EPSRC Retrofit 2050:
Abstracts for Expert Reviews

Retrofit 2050

Working document

March 2012

Background and context

More than twenty expert review papers have been commissioned from academics and practitioners based in the UK and overseas. Each author has been asked to write a paper structured in such a way as to consider 'current science' and 'future advances to 2050' with a primary focus at city-scale. Each paper will cover:

- Data and trends (including historical data)
- Policies or government legislation/programmes related to the field
- Current state of 'scientific' understanding
- Key challenges
- Key technological advances (including disruptive and systemic technological innovations)
- Change issues and critical uncertainties
- Future visions based on current knowledge.

A selection of papers will be featuring in a special review issue of Building Research & Information (Summer 2013). The Special Issue will also feature an editorial and an overview article written by members of the Retrofit 2050 project team, to consider not only the innovative knowledge and technical tools available, but how to implement them in real cities by 2050

The proposed content will comprise:

- Urban Retrofitting and the Transition to Sustainability 'Editorial'
- 'Key Challenges in Urban Retrofitting to 2050: Towards an Integrated Socio-Technical Perspective'
- Six further papers will be selected from the expert reviews base around the following areas:
    - Social practices and governance
    - Economics and Financing
    - Energy
    - Water
    - Materials and Resource Efficiency

Reference	Title	Author	Institution
	OVERVIEW PAPERS		
1	Innovation for Sustainable Urban Development and Redevelopment: Prospects and Progress	Peter Newton	Swinburne University of Technology
2	Governance, Planning and Urban Retrofit	Kate Theobald	Durham University
3	Economics and Financing of Urban Retrofit	Andy Gouldson	Leeds University
4	Towards Low Carbon Housing in the UK: The Emergence of Meso-Scale Infrastructure	Andy Karvonen	Manchester University
5	Suburban Neighbourhood Adaptation for a Changing Climate (SNACC)	Katie Williams and Rajat Gupta	UWE and Oxford Brookes
6	Social Justice, Fuel Poverty and the future of Urban Retrofit	Dr Duncan McClaren	Consultant
7	Retrofitting Cities in the Global South	Dr Jonathan Silver	Durham University
8	Socio-technical issues in retrofit strategies for buildings in the UK	Chris Tweed	BRE Centre for Sustainable Design of the Built Environment Welsh School of Architecture Cardiff University
9	Retrofitting existing housing: how far, how much?	Phil Jones, Simon Lannon and Jo Patterson	Welsh School of Architecture, Cardiff University
10	Urban Design and the Retrofit Agenda	Professor Georgia Butina Watson	Oxford Brookes University
	ENERGY		
11	Transport and Energy	David Banister and Robin Hickman	Transport Studies Unit, University of Oxford
12	Energy Management Systems	John Counsell	Strathclyde University
13	The smart grid and the interface between energy and ICT: retrofitting and integrating urban infrastructures	Andres Luque	Durham University

14	Solar Energy	Stuart Irvine	Centre for Solar Energy Research OpTIC Glyndŵr
15	Non-Solar Renewable Energy for Retrofit 2050	Professor Neil J Hewitt	University of Ulster, Centre for Sustainable Technologies
	WATER		
16	Water – Energy Nexus – Retrofitting Urban Areas to Save Water and Achieve Net Zero GHG Emissions and Pollution	Vladimir Novotny	Professor Emeritus, Marquette University and Northeastern University Managing Partner AquaNova LLC
17	Retrofitting for Sustainable Integrated Water Management I: a framework for addressing water scarcity, flooding and pollution.	David Butler, Sarah Ward and Sarah Bell	Centre for Water Systems, University of Exeter
18	Retrofitting for Sustainable Integrated Water Management II: interventions at household, building and urban scales.	Sarah Bell (with Sarah Ward and David Butler)	UCL
	WASTE		
19	Solid Waste Sector	William Powrie	University of Southampton
20	Energy, Waste and Urban Metabolism	Matthew Leach, Sandip Deshmukh, Damiete Ogunkunle	Centre for Environmental Strategy, University of Surrey
	INFORMATION TECHNOLOGY AND MATERIALS		
21	How will cities develop the knowledge and capability to systematically re-engineer their built environment and urban infrastructure in response to climate change and resource constraints?	John Worthington	DEGW
22	Advanced High Performance Cladding Systems Using Vacuum Technology	Ray Ogden, Sean Wang	Oxford Brookes University

OVERVIEW PAPERS

Innovation for Sustainable Urban Development and Redevelopment: Prospects and Progress

Peter W. Newton
Swinburne University of Technology

Innovations capable of initiating a sustainability transformation of Australian cities by mid 21st century are presented against a backdrop of urban infrastructures (housing, transport, water, energy) that are exhibiting signs of stress in the face of sustained levels of high population growth and an ageing asset base. Indicators of infrastructure stress will be presented.

To be sustainable, cities need to be in a position to draw from a pipeline of innovative technologies, products and processes that can be substituted as existing infrastructures show signs of failure. A three horizon model of urban technology innovation will be developed and populated. Cities also need to be innovative in the process of urban planning and design, especially in how they retrofit their brownfield and greyfield precincts in the inner and middle suburbs – to encourage movement of population and investment inwards rather than outwards (greenfield sprawl). New models of urban property development are required here. Change is also required in how built environments are operated as distinct from how they may have been designed to operate. Here, current patterns of urban resource consumption in Australia are demonstrably unsustainable (water, energy, housing space, urban travel) and evidence-based interventions are required from the demand side as well as the supply side to wind back current levels of household consumption.

An overarching challenge involves the prospect for institutional change – the principal uncertainty associated with prospects for transitioning to more sustainable urban development. The alternative is incremental change and path-dependent lock-in to the now unsustainable 20th century model of urban development.

Governance, Planning and Urban Retrofit

Dr Kate Theobald
Northumbria University

This review examines current academic understanding and policy developments around governance and planning processes and mechanisms in relation to retrofitting at city scale. Within this broad framework the review focuses on the socio-technical challenges facing cities in the coming decades in reducing the carbon footprint of domestic, commercial, and public buildings.

Central to this area of work are academic debates on the rapidly developing (and contested) discourse of resilience and its links to climate change adaptation; and understandings of city-scale governance, specifically the role of local governments in both leading the way and facilitating change. Two key issues here are the ways in which local governments interact with the private sector and

other public sector stakeholders (local, regional, national) in this arena, and the relationship they have with local communities and residents.

The review assesses the key legislative and policy drivers (UK and European) and assesses the impact of policy tools in providing a foundation for cities to take integrated action for retrofitting on a large-scale (eg Covenant of Mayors and the requirement to produce Sustainable Energy Plans). It explores the role and impact of financial incentives that are being introduced such as FITs, and assesses the opportunities that these may present for city governments, both through working with private sector and social housing providers and through supporting individual households in undertaking retrofitting of their properties. It also considers the implications for social equity of retrofit programmes, and the governance challenges for cities in terms of public acceptance of new technologies and associated changes in behaviour.

The Economics of Low Carbon Cities: Stimulating Major Scale Investments in City-Scale Retrofit

Andy Gouldson (1), Corrado Topi (2), Phi Webber (1) and Mark Freeman (3)
1. University of Leeds 2. University of York and 3. University of Loughborough

The results of a recent city-scale mini-Stern review indicate that there is a compelling business case for major scale investments in low carbon options at the city scale. The results also suggest that this business case is underpinned by a wider social and economic case that is equally compelling as such investments would reduce energy bills, enhance competitiveness, create employment and reduce fuel poverty. After reviewing the strength of this business case, this paper considers how we can stimulate, structure and deliver major scale investments in energy efficiency and low carbon options at the city scale. A ten-stage process is put forward as one way in which major scale investments can be secured. After building understanding of the nature of the investment opportunity, the multiple options have to be consolidated to create an opportunity to invest at scale. Awareness then has to be built amongst key decision makers in the public and private sectors, and risks reduced before new business models for the dispersal of finance and the recovery and potential recycling of returns are developed. Complementary finance then has to be secured, and early stage investments need to be under-written, often by the public sector. Trusted and reliable delivery vehicles then need to be developed and take-up promoted. A process of rapid evaluation and learning is then required before more substantial second phase investments are secured. This process is briefly evaluated against examples of current and future practice before conclusions on its wider applicability and its potential to deliver deep decarbonisation at the city scale are drawn. Key issues are raised about the compatibility of the measures that seem most likely to be adopted in the period to 2022 with the measures that are likely to be needed to secure deeper carbon cuts in the period to 2050.

Towards Low Carbon Housing in the UK: The Emergence of Meso-Scale Infrastructure

Andrew Karvonen, University of Manchester

Reducing the carbon footprint of the 25 million dwellings in the UK is an enormous endeavour in the transition to a low carbon economy of the future. To date, the debates around low and zero carbon housing have revolved around the houses themselves and involve technical and economic strategies to create tighter building envelopes, highly efficient heating and hot water services, and energy efficient appliances. However, it is becoming increasingly clear that achieving zero carbon housing will require significant changes not only within the household but also upstream to the source of energy generation. District infrastructure networks are becoming more common for supplying electricity and hot water via renewable energy sources for clusters of houses. These meso-scale infrastructures require new forms of governance and management at a scale between the universal infrastructure networks and the individual house.

In this paper, I will review the current state of practice and policy of low and zero carbon housing policies in the UK and address some of the critical challenges for the coming decades. The pursuit of zero carbon housing will require future energy networks to include a complex mix of micro, meso, and macro infrastructure networks that reinforce and interact with one another to provide reliable, continuous, and secure energy services to dwellings. The new energy portfolio will not only require substantial technical and economic expertise but also changes to the entire chain of domestic energy actors – from policymakers, developers, designers, to builders, installers, and occupants – in the pursuit of a low carbon UK economy.

Suburban Neighbourhood Adaptation for a Changing Climate (SNACC)

Katie Williams, UWE and Rajat Gupta, Oxford Brookes

The SNACC Project seeks to answer the question: How can existing suburban neighbourhoods be best adapted to reduce further impacts of climate change and withstand ongoing changes? The research focuses on adaptations to the built environment, through changes to individual homes and larger neighbourhood scale adaptations (urban re-design). SNACC focuses on suburbs because they are the most common type of urban area in the UK, housing 86% of the population. The project will identify successful adaptation and mitigation measures: these are classed as those that perform well technically (i.e. they protect people and property from climate change impacts and mitigate against further climate change) but are also those that are the most practical and acceptable for those who have to make them happen.

The paper will contextualise the challenges of suburban adaptation including future climate change risks, setting out the nature of the built environment in suburbs, the range of potential agents of change (e.g. home owners, tenants local authorities, utilities) and the complexity of 'neighbourhood change' processes. It will then present a range of potential solutions that could be adopted, at the home, garden and neighbourhood scale. It will report on project findings which have tested these

solutions through modelling in selected case studies, using DECoRuM and a hedonic modelling to identify the most effective, acceptable and feasible future adaptation and mitigation options.

The paper will also discuss potential pathways to 'future visions' of sustainable and resilient suburban neighbourhoods. Using the findings from the workshops with residents and stakeholders a number of future scenarios will be discussed. These could range from 'minimal, low cost' changes through to 'large scale neighbourhood redesign'. The workshops will inform us about the feasibility and acceptability of this range of scenarios.

Social Justice, Fuel Poverty and the future of Urban Retrofit

Dr Duncan McClaren, consultant

The case for retrofitting to reduce carbon emissions – especially from energy use in buildings and vehicles - is compelling, but there are good reasons to believe that foreseeable technical and economic options may undermine social justice. For instance, not all energy poverty be eliminated by building efficiency improvements or the addition of household scale renewable energy, some will require demolition and rebuild, with potentially severe social impacts.

This review seeks to identify experience and approaches for just and sustainable urban redevelopment and regeneration, especially in the field of approaches to tackle energy poverty.

The review will examine approaches to policy, practice and financing in the UK and overseas (with particular reference to Germany), focusing on approaches to the improvement of existing buildings, and the relative efficacy of different technical approaches (eg incremental, whole-house, area-based), and different policy/financing approaches (eg means-tested, or universal grants, regulations, supplier obligations).

It will seek to identify key trends and potential innovations in technology, procedures, financing and policy, and the obstacles to their deployment at scale. It will focus on energy use in residential buildings, but will seek to identify parallels in energy use in transport.

It will situate the review of current and future approaches to energy poverty in alternative paradigms of urban futures, with a wider consideration of social justice issues arising in the planning, implementation and financing of urban redevelopment and retrofit, (such as the role of land value and rent across economic cycles; or the balance of private and public resources and property in cities) so as to highlight key challenges arising by 2050.

Retrofitting Cities in the Global South

Dr Jonathan Silver, Durham University

Over the next twenty years the growth of urban populations, particularly in the global South, will mean that by 2030 around three-quarters of the world's population will be urban. UN-HABITAT predicts that the explosive growth of cities in the global South will mean that this urban population will rise

considerably by 2050. This rapid urbanization will account for nearly all population growth across the global South. Furthermore, since the postwar period the migration of those seeking economic opportunities, fleeing insecurity or joining family members in global South cities has contributed to the millions of rural poor moving to urban areas in one of the largest migrations in human history. This poses considerable challenges to communities, planners, policy makers and others as a convergence of explosive urban growth, climate change, poverty and insecure energy futures creates huge pressures on global South cities requiring massive infrastructural investment in retrofitting programs. In global South cities the requirements of urban poor communities continue to dominate debates around infrastructure investment and the need to retrofit housing, energy, sanitation and other systems to provide a decent standard of life for citizens. Slum improvement projects provide a long history of attempts by the local and regional state institutions to retrofit urban poor areas whilst new global environmental challenges and technological advances open emerging retrofitting pathways around low carbon futures, climate change adaption and the rise of the green economy.

This paper seeks to understand how these processes are shaping global South cities toward 2050 by providing a comparative analysis of retrofitting processes emerging from cities such as Sao Paulo, Cape Town and Mumbai. The paper explores how wider socio-technical landscape pressures shape particular policy responses, the emergence of technological innovations across infrastructure systems and new urban knowledge constructions in global South cities. As retrofitting becomes an increasingly important issue across urban infrastructure in the global South the paper reflects on a range of critical uncertainties around how the developing agenda is conceived in the Southern city, the debates taking place about who and where is involved in these processes and the implications for social justice in the city. Finally, the paper draws together these emerging foresights and reflects on whether scholars can conceive of the urban retrofit across global South cities as an interconnected process of infrastructure investment or a diverse series of urban transformations.

Socio-technical issues in retrofit strategies for buildings in the UK

Chris Tweed
BRE Centre for Sustainable Design of the Built Environment
Welsh School of Architecture
Cardiff University

The purpose of this paper is to review strategies for retrofitting buildings at an urban scale. There is ample evidence to show that many of the UK's existing buildings will still be in operation in 2050 and, as such, pose a significant problem in reducing carbon dioxide emissions and energy consumption. After a relatively slow start in recognising this issue, during which most effort was directed towards improving standards for new buildings, the UK Government and other organisations have committed to developing plans for refurbishing much of the country’s building stock. This has resulted in a wide range of technical and policy solutions with different ramifications for the construction and housing industries as well as for society as a whole. The paper will begin, therefore, by reviewing the different estimates of the scale of the retrofit problem facing the UK and the targets for retrofitting including

number of buildings to be treated and the likely carbon dioxide emissions savings. This followed by a review of the different approaches to dealing with the problem, ranging from the 40% house proposal to demolish 3.2m dwellings by 2050 out of a stock of 25m in 2005, to the radical proposal to refurbish "a room a minute". More radical still, the Great British Refurb movement led by Kevin McCloud establishes a rate of refurbishment roughly equivalent to treating an entire city the size of Cardiff in four days. Regardless of the technical feasibility of these proposals, they imply major changes to the way we treat the built environment. The conclusion of the paper will discuss the main issues to emerge from these and other refurbishment strategies.

Retrofitting existing housing: how far, how much?

Phil Jones, Simon Lannon and Jo Patterson, Welsh School of Architecture, Cardiff University

It is widely quoted that a large proportion of buildings that will exist in 2050 already exist and that if we are to achieve government targets for reducing carbon dioxide emissions we have to tackle the problem of what we do about our existing housing. Much of our housing stock in Wales and the UK in general is sub-standard. Many occupants, possibly up to 25%, live in fuel poverty, where affordable warmth is of greater concern to them than global warming. Recent initiatives have made some inroads to improving our existing stock, for example, CESP, CERT and FITS schemes have resourced the installation of energy saving measures and renewable energy systems. In Wales, the ARBED regeneration programme has provided finance for local authorities and RSL's to upgrade the energy performance of their housing portfolios. Although the impact of such schemes has been limited, they have served to some extent to 'kick start' the industry; though whether this has been enough to provide a stable industry that can reduce its costs and provide quality, remains to be seen. The forthcoming 'green deal', the revision of CERT and CESP schemes, and, possible future developments in building regulations, will play a major role in reducing the carbon footprint of our existing housing.

An important area, in relation to carbon dioxide emissions for existing buildings, is the ability to predict the impact of retrofitting. Of particular concern is identifying the most appropriate package of measures to be applied to specific house types, what is the cost, and what are the savings and other benefits, such as increased comfort. In terms of reducing emissions a major consideration must be how much should be achieved on the building, and how much by decarbonising the supply (or some other means of offsetting). From recent studies the indication is that as savings increase beyond about 50%, the costs increase rapidly (see figure), although costs information is currently extremely variable. Other considerations include the skills and training to produce the people in sufficient numbers to carry out this work.

This paper considers such issues associated with improving the energy performance of existing housing from three aspects. Firstly, the results from large area modelling, will be considered, based on the EEP (Energy and Environmental prediction) tool. Secondly, work in Wales, associated with large scale installation schemes, for example, associated with CERT and CESP activities, will be

reviewed. Thirdly, specific case studies of intensive improvements will be discussed. The paper will summarise what has been achieved, at what cost, and where future efforts should be focussed.

Urban Design and the Retrofit Agenda

Professor Georgia Butina Watson, Oxford Brookes University

Sustainable urban design is concerned with issues of liveable communities that offer their users a broad range of life opportunities. We need to create places that support a variety of urban qualities whilst also making cities more sustainable.

The paper will introduce the current thinking about the 'art' and the 'science' of place making'. This will include current theories on delivering sustainable urban design (e.g. ecoresponsive urban design); Planning Policy Guidance and government legislation (including delivering sustainable communities, transport, energy efficiency, waste recycling and water resources); and current technological innovations already available and tested in specific cases. A number of projects will be identified and critically discussed including Curitiba, Boston, Copenhagen, Amsterdam, Masdar, Sheffield and London. These case studies will illustrate wider societal benefits and dis-benefits of linking innovative technologies and urban design qualities, implemented as part of the 'place making agenda'.

The second part of the paper will identify emerging and future technologies and examine how key technological advances (including disruptive and systemic) could be of value in future retrofitting of cities, and the key challenges that will face experts, politicians and broader communities. This will be discussed from the point of view of political leadership and commitment, community and other key actor engagement and broader issues of funding and implementation.

The paper will conclude with a synthesis of two urban design paradigms: 'artistic' in terms of designing places that promote and support a range of urban design qualities and a 'scientific' one, dealing with technological incorporation into future retrofitting of cities.

ENERGY PAPERS

Transport and Energy

David Banister and Robin Hickman, Transport Studies Unit, University of Oxford

This paper describes the inter-relationships between transport and energy in the context of urban retrofitting. It considers the current evidence and science and 'future advances to 2050'. The focus is at the city-scale with commentary on:

- Data and trends (a summary of historical road transport consumption, 2005, 2006, 2007, 2008 and 2009, NUTS4, DECC data), and relation to the likely rise and fall of modes over the longer term (Grübler, 1990);
- Policies and government legislation/programmes related to the field;
- Current state of 'scientific' understanding, covering relationships between urban structure and energy consumption in travel, including consideration of built environment variables, such as density, mix of use, location of development, local neighbourhood design (Ewing and Cervero, 2010; Hickman et al., 2009), and their likely contribution to energy consumption in travel.

The paper will then change focus to consider key trends and challenges for the future to 2050, including likely technological advances in transport (including disruptive and systemic technological innovations), change issues and critical uncertainties. Likely visions of the future will be developed for transport based on the current baseline, trends and uncertainties, and our current knowledge. Behavioural interventions and responses will also be important to changed travel behaviours and these will be discussed within the future visions.

Retrofitting for Energy Utilisation and Energy Management in UK Homes: 2015-2025 and beyond

Professor John Counsell, University of Strathclyde

The report discusses how electrical appliances in UK homes will change beyond all recognition compared with those appliances in common use today. The impact of the European Energy in use Directive (EuP) on device energy consumption and functionality will drive technology and purchasing habits towards LED/OLED based lighting and displays and eradicate standby power use from inefficient small device power supplies. Microprocessors for mobile computing requirements will drive power efficiency in computing devices, servers and gaming machines. These trends will reduce electrical demand in this period by 50% compared with 2011 levels. In addition to this, the reducing cost of micro-generation, e.g. PV and possibly micro-CHP systems will produce an unprecedented reduction in the need for grid based electricity.

The report will highlight that, in the context of cities and urban areas, innovation in retrofitting homes with insulation, even with those with solid wall construction, will enable heat demands of 2011 to be significantly reduced for all homes. Furthermore, Internet based energy services will provide more sophisticated control of heating systems through tighter temperature control and zone control solutions. These heat and electricity reduction measures will bring UK building consumption down by between 30% and 50% in the period 2015-2025.

Finally the report assesses the impact that energy reductions in buildings will have on the economics of the then existing highly capitalised utility grid infrastructures. It discusses how energy demand reduction in the longer term to 2050 will lead to necessary change in utility business models to ones based on IT energy services for energy demand management and metering and electricity load profile management.

The smart grid and the interface between energy and ICT: retrofitting and integrating urban infrastructures

Andrés Luque Department of Geography, Centre for Doctoral Training in Energy, Durham University, United Kingdom

This paper looks at the interface between smart grids and cities. Based on a brief review of smart grid pilot initiatives carried out by cities and energy utility companies in Europe and North America, the paper focuses on the ways by which smart grids are developing a new way of thinking about the city. It also looks at the potential and future implications of the smart grid for urban transitions towards low carbon and sustainable systems.

The smart grid is an emerging energy distribution mode based on the integration of ICT technologies and the electricity network. Its defining characteristic is a bidirectional flow of both energy and information, enabling real time communication between the final energy user and the nodes for generation and distribution. Through the smart grid, consumption and demand can be altered to better match energy availability at any given time resulting in greater energy efficiency, lower carbon emissions and a better use of existing infrastructure. The smart grid also enables the electricity network to adopt distributed generation, opening possibilities the widespread use of micro-renewable decentralised technologies in the city such as solar or wind.

While smart grid projects can be found at national, regional and metropolitan levels, their implications for the city are significant. The development of smart grids implies a retrofit of local electricity networks as well as domestic energy systems and practices. Smart meters, smart appliances and other digital home technologies become a fundamental part of the city's energy network. Given its use of digital communication technologies, the smart grid acts as a platform for the integration of a multiplicity of urban infrastructures such as water (e.g. digital water metering) and transport (e.g. adoption of electric vehicles). In addition, the smart grid highlights the increasing role of electronics and software companies in shaping urban dynamics, underpins urban growth strategies based on ICT

and low carbon technologies, and promotes emerging urban discourses such as that of the 'smart city'. The paper also identifies a variety of emerging trends in the current smart grid/smart meter roll out efforts, discussing possible socio-technical development pathways towards the evolution of the smart grid to 2050.

Solar Energy

Stuart J. C. Irvine, Centre for Solar Energy Research OpTIC Glyndŵr

The increase in global population by 3 billion and need to reduce carbon emissions by 80% provide the context for the role of solar energy (both solar thermal and photovoltaic (PV)) in the urban environment by 2050. Short term scenario models for renewable energy generation are limited when looking at a longer time scale and is placed in the context of the existing infrastructure. However, the approach for a 2050 scenario has to take a different starting point where there will be radical changes in energy efficiency of buildings and a different infrastructure will exist. Solar energy has been proved to be the easiest form of renewable energy to be retrofitted at the building scale but the current penetration into the market are low and the potential contribution to energy supply is mostly underestimated. Uptake of solar PV could be 30% and solar thermal 60% by 2050. This study will explore the context for high efficiency and low cost PV generated electricity combined with reduced energy demand per household. The current view of solar energy is very much as a bolt-on of standard products onto a roof or building façade. New developments in PV technology will enable greater incorporation of PV into the building fabric and consider how this can be done in the context of changes to use of materials and design to improve energy efficiency

Non-Solar Renewable Energy for Retrofit 2050

Professor Neil J Hewitt, University of Ulster, Centre for Sustainable Technologies

In the UK domestic building stock, external fabric enhancements and behavioural change represent some of the most challenging facets of retrofit. Fabric changes may alter the architectural and cultural significance of an area whilst long-term behavioural change may require the significant stimulus of legislation to secure energy efficiency gains. Thus renewable energy integration is seen as not only an addition to energy efficiency but as an alternative as well.

Heat pumps with integrated thermal storage will allow electricity tariffs to be managed thus meeting thermal comfort needs. Such electricity tariffs could be based on the ability of the domestic built environment to act as a virtual energy store with heat pumps and integrated energy storage working together to manage large scale wind energy penetration and its inherent variability.

Biomass systems (combustion of waste derived oils including pyrolysis, woody and lignocellulose based materials), community gasification systems and waste anaerobic plants will provide lower calorific value gases for direct use in building power, heating and cooling systems in areas where

potential atmospheric emissions are allowed. Buildings must also accommodate fuel storage and regular deliveries to facilitate lower energy density fuel use.

Thus non-solar renewable energy integration may through their potential intermittency, ensure changes in how we engage with energy. Either we operate around their availability or we employ smart interfaces to maximise their use with less time dependant operations (washing machines, dish washers, hot water etc) or we engage in variable (and hopefully favourable) tariff systems that allow net generation to be profitable for both householder and regional energy companies. Alternatively bioenergy approaches may result in complexity associated with differing calorific values and this energy outputs. In either case, potential solutions require greater householder involvement in either technology or tariff.

WATER PAPERS

Water – Energy Nexus – Retrofitting Urban Areas to Save Water and Achieve Net Zero GHG Emissions and Pollution

Vladimir Novotny, Professor Emeritus, Marquette University and Northeastern University
Managing Partner AquaNova LLC.

A major paradigm shift from the current unsustainable status to sustainable new developments and retrofitted historic communities by the middle of the 21 century (or sooner) is on the horizon in many countries. The new paradigm is striving towards meeting the net zero green house (GHG) emission targets, reuse and recycle water, and recovering energy, nutrients, and other resources. The proposed work and expert report will present trends and links between water conservation, reclamation, reuse and energy use, including also the trends in urban drainage as related to the above sustainability goals. The report will define sustainability flaws in the current linear urban metabolism, define global and regional footprints, outline the trends towards the sustainable water-energy nexus in future ecocities and steps towards reducing energy use due to water and used water by the city on domestic, cluster (ecoblock) and regional levels. It will point out the limits of the linear and closed loop water/stormwater/wastewater management systems. An example of a double loop water reclamation/reuse system separating black and gray water requiring less fresh water will be featured and quantitatively compared with a current US linear water system with excessive water use and currently emerging more frugal and sustainable EU (UK) and Chinese systems. The future system would reclaim clean water, nutrients and other resources, and produce excess energy. Hydrogen based energy recovery and conversion to electricity in an integrated resource recovery facility will be proposed for the future cities and applied to two selected UK pilot cities. Triple Bottom Line-Life Cycle Assessment methodologies for evaluating the economic, social and ecological benefits of the paradigm shift will be outlined along with the methods for estimating the value of intangible social and ecological benefits and costs such as contingent valuation in the Willingness to Pay of people for retrofitting which also defines personal and societal drivers for change. These methods can be used to find out quantitative social values of nonmarket commodities such as ecological enhancement, sustainability, improvements of water quality and aesthetic assets, and reduction of GHGs emissions.

Retrofitting for Sustainable Integrated Water Management I: a framework for addressing water scarcity, flooding and pollution

David Butler & Sarah Ward (and Sarah bell, UCL), Centre for Water Systems, University of Exeter

Provision of clean drinking water, removal of contaminated water and protection from flooding are essential for good public health in cities. In recent decades the principles underpinning the

engineering systems for managing water in cities have come under question. Many cities, such as London, have reached the limits of available water resources and are turning to expensive and energy intensive technologies such as desalination to provide water to meet demand. Growing public interest in improving the ecological health and biodiversity of urban environments has drawn attention to the impact of engineered drainage and wastewater systems on local waterways and wetlands. In particular, the European Framework Directive on Water has highlighted the impact of wastewater discharge and combined sewer overflows on aquatic ecosystems. Floods in cities and towns such as Hull and Gloucester have caused major disruption to people's lives and local economies, and have resulted in major reforms to flood policy and management in the UK. All of these challenges become more complicated as rainfall patterns become more uncertain under climate change and as urban populations increase.

This review outlines the principles of SIWM as a framework for retrofitting cities to meet the needs of people and the environment under the uncertainties of climate change and population growth by 2050. The overall aim of the chapter is to contribute to the understanding of the long-term socio-technical changes required to transition to retrofitting at the city-scale for SIWM objectives. More specifically, this review will examine existing and proposed urban retrofit solutions that assist in tackling the three grand water quantity and quality challenges of drought, flooding and water pollution. It begins with an overview of current urban water management in the UK and immediate policy changes towards SIWM. It then outlines the vision of SIWM as the basis for backcasting to identify the main challenges and pathways to retrofitting. The final section provides a short discussion and concludes with a summary of the socio-technical challenges and solutions for achieving SIWM.

The review will draw from an understanding of data and trends to indicate examples of need and effect. Key government policies and British and European legislation will be reviewed where relevant. The Flood and Water Management Act 2010 is particularly apposite to this discussion. The review will draw too from parallel EPSRC SUE projects such as Urban Futures and ReVISIONs, the EU FP7 project SWITCH and the developing British Standard (BS8585) on Strategy for Water Reuse to ensure complementarity and cross-learning

Retrofitting for Sustainable Integrated Water Management II: interventions at household, building and urban scales

Sarah Bell (with Sarah Ward and David Butler, Exeter University), UCL

Urban water management has conventionally been the responsibility of large utilities and municipal governments. Management of water systems has been centralised to enable the high levels of control required to deliver good public health outcomes, and to improve efficiency of investment and operation. The transition to Sustainable Integrated Water Management (SIWM) will require changes to urban water systems at different scales, with increased importance given to decentralised and distributed technologies. Retrofitting cities for SIWM may involve changes to individual fittings and appliances, building scale water supply systems such as rainwater harvesting, water sensitive urban

design, neighbourhood supply schemes including non-potable distribution networks, and urban scale potable water recycling. Changes to the physical scale of the technologies and infrastructure of water supply, treatment and use will require economic, social, and institutional reform.

This review addresses retrofitting for SIWM at different scales. It begins with an overview of SIWM principals to highlight the need for reform at multiple scales. It then outlines three cases for retrofitting for SIWM at three different scales – the personal, the building and the city. Personal water use is addressed through domestic demand management, the building scale is addressed through the retrofitting of rainwater harvesting, and the urban scale is considered through the case of indirect potable water reuse (IPR). Each case is described in terms of the technical, social, economic and institutional changes required to enable retrofitting. The analysis identifies opportunities and drivers for change, as well as obstacles to retrofitting and reform. The paper concludes with the need for the involvement of a wider range of actors in urban water management. Retrofitting for SIWM will change the role of water companies, regulators, government and users in cities, and will create new opportunities and responsibilities for developers, plumbers, designers, local authorities, entrepreneurs and engineers.

WASTE PAPERS

Solid Waste Sector

William Powrie, University of Southampton

- Data and trends (including historical data) – For the ITRC project, UK historical data has already been gathered on MSW, commercial and industrial (C&I) and construction and demolition (C&D) waste arisings. These have been used to create trends of future waste arisings have been made on the basis of GDP and population projections.
- Policies or government legislation/programmes related to the field: The principle legislation is the 1999 EU Landfill Directive which sets targets for the reduction of biodegradable municipal waste (BMW) to be landfilled. Additionally national targets have also been set on the amount of waste to be recycled, composted and reused. We will look at waste legislation around Europe and consult with key figures in the waste management industry, the Environment Agency and Defra in order to try and understand how waste management legislation is likely to change in the future.
- Current state of 'scientific' understanding. For the last 30 years or so the principle purpose of waste management has been to remove waste from anthroposphere and prevent it from polluting the environment. A by-product of this has been energy from landfill gas and from the incineration of wastes.
- Key challenges: We will consider the potential impacts of energy and resource scarcity and security; emerging technologies; environmental protection and legislative and socio-economic drives.
- Key technological advances (including disruptive and systemic technological innovations): We will examine the technological developments in waste management over the last 30 years, including experimental technologies (e.g. the Defra-funded New Technologies Demonstrator Project, on which the reviewer was the chair of the technical advisory committee) and those that have been adopted outside the UK.
- Change issues and critical uncertainties: Given the effect that the Landfill Directive has had on changing the landscape of UK waste management, it is clear that future legislation is likely to be one of the dominant factors in shaping the future of waste management at the city scale, as highlighted above.

Energy, Waste and Urban Metabolism

Matthew Leach, Sandip Deshmukh, Damiete Ogunkunle, Centre for Environmental Strategy, University of Surrey

Sustainable energy generation and waste management are key fundamental elements of urban metabolism. This paper explores possible pathways to low carbon urban development by investigating the influences of urban form, approaches to energy efficiency, incorporation of

renewable energy sources and waste to energy activities on the flows of energy and materials that underpin urban metabolism. Within this exploration, factors that influenced the UK's past energy transitions, recent trends, emerging policy drivers, technological opportunities, and social preferences will be addressed.

The paper then outlines one prospective pathway to achieving a low carbon economy by 2050 at a city-level scale, in which society has focused on local delivery of high efficiency buildings, small-scale energy supply and greater consumer engagement. Through the narrative development and quantification of such a pathway the key challenges for its realization (such as the retrofitting requirements for buildings and the technological advances needed) are exposed. Pertinent change issues and critical uncertainties are explored, such as the apparent need for mass-uptake of heat pumps. Finally, the paper concludes that there are many ways in which a low carbon future could be pursued, but that under most such pathways there will be similar needs: radically higher energy efficiency in buildings and development and deployment of community scale energy generation are two such examples.

INFORMATION TECHNOLOGY AND MATERIALS PAPERS

How will cities develop the knowledge and capability to systematically re-engineer their built environment and urban infrastructure in response to climate change and resource constraints?

John Worthington, Co-Founder DEGW, Director the Academy of Urbanism

Crystal ball gazing is an uncertain pastime. With hindsight the future is full of *Predictable Surprises* (1) to which perceived wisdom often blinds us. What is clear is that the future is incrementally unfolding, punctuated by with a major paradigm shifts every 20-30 years. The early 1970's saw a shift from an industrial to a service economy with twenty years later the last recession which was more than a recession but the restructuring of the office service economy. Today again we are confronted by a seismic shift reflecting a reappraisal of the financial service economy and a concern to achieve a sustainable lifestyle (2).

Change is both physical and perceptual. Whilst the configuration and character of much of our urban fabric for the next forty years will be moulded by our existing infrastructure and planning decisions, subtle changes will be triggered by shifts in political and economic outlooks and personal expectations. This position paper l aims to set out the current themes, policies and current technologies that may impact on future thinking. Two major drivers of change will be explored. Firstly the impact of impact of ubiquitous, cheap, mobile, hand held information and communications technology (ICT) a means of both increasing collaboration and innovation and yet also speeding up communication to fuel uncertainty and discontent. Secondly the constraints and opportunities of recognising the importance of organically developing new solutions within the context of an installed base of physical infrastructure, and well established processes and business models. Our existing constructed environment can be an asset in that it can yield untapped capacity but also a hindrance in representing inefficient methods of operating.

Step changes in the way we plan, deliver and manage our built environment will require, in addition to technological innovation, organisational innovation and a radical willingness to rethink education, professional structures, resource allocation and the management of assets (3).

References

(1) Bazeman & Watkins: Predictable Surprises: The disasters you have seen coming and how to prevent them; Harvard business School Press. Boston 2004
(2) Charles Landry; Riding the Rapids: Urban Life in an age of complexity. CABE/RIBA Building Futures London 2004
(3) John Worthington; Sustainable Real Estate for a Changing Climate, Chapter in Dobbelsteen, van Dorst, van Timmeren, Smart Building for a Changing Climate; Techne Press, Amsterdam 2009

Advanced High Performance Cladding Systems Using Vacuum Technology.

Ray Ogden, Sean Wang, Oxford Brookes University

In the next decade building regulations and the imperative to reduce the energy consumption of existing buildings, will require building envelope systems that can deliver high standards of thermal performance. There will be resistance, especially in urban environments, to the use of physically thick wall construction which can lead to adverse internal net to gross building areas, reduced site capacity, and limited retrofit potential.

Many conventional cladding systems will struggle to achieve the standards that may be sought in the future. New more highly performing insulation materials and techniques will be required that deliver improved performance at minimum thickness. As a result Oxford Brookes University has been working with the international steel sector and UK government to develop advanced cladding systems based on vacuum insulation. This technology has been identified as having particular potential to deliver step change.

Research has demonstrated that vacuum cladding systems are unlikely to be economic for U-values of 0.2 and higher, as these are within the practical ability of conventional insulation materials. However, where U-values lower than 0.2 are required, and certainly where U-values are in the range 0.15 to 0.05, very significant benefits can be achieved due to the relative physical thinness of panels (circa. 15%-25% of conventional solutions).

This paper will review both the technical and economic case for adopting highly insulted building envelope systems based on vacuum insulation panel technology in both the refurbishment and new build sectors. Appropriate technology will change as performance targets adjust. Simply put, products for which there is current, limited economic and technical demand may suddenly become sought-after vis-a-vis 'disruptive' innovations, whilst existing technology becomes obsolete. The paper will set the context and potential for technological change within the wider insulation technology arena and will assess the potential drivers and inhibitors for change in the VIP sector within the context of urban retrofit to 2050.