MAKING THE CONNECTIONS ON CLIMATE

HOW CITY REGIONS CAN JOIN THE DOTS BETWEEN TRANSPORT, ENERGY AND THE BUILT ENVIRONMENT

URBAN TRANSPORT GROUP

URBAN TRANSPORT GROUP

The Urban Transport Group
represents the seven strategic transport bodies which between them serve more than twenty million people in Greater Manchester (Transport for Greater Manchester), Liverpool City Region (Merseytravel), London (Transport for London), Sheffield City Region (South Yorkshire Passenger Transport Executive), Tyne and Wear (Nexus), West Midlands (Transport for West Midlands) and West Yorkshire (West Yorkshire Combined Authority). The Urban Transport Group is also a wider professional network with associate members in Strathclyde, Bristol and the West of England, Tees Valley, Nottingham and Northern Ireland.

Report authors: Jonathan Bray and Clare Linton

November 2019

CONTENTS

WHY WE NEED TO MAKE MORE CONNECTIONS ON CLIMATE

1

The world is facing a climate crisis with rising temperatures already leading to more extreme weather conditions. In response, both at an international, national and local level, demanding targets are being set for reducing greenhouse gas emissions and climate emergency declarations are being made.

If these ambitions are to be met, then we need to move beyond a siloed approach to reducing carbon emissions from different sectors and sub-sectors in isolation and instead seek to make more connections between those sectors at the level of both overarching policy making, as well as at the individual project level.

As the Urban Transport Group, this report focuses in particular on the connections that can be made on climate at the city region level between transport and energy, and between transport and the decarbonisation and adaptation of the built environment. In doing so, this report also suggests both practical interventions that can be made on a host of different types of projects as well as profiling how a city can make these connections in an increasingly systematic way - using Nottingham and Munich as case studies.

This report does not aim to provide a comprehensive treatise on all the issues around climate change, transport, the built environment and energy. There are many other reports which do this. What this report aims to do instead is to provide those working for city region transport authorities with a source of inspiration, ideas and a sense of agency on an issue that can seem overwhelming in its scale and urgency.

The good news too is that many of the projects and policies that feature in the report not only either reduce carbon emissions, or improve climate resilience, they also have multiple wider benefits including:

- Cost savings, including through lower energy costs, and reducing the costs of disruption, clean-up and repair by reducing impacts of flooding and other extreme weather events
- Creating good jobs and contributing to good growth
- Making cities more attractive places to live, work, visit, spend time and invest in
- Contributing to wider public health goals on improving mental and physical health
- Improved air quality
- Higher levels of job satisfaction from employees and customer satisfaction from transport users

There may also be opportunities to build in climate connections to transport projects that are being progressed anyway, and at low cost – if there is the awareness of the options in the first place. Building awareness of those options is one of the goals this report seeks to achieve.

In short, it's time to make the connections on climate!

THE CONTEXT

2

Transport now the biggest source of UK carbon emissions...

In the UK, CO_2 emissions are falling, now at 37% below the 1990 baseline level[1], and fell 41% between 2007 and 2016[2]. Despite substantial reductions in CO_2 emissions over the last three decades, transport emissions have barely fallen, down just 2% on 1990 levels in 2017, the year when transport overtook energy supply as the largest emitting sector[3]. Overall, transport now accounts for 27% of UK greenhouse gas emissions[4].

The UK government targets on carbon...

The UK was one of the first countries it the world to establish legally binding carbon emission reduction targets, in the 2008 Climate Change Act[5]. This mandated emission reductions of 80% by 2050. In 2019, the Committee on Climate Change recommended that this be extended to a Net Zero greenhouse gas emissions target for 2050 in order to meet the commitments under the Paris Agreement[6]. This recommendation was incorporated into law as an amendment to the 2008 Climate Change Act in June 2019[7]. And in May 2019, the UK Parliament declared a climate change emergency, recognising the scale of the challenge we face[8].

Cities and carbon...

According to C40 Cities[i], cities account for more than 70% of global CO_2 emissions and consume over two thirds of the world's energy, despite covering just 2% of the earth's landmass[9]. And the impacts of climate change are sometimes felt more intensely in urban environments[10].

Cities account for 54% of the population in the UK, and 46% of emissions, and cities have reduced their emissions faster than the national average[11]. Figure 1 shows the emission reductions achieved in key UK cities in the ten years up to 2016[12].

i. C40 Cities is a network of more than 90 megacities committed to acting on climate change.

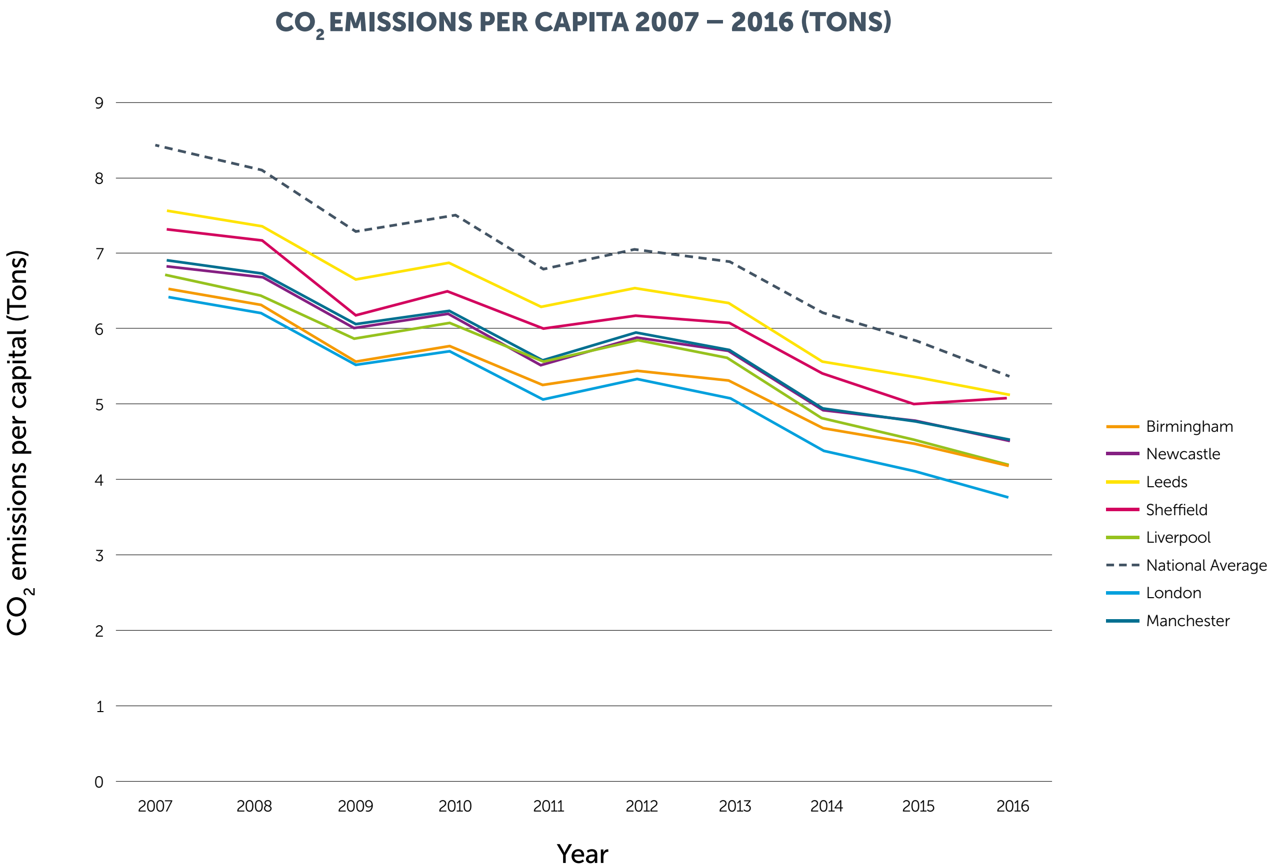

Figure 1 – Reduction in CO_2 emissions per capita for UK cities (grey dashed line shows national average), data taken from Centre for Cities Data Tool[13]

The impact of a warming world on city regions...

Climate change will likely lead to the following effects in the UK:

- hotter, drier summers
- milder, wetter winters
- rising sea levels
- more extreme weather events[14]

This in turn will lead to more droughts and flooding[15]. Some of the effects of climate change will be more extreme in urban environments. The need for more effective management of water resources and sewage systems will become more pressing in the coming decades, with heavier rainfall having an impact on drainage and flow[16].

Summer temperatures could regularly reach 38.5°C by the 2040s[17]. Urban heat island effects mean that heat stress risks are more severe in cities, with heat-related deaths projected to rise from 2,000 a year at present, up to 7,000 in 2050[18]. Urban green spaces can help to mitigate heating effects, reducing air temperatures by as much as 8°C[19], and help to manage drainage issues by slowing and containing run off from heavy rainfall.

It will also be important to design new infrastructure, and modify existing infrastructure, to be resilient to the impacts of climate change and future weather conditions, anticipating the risks and taking appropriate steps to adapt to them[20].

How cities are responding...

In response, more cities are pledging ambitious net zero targets as well as declaring climate emergencies[21]. London, for example, has pledged to reduce emissions by 60% by 2025 as part of its commitment to C40 Cities[22] and the London Assembly has passed a motion to bring forward plans for the city to be carbon neutral from 2050 to 2030[23]. Mayor Sadiq Khan declared a climate emergency before the UK Parliament in December 2018, stating: *"We are in the midst of a climate emergency which poses a threat to our health, our planet and our children and grandchildren's future"[24].*

Examples elsewhere include the Leeds Climate Commission which was established in 2017 to help decision making in the city to respond to climate change and mitigate emissions[25]. Informed by the Committee on Climate Change, it brings together individuals and organisations from the public and private sector[26]. This is part of a wider programme called Can-do Cities, which aims to inspire cities, communities and regions to establish local climate commissions[27].

Bristol aims to double its tree canopy by 2050 in order to help combat climate change and air pollution, enhance biodiversity and promote health and wellbeing[28].

The obstacles and opportunities for city regions...

However, many of the drivers for how fast carbon emissions will be reduced are outside of the control of local and city government including the pace at which the electricity grid is decarbonised, vehicle taxation policies, as well as how quickly the cost of green vehicle technologies falls and how reliable that technology becomes. The UK is also highly centralised with Whitehall Departments keeping control of key funding levers (often micro managing them through competition funding). In addition, rail and bus are largely privatised and key utilities (water and energy) are also largely outside the control of city and local government. Further devolution of powers could be a key enabler for cities and city regions to take action on reducing emissions and improving resilience to climate change impacts[29].

Yet cities do still have significant levers at their disposal such as how they choose to deploy what resources they control (for example energy efficiency of public housing and buildings or how transport investment is targeted). There is also the beginnings of a shift back to local authorities providing services and developing infrastructure directly, including local authorities operating mass transit systems directly, taking control of local bus networks, council house building, establishing council owned development companies, combined heat and power projects, setting up not-for-profit energy companies and so on.

MAKING THE CONNECTIONS ON TRANSPORT AND ENERGY

In this section we step back from exploring some of the mega issues around transport and energy, such as the electrification of vehicle fleets and the interplay between transport and energy at the national level, as these issues are well explored elsewhere. Instead we focus on the connections between transport and energy that can be made at the project level and which regional or city authorities could have influence over, or replicate aspects of.

Public transport consumes energy but also generates energy (or potential energy), often in the form of heat. There are both opportunities to reduce energy use, provide that energy from more sustainable sources, and to capture the waste energy that public transport generates. This section provides some examples of schemes that have sought to do just that.

RENEWABLE ENERGY

Netherlands railways 100% renewably powered

Since 2017, all electric trains in the Netherlands run on renewable electricity[30]. The Dutch Railway operator NS works with energy company Eneco to use wind turbines to generate electricity for the operation of its trains[31]. One turbine running for an hour can power a train for 120 miles[32].

The Dutch infrastructure manager ProRail is also working to install solar panels on stations[33]. For example, Eindhoven railway station has installed 1,900 solar panels, generating 450,000 kWh a year and providing 60% of the energy for the station[34]. In addition, all Dutch railway stations now use more energy efficient LED lighting[35].

Solar roofing at scale in New York and London

In New York City, the Metropolitan Transportation Authority is leasing more than 100 rooftops of bus depots and train yards for installations of solar panels[36]. The project is seeking to generate money for the authority and, once fully realised, could generate enough electricity for 18,000 homes in New York[37].

In 2014, the world's largest solar-powered bridge opened at Blackfriars rail station in London[38].

The installation of 4,400 solar panels provides half of the station's energy, reducing carbon emissions by 511 T a year[39].

The solar array cost £7.3m and was funded through the Department for Transport's Safety and Environment Fund[40]. Other sustainability measures were implemented during the developments at the station, including rain water harvesting and sun pipes for natural lighting[41].

3

Figure 2 – Blackfriars rail bridge, London

Solar powered shelters and railways

UK based company Polysolar has developed a bus shelter with a transparent solar photovoltaic layer[42]. The shelter, which has been introduced in Canary Wharf, London, generates enough electricity to power the average London apartment and will be used to power the shelter's lighting and signage[43].

South Western Railway (SWR) is working with climate charity Possible (formerly 10:10 Climate Action) to develop renewable energy sources for railway infrastructure[44].

The project, called Riding Sunbeams, conducted a number of feasibility studies to explore how trackside community-owned solar farms could supply electricity for trains[45]. SWR is now installing 135 solar panels on derelict land near Aldershot station which will supply power for lights and signalling equipment[46]. The data gathered from the scheme will be used to explore how further solar farms could be used to power the trains themselves[47].

Figure 3 – Transparent solar bus shelter, London (Image source: Polysolar)

Wind power at stations and shelters

Transport for Greater Manchester (TfGM) installed an 11kW wind turbine at Horwich Parkway Rail Station in 2013 to contribute to carbon emission reduction targets and raise awareness of the application of renewable energy in public transport[48]. The turbine cost £68,000 and the total investment was £198,000 which included diverting overhead cables for installation[49].

This was funded through an EU INTERREG grant (50%) and contributions from the regional development agency, local council and TfGM[50].

In Iceland, a start-up called IceWind is installing small wind turbines on bus stops[51]. Each bus stop has two customised turbines which provide lighting, WiFi, mobile charging and the energy for advertising screens, and charges batteries to provide up to 48 hours of energy in case of low winds[52].

A hydro-powered interchange

Rochdale Interchange (opened in 2013) is an £11.5m transport interchange which links bus and tram services on a transformed former brownfield site[53]. A micro hydropower scheme was installed at the new interchange during construction in order to provide renewable electricity for the interchange[54].

The turbine uses an Archimedean screw with a diameter of 2.1 metres to harness the kinetic energy of the River Roch which flows adjacent to the interchange[55].

The Archimedean screw is protected by a screen to prevent debris and large fish from entering the turbine. A fish pass was also installed alongside to allow migratory fish to pass upstream.

The turbine produces 86,000 kWh of electricity per annum and aimed to reduce the interchange's carbon footprint by a quarter. It is expected that it will deliver lifetime CO_2 savings of 1,900 T[56]. The scheme cost £368,000 and was funded through a combination of EU INTERREG grant (50% of the cost) and other grants from the North West Development Agency and the Environment Agency.

Figure 4 – Rochdale Interchange (Image source: Transport for Greater Manchester)

ENERGY EFFICIENCY

Interchanges and stations are a key part of our transport infrastructure but can use a lot of energy. There are a number of approaches to making these buildings more energy efficient, including improving the management of heating, cooling and lighting.

Energy efficient stations and interchanges

Refurbishment of Ainsdale station, Merseyside, in 2018, made it 'the most eco-friendly station' on the Merseyrail network[57]. Solar panels were installed at the station along with LED lighting, and rain water harvesting tanks are used for the toilets[58].

TfGM has improved lighting controls at Shudehill Interchange, which includes a tram, bus and a car park[59]. The scheme installed a new automated lighting control system and has reduced the energy used for lighting by 10%[60]. The project cost €17,000, with annual CO_2 savings of 41 T and annual cost savings of €9,000 in energy use and €3,600 in maintenance[61].

TfGM also switched the lighting at Hyde bus station to LEDs, at a cost of €35,000[62]. This resulted in a 20% reduction in energy use for lighting, CO_2 savings of 16 T a year and cost savings of €3,650 in energy use and €6,000 in maintenance[63]. As a result of the cost and energy savings demonstrated at Hyde, TfGM progressively moved all bus station lighting to LEDs[64]. These energy efficient lighting schemes demonstrate that new, more energy efficient technologies can deliver substantial CO_2 reductions and reduce the costs of maintenance for transport authorities.

HEAT

Capturing wasted heat and energy from rail

In Rotterdam, the RET public transport depots implemented a strategy for heat use, where previously there hadn't been one[65]. Gas heating use is restricted to normal working hours on days where the temperature is below 15°C and information campaigns have been conducted for staff to help them understand the changes[66]. This reduced gas consumption by 25%, saving 19 TCO_2 and €200,000 annually across seven depots[67].

Heating homes from the Tube

In Bunhill Ward, Islington, London, a local energy centre has generated combined heat and power since 2012 and the heat is piped into 800 homes via a district heating network[68]. Phase 2 of the project delivers a new energy centre which will harness waste heat from the London Underground and feed this into the district heat network, expanding capacity for a further 1,000 homes[69].

A 1MW heat pump draws the waste heat from a ventilation shaft of the Northern Line and transfers the heat to homes as hot water.

During the summer, the system can be reversed to draw cool air into the Tube[70]. The scheme is being delivered by Islington Council in collaboration with London Underground, the Greater London Authority and Colloide Engineering[71]. The initial pilot was funded through an EU FP7 project called Celsius[72] and the ongoing work is supported through an EU Horizon 2020 project called Thermos[73]. The Greater London Authority estimates that waste heat in London could meet as much as 38% of the city's heating demand[74].

Figure 5 – London Underground (Image source: Dan Roizer on Unsplash)

HS2 is proposing to recover heat from the brakes and engines of its trains to provide hot water to around 500 nearby homes[75].

Pumps will draw heat from the tunnels using heat pumps and feed this into a district heating network[76]. Based on current energy prices, it would expect to recover its costs in around four years and reduce the carbon footprint of the homes it serves by 22% compared to heating through conventional gas boilers[77].

A scheme on the Victoria line captured energy from the Tube train brakes, in the first trial of its kind anywhere in the world. An 'inverter' installed at Cloudesley Road substation recovered enough power in a week to run a station the size of Holborn for two days a week[78]. 1 MWh hour of energy can be captured per day, enough to power over 100 homes per year[79]. The technology reduces carbon emissions and could save as much as £6m a year for the transport authority[80].

Air source heat pump

Elsewhere, RATP has installed an air source heat pump in a Paris Metro station, which enables heating and cooling for the station office facilities[81]. The new station "Front Populaire", in the north of Paris, was opened in 2012. When the outside temperature is between -5°C and 19°C the heat pump produces hot water to feed air treatment units.

Between 19°C and 24°C the heat pump is not used and if the temperature exceeds 24°C the pump is used for cooling[82]. The investment cost €77,000 and is saving €9,660 a year, meaning the installation will payback the initial cost in around six years[83].

The Swiss low carbon railway

Not only does Switzerland have arguably the best railway system in the world, SBB (Swiss national railways) is also taking a progressive, strategic, methodical and innovative approach to reducing and decarbonising its energy use.

Currently around 90% of train power comes from SBB's own hydro power plants[84]. SBB aims to save 20% of its forecast annual energy consumption by 2025, or a total of 600 GWh. From 2025, its electric trains will be 100% powered from renewable energy sources. This follows improvements in energy efficiency of 17.8% to date compared with the base year of 2006 (and in the context of increased rail use)[85].

By saving energy and switching to renewable energy, SBB has reduced its CO_2 emissions since 1990 by 37%. SBB now wants to cut its CO_2 emissions by half between 1990 and 2025[86]. It also intends to tackle indirect emissions from the supply chain and emissions generated by product use.

SBB is also part of the 'Exemplary in Energy' initiative which brings together the Swiss Government with key state-owned entities and major national and regional organisations (including Swiss Post, Swisscom and Services Industriels de Genève, a major utilities provider) who are working together to achieve a binding action plan to improve energy efficiency by 25% by 2020[87]. The initiative comprises 39 joint measures in three action areas, plus a series of specific measures determined by each organisation individually. The annual reports show how each of the organisations involved are delivering on their commitments[88].

Among its energy saving innovations, SBB has developed a "green wave" system for train drivers which makes recommendations enabling them to avoid unplanned stops ahead of signals[89]. Trains run more smoothly and with greater energy efficiency, saving SBB 72 GWh of power per year. This is the equivalent of the annual energy consumption of all households in the city of Fribourg, which has around 38,000 inhabitants.

Some of Zurich's S-Bahn train fleet is only in use for a few hours each day during the rush-hour. Thanks to the application of new technologies, the trains know when they will next be in service enabling them to heat up automatically only when they will be used by passengers[90], saving 5 GWh a year.

Whenever technically and commercially viable, renewable energy is used by SBB to heat new buildings or the renovation of existing buildings. This includes using carbon-neutral pellets made from scrap wood from sawmills. This has enabled some 1.1 million litres of heating oil to be replaced by wooden pellets at almost 80 sites across Switzerland since 2015, saving approximately 3,330 T of CO_2[91].

Technology is also being deployed to reduce the costs of heating points. Trackside monitors assess the weather conditions and use this data to ensure that the point heaters are switched on only when required, given the weather conditions[92]. This generates annual savings of 9.3 GWh and will deliver a 1,600 T reduction in CO_2 emissions by 2030. SBB is also trialling the use of geothermal energy via heat pumps for point heaters which could reduce energy use by 30%.

Figure 6 – Swiss railway

MAKING THE CONNECTIONS BETWEEN TRANSPORT AND THE ADAPTATION AND DECARBONISATION OF THE BUILT ENVIRONMENT

Construction of the built environment makes a major contribution to carbon emissions through the embodied carbon in building materials and the processes involved in construction. In the UK, the built environment contributes around 40% of the UK's total carbon footprint, including energy used in buildings and infrastructure[93]. New buildings are more efficient than existing buildings, but 80% of the buildings that will be in use in 2050 have already been built, so decarbonising the current building stock is also important[94]. Key interventions for decarbonising the built environment can include energy efficiency improvements, choosing lower carbon raw materials and managing in-construction emissions such as transport and waste management[95].

As well as considering the built environment's contribution to carbon emissions, we need to consider how our changing climate will affect the built environment. Climate change will have a number of profound impacts on our cities, from high temperatures and heat stress to extreme weather events including drought and flooding. The materials that are used in the built environment influence the ability to adapt to these impacts. Transport authorities are well placed to make the connections on transport and the decarbonisation and adaptation of the built environment by integrating innovative approaches into a range of urban transport schemes. This section presents a number of case studies of where this is happening from the UK and abroad.

GREEN BUILDINGS

West Ham – top of the league for green buildings

West Ham is one of the UK's largest and greenest bus garages[ii]. The garage has an A+ energy performance certificate rating of 24 where existing buildings of this type would more typically have an E rating of around 107[96]. With accommodation for 320 buses and 900 staff, the environmentally friendly design and structure was designed to reduce CO_2 emissions by 27% compared to a traditional bus garage.

Covering a seven-acre site, the garage has 80,000 square feet of barrel vaulted roof covered space. Sedum has been planted on the two outer arches of the timber roof, creating a green roof which acts like a sponge for rain water, releasing it slowly into the drainage system thus reducing the likelihood of flooding. As well as being aesthetically pleasing, the roof is designed to provide a habitat for nesting birds and insects. Rain water is harvested from the rest of the roof and stored in underground tanks and then used to flush on-site toilets.

ii. This case study is based on PRS Architect's article: http://www.prsarchitects.com/news/publications/tfl-west-ham-bus-garage-green-price

4

To reduce energy use, only meeting, training and computer server rooms are air conditioned. Other rooms have a ventilation system that draws in colder air overnight ready for day time use. Biomass boiler and combined micro heat and power units help reduce reliance on fossil fuels and a high profile on-site 37 metre high 100kW wind turbine was designed to meet around 10% of energy needs.

Natural light is used to illuminate the workshop, reducing the need for electric lighting. There is electric vehicle charging points at the garage's visitor car parking and Star Lane, a DLR (Docklands Light Railway) station, is adjacent to the garage.

Figure 7 – West ham bus garage, London (Image source: PRS Architects, credit: Edmund Sumner)

Eco rail station

Accrington Railway Station in Lancashire has achieved a BREEAM 'Excellent' rating through its use of roof mounted solar panels (producing up to 30% of the electricity needed at the station and hot water for the station); rainwater harvesting; more sustainable materials (concrete for the station is at least 30% recycled material); specification of fittings such as low energy LED lighting; use of reclaimed local stone from a quarry less than three miles away; and a majority timber frame structure from sustainable sources[97].

The building also contains a unique classroom facility in the basement area where pupils of local schools can attend lessons in a sustainable building, using the station itself as a real example[98].

Figure 8 – Accrington Eco station, Lancashire (Image source: Community Rail Lancashire)

GREEN-BLUE INFRASTRUCTURE

'Sponge cities' is the idea that our cities can be made more absorbent to rainfall by greening our cities, rather than using hard surfaces like concrete and tarmac over which rainfall runs off into our drains. Using green-blue infrastructure to deliver sponge city concepts, as well as other positive interventions, can help to mitigate climate change, make our cities more resilient to extreme weather events while creating heathier, more liveable places[99]. This is a key part of the decarbonisation and adaptation of the built environment.

Green-blue infrastructure can include, but is not limited to:

- Green roofs and walls
- Sustainable urban drainage systems (SuDS) and water management
- Urban parks
- Community gardens and urban farming
- Urban wetlands
- Urban woodlands and city trees

Many of these interventions can be incorporated into transport infrastructure developments, including green walls and roofs, water storage in transport interchanges or bus stops, and pocket parks as part of a Healthy Street scheme. And urban green spaces, sustainable drainage schemes and community gardens can even be implemented on disused transport infrastructure including rail lines and road carriageways.

Green roofs and walls

Green roofs and walls can be installed on existing and new buildings and have a number of environmental benefits. They do not attract as much heat as conventional roofs and walls, keeping buildings cooler in summer and warmer in winter, thus reducing building energy use.

They also retain rainwater, contribute to biodiversity, and capture particulate matter, improving local air quality, as well as looking attractive and interesting[100].

Figure 9 – Green Wall at Elephant and Castle Tube Station, London

Manchester's green ambitions

Manchester has a strategy for protecting and enhancing its green-blue infrastructure[101]. Retrofitting new green infrastructure to existing buildings, particularly in the city centre, is one of the actions as part of this strategy. During the extension of Manchester City Council's Town Hall in 2013, a 500m^2 green roof was installed[102] at a cost of £30,000[103]. Other initiatives as part of the strategy include planting 4,000 new trees a year, establishing new community gardens and food growing programmes and supporting people to protect and enhance private gardens[104].

At Deansgate-Castlefield Metrolink station, Transport for Greater Manchester has made changes to make it a more pleasant environment for passengers and a more sustainable facility. A new green wall was installed, with a range of plants and flowers, creating a haven for nature[105]. And green infrastructure has been incorporated into the tram tracks, with low maintenance grass and sedum placed between the tracks[106].

Figure 10 – Greening the tram tracks in Manchester (Image source: Firing up the quattro, Flickr)

A green wall has been installed at Elephant and Castle Tube Station, in London[107], with the plants chosen to capture particulate matter in order to improve air quality and attract pollinating insects[108].

Architects WVTTK installed a green bus stop in Eindhoven, The Netherlands, creating a luscious and pleasant environment for passengers waiting for the bus[109]. The planting chosen creates a biodiverse environment and hopes to raise public awareness of the environment.

Figure 11 – Green Bus Stop in Eindhoven, The Netherlands

Repurposing transport land or infrastructure

Urban green spaces can provide a number of vital functions in our cities including recreation, food production, nature development, water storage, active travel routes, improved air quality and urban cooling[110]. On hot days, areas with large amounts of vegetation can be up to 10°C cooler than heavily bricked or concreted areas, helping to combat urban heat island effects[111]. Non-operational transport land and infrastructure can be opened up for creation of new parks and gardens, some examples of which are presented below.

A greener NYC

Perhaps the most famous example of repurposing transport infrastructure into public space is The High Line in New York City. The elevated railway line, built in the 1930s, was listed for demolition in the late 1990s, when 'Friends of the High Line' together with the City of New York began exploring ways to preserve the structure and create a park[112].

The development began in 2002 and was constructed in phases, with the third and final phase opening in 2014[113]. The planting includes trees and grasses, and incorporates those which had started to grow of their own accord, contributing to biodiversity in the local area[114].

Figure 12 – High Line, New York City

Figure 13 – Jardin Atlantique, Paris

Jardin Atlantique is public park built on the roof of Gare Montparnasse railway station in Paris[115]. Opened in 1994, the 3.4 hectare garden covers the tracks and platforms of the station below and railway announcements can be heard throughout the park[116].

In Berlin, a former railway yard was deserted following the Second World War, leaving nature to take over[117]. In the 1990s it was discovered that the spontaneous growth in the area was home to a wide range of species including some rare and endangered animals and plants, and much of the park was classified as landscape and nature conservation areas[118].The Natur-Park Schöneberger Südgelände was opened to the public in 2000, and some of the original buildings and railway artefacts remain, as well as new visual art and sculpture installations[119].

In Sheffield, the 'Grey to Green' project is transforming 1.3km of former road carriageway into high quality public space[120]. The scheme includes flower meadows, sustainable urban drainage, rain gardens, footways and street furniture[121]. The drainage systems allow rainfall to run off more slowly via the soils and planting, and reconnect with the River Don, cutting out the need for gulleys and sewers, increasing resilience to future extreme rainfall and relieving pressure on the sewage systems[122]. Phase one of the scheme cost £3.4 million, with funds from EU Regional Development Funds, Sheffield City Region Investment Fund and Sheffield City Council[123].

Figure 14 – Sheffield Grey to Green scheme (Image source: Sheffield City Council)

Whilst not on the scale of some of the larger schemes highlighted above, Dalston Eastern Curve Garden in Hackney, London, is a community garden built on derelict railway infrastructure in 2010[124]. It provides vital open space for the local community in a densely populated area, and offers a range of inclusive activities[125]. The space encourages wildlife friendly planting and has spaces for community food growing activities[126].

The Edible Bus Stop project created an Edible Bus Route along the 322 route in London, which runs from Clapham to Crystal Palace[127]. Neglected and disused spaces along the route were developed into community growing spaces and pocket parks. The schemes engage with the local community to improve and transform spaces, with volunteers maintaining the gardens.

Figure 15 – Dalston Eastern Curve Garden, Hackney, London

Water holding and slow release

Management of rain water will become a greater challenge with climate change. The green-blue infrastructure highlighted in the case studies above go some way to managing this. Water storage and slow release facilities, either in public squares and plazas, beneath buildings in car parks or on roof tops, can also help to manage extreme rainfall.

The Netherlands are ahead of the curve on developing these kinds of facilities, in part due to their vulnerability to sea level rise and flooding. Water squares or plazas are being incorporated into the Dutch urban realm to temporarily collect storm water runoff. In Rotterdam, a water square has been incorporated into Bellamypark in the Spangen district, an area with a large proportion of paved surfaces and no open water[128].

The green park has a lowered paved area designed for temporary storage of rainwater which flows beneath the green play area and porous lava stones[129].

Flat roof tops can be used to store rain water by situating the drain higher than the roof top[130]. The water is stored for a short period and then drained off at a slow pace[131]. Additional load of the roof, as well as waterproofing, needs to be accounted for in design and construction[132].

It is also possible to store excess rainwater beneath buildings, using vacant space above car parks. Several car parks in Rotterdam have been adapted for this use, including Kruisplein car park at Rotterdam Central Station, which has the ability to store 2,300m^2 of water[133]. Another storage facility has been installed at Museumpark, with the capacity to store 10,000m^2 of water[134].

These measures for storing rainwater could be incorporated into urban realm schemes and building and car park designs, in order to create cities that are more resilient to the extremes in rainfall we can expect in the future associated with climate change impacts.

Figure 16 – Rotterdam water square

STRATEGIC APPROACHES TO MAKING THE CONNECTIONS ON CLIMATE – MUNICH AND NOTTINGHAM

MUNICH

Stadtwerke München (SWM) is Munich's municipally owned company which provides public transport and key utilities (electricity, gas, heating, water and telecomms). It is one of the largest municipal utility companies in Europe making an after tax profit of €225 million in 2018 and with overall investment in the billion Euro range[135].

On transport…

Public transport use is growing in Munich. Nearly 600 million passengers now use the high quality and integrated public transport network of 79km of trams, 95km of underground and 467km network of bus services that SWM runs for the city via its MVG public transport providing subsidiary[136]. MVG is also part of the wider Munich Transport and Tariff Association which provides 'one network, one ticket, one schedule' for public transport across a much wider area of 5,500 square kilometres (including Bavaria, Munich, eight administrative authorities and 40 transport providers).

MVG is supporting Munich's aim that 80% of traffic volume will be public transport, cycling and walking by 2025. MVG innovation includes IsarTigar, a new ride sharing concept which will use existing bus stops but not on fixed routes or schedules[137]. MVG is also looking to establish twelve e-mobility stations (two pilots were set up in 2018) combining charging stations for electric cars as well as a hire points for shared bikes, e-bikes and e-trikes (for cargo) as well as electric cars.

Figure 17 – A Munich tram

5

On energy...

In 2008, SWM launched a renewable energy expansion programme with the aim of generating sufficient green electricity from its own plants to cover all of Munich's consumption by 2025[138]. Good progress has already been made with 70% achieved. Given practical constraints, Munich cannot generate its own energy within its own geographical area, so it has undertaken a joint venture with TronderEnergi (Norwegian municipal energy utility) with whom it jointly operates four wind parks in Norway and will build four more by 2021 (generating enough energy to cover 409,000 households). SWM is also developing smart grids which will enable residents and businesses to generate, store and optimise their electricity use.

Figure 18 – View from Munich's Olympic Park

On heating and cooling...

SWM has an extensive district heating network and the intention is that this will be CO_2 neutral by 2040. To achieve this, SWM is tapping into deep geothermal energy from the vast hot water reserves that exist several thousand metres below Munich including building the largest geo thermal plant in Germany which is due for completion in 2020 and will provide heat for 80,000 customers[139]. Three further plants will be constructed by 2025.

With rising demand for air conditioning, Munich also provides centrally cooled water (provided by three cooling plants) piped to customers' properties by a district cooling grid. Central generation reduces electricity consumed by 70% when compared with conventional air conditioning[140].

On water...

SWM supplies Munich with some of Europe's best drinking water from three catchment areas which are safeguarded by Water Protection Areas[141]. This includes one of the largest contiguous organically farmed regions in Germany. SWM also runs 18 modern indoor and outdoor pools, ten saunas, an ice stadium and two fitness centres. The aim is for CO_2 free operation of all Munich public pools by 2040.

On telecoms...

SWM is rolling out one of Europe's fastest (1GB per second) and most modern fibre optic networks which will reach 70% of all Munich households and businesses by 2021 en route to 100% coverage[142]. It has also established a long range radio network which creates the basis for an 'internet of things' which will allow for pro-active maintenance of public transport equipment and vehicles (for example, sensors in brake-sand containers for trams will be able to report when sand levels for adhesion are running low).

On property development...

SWM is using its land holdings to help create affordable homes for employees with the aim of having 1,100 SWM-owned flats by 2022[143]. This will also contribute to SWM's aim of being one of the top five most attractive companies to work for in Munich by 2025.

On making the connections...

Existing public transport, and the e-mobility stations, are powered by renewable SWM energy. The aim is that when the bus fleet is electrified by 2025 they will also be powered in the same way, as will the growing number of charging points for e-vehicles in the city (350 in 2018 with the aim of 550 by end of 2019). Energy consumption has also been reduced by 90% at two stations with the help of groundwater heat pumps.

NOTTINGHAM

Nottingham aims to be first the first carbon neutral city in the UK with Nottingham City Council setting itself an ambitious target to achieve this by 2028[144]. The key to Nottingham's success is long standing commitment to promoting environmental sustainability and far greater retention of ownership of municipal utilities than is common in the UK. All of which has led to more municipal entrepreneurialism and innovation – as well a growing confidence in making connections across policy silos in pursuit of decarbonisation and other wider public policy goals, such as social inclusion.

On transport...

The city owns the main city bus operator, Nottingham City Transport. It has built a tram system (which is operated under a franchise) and was also the first city in the UK to introduce a Work Place Parking Levy which enabled it to accelerate investment in public transport[145].

This in turn has led to some of the highest levels of public transport use per head in the country[146]. Alongside this, the local authority (and its bus companies) have sought to green the public transport fleet. It was an early pioneer of electric buses and for a period, in 2017, had the largest such fleet in Europe (59 buses) as well as having the biggest city wide infrastructure of charging facilities for buses[147]. All the non-commercial services in the city are provided by electric buses (which have now travelled over one million miles). Meanwhile, Nottingham City Transport, which already had one of the youngest and most environmentally friendly bus fleets in the country, is now the largest operator of double deck biogas buses in the world[148]. Launched in 2017, the buses reduce CO_2 emissions by up to 84% compared to Euro V diesel equivalents.

Nottingham has also sought to play a key role in accelerating the take up of ultra-low emission vehicles more widely, including through working with individuals, businesses and public sector bodies to support them in converting their own vehicles to ultra-low emission vehicles (ULEVs) through the Go Ultra Low initiative[149].

Figure 19 – Nottingham City Transport Gas Bus (Image source: Nottingham City Council)

This has been backed up through installing over 300 charge points, training and support for ULEV technicians and the supply chain as well as a car club network.

The council is also making progress on its plans to transition the 240 public service vehicles it runs to ultra-low emission. As of early 2019, the streets of Nottingham are already cleaned by battery-electric street sweepers and the bins are emptied by battery-electric cage tippers (the first such vehicles to be used by a local authority in the country)[150].

Nottingham's 2017 Taxi and Private Hire Vehicle (PHV) Strategy is seeking to help the taxi and PHV fleet transition to low emission and energy efficient vehicles[151]. This includes ensuring that 100% of taxis and 50% of PHVs are ULEVs by 2025; mandatory eco-driver training as part of the licensing process; reduced license fees for ULEVs, and access to the fast charging infrastructure that is being installed in the city.

Figure 20 – Battery-electric cage tippers used for refuse collection in Nottingham (Image source: Nottingham City Council)

On energy…

The council owns the EnviroEnergy company which has a power station (fuelled by municipal waste) and a heat and power grid[152]. The power station provides heat and power for 4,700 homes and 100 businesses across Nottingham (including major facilities like the Victoria and Broadmarsh shopping centres, the National Ice Centre Arena and Nottingham Trent University)[153]. This makes it the largest municipal heat and power provider in the UK.

The council also owns Robin Hood Energy, a not-for-profit energy company which supplies gas and electricity nationally to both homes and businesses. It was the first local authority energy company to be established and since July 2018 all the electricity it purchases is from renewable sources[154]. The aim of the business is to provide low-cost energy to households and address fuel poverty by providing special tariffs to residents within the boundaries of Nottingham City Council and through offering a socially orientated pricing structure to the entire UK.

Figure 21 – Nottingham City Homes (Image source: Nottingham City Council)

On the built environment…

The council has an extensive programme of installing solar panels on municipal buildings which will be further rolled out in coming years[155]. The council will also be piloting cutting edge fuel cell technology in three of its high energy consuming buildings; gas boilers will be replaced with fuel cell systems, significantly reducing energy demand and costs, and if successful, this will be rolled out to many other buildings across the city.

On the greening of municipal housing, Nottingham is also a UK exemplar. Nottingham City Homes (an Arms' Length Management Organisation for Nottingham City Council) has 29,000 homes and is one of the largest social housing providers in the country[156]. It was recently awarded a gold standard as a provider of sustainable homes by SHIFT (Sustainable Homes Index For Tomorrow) which is a sustainability standard for the housing sector[157].

Over the last few years, Nottingham City Homes (NCH) has rolled out a raft of domestic energy efficiency measures such as new boilers, A-rated windows, solar rooftops and external wall insulation through its 'Greener Housing' scheme to tackle the city's coldest and most energy inefficient homes[158].

NCH is also the first housing organisation in the country to adopt the ground-breaking 'Energiesprong' approach to tackle climate change and fuel poverty challenges arising from older housing stock.

The 'whole house' project radically upgraded the efficiency of ten homes with new outside walls and windows, a solar roof, and a state of the art heating system; making the homes warmer, healthier and much more affordable to heat for residents[159]. The intention is to roll this out more widely across the city. In addition, solar panels have now been fitted on 4,500 domestic properties across the city and every new council house will be built with solar panels. Some of these schemes benefit from collaborations with one of the UK's leading sustainable housing research centres which is based at the University of Nottingham.

On making the connections...

Nottingham's gas-powered double deck buses are fuelled by bio-methane which is derived from sewage and household waste[160]. Nottingham's trams are now powered by the Robin Hood Energy company from renewable sources[161]. The ultimate aim is that an electrified local transport system will operate on electricity sustainably generated from local waste incineration and solar energy, and that Nottingham will become a fully self-sufficient 'energy city'.

Nottingham was the first city to have a publicly owned car park with solar panels above the parking spaces. The 448 solar panels at the council's Harvey Hadden sports centre is expected to generate more than 50 MWh of electricity per year, generating revenue worth more than £10,000 per year[162]. Nottingham is one of four cities taking part in a EU-funded vehicle-to-grid trial using 40 new electric vehicles, stand-alone batteries and solar panels to balance energy use, generation and storage (for example, through using the electric vehicle batteries and stand-alone batteries to store energy in order to reduce the peak draw on the grid)[163].

Figure 22 – Nottingham City Council ULEV schemes (Image source: Nottingham City Council)

The aim is to work out how electric vehicle storage and on-site generation can help optimise charging, maximise use of renewable generation and help balance the grid. This forms part of the council's wider plan to electrify its own vehicle fleet.

Nottingham now has a 10km 'eco expressway' which is the first in the country to give priority not only to public transport and active travel but also to ultra-low emission vehicles[164].

Nottingham City Council has a 50% stake in Blueprint, a local property developer that specialises in the development of sustainable homes and workplaces. Blueprint is the developer for the award winning Trent Basin housing project,[165] built on sustainability principles including being home to the largest communal battery in Europe, which distributes energy throughout the complex. Any unused energy is then sold back to the grid and the money is shared among residents. Solar panels and thermal energy sources are also used to minimise carbon emissions and maximise sustainability. Other transport features of the development are extensive charge points for electric vehicles, good public transport and bike access to the city centre via the eco expressway, discounted access to Enterprise car hire and a lay-out for the development which prioritises people over vehicles.

CONCLUSION

Given the urgency of the climate crisis, we need to break out of a siloed approach to both reducing carbon emissions and adapting to a warming world. This report has focused specifically on building awareness of the climate connections that can be made between transport and energy, and between transport and the decarbonisation and adaptation of the built environment. It does this at the city region level rather than the macro national or international level. It also focuses on policies and projects which city regions have a degree of autonomy over.

Whilst this report does not claim to be comprehensive in its coverage of these topics, it does seek to provide a non-technical framework for thinking through the options; to inspire; and to provide an insight into what is possible. It also shows the growing diversity of options (and good practice that can be learnt from) which can be built into transport projects and policies elsewhere.

The kind of projects, initiatives and policies featured in this report not only reduce carbon emissions, or improve climate resilience, they can also realise multiple wider economic, social and environmental benefits. These include lower energy, operating and maintenance costs; job creation; greener, healthier and more prosperous cities; improved air quality, and higher satisfaction among employees and customers of transport systems.

The report also highlights Nottingham as arguably the most advanced local authority in the UK in making these connections in a strategic way. It concludes that two factors have helped contribute to this: a long standing commitment to promoting environmental sustainability; and far greater retention of municipal ownership than is the norm in the UK. All of this has led to more municipal entrepreneurialism and innovation – as well a growing confidence in making connections across policy silos in pursuit of decarbonisation and other wider public policy goals, such as social inclusion.

In an era of centralisation, deregulation and privatisation, outside London in particular, Nottingham has been an outlier on municipal ownership. However, this may be changing. There are now examples of mass transit systems (including the Tyne and Wear Metro and the Midland Metro) where the operation is in public hands. Some city regions are now looking at taking direct control of the provision or ownership of their local bus services, the brakes are off on council housing construction, more local authorities now have their own development companies and more local authorities are running their own energy companies or initiating combined heat and power projects.

6

There are many reasons why this is happening including the strong economic argument that it can be cheaper to provide services directly. However, municipal control also arguably enables city region authorities to 'just get on with it' and make the connections more rapidly and effectively than having to negotiate with private sector companies which may have different motivations, goals and priorities.

The report's profile of Munich (home of one of Europe's largest municipal transport and utility companies) also shows how municipal ownership can help enable a city region to join the dots on energy and transport in pursuit of rapid decarbonisation.

Finally, the report demonstrates that we are just at the beginning of an accelerating process where what are initially pioneering projects, quickly become the new norm for all projects and policies.

This is essential as the transport infrastructure we build today will have to cope with more extreme weather that we face tomorrow. At the same time, the transport strategies we pursue now, have ramifications far beyond the small window in which climate scientists say we have to restrict climate change.

Now is the moment to systematically join the dots on climate.

REFERENCES

1. Department for Business, Energy and Industrial Strategy (2019) 2017 UK Greenhouse Gas Emissions ***https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/776083/2017_Final_emissions_statistics_one_page_summary.pdf***

2. Department for Business, Energy and Industrial Strategy (2019) 2017 UK Greenhouse Gas Emissions final figures – data tables ***https://www.gov.uk/government/statistics/final-uk-greenhouse-gas-emissions-national-statistics-1990-2017***

3. Department for Business, Energy and Industrial Strategy (2019) 2017 UK Greenhouse Gas Emissions ***https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/776083/2017_Final_emissions_statistics_one_page_summary.pdf***

4. Ibid.

5. HM Government (2008) Climate Change Act ***https://www.legislation.gov.uk/ukpga/2008/27/contents***

6. Committee on Climate Change (2019) Net Zero – The UK's contribution to stopping global warming ***https://www.theccc.org.uk/publication/net-zero-the-uks-contribution-to-stopping-global-warming/***

7. Prime Minster's Office (2019) PM Theresa May: we will end the UK contribution to climate change by 2050 ***https://www.gov.uk/government/news/pm-theresa-may-we-will-end-uk-contribution-to-climate-change-by-2050***

8. BBC News (2019) UK Parliament declares a climate change emergency ***https://www.bbc.co.uk/news/uk-politics-48126677***

9. C40 Cities (2019) Why Cities? ***https://www.c40.org/why_cities*** date accessed 16/05/2019

10. Holmes (2018) Climate change: the future of UK cities ***https://www.theccc.org.uk/2018/01/04/uk-cities-climate-change/***

11. Bailly (2018) Cities have led the way in reducing UK carbon emissions, but should do more to tackle transport pollution ***https://www.centreforcities.org/blog/cities-led-way-reducing-uk-carbon-emissions-tackle-transport-pollution/***

12. Centre for Cities (2019) CO_2 Emissions per Capita – taken from Cities Data Tool ***https://www.centreforcities.org/data-tool/su/98745615*** date accessed 21/05/2019

13. Centre for Cities (2019) CO^2 Emissions per Capita – taken from Cities Data Tool ***https://www.centreforcities.org/data-tool/su/98745615*** date accessed 21/05/2019

14. Environment Agency (2018) Climate change impacts and adaptation ***https://www.gov.uk/government/publications/climate-change-impacts-and-adaptation***

15. Ibid.

16. Holmes (2018) Climate change: the future of UK cities ***https://www.theccc.org.uk/2018/01/04/uk-cities-climate-change/***

17. Environmental Audit Committee (2018) Heatwaves: adapting to climate change ***https://www.parliament.uk/business/committees/committees-a-z/commons-select/environmental-audit-committee/news-parliament-2017/heatwaves-report-publication-17-19/***

18. Holmes (2018) Climate change: the future of UK cities ***https://www.theccc.org.uk/2018/01/04/uk-cities-climate-change/***

19. Town and Country Planning Association (2018) Evidence to Environmental Audit Committee inquiry – Heatwaves: adapting to climate change ***http://data.parliament.uk/writtenevidence/committeeevidence.svc/evidencedocument/environmental-audit-committee/heatwaves-adapting-to-climate-change/written/83056.html***

20. Living With Environmental Change partnership (2015) Infrastructure Report Card ***https://nerc.ukri.org/research/partnerships/ride/lwec/report-cards/infrastructure/***

21. Declare a Climate Emergency (2019) ***https://climateemergency.uk/***

22. Milligan (2019) The UK's cities are leading the charge to reduce carbon emissions ***https://www.energysavingtrust.org.uk/blog/uk%E2%80%99s-cities-are-leading-charge-reduce-carbon-emissions***

23. Taylor (2018) London's mayor unveils plan to tackle 'climate emergency' in The Guardian ***https://www.theguardian.com/uk-news/2018/dec/11/london-mayor-sadiq-khan-city-climate-emergency***

24. Ibid.

25. Leeds Climate Commission (2019) About Leeds Climate Commission ***http://leeds.candocities.org/about-leeds-climate-commission***

26. Ibid.

27. Can-do Cities (2019) About Can-do Cities ***http://www.candocities.org/about-can-do-cities***

28. Bristol Green Capital Partnership (2019) New ambitious target launched to double city tree canopy cover by 2050 ***https://bristolgreencapital.org/new-ambitious-target-launched-double-city-tree-canopy-cover-2050/***

29. Holmes (2018) Climate change: the future of UK cities ***https://www.theccc.org.uk/2018/01/04/uk-cities-climate-change/***

30. Woolaston (2017) 100% of electric Dutch trains now run on wind power ***https://www.wired.co.uk/article/dutch-trains-wind-power***

31. Ibid.

32. Guardian (2017) Dutch electric trains become 100% powered by wind energy ***https://www.theguardian.com/world/2017/jan/10/dutch-trains-100-percent-wind-powered-ns***

7

33. Rail Tech (2019) Dutch train stations will generate more solar energy ***https://www.theguardian.com/world/2017/jan/10/dutch-trains-100-percent-wind-powered-ns***

34. Ibid.

35. Ibid.

36. Splvack (2019) MTA looks to rooftop solar power to raise much-needed funds ***https://ny.curbed.com/2019/4/23/18511589/mta-nyc-transit-leases-rooftop-solar-power-profits***

37. Ibid.

38. Business Green (2014) World's largest solar-powered bridge opens in London ***https://www.theguardian.com/environment/2014/jan/22/worlds-largest-solar-powered-bridge-opens-in-london***

39. Ibid.

40. Railway Technology (2019) London Blackfriars Station Redevelopment, London ***https://www.railway-technology.com/projects/london-blackfriars/***

41. Business Green (2011) Work starts on solar bridge at Blackfriars ***https://www.theguardian.com/environment/2011/oct/04/solar-bridge-blackfriars-station***

42. Climate Action (2016) Canary Wharf launches solar power bus shelter ***http://www.climateaction.org/news/canary_wharf_launches_solar_power_bus_shelter***

43. Polysolar (2019) Transparent Solar Bus Shelter ***http://www.polysolar.co.uk/solar-pv-case-studies/transparent-solar-bus-shelter***

44. Burroughs (2019) British operator to test lineside solar power supply International Railway Journal ***https://www.railjournal.com/infrastructure/british-operator-to-test-lineside-solar-power-supply/***

45. Ibid.

46. Ibid.

47. Ibid.

48. TfGM (2014) Wind turbine at a rail station TfGM (Manchester) ***http://www.stib-mivb.be/irj/go/km/docs/resource/tickettokyoto/sites/default/files/downloads/T2K_WP2_Inv19_TfGM_wind_turbine.pdf***

49. Ibid.

50. Ibid.

51. IceWind (2016) IceWind's Storm Shelter launched ***http://icewind.is/en/icewinds-storm-shelter-launched/***

52. Ibid.

53. Renewables First (2011) Case study: Rochdale hydropower Archimedes screw turbine [online] ***https://www.renewablesfirst.co.uk/project-blog/rochdale-hydropower-scheme/***

54. Ibid.

55. TfGM (2014) Micro-hydroelectric power scheme TfGM (Manchester) – Investment Sheet [online] ***http://www.tickettokyoto.eu/sites/default/files/downloads/T2K_WP2_Inv20_TfGM_hydroelectric_power.pdf***

56. Ibid.

57. Merseyrail (2019) Our Achievements ***https://www.merseyrail.org/about-merseyrail/our-achievements.aspx***

58. Ibid.

59. TfGM (2014) Lighting control in a Manchester Interchange ***http://www.stib-mivb.be/irj/go/km/docs/resource/tickettokyoto/en/cases/lighting-control-manchester-interchange-tfgm.html***

60. Ibid.

61. Ibid.

62. TfGM (2014) Use of LED lighting in a Manchester Interchange ***http://www.stib-mivb.be/irj/go/km/docs/resource/tickettokyoto/en/cases/use-led-lighting-manchester-interchange-tfgm.html***

63. Ibid.

64. Ibid

65. RET (2014) Optimising heating installations in depots in Rotterdam ***http://www.stib-mivb.be/irj/go/km/docs/resource/tickettokyoto/en/cases/optimising-heating-installations-depots-rotterdam-ret.html***

66. Ibid.

67. Ibid.

68. Islington Council (2019) Bunhill heat network ***https://www.islington.gov.uk/energy-and-pollution/energy/bunhill-heat-network***

69. Ibid.

70. Ibid.

71. Euroheat & Power (2017) Bunhill Heat and Power – capturing waste heat from the London Underground – Case Study [online] ***https://www.euroheat.org/knowledge-centre/bunhill-heat-power-capturing-waste-heat-london-underground/***.

72. Celsius, Smart Cities (2018) Waste heat capture from the London Underground [online] ***http://celsiuscity.eu/Demonstrator/waste-heat-capture-and-utilisation%E2%80%8B/***

73. Thermos (2018) Pilot Cities – Islington, UK [online] *https://www.thermos-project.eu/cities/pilot-cities/#c178*

74. Shipman (2019) Warmth from the Tube's Northern line to be piped into hundreds of London homes by the end of the year in The Telegraph *https://www.telegraph.co.uk/news/2019/08/26/underground-line-set-heat-hundreds-homes-end-year/*

75. Passenger Transport (2019) HS2 could offer green energy for new homes, Issue 205

76. Ibid.

77. Ibid.

78. Transport for London (2015) Recycling energy from Tube trains to power stations *https://tfl.gov.uk/info-for/media/press-releases/2015/september/recycling-energy-from-tube-trains-to-power-stations*

79. Ibid.

80. Ibid.

81. RATP (2014) Heat pump in a metro station RATP (Paris) *http://www.stib-mivb.be/irj/go/km/docs/resource/tickettokyoto/sites/default/files/downloads/T2K_WP2_Inv26_RATP_heat_pump_metro.pdf*

82. Ibid.

83. Ibid.

84. SBB (2019) Energy efficiency *https://company.sbb.ch/en/sbb-as-business-partner/services-rus/energy/energiesparen.html*

85. Exemplary in energy initiative (2019) Annual report 2018 - Exemplary in energy *https://www.energie-vorbild.admin.ch/dam/vbe/en/dokumente/jahresbericht_2018.pdf.download.pdf/Energie-Vorbild-Jahresbericht-2018-EN.pdf*

86. SBB (2019) Setting standards in climate protection *https://company.sbb.ch/en/the-company/responsibility-society-environment/environment/climate-protection.html*

87. Exemplary in energy initiative (2019) Annual report 2018 - Exemplary in energy *https://www.energie-vorbild.admin.ch/dam/vbe/en/dokumente/jahresbericht_2018.pdf.download.pdf/Energie-Vorbild-Jahresbericht-2018-EN.pdf*

88. Ibid.

89. SBB (2019) Energy efficiency *https://company.sbb.ch/en/sbb-as-business-partner/services-rus/energy/energiesparen.html*

90. Ibid.

91. SBB (2019) Setting standards in climate protection *https://company.sbb.ch/en/the-company/responsibility-society-environment/environment/climate-protection.html*

92. Ibid.

93. UKGBC (2019) Climate Change *https://www.ukgbc.org/climate-change/*

94. Ibid.

95. Carbon Trust (2012) Building a lower-carbon construction industry *https://www.carbontrust.com/news/2012/02/building-a-lower-carbon-construction-industry-1/*

96. PRS Architects (2010) TfL West Ham Bus Garage – Green: at a price *http://www.prsarchitects.com/news/publications/tfl-west-ham-bus-garage-green-price*.

97. Strzala Architects (2019) Accrington Eco Station *https://www.strzarch.co.uk/accrington-station* and Community Rail Lancashire (2015) Accrington Eco Station *https://www.communityraillancashire.co.uk/wp-content/uploads/2015/05/Accrington-Leaflet.pdf*

98. Ibid.

99. Pötz (2016) Green-blue grids – Manual for resilient cities, atelier GROENBLAUW

100. Pötz (2016) Green-blue grids – Manual for resilient cities, atelier GROENBLAUW

101. Manchester City Council (2015) Manchester's Great Outdoors – a Green and Blue Infrastructure Strategy for Manchester 2015-25 *https://www.manchester.gov.uk/downloads/download/6314/manchester_green_and_blue_strategy*

102. Ibid.

103. Horticulture Week (2013) Green roof installed on Manchester Town Hall *https://www.hortweek.com/green-roof-installed-manchester-town-hall/landscape/article/1185152*

104. Manchester City Council (2015) Manchester's Great Outdoors – a Green and Blue Infrastructure Stakeholder Implementation Plan *https://www.manchester.gov.uk/downloads/download/6314/manchester_green_and_blue_strategy*

105. Hibbert (2015) It's alive! New 'Living Wall' planted as finishing touches put on Deansgate-Castlefield tram stop Manchester Evening News *https://www.manchestereveningnews.co.uk/news/greater-manchester-news/deansgate-castlefield-living-wall-tram-9723668*

106. Fitzgerald (2015) Beetham Tower architect Ian Simpson has tram stop turned into 'green oasis' to improve city centre view Manchester Evening News *https://www.manchestereveningnews.co.uk/news/greater-manchester-news/beetham-tower-architect-ian-simpson-9584554*

107. Sherwood (2019) Battle for clean air is sending our gardens to new heights The Guardian *https://www.theguardian.com/environment/2019/jul/13/living-walls-bloom-cities-tackle-air-pollution*

108. Biotecture (2016) Elephant and Castle Tube Station *https://www.biotecture.uk.com/portfolio/elephant-and-castle-tube-station/*

109. Inhabitat (2012) WVTTK Architect's Living Bus Shelter in Eindhoven is Overflowing with Plants *https://inhabitat.com/wvttk-architects-living-bus-shelter-in-eindhoven-is-overflowing-with-plants/*

110. Pötz (2016) Green-blue grids – Manual for resilient cities, atelier GROENBLAUW

111. Ibid.

112. Pötz (2016) Green-blue grids – Manual for resilient cities, atelier GROENBLAUW

113. Ibid.

114. Ibid.

115. Paris (2019) Jardin Atlantique *https://www.paris.fr/equipements/jardin-atlantique-1775*

116. Ibid.

117. Visit Berlin (2019) Natur-Park Schöneberger Südgelände *https://www.visitberlin.de/en/natur-park-schoneberger-sudgelande*

118. Grün Berlin (2019) Natur-Park Südgelände *https://gruen-berlin.de/en/natur-park-suedgelaende/about-the-park*

119. Ibid.

120. Sheffield City Council (2016) Grey to Green Phase 1 *http://www.greytogreen.org.uk/phase_1.html*

121. Ibid.

122. Sheffield City Council (2016) Sustainable Urban Drainage Systems *http://www.greytogreen.org.uk/suds.html*

123. Sheffield City Council (2016) Grey to Green Phase 1 *http://www.greytogreen.org.uk/phase_1.html*

124. Landscape Institute (2013) Creating healthy places: Dalston Eastern Curve Garden *https://www.youtube.com/watch?v=D0E4hfuoYvs*

125. Landscape Institute (2013) Public Health and Landscape – Creating healthy places *https://landscapewpstorage01.blob.core.windows.net/www-landscapeinstitute-org/2013/11/Public-Health-and-Landscape_FINAL_single-page.pdf*

126. Ibid.

127. The Edible Bus Stop (2019) The Edible Bus Route *https://theediblebusstop.org/edible-bus-route/*

128. Pötz (2016) Green-blue grids – Manual for resilient cities, atelier GROENBLAUW

129. Berger (2016) The 'Climate-Proofing' of Rotterdam, The Huffington Post *https://www.huffpost.com/entry/the-climate-proofing-of-rotterdam_b_57bf524fe4b0b01630de2431?ncid=engmodushpmg00000004*

130. Pötz (2016) Green-blue grids – Manual for resilient cities, atelier GROENBLAUW

131. Ibid.

132. Ibid.

133. Rotterdam Climate Initiative (2008) Rotterdam Climate Proof – adaptation programme *https://sdr.gdos.gov.pl/Documents/Wizyty/Belgia%20i%20Holandia/Program%20adaptacji%20do%20zmian%20klimatu%20w%20Rotterdamie.pdf*

134. Ibid.

135. SWM (2019) Annual Report *https://www.swm.de/dam/swm/dokumente/english/swm-annual-report.pdf*

136. MVG (2019) MVG in figures *https://www.mvg.de/dam/mvg/ueber/unternehmensprofil/mvg-in-figures-s*

137. SWM (2019) Annual Report *https://www.swm.de/dam/swm/dokumente/english/swm-annual-report.pdf*

138. SWM (2019) Renewable Energies *https://www.swm.de/english/company/renewable-energies.html*

139. Ibid.

140. Ibid.

141. SWM (2019) Annual Report *https://www.swm.de/dam/swm/dokumente/english/swm-annual-report.pdf*

142. Ibid.

143. Ibid.

144. Nottingham City Council (2019) Nottingham aims to be first carbon neutral city in the UK *http://www.mynottinghamnews.co.uk/nottingham-aims-to-be-first-carbon-neutral-city-in-the-uk/*

145. Nottingham City Council (2019) Workplace Parking Levy *https://www.nottinghamcity.gov.uk/wpl*

146. Department for Transport (2019) Light Rail Statistics LRT0109 *https://www.gov.uk/government/statistical-data-sets/light-rail-and-tram-statistics-lrt#passenger-journeys-vehicle-miles-vehicle-kilometres-and-occupancy-lrt01* and Department for Transport (2019) Local bus passenger journeys BUS0110 *https://www.gov.uk/government/statistical-data-sets/bus01-local-bus-passenger-journeys#table-bus0103*

147. Nottingham City Council, New electric buses power Nottingham's clean air ambitions *http://www.mynottinghamnews.co.uk/new-electric-buses-power-nottinghams-clean-air-ambitions/*

148. Nottingham City Transport (2019) Gas Buses *https://www.nctx.co.uk/gasbus*

149. Nottingham City Council (2019) Ultra Low Emission Vehicles *https://www.transportnottingham.com/driving/ultra-low-emission-vehicles/*

150. Nottingham City Council (2019) Cleaner streets, cleaner air – electric sweepers take to the streets *http://www.mynottinghamnews.co.uk/cleaner-streets-cleaner-air-electric-sweepers-take-to-the-streets/*

151. Nottingham City Council (2017) Hackney Carriage and Private Hire Vehicle Strategy 2017-2020 *https://www.nottinghamcity.gov.uk/media/456172/taxi-strategy-feb17.pdf*

152. EnviroEnergy (2019) About us *https://enviroenergy.co.uk/about-us/*

153. Ibid.

154. Robin Hood Energy (2019) About *https://robinhoodenergy.co.uk/about/*

155. Nottingham City Council (2018) Nottingham City Council sites have generated over ONE MILLION kilowatt hours of solar power in 2018 *http://www.mynottinghamnews.co.uk/nottingham-city-council-sites-have-generated-over-one-million-kilowatt-hours-of-solar-power-in-2018/*

156. Nottingham City Homes (2019) About us *https://www.nottinghamcityhomes.org.uk/about-us/*

157. Nottingham City Homes (2018) Gold award for Nottingham City Homes' approach to sustainability *https://www.nottinghamcityhomes.org.uk/about-us/news-and-newsletters/latest-news/gold-award-for-nottingham-city-homes-approach-to-sustainability/*

158. Ibid.

159. Ibid.

160. Nottingham City Transport (2019) Gas Buses *https://www.nctx.co.uk/gasbus*

161. Robin Hood Energy (2019) Robin Hood Energy wins Nottingham Tram contract from Big Six *https://robinhoodenergy.co.uk/news/nottingham-tram-contract/*

162. EvoEnergy (2015) Harvey Hadden Solar Carport Case Study *https://www.evoenergy.co.uk/case-studies/harvey-hadden-sports-village/*

163. Nottingham City Council (2019) Leading by example *https://www.transportnottingham.com/leading-by-example/*

164. D2N2 LEP (2017) New route for Nottingham's Ecolink *http://www.d2n2lep.org/News/new-route-for-nottinghams-ecolink*

165. Blueprint (2019 Trent Basin *https://www.blueprintregeneration.com/project/trent-basin-nottingham-waterside/*

Wellington House,
40-50 Wellington Street,
Leeds LS1 2DE

T 0113 251 7204
E info@urbantransportgroup.org
www.urbantransportgroup.org

URBAN TRANSPORT GROUP