Forging Scotland's Way Ahead: Low Carbon Transport Infrastructure

Valerie Robertson, Principal Environmental Economist, Jacobs

1 Introduction

The Scottish Government has set out a plan to dramatically reduce greenhouse gas emissions by 2050. While significant progress has been made in some areas, substantial challenges remain in many areas including transport if the 2050 targets are to be met. The urgent step-change that is required will only be achieved through significant investment in low carbon infrastructure.

Jacobs have also been working with the Low Carbon Infrastructure Taskforce to identify the kind of infrastructure which will be needed to forge Scotland's low carbon future. Of the final ten case studies, four are transport related and define projects or programmes that would make significant contributions to reducing carbon from transport, as well as providing many wider benefits.

This paper looks at the four transport case studies: major upgrades to the rail network, a new high speed rail line, low carbon transport hubs, and re-engineering cities for non-motorised transport. For each case study we explore the justification, current policy and key trends, economic viability and the wider economic, environmental and social impacts.

1.1 Background to this paper

1.2 The global risk of climate change

According to the World Economic Forum's Global Risk Report for 2016[i], failure of climate change adaptation and mitigation is the number one global risk in terms of impact and the third highest in risk in terms of likelihood. This is the eleventh such report and it notes that

> *"Environmental worries have been at the forefront in recent years, reflecting a sense that climate change–related risks have moved from hypothetical to certain because insufficient action has been undertaken to address them."*

Climate change is unequivocally happening already. The most recent IPCC report affirms that each of the last three decades has been successively warmer than any other decade since 1850. The atmosphere and oceans have warmed, sea level has risen and amounts of snow and ice have diminished. Many of these observed changes are unprecedented at any other time going back decades to millennia. At the same time, recent human-induced emissions of greenhouse gases are the highest in history.

1.3 Scotland's climate change targets

Scotland has world-leading ambitions to mitigate climate change. The Climate Change (Scotland) Act 2009 set statutory targets for emissions reductions in Scotland of:

- 42% reduction by 2020; and
- 80% reduction by 2050.

These targets surpass those in place at a UK level, and Scotland is making faster progress on cutting emission than the UK as a whole. However, the Scottish Government has not succeeded in meeting its first four annual targets despite significant progress in some sectors such as renewable electricity.

A requirement of the Climate Change (Scotland) Act is to report on the policies and proposals for meeting the annual, interim 2020, and 2050 targets. The reports must also set out the respective contributions toward meeting the targets that should be made by energy efficiency, energy generation,

land use and transport. The 2015 report on policies and proposals (RPP2) by the UK Committee on Climate Change concludes that the policies and proposals in RPP2 have the potential to deliver emissions abatement that would meet the targets set to 2027. However, substantial challenges remain in many areas including transport, if the emissions targets are to be met by 2050.

RPP3 which will report on the next set of targets for up to 2032 is due to be published in 2016/2017. The window of opportunity to influence the policies and proposals selected for RPP3 is now and it is critical that low carbon transport is a key feature.

2 The case for low carbon infrastructure

Significant development in low carbon infrastructure is required if Scotland is to meet its emissions reduction targets. Putting in place the right foundations now is critical to avoid locking Scotland into a high carbon future. These strategic decisions will dictate how we travel, heat our homes and power our industries now and through to 2050. They will also shape the profile of our economy, influencing the types of jobs we will have in the future.

Transitioning to a low carbon economy in Scotland requires billions of pounds in investment, but much of this cost needs to be spent anyway to modernise and maintain our infrastructure networks. Reorienting investment to include low carbon infrastructure and technology will reduce overall costs and secure lower emissions in the future.

The Scottish Government's current Infrastructure Investment Plan[ii] acknowledges that infrastructure should be viewed as a tool for supporting positive social and economic outcomes, namely high value public services and improved connectivity to support access to employment and to build economic resilience. The economic strategy echoes this position and also notes that investment must be prioritised to maximise "the opportunities offered by the transition to a more resource efficient, lower carbon economy."[iii]

In addition to emissions reductions, the benefits of low carbon infrastructure are numerous:

- Economy
    - Economic progress and resilience;
    - Economic progress and resilience
    - Job creation and skills development.
    - Supporting domestic industry
    - Driving innovation
    - Energy security
- Environment
    - Improving air quality
    - Influencing behaviour change
- Social
    - Health benefits
    - Reducing fuel poverty
    - Strengthening local communities

Given these opportunities and co-benefits, it is clear that a low carbon approach should be adopted for all infrastructure development.

3 Top ten low carbon infrastructure projects for Scotland

3.1 The long list

Jacobs recently delivered a report entitled *Forging Scotland's Way Ahead: Top Ten Low Carbon Infrastructure Projects for Scotland*[iv] for the Low Carbon Infrastructure Task Force, an independent

body established as part of a WWF Scotland initiative. The objective of the Task Force is to champion and encourage the public sector to fund and/or facilitate the finance of low carbon infrastructure. It brings together key figures across the infrastructure lifecycle in Scotland, from the public and private sectors, construction and finance industries, and academia, under an independent chair.

A 'long list' of infrastructure projects was developed that are of a sufficient scale to help achieve the transition to a low carbon Scotland as required by the Climate Change (Scotland) Act. The term 'project' here refers to possible projects (and programmes that could enable such projects) that the Scottish Government could support through policy development and direct investment. These projects are intended to be bold, transformative, and could be scaled to match investment on the level of major highways schemes. They are also intended to be additional to committed infrastructure spend and long term in their outlook.

The final list of projects is shown below:

1. Major upgrades of existing rail network
2. New high speed rail in Scotland
3. Re-engineering cities to favour non-motorised transport
4. Low carbon transport hubs
5. Programme of district heating schemes targeted at high rise domestic properties
6. Semi-rural district heating networks
7. City centre district heating network
8. Energy efficiency retrofit programme, addressing domestic, public sector and commercial buildings
9. Grow local energy economies with community scale energy storage
10. Energy from wastewater programme

The remainder of this section will focus on the four transport-related projects.

3.2 Major upgrades of the existing rail network

3.2.1 Overview

This programme consists of an accelerated upgrading of existing rail lines between the seven Scottish cities through dualling and electrification.

As an intermediate step, there is a need to remove current blockages from the network where insufficient 'loading gauge' clearance is limiting the cost-effective passage of taller and wider modern-generation freight containers.

The preferred first leg for improvement is the Highland Main Line from Perth to Inverness which is primarily single track. An upgrade would provide a significant increase in capacity for both passenger spaces and freight. Currently freight trains are required to divert to allow for passenger trains to pass, significantly increasing journey times for goods. Dualling and blockage clearance would allow the use of 28 container freight trains to travel on the line (currently limited to 20 containers) as well as more frequent passenger and freight services. This increase in volume would make rail freight more economical and therefore more competitive with road freight. It would also enhance the growth and development that has taken place in Inverness and the region in recent years.

There is an existing £5 billion package of funding and investment for Scottish railways until 2019. This is supporting improvements to infrastructure and services across the network, including substantial improvements to the Highland Main Line and the route between Aberdeen to Inverness. These may partially address some of the network constraints highlighted here, however further investment is required to facilitate freight modal shift.

3.2.2 Justification

There is a need to transform Scotland's rail capability in order to compete with road journeys both for passengers and freight. The planned programme to dual the A9 and A96 will substantially strengthen the competitive position of road haulage against rail freight in the medium to long term, while in the short term the trial of a higher speed limit of 50mph (up from 40 mph) for lorries on single-carriageway sections of the A9 has already allowed road hauliers to cut journey times from the Central Belt to Inverness by up to half an hour – with no compensating enhancements for rail freight. A more balanced level of investment should be directed towards dualling single-track sections of the rail network to redress this imbalance.

There are significant energy and carbon savings in rail travel in comparison to road journeys, particularly for freight transport. Rail freight is estimated to require approximately a quarter to a third of the energy required for road haulage[v]. This saving would be further enhanced by electrification of the rail network, increasing over time through decarbonisation of the grid.

The shift of freight and passengers to rail is recognised by Network Rail as having significant advantages beyond carbon savings including improved air quality, reduced journey times and associated economic benefits, safer journeys and reduced road maintenance costs by lessening the wear and tear imposed by 44-tonne lorries on road surfaces.

This programme would be an appropriate response to the growth in both passenger and rail freight traffic. Passenger rail use has grown by 50% over the period 2003-2013[vi] (average 4% growth per year). Rail freight in Scotland has increased slightly from the mid-1990s "all time low" to around 7-14 million tonnes in recent years. However, road accounts for the vast majority of freight traffic in Scotland both in terms of "tonnes lifted" and "tonne – kilometres"[vii]. Rail freight is most economical for long-haul journeys of 300km or greater, although short haul journeys can achieve good returns in comparison to road depending on the volume transported and other factors. Over one-third (36%) of road freight movements in Scotland are over long haul distances of 300km or more[viii]. These journeys are more likely to be suited to modal shift onto rail.

3.2.3 Economic viability

Based on costs from recent major rail schemes in Scotland, the estimated cost of rail upgrade to dualling and electrification is between £20-30m per mile. A review of recent road projects throughout the UK reveals a huge variation in road dualling costs, ranging from £1.1 - £146m per mile, with a median cost of £18m and a mean of £30m per mile[ix]. The dualling and electrification of all major lines between the cities is yet to be quantified. An initial cost estimate for the Perth to Inverness leg is £1bn[x].

The upgrading of existing lines must go hand-in-hand with terminal development to allow freight access onto the railways. Existing terminals will require upgrading and additional terminals will be required – starting with Dundee, Tayside and Fife in order to serve the whisky industry. It is likely that the terminal development would be part funded by government and service providers. Potential private sector contributions could include major industry players such as the whisky and forestry sectors.

3.2.4 Benefits assessment

Table 1 below summarises the complementary benefits of a major programme of upgrades to the existing rail network.

Table 1: Wider benefits of major programme of upgrades to the existing rail network

Benefits Assessment	
	**Additionality (Amber)** Over and above existing efforts. There are plans to upgrade individual sections of the network; however an accelerated programme is needed with a commitment to address all of the lines linking the seven cities.
	**Prosperity (Green)** Construction job creation as well as improved access to labour markets through connectivity.
	**Co-benefits (Green)** Significant potential benefits include safety and reduced maintenance costs of displacing passenger and freight journeys from road to rail.
	**Environment (Green)** Air quality benefits from electrification based on existing rail use patterns. Further air quality benefits from inducing modal shift from road to rail.
	**Behaviours (Green)** Enables public and businesses to make low carbon transport choices and encourages modal shift.

3.3 New high speed rail in Scotland

3.3.1 Overview

The project would develop new high speed rail capacity in Scotland. High speed refers to travel at speeds of up to 150 mph, rather than the 225 mph speeds proposed for HS2 which come at a significant cost premium. The motivation behind new high speed lines is to reduce travel times, increase capacity and connectivity between the north east and the Central Belt and further south, both through new lines and by freeing capacity on existing lines. The goal is to encourage modal shift for both passengers and freight, away from road and air.

Ensuring Scotland's inclusion in a UK high speed rail network is a priority for the Scottish Government[xi], but it is noted that this would be contingent on the UK Government committing to building to the border. There are several potential route options; however this case study explores the opportunity to develop a new high speed electrified rail link between Glasgow/Edinburgh and Aberdeen. This would cut journey times to 80 minutes compared to current times of around 160 minutes. Improving the connectivity between Scotland's largest northerly city and the Central Belt would create new employment flexibility and access to labour markets. It would also significantly increase passenger and freight capacity, through adding both speed and line capacity to the existing rail infrastructure.

This need to improve connectivity particularly between Edinburgh and Aberdeen was recognised as a key project in the Strategic Transport Projects Review (STPR) but this proposed project would achieve carbon savings and connectivity benefits at a scale significantly greater than the measures suggested in the STPR. Significantly it would also free up capacity of the existing line which links Aberdeen with Montrose, Arbroath and Dundee to maximise the potential for freight modal shift.

There are further opportunities for improving rail connectivity and journey times between Scotland's cities, such as the 'Inter-City Express' concept proposed by Transform Scotland , which includes a range of measures including a new route between Edinburgh and Perth.

3.3.2 Justification

It is recognised that connectivity between Scotland's cities is a key factor to fostering economic resilience. As the economy of Aberdeen begins to diversify it is important that the links to the Central Belt, and on to strategic centres in England such as London, Manchester, Leeds and Birmingham, are enhanced to support that diversification and investment. This need for connectivity must be achieved in a sustainable manner and a modal shift from road to rail fits with that aspiration.

While Edinburgh, Glasgow, Perth and Dundee are all within a reasonable travel time of each other, the journey time to Aberdeen is between two and three hours depending on the time of day. Both the distance and average speeds attributed to the nature of the existing infrastructure act as constraints, limiting Aberdeen's ability to interact with the major economic centres of Edinburgh and Glasgow and to derive benefits from business or freight movements. The existing single track line means that services are interrupted by having to pull in to wait for trains to pass in the opposite direction. In order to displace road journeys, a significant reduction in rail journey times is required.

Rail Enhancements between Aberdeen and the Central Belt is identified as one of the 29 targeted infrastructure improvements in the STPR. However this would reduce journey times by only 20 minutes and offer limited improvements in freight capacity. There is also recognition in the STPR that the current provision will not accommodate future demand. A new rail link would offer greater benefits in terms of carbon savings and improved connectivity to Scotland and the rest of the UK.

The Rail Enhancement measures in the STPR also include upgrading the single track section through the Montrose Basin which is an internationally designated site of importance for breeding birds. The new rail link would potentially avoid negative environmental impacts on the basin from the proposed works.

3.3.3 Economic viability

The costs of a new rail link would be substantial, estimated to be in the order of £4-10bn pounds for 100 miles of new track.

The low end estimate is based on an international study on unit cost projections for new transport infrastructure[xii] which reported figures of £36-£50m per mile of high speed track in OECD countries. The high-end cost is based on an estimated £120-£130m per mile for HS2[xiii]; however the proposed link would not be expected to achieve the 225mph speeds of HS2 therefore would not be as expensive.

3.3.4 Benefits assessment

Table 2 below summarises the complementary benefits of a new high speed rail link in Scotland.

Table 2: Wider benefits of a new high speed rail link in Scotland

Benefits Assessment	
	**Additionality (Green)** Additional to existing efforts. This is an ambitious project which is outside the scope of current national infrastructure plans.
	**Prosperity (Green)** Contributes toward economic resilience of Aberdeen as the economy diversifies and access to markets in Scotland and the UK becomes increasingly important.
	**Co-benefits (Amber)** Potential benefits include safety and reduced maintenance costs from displacing passenger and freight journeys off of roads.

	**Environment (Amber)** Improved air quality through displacing passenger journeys from road/air and freight journeys from road to rail.
	**Behaviours (Green)** Enables public and businesses to make low carbon transport choices and encourages modal shift.

3.4 Re-engineering cities to favour non-motorised transport

3.4.1 Overview

This project is aligned with the policy direction of the Scottish Government around both active travel infrastructure and Low Emission Zones, but proposes a step change in the ambition level.

The goal is to create more 'liveable' cities with lower dependence on private car ownership, reduced air pollution and that are safer for pedestrians and cyclists. This would be achieved through re-engineering areas of city centres to be predominantly car-free, with well-designed and connected infrastructure for pedestrians and cyclists to connect these areas to surrounding populations and a systems level approach to public transport. The scope of this objective is to deliver change to all urban areas across Scotland, but Glasgow, as the largest city, is used as an example in this case study.
Measures to favour non-motorised transport include:

- Transformational change in the provision of cycling infrastructure. This would include segregated cycle paths along strategic routes into the city from suburban areas. An increase in the number of secure, undercover parking spaces for bikes in cities would be required. Cycle share schemes would be initiated, or expanded to cover larger areas of cities where they already exist.
- Significant restrictions on the use of private motorised vehicles in city centres. There are various approaches to this. Large areas of the city centre could be completely closed to private vehicles, with only taxis, buses and distribution vehicles allowed in these zones with reductions in speed limits. Alternatively a congestion charging approach could be adopted, or traffic circulation plans introduced, to displace traffic from the city centre and promote cycling as the preferred means of transport for cross-city trips.
- Ultra-low emission zones in city centre areas to discourage use of internal combustion engine vehicles. A system to ensure compliance and manage fines or charges, such as a network of cameras, would need to be installed and operated.
- Improve cities for pedestrians in terms of safety, health and aesthetics by increasing the scale and number of walkways uninterrupted by traffic, or pedestrianising streets to 'reclaim' cities from cars. Greenways design characteristics could be adopted to create attractive, green pedestrian environments where people want to spend time. This is done by adding landscaping and vegetation to walkways and cycle paths.
- A systems approach to urban travel would need to be adopted to ensure good access to the city centre is retained. This might include a variety of travel modes, including rail and surface transport, support for car clubs or park and ride schemes.

The ambition and type of measures adopted will depend upon the characteristics of the city in question and the political will at a local government level to make these types of bold changes. The level of ambition could be increased to a coordinated programme of re-allocating city space away from motorised transport across all main cities if it were deemed strategically important at a national level.

3.4.2 Justification

The majority of Scotland's population (81%) live in urban areas and the general trend is towards increased urbanisation. The seven cities of Aberdeen, Dundee, Edinburgh, Glasgow, Inverness, Perth and Stirling account for roughly 1.7m or 33% of the total population. Cities become 'locked in' to particular patterns of transport use, predominately due to historical infrastructure investments and institutional inflexibility. Understanding how to re-engineer cities and urban infrastructure will be essential for transforming the built environment and achieving a low carbon Scotland.

Reducing private vehicle use in cities, and particularly reducing or completely removing internal combustion engine vehicles, can make significant reductions in carbon emissions, but also improve local air quality, with associated health and economic benefits to city populations and services.

The Scottish Government is supportive of approaches to make cities more liveable, including reducing harmful emissions and promoting walking and cycling for short journeys. Low Emission Zones (LEZs) are part of proposals outlined in the Cleaner Air for Scotland (CAFS) strategy[xiv] which features a Low Emission Zone Framework. This will follow the principles of Scottish Transport Appraisal Guidance (STAG) in order to properly appraise the benefits or otherwise of an LEZ for an AQMA area.

Glasgow is a city where the existing transport infrastructure, property and business types lend themselves to being adapted. Glasgow air pollution is among the UK's worst, and there are Air Quality Management Areas (AQMAs) in three parts of the city[xv].

Cycling is becoming an increasingly popular mode of transport in Glasgow, with an increase of 207% between 2007 and 2014[xvi]. This project would tie in with the Glasgow and Clyde Valley City Deal – the first City Deal to be agreed in Scotland. UK Government, Scottish Government and local authorities have jointly contributed funding of £1.1bn. So far, approximately £415m has been committed to infrastructure projects, with approximately £280m related to improved pedestrian and cycle access[xvii]. There is potential to tap into the remaining budget available to expand on these measures and truly transform Glasgow's city space as an exemplar for other Scottish cities.

3.4.3 Economic viability

While isolated cycling infrastructure schemes are relatively inexpensive in comparison to road schemes, a bold reengineering of a city would involve significant public consultation and capital expense, particularly when additional public transport services need to be funded. The introduction of LEZs would require a compliance system to be installed, and there would be operating costs for maintenance and resourcing that are not covered by the collection of fines.

Taking a more holistic view, it has long been recognised that with regard to cycling infrastructure, societal benefits far outweigh the costs – with benefits including physical fitness, reduction in absenteeism and reduced air pollution. This may result in direct savings to the NHS, the employers and cyclists. A UK Government appraisal showed a 5.5 to 1 benefit to cost ratio for cycling grants[xviii]. The cost of air pollution to society is also highlighted, with the World Health Organisation estimating that air pollution cost the UK £54B, or 3.7% of GDP per year.

3.4.4 Benefits assessment

Table 3 below summarises the complementary benefits of reengineering cities to favour non-motorised transport.

Table 3: Wider benefits of reengineering cities to favour non-motorised transport

Benefits Assessment

	**Additionality (Green)** Significantly additional to existing investment in active travel infrastructure and Low Emissions Strategy Consultation.
	**Prosperity (Green)** Despite concerns from local businesses, international experience has shown that removal of car traffic supports local businesses and can regenerate areas.
	**Co-benefits (Green)** Health benefits for local population, both due to active travel and cleaner air.
	**Environment (Green)** Air quality improvements and water quality improvements through reduced surface runoff, provided problems aren't transferred elsewhere.
	**Behaviours (Green)** Will actively promote behavioural change to support low carbon healthy lifestyles.

3.5 Low carbon transport hubs

3.5.1 Overview

This project involves the creation of transport hubs in and around major cities dedicated to recharging provision for low-carbon travel. They would primarily be for the use of electric vehicles (EVs), but could also be used for hydrogen generation and refuelling. The concept would see the hubs serving a variety of users - available to the general public but also serving an array of businesses and service providers, such as EV taxi companies, EV car clubs, EV distribution companies taking the "last mile" of goods deliveries, and hydrogen refuelling for city bus services. The concept could also be viewed as providing future bases for driverless electric cars which could provide taxi services.

3.5.2 Justification

A 2010 report by WWF estimates that 1 in 10 cars on the road must be electric by 2020 if Scotland is to achieve its climate targets[xix]. The Scottish Government has expressed its aim for towns and cities to be free of petrol/diesel emissions by 2050[xx] and has also launched the Cleaner Air for Scotland Strategy to address air quality emissions through increased uptake of low and zero carbon fuels. While currently there are an estimated 37,000 EVs on the road in the UK[xxi] the trend is still towards petrol and diesel fuels. Transformational change is needed to support a larger number of Electric and low carbon vehicles – a move away from individual charging points towards larger hubs on strategic corridors which cater for transport needs.

To date, ChargePlace Scotland electric charging infrastructure has been funded by Transport Scotland and installed where local authorities have existing land available. The network now comprises over 800 public charging bays across all 32 local authorities. In addition to providing a wide distribution of chargers, a particular focus has been on providing rapid chargers on strategic routes connecting Scotland's towns and cities. Thu far, there has not been the resources available to purchase land in strategic locations to provide hubs with multiple chargers (suggested maximum intervals of 35 miles and coverage in city centres) to accommodate the growing number of EVs.

While the primary means of charging electric vehicles is at home, it must be recognised that many householders, such as those living in tenement blocks, don't have access to off street parking and therefore there is a role for the public sector in ensuring access to charging infrastructure.

The "last mile" of distribution into dense urban areas is often highlighted as problematic, for several reasons including air quality, carbon emissions and congestion. Transport of goods to the periphery of urban centres is likely to involve diesel or LPG vehicles, due to the loads and distances involved. However, the use of low carbon vehicles could replace the final distribution stage into cities to supply retailers, other businesses and individuals.

In addition to EV charging points, the hubs could also install electrolysers to generate hydrogen for refuelling fuel cell buses and cars. The deployment of rapid EV chargers requires distribution network upgrades, and given that these power sources would only be required intermittently, there is the potential to use spare capacity to generate hydrogen, particularly during periods when the grid has surplus energy.

Existing infrastructure would be well utilised and enhanced by this project, which would rely on the current road network and freight distribution channels already in place. It would coexist well with Transport Scotland's plans to extend the EV charging network in Scotland as outlined in the plug-in vehicles 'roadmap'[xxii] and could take guidance from Aberdeen from how best to incorporate hydrogen from its capacity as Europe's 'hydrogen hub'.

3.5.3 Economic viability

The infrastructure cost for the hubs would need to include land purchase, building development costs, EV charging equipment, plus hydrogen generation, storage and fuelling equipment. There would also be a need to update road infrastructure in the surrounding areas.

Grants provided for rapid EV chargers are currently £40K, which breaks down into roughly £25K for the unit and £15K for the electrical connection and other costs. Assuming some efficiencies of scale, 50 rapid chargers to support a diverse range of EV businesses may cost in the order of £1.5-2m.

For the hydrogen infrastructure, purchase of electrolysers for producing and storing hydrogen cost around £2m per MW of electrolyser capacity. If this was to be linked to fuel cell buses, these cost around £1m each but the price would reduce to around £650K if large numbers were procured. A hydrogen refuelling station for the buses would cost around £700K[xxiii].

The total cost would depend upon the configuration of the hub and land purchase costs, but based on these indicative costs it could be in excess of £5-10m.

The ongoing business case for the hub would be based upon the value of the electricity/ hydrogen to the individuals and businesses served. The value of this market would be expected to grow over time as businesses and public adapt.

3.5.4 Benefits assessment

Table 4 below summarises the complementary benefits of low carbon transport hubs.

Table 4: Wider benefits of low carbon transport hubs

Benefits Assessment	
	**Additionality (Amber)** EV infrastructure is being developed across Scotland, including some isolated cases of hydrogen infrastructure, but this proposal is a significant increase in scale.

	**Prosperity (Amber)** Local employment during development and a small number of ongoing jobs in operation.
	**Co-benefits (Green)** Health benefits from improvements in air quality, reduction in congestion if reliance on private car ownership is reduced.
	**Environment (Amber)** Improvements in local air quality. Some concerns over the environmental impacts of EV batteries.
	**Behaviours (Green)** A multi-stranded approach (taxis, car-clubs, distribution vehicles, high profile infrastructure) will encourage a high degree of public engagement.

4 Conclusions

The progress that has been made towards reducing Scotland's carbon emissions provides a good foundation and policy framework from which to build. However, a step change in the pace and scale of low carbon infrastructure development is required. The infrastructure that is built over the next five to ten years will be the infrastructure in use in 2050, and it is crucial that this infrastructure enables low carbon behaviours for all, rather than locking us into a high carbon trajectory.

The case study projects set out here are intended to stimulate debate within Scotland on the type and location of new infrastructure that we need to help us meet our climate change targets. The approach to developing low carbon infrastructure needs to be at a systems level, taking an area based and cross-sectoral view to understand how projects complement each other. There are lessons that Scotland can learn from infrastructure development internationally, where evidence based strategic plans are developed and followed through.

The key to maximising the wider benefits delivered by infrastructure is to focus on outcomes rather than outputs. This may require a change in approach to the way transport and other infrastructure projects are appraised, as well as much deeper collaboration across sectors (e.g. health and transport).

Acknowledgements

The report '*Forging Scotland's Way Ahead: Ten Projects for a Low Carbon Future'* (Jacobs 2015) was developed in collaboration with the Low Carbon Infrastructure Task Force:

Sara Thiam, Chair, Institution of Civil Engineers
Elizabeth Dirth, 2050 Climate Group
Sam Gardner, WWF Scotland
Alex Hilliam, Changeworks
Andy Kerr, Edinburgh Centre for Carbon Innovation
Ross Martin, SCDI
Janice Pauwels, Scottish Cities Alliance/City of Edinburgh Council
Paul Steen, Ramboll
Gavin Templeton, Green Investment Bank
Katherine Trebeck, Oxfam GB
Kate Turner, Pinsent Masons
Brian Veitch, Veitch Consult

Observer
Mary McAllan, Scottish Government

In addition, a number of experts were interviewed when developing the ideas presented in the report, and their contributions are gratefully acknowledged:

Andrew Howie (Air Products)
Chris Morris (Local Energy Scotland)
Ciaran Higgins (Glasgow Future Cities Programme)
Colin Cunningham (University of Strathclyde)
Colin Imrie (Scottish Government)
Dave Pearson (Star Renewables)
David Forbes (SSE Heat Networks)
David Spaven (Rail Freight Group)
David Townsend (Town Rock Energy)
Dr Derek Pedley (Environmental Sustainability KTN)
Emma Greer (Massachusetts Institute of Technology)
Ewan Swaffield (Transport Scotland)
Gregor Patterson-Jones (Green Investment Bank)
Ian Arbon (University of Glasgow / Engineered Solutions)
Jim Purves (Celtic Renewables)
Julie Alexander (Siemens)
Keira McLuskey (Network Rail)
Laurence Kenny (Transport Scotland)
Malcolm Ball (Green Investment Bank)
Mark Williams (Scottish Water)
Martin McCaffrey (Green Investment Bank)
Nicholas Gubbins (Community Energy Scotland)
Nigel Holmes (Scottish Hydrogen and Fuel Cell Association)
Nigel Wunsch (Network Rail)
Paul Younger (University of Glasgow)
Prof. Dr. Eduard Heindl (Heindl Energy)
Professor Mercedes Maroto-Valer (Heriot Watt Energy Academy)
Richard Bellingham (University of Strathclyde)
Richard Braakenburg (Green Investment Bank)
Robert Werner (Heindl Energy)
Rufus Ford (SSE Heat Networks)
Simon Parsons (Scottish Water)
Simon Tricker (Urban Tide)
Stephen Carr (Highland Council)
Stephen Good (Construction Scotland Innovation Centre).

[i] http://knowledge.zurich.com/risk-interconnectivity/global-risks-report-2016/?WT.mc_id=z_cp_b2b_ba_4250369_8745264_1513381_127428540_63013356

[ii] Scottish Government, Edinburgh (2015). Infrastructure Investment Plan 2015.

[iii] Scottish Government (2015) *Scotland's Economic Strategy Summary* [Online] Available from: http://www.gov.scot/Publications/2015/03/8171 [Accessed August 2015].

[iv] Jacobs (2015). *Forging Scotland's Way Ahead: Ten Projects for a Low Carbon Future*. [Online] Available from: https://scotlandswayahead.org.uk/news/tenprojectsreport [Accessed March 2016].

[v] Rail Delivery Group (2015) Freight Britain continuity and certainty for rail freight. [Online] Available from: http://www.raildeliverygroup.com/what-we-do/publications.html?task=file.download&id=287 [Accessed August 2015].

[vi] Transport Scotland (2014) Tables SUM2: Summary of transport in Scotland. [Online table] Available from: http://www.transportscotland.gov.uk/statistics/j333840-09.htm#sthash.dKbusmX7.dpuf [Accessed August 2015].

[vii] Transport Scotland (2014) Freight Transport. [Online] Available from: http://www.transportscotland.gov.uk/statistics/statistical-trends/freight-transport [Accessed August 2015].

[viii] Transport Scotland (2014) Chapter 3: Road Freight. [Online] Available from: http://www.transportscotland.gov.uk/statistics/j357783-06.htm [Accessed August 2015].

[ix] Campaign for Better Transport (n.d.) Current road proposals. [Online] Available from: http://www.bettertransport.org.uk/roads-nowhere/map-text [Accessed August 2015].

[x] Intercity Express (n.d.) Inverness to Perth. [Online] Available from: http://intercityexpress.transformscotland.org.uk/what-we-want/perth-inverness/ [Accessed August 2015].

[xi] Transport Scotland (2015) Cabinet Secretary Keith Brown announces step forwards for high speed rail in Scotland. [Online] Available from: http://www.transportscotland.gov.uk/news/cabinet-secretary-keith-brown-announces-step-forward-high-speed-rail-scotland [Accessed August 2015].

[xii] UNECE Workshop (2014) Estimating and Benchmarking Transport Infrastructure. [Online] Available from: http://www.unece.org/fileadmin/DAM/trans/doc/2014/wp5/7_Mr_Tsamboulas_WP5_workshop_8Sept2014.pdf [Accessed August 2015].

[xiii] BBC News (2013) HS2: 12 Arguments for and against. [Online] Available from: http://www.bbc.co.uk/news/magazine-24159571 [Accessed August 2015].

[xiv] Scottish Government, Edinburgh (2015). Cleaner Air for Scotland: The Road to a Healthier Future. [Online] Available from: http://www.gov.scot/Resource/0048/00488493.pdf [Accessed March 2016].

[xv] Glasgow City Council (2014) Local Air Quality Management [Online] Available from: http://www.glasgow.gov.uk/localairqualitymanagement [Accessed August 2015].

[xvi] Glasgow City Council (2014) Cycling journeys into Glasgow increase by over 200% [Online] Available from: https://www.glasgow.gov.uk/index.aspx?articleid=14219 [Accessed August 2015].

[xvii] Evening Times (2015) The City Deal in detail...how Glasgow will spend share of £1.13bn [Online] Available from: http://www.eveningtimes.co.uk/news/13331778.The_City_Deal_in_detail___how_Glasgow_will_spend_share_of___1_13bn/ [Accessed August 2015].

[xviii] DfT (2014) Value for Money Assessment for Cycling Grants [Online] Available from: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/348943/vfm-assessment-of-cycling-grants.pdf [Accessed August 2015].

[xix] WWF, 2010. Watt Car? Available from: http://assets.wwf.org.uk/downloads/evs_report_web2.pdf [Accessed August 2015]

[xx] BBC News, 2013. Scottish government pledge to end car emissions by 2050. Available from: http://www.bbc.co.uk/news/uk-scotland-24063461 [Accessed 08/15]

[xxi] Next Green Car, 2015. Electric car market statistics. http://www.nextgreencar.com/electric-cars/statistics/ [Accessed 08/15]

[xxii] Transport Scotland, 2013. Switched on Scotland: A Roadmap to Widespread Adoption of Plug-in Vehicles. [Online] Available from: http://www.transportscotland.gov.uk/sites/default/files/documents/rrd_reports/uploaded_reports/j272736/j272736.pdf [Accessed August 2015]

[xxiii] Aberdeen City Council, 2015. H2 Aberdeen: Hydrogen Bus Project. Available at: http://aberdeeninvestlivevisit.co.uk/Invest/Aberdeens-Economy/City-Projects/H2-Aberdeen/Hydrogen-Bus/Hydrogen-Bus-Project.aspx [Accessed 08/15]