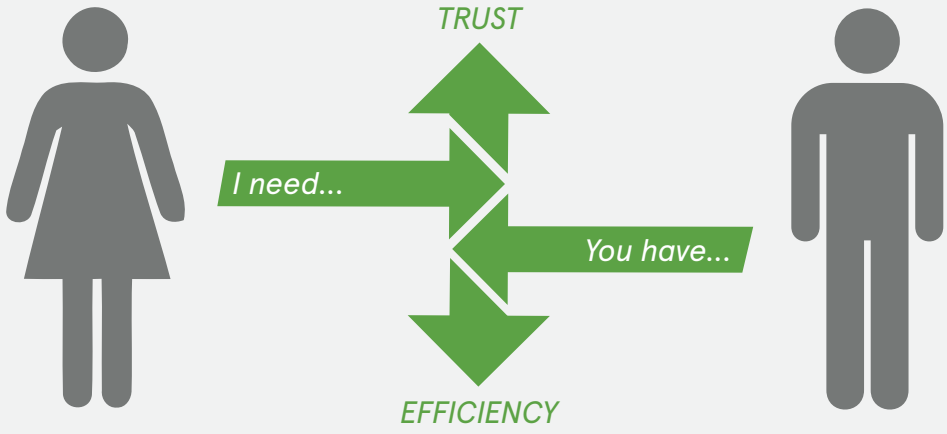
Inner Loop: Are we getting the value we want? Challenges users to widen the value network and proposition to consider the broadest possible sources of finance and funding, as well as non-financial components.

Middle Loop: Are we considering the right interventions? Encourages consideration of how an intervention or solution may need to be adapted or radically changed to improve the business model.

Outer Loop: What haven't we thought of? Provokes users to revisit their original assumptions and ask why the original idea, concept or vison was proposed.

The framework has been tested and applied to several infrastructure case studies where it has traditionally been difficult to make the investment case for interventions. These include resilience and adaptation of existing infrastructure; upfront investment of new infrastructure; support for new technologies; and for regeneration projects in particular at the community scale.[122] Adoption of the framework would represent a clear validation of the process, and would demonstrate the value of placing innovative forms of engineering within particular local infrastructure business models.

BOX 15: Unlocking the sharing economy



Based on the principles of the 'sharing' economy, the Canadian start-up SWTCH has developed a peer-to-peer online platform which connects EV drivers with privately owned EV charge points. The business works via an online mobile application. Upon registering with SWTCH, GPS-based software acts as a matchmaker for EV drivers and privately owned charge points. Private owners are able to rent out their charge points to EV drivers in need of electricity and SWTCH generate revenue from a 10% commission fee attached to every transaction. The entire process is facilitated by automatic payment and billing. The SWTCH software is based on an algorithm which calculates the cost of electricity for each transaction (based on duration, type of car, and whether or not the owner has placed a surcharge). In simple terms, it is defined as Airbnb for EVs.[123] *This form of end-user innovation provides them with a solution to a problem, but also one that can be commercialised.*

[122] Walsh, C.L., Glendinning, S., Dawson, R.J. et al. (In preparation) Maximising value from infrastructure engineering and business model interventions, iBUILD Working Paper, iBUILD: Newcastle University.

[123] Electrans (2017) SWTCH is Airbnb for your EV, 29 May: https://www.electrans.co.uk/swtch-airbnb-ev/

Some concluding reflections...

iBUILD has been a positive example of how researchers can work effectively both across disciplinary and institutional 'boundaries' and with public, private and voluntary sector partners to produce academically rigorous, but also impact-orientated and applied, research that addresses major economic, societal and environmental challenges. While we have shown how research funders, institutions and companies can play a major role in incentivising multi-disciplinary teams to engage in inter-disciplinary research, and that this is essential if challenges are to be met in the complex, interdependent system of systems that comprise local infrastructure. Arguably, it is iBUILD's movement towards trans-disciplinary working that has yielded the greatest rewards, both in terms of its outputs and development of its research team.

The conclusions and recommendations in this report have been developed on the basis of an exhaustively crafted evidence base, and reflect much of our own interpretation and analysis, but the iBUILD team has benefitted enormously from collaborations and discussions with an extensive stakeholder group drawn from local communities, industry, and local and national government. This has enabled researchers to apply and test emerging research on real case studies, and for stakeholders to access, in many cases co-create and benefit from the application of this work.

Since its inception, the iBUILD research centre connected to a wider network of projects, strengthening the research base and helping to build a new community of researchers that are able to work effectively across disciplinary boundaries. During the programme these led to new 'cities' or 'urban' themes within each of the three university partners and, building on these strengths, iBUILD's three universities were awarded three of the five Research Council UK Urban Living Partnership projects.

Although the iBUILD team is now moving on to new projects in name, they are often in related fields to iBUILD's research. Perhaps the most substantial legacy is the central role iBUILD researchers have had in shaping the contours of the UK Collaboratorium for Research in Infrastructure and Cities (UKCRIC) programme, which spans fourteen universities. UKCRIC is examining how to make infrastructure more resilient to extreme events and more adaptable to changing circumstances and contexts, and how infrastructure can provide services that are more affordable, accessible and usable to the whole population.[124] Newcastle University hosts the Urban Observatory and the National Green Infrastructure Facility, the University of Birmingham the National Buried Infrastructure Laboratory and the University of Leeds hosts one of the Infrastructure Materials Laboratories.

These new large-scale facilities, part of a coordinated set of national laboratories, will provide a next generation of capability in large- and demonstration-scale experimentation, city-scale observation, modelling and simulation. The research and innovation potential of not just the facilities but, perhaps more importantly, the network of collaborators and the research staff trained in programmes such as iBUILD provides an unprecedented opportunity to advance inter-disciplinary infrastructure research.

[124] http://www.ukcric.com/

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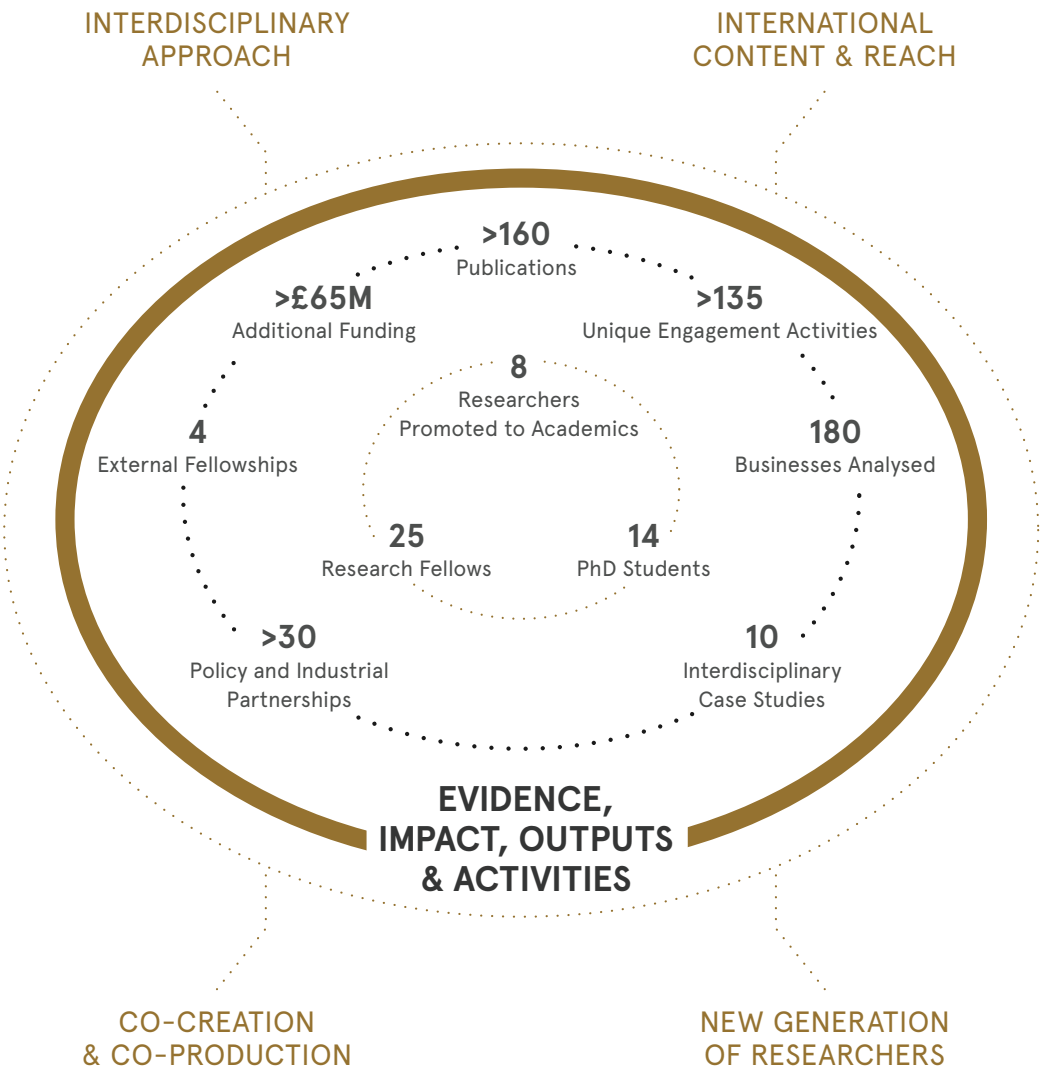
Evidence, Impact, Outputs & Activities



In August 2013 the iBUILD Centre brought together a multi-disciplinary team from Newcastle, Birmingham and Leeds Universities with expertise spanning systems analysis, civil and infrastructure engineering, economics, planning and social sciences, alongside an extensive stakeholder group.

The research programme has developed and demonstrated a suite of alternative infrastructure business models for local infrastructure. This final report summarises five priority action areas to help governments and infrastructure policy-makers and practitioners unlock better and more sustainable infrastructure business models. This will require:

- *Adopting a broader, integrated and more holistic appreciation of infrastructure.*
- *Strengthening and empowering local areas to realise the infrastructure they need.*
- *Facilitating and capturing all forms of long-term value, not just economic value.*
- *Aligning organisational capabilities and applying circular economy principles to achieve more efficient and less wasteful infrastructure delivery.*
- *Accelerating the knowledge exchange of innovations through practical action and demonstration.*