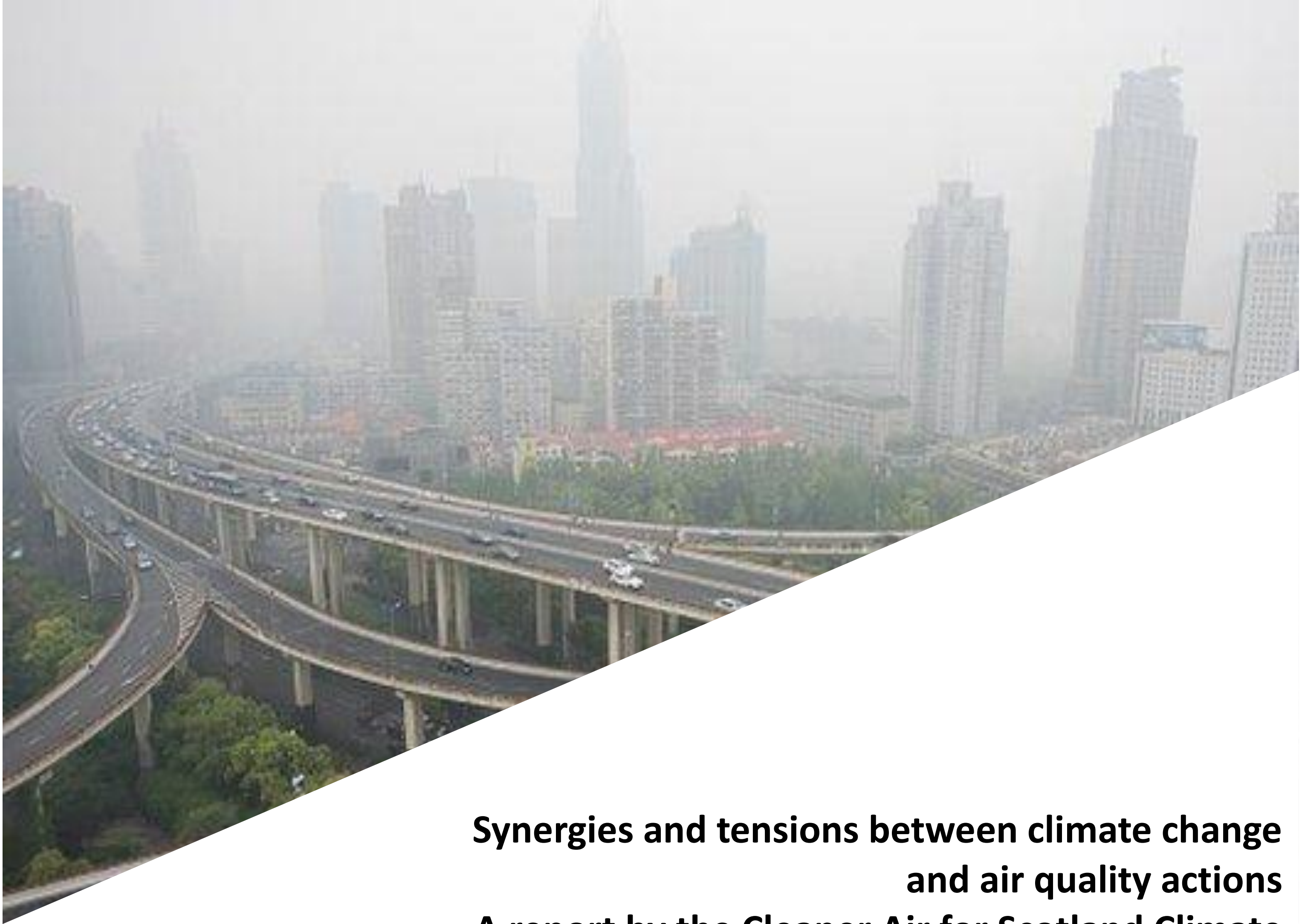

# Synergies and tensions between climate change and air quality actions

## A report by the Cleaner Air for Scotland Climate Change Sub-Group

**October 2016**

# An assessment of the major potential synergies and tensions between climate change actions and air quality actions in Scotland

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**October 2016**

This report was commissioned by the Cleaner Air for Scotland Governance Group and prepared by its Climate Change Sub-Group. The contents of the report are solely the responsibility of the Climate Change Sub-Group.

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## Foreword

This report was prepared by the Cleaner Air for Scotland (CAFS) Climate Change Sub-Group in fulfilment of action CC1 in the Scottish Government document "Cleaner Air for Scotland – The Road to a Healthier Future" (November 2015).

Action CC1 states "Ensure that future updates to the 'Low Carbon Scotland: Meeting our Emission Reduction Targets' publication on meeting our climate change targets take into account air quality impacts". This report was therefore prepared for, and submitted to, Scottish Government in time to support the final drafting of the update during late 2016.

This report does not offer either a reflection, or critique, of current Scottish Government policy.

This report represents the best endeavours of the authoring group. Given the time and resource constraints, it is not claimed to be either fully comprehensive or definitive. The report does not offer recommendations but only findings; it should be used as a first-pass filter for intended climate change and air quality actions, prompting further more detailed technical assessment.

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**Front cover:** *"Don't blow it – good planets are hard to find"* Time Magazine

Climate change and air quality are globally interconnected problems

We must learn from good and bad practice around the world

# 1. Executive Summary

## The 50 Key Findings of this Report

This report identifies six key sectors which can contribute positively to reducing Scotland's climate change emissions while at the same time supporting reductions in air pollution levels.

The findings suggest that travel choices can evolve to unlock multiple benefits, not just for climate and air quality, but also for personal health and welfare, for safety and for population health; however, the achievement of modal shifts in transport choices will require much more focus, priority and investment given to active and sustainable transport. Equally, it is found that land management can often reduce costs while maintaining productivity if appropriate climate and air quality actions are considered. It seems there may be further opportunities for modernised regulation to support industry in attaining improved carbon and other atmospheric emissions while, at the same time, encouraging economic success and community protection. A gathering momentum towards a circular economy will deliver significant co-benefits.  There is evidence that we can create better civic space, buildings and homes which are more energy-efficient and use materials that embody lower resource-use.  Such spaces can be more attractive as places in which to invest and in which to live and work. There are opportunities to revise Scotland's planning system to facilitate all of these beneficial changes and to grasp the available multiple benefits.

Scotland has shown itself to be a world-leader in climate change action.  Now it can also lead in demonstrating the multiple benefits which can be unlocked through further ambition and innovation in the linking of climate change to air quality.

Further detail is provided for each of the six sectors

### *Transport Sector*

*It is important to be clear that no single approach is appropriate and, indeed, there should be commitment to multiple, concurrent approaches that taken together will have a positive and synergistic impact on both climate change emissions and air quality. Underlying the specific findings listed below is the presumption that increased investment in more sustainable forms of active and public transport should be matched by more focused evaluation of less sustainable development.*

1. *Significantly increasing the long-term investment in active travel to increase walking and cycling in towns and cities. Specifically:*

*Increased investment in walking and cycling infrastructure supported by behaviour change campaigns and road speed reductions, such as 20 mph zones*

*Integrating journey options for active travel and public transport locally and nationally*

*Promoting a modal shift away from the car through local and national policies, school streets projects, urban planning, car share schemes*

*It is suggested that the Place Standard has a role in encouraging the design of neighbourhoods that prioritise walking and cycling, restrict traffic speed, and promote safe travel to school.*

2. *Increasing investment in active travel will help reduce air pollution problems locally and climate change emissions overall. However, alongside and linked to this, there needs to be continuous improvement in the methodology for assessing the need for and impact of road building, taking much more explicit account of climate change, air quality and health impacts. It is also suggested that a policy position be adopted to provide redirected funds for alternative more sustainable transport options, and to help arrest the continuing upward trend in car distances driven and registered motor vehicles in Scotland.*
3. *Future low emission zones could regulate for air pollution and climate change emissions at the same time.*
4. *Promoting and increasing investment in bus and train travel as alternatives to the car and to air travel, for local and particularly for longer distance journeys, and integrating this investment with improvements to active travel facilities and infrastructure. Without this action it is difficult to see how the trends in road use could be arrested.*
5. *There are synergies to be gained within freight transport through the adoption of more efficient supply chain processes that can reduce travel and emissions. The adoption of fleet schemes can help promote reduced fuel consumption and lower emissions.*
6. *Investment and support is needed for the infrastructure and linked economic drivers that will encourage a higher uptake of electric vehicles. However, large numbers of electric vehicles will not be enough to achieve the shift to a low-carbon economy.*
7. *Investment could be increased in publicly-funded bus services to increase their usage and decrease personal car use. Continued investment in the use of alternative fuel sources, such as hydrogen and biofuel, is advocated where these also deliver reduced levels of air pollutants.*
8. *There should be a continuing electrification programme of the Scottish railway network and accompanying efforts to encourage train use over car use for commuting and other common journeys. Hydrogen-fuelled drive systems are also becoming available.*
9. *Actions relating to shipping should focus on continued efforts to provide more efficient powering, hybrid diesel-electric engines and other low emission alternative fuels.*
10. *Promotion and investment in alternatives to air travel for short-medium trips should be encouraged; for example, use of rail alternatives for travel within UK. A reduction in air passenger duty would be a retrograde step in relation to achieving a reduction in climate change emissions and associated air pollution.*

***Agriculture and Land Management Sector***

*11. Application of inorganic fertilisers and manures/slurries should be sensitively co-managed. If so, embedded carbon will be reduced, as well as GHG emissions from land and potential air pollutants.*
*12. Good soil and nutrient management practices will reduce GHG emissions and improve soil quality. Soil pH management is also important.*
*13. Nitrogen-fixing crops must also be considered as part-replacement for less sustainable soil fertilisation methods.*
*14. Where practical and on suitable sites, slurry and manure should be rapidly incorporated into soil after application.*
*15. Slurry and manure storage should be undertaken, wherever possible and practical, with attention to isolation from the open air.*
*16. Dietary manipulation for livestock, and also better control of livestock diseases, both hold potential for reductions in GHG emissions and improved air quality.*
*17. Soils are a non-renewable resource and must be managed in ways to retain their capacity for carbon sequestration and resilience to deposition of air pollutants.*
*18. Restoration of damaged peatlands can lower GHG emissions and will improve likely resilience.*
*19. Anaerobic digestion of organic wastes should be encouraged with maximum useful energy recovery.*
*20. Biofuel production should only be supported where it does not require heavy input of inorganic fertilisers.*
*21. Farm businesses could maximise their own local production and use of renewable energy sources, including solar, wind and geothermal.*
*22. A key requirement for encouraging good practices and behaviour change across farms is the provision of good quality advice.*
*23. Growing trees is a key measure to increase the natural carbon reservoir. However, on deep peats, forestry will result in increased GHG emissions and it is probable the net GHG balance would be negative.*
*24. Rural land management, including the planned extensive planting of trees, needs careful management in order to eliminate wildfire risk.*
*25. The forthcoming review of the Muirburn Code ought to take account of air quality issues and ensure that the cycle of muirburn is such as to deliver climate change mitigation.*
*26. Rewilding and habitat defragmentation should be explored as a means to rebuild biodiversity, strengthen ecosystem services, and facilitate enhanced carbon sequestration and deposition of air pollutants.*
*27. Careful design and siting of greenspaces, green roofs, urban trees, and active travel routes can certainly reduce climate change emissions, enhance air quality, and deliver improved lifestyles and human health. Only certain species should be considered.*

***Business, Industry and Public Sector***

*28. The space-heating and fitting-out and management of both domestic and commercial buildings needs careful thought. There is a risk of serious cumulative impacts on air quality of using increasing amounts of biofuels. It can be argued* *that there should be more emphasis on primary use of electricity as the energy supply of choice as the Scottish grid becomes increasingly green.*

29. *An increased use of natural and sustainably designed materials/fittings internally in buildings holds the prospect of reduced embedded carbon along with improved indoor air quality.*
30. *The most significant emissions from industry are controlled by regulatory legislation in Scotland. The requirement for businesses to adopt best available techniques does not always, or necessarily, ensure that resource-use efficiency is more generally promoted. There may be opportunities more strongly to synergise air quality and climate controls into regulation.*
31. *Similarly, Scotland's environmental regulator, SEPA, should be supported in its intention to encourage all businesses to go beyond compliance and to seek a one-planet future with co-benefits for climate change and air quality.*

### ***Domestic and Communities Sector***

32. *Links could be strengthened in public messaging on the co-benefits of air quality improvements and climate change mitigation.*
33. *More natural materials, with lower embedded carbon, should be encouraged in the home. There will be carbon and air quality benefits.*
34. *Legislative drivers could be employed to drive deeper and more rapid deployment of higher standards of energy-efficiency in new domestic properties, including retrofit to older buildings.*
35. *As for the business sector, there must imminently be constraints on investment in new gas or biofuel heating. As Scotland's electricity grid rapidly reduces its carbon intensity, there must be wider adoption of electricity as the energy source of choice – thereby reducing GHG emissions and potential future air quality deterioration.*
36. *Fuel poverty remains a serious issue and mechanisms could be introduced to support lower-income groups.*
37. *Community renewables deliver multiple benefits: social, economic and environmental.*
38. *Community capacity needs enhancement to take full advantage of community empowerment and spatial planning reform.*
39. *Community Planning Partnerships and Local Outcome Improvements should be expected to address air quality and climate change as local issues.*
40. *Decision-making tools should be provided to assist local authorities take a systems-based approach to co-ordinated allocation of resources for climate change and air quality. The Place Standard is a useful starting point.*
41. *Behaviour change and greener campaigns must, in future, address multiple objectives including air quality and climate change.*

### *Waste and Circular Economy Sector*

*42. More than two thirds of all GHG emissions in Scotland are associated with the production, manufacture, distribution and retail of food and consumer goods, and the extraction of raw materials and construction. A more circular Scottish economy could reduce territorial emissions by 11 million tonnes CO2e per year by 2050 and help reduce air pollution, whilst still providing continued economic growth.*

*43. The waste management industry needs encouragement to attain the standards required for the circular economy and some sectors are more challenging than others. High quality recycling should be promoted as a mainstream activity to support the foundation of a circular economy.*

*44. There has been a substantial reduction (almost 80%) in GHG emissions from the waste sector since 1990. The contribution of this sector to total GHG emissions decreased from 13% in 1990 to 5% in 2014. The majority (85%) of the 2014 contribution came from landfill. This sector is a small contributor of air pollutants.*

*45. It is better to collect and burn landfill gas for energy generation in a controlled manner than allow fugitive emissions that have a negative impact on local air quality.*

*46. The generation of energy from residual waste by incineration can help Scotland meet its renewable energy and electricity targets without adversely affecting GHG and air pollutant emissions. However, thought must be given to feedstock supply as Scotland moves towards a more circular economy.*

*47. There are opportunities to use section 82 of the Climate Change (Scotland) Act 2009 to encourage targeted feedstock supply and to promote indigenous businesses.*

### *Land Use Planning*

*48. The current review of the land-use planning system provides many opportunities for an enhanced planning process to deliver significant beneficial impact on future climate change and air quality actions. Efforts should be made to ensure every opportunity is maximised to give the planning system a more influential cross-council role.*

*49. The land-use planning system can also exert profound influence on decisions to ensure both climate change and air quality impacts are minimised through specific decisions on design and location of buildings, transportation and infrastructure.*

*50. In future the planning system may actively encourage community participation and empowerment. This will deliver improved buy-in and long-term commitment to local environmental improvements.*

## 2. Introduction

There are many sources of greenhouse gas (GHG) emissions in Scotland, summarised in Fig 2.1. The principal gases include carbon dioxide ($CO_2$) which is not described as an air pollutant since it has no significant detrimental effects on either human health or the environment at low concentrations. However, it is seriously implicated in ecologically damaging acidification of the oceans. Methane ($CH_4$) is a more powerful GHG and, again, is not recognised as an air pollutant at the concentrations usually encountered in Scotland. However, it is a precursor gas to the formation of ozone in the lower atmosphere which is a potentially damaging air pollutant. Nitrous oxide ($N_2O$), also known as laughing gas, is again not considered as an air pollutant at normal atmospheric concentrations but is a very powerful GHG and is often co-released during activities that pose other air pollution risks. It is also now considered the most important emitted stratospheric ozone-depleting substance. Various fluorinated gases comprise the remaining GHGs. Again these aren't considered air pollutants as such, although some cause serious damage to the stratospheric ozone layer at high latitudes.

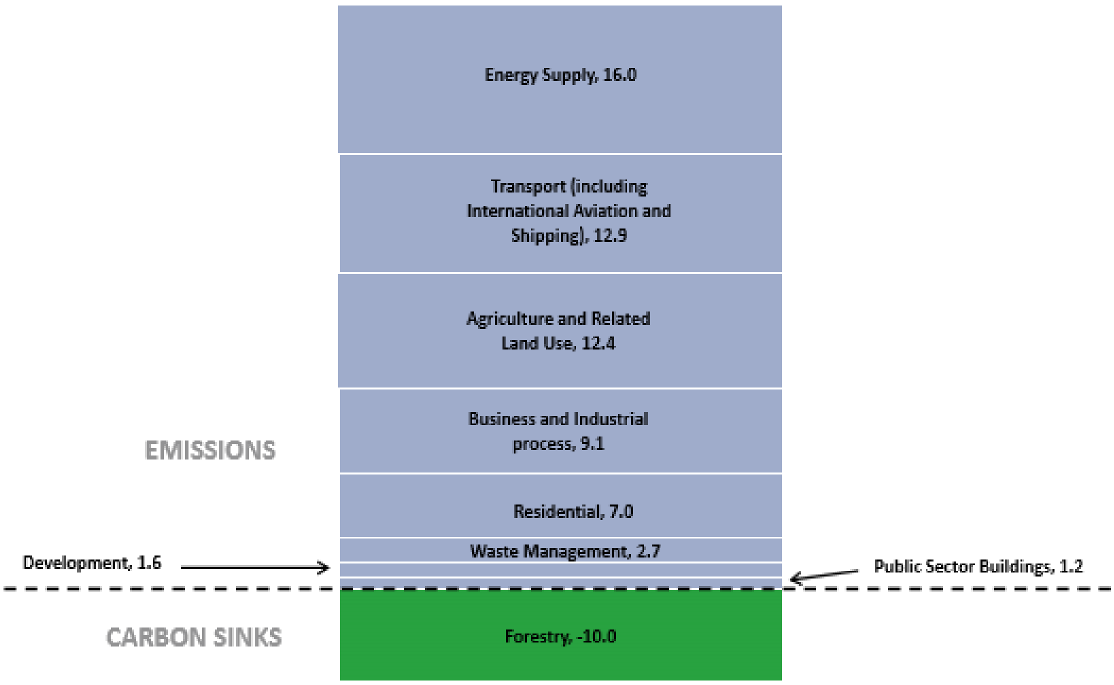



Fig 2.1 Sources and sinks of Scottish greenhouse gas emissions 2013, $MtCO_2e$ (Scottish Government, 2015a)

The main air pollutant gases are listed in Fig 2.2 and include ammonia ($NH_3$) which can have significant negative impacts on the natural environment through deposition and eutrophication, and is also a precursor of air-borne particulate materials (PMs). The various nitrogen oxides ($NO_x$) can have a direct effect on human health through respiration at concentrations encountered in built-up areas. Non-methane volatile organic compounds (VOCs) comprise chemicals like isoprenes produced by vegetation and man-made solvents like acetone; they have direct health impacts and also react with $NO_x$ in the atmosphere to generate ozone. Particulate matter (either $PM_{10}$ or the smaller fraction $PM_{2.5}$) comprises complex air-borne solid and liquid materials that can have a huge number of exotic chemicals bound to them; they can penetrate deep into the lungs and have damaging health effects. Sulphur dioxide ($SO_2$) has human health impacts and contributes, along with $NO_x$, to acidification which damages vegetation and also buildings.

| Overall Rank | Sector | Ammonia | Carbon monoxide | Nitrogen oxides | Non methane volatile organic compounds | $PM_{10}$ | Sulphur dioxide | Lead |
|---|---|---|---|---|---|---|---|---|
| 1 | Other Combustion | 1.3% | 38.3% | 11.6% | 3.8% | 35.2% | 7.5% | 27.6% |
| 2 | Transport Sources | 1.8% | 30.2% | 38.5% | 2.4% | 16.4% | 2.7% | 7.0% |
| 3 | Industrial Combustion | 0.0% | 22.6% | 13.0% | 1.0% | 5.0% | 7.5% | 31.1% |
| 4 | Energy Industries | 0.0% | 6.5% | 34.6% | 0.0% | 5.7% | 79.4% | 20.8% |
| 5 | Industrial Processes | 0.2% | 0.0% | 0.0% | 47.1% | 8.7% | 1.6% | 10.4% |
| 6 | Agriculture | 86.6% | 0.0% | 0.0% | 9.8% | 21.1% | 0.0% | 0.0% |
| 7 | Other | 5.6% | 1.7% | 2.3% | 1.0% | 6.0% | 1.4% | 0.3% |
| 8 | Solvent Processes | 0.0% | 0.0% | 0.0% | 20.5% | 1.8% | 0.0% | 0.0% |
| 8 | Fugitive | 0.0% | 0.6% | 0.0% | 14.5% | 0.0% | 0.0% | 0.0% |
| 10 | Waste | 4.5% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 2.9% |
| | **Total** | **100%** | **100%** | **100%** | **100%** | **100%** | **100%** | **100%** |

Fig 2.2 Pollutant emissions by sector in Scotland 2013 (Scottish Government, 2015b)

It is clear that there is little commonality between the list of greenhouse gases and the list of air pollutants. But it is important to remember that they are very often co-produced by the same human activities. For example, livestock manure and spreading of agricultural fertilisers is the biggest contributor to $N_2O$ emissions while it also represents an important source of atmospheric $NH_3$.

The purpose of this report is to investigate the existence of, and potential synergies or tensions between, various likely interventions to mitigate climate change emissions and to mitigate air pollution. Scotland has set itself demanding climate change mitigation targets and also committed to reducing air pollution and meeting European air quality standards in year 2020. So this investigation is important and timely.

During the preparation of this report, the authors have tried to ensure that other relevant factors are considered, even if not overtly expressed in the text. These include financial costs, practicability, equalities, social justice, the sharing economy, locational sensitivities, public/private collaborations, consumption patterns, and innovative solutions. The report is resolutely focused on the interface between climate change and air quality but, occasionally, it has been felt important enough to mention other related environmental implications. Recently it has been indicated that there is low certainty in predictions of the impact of climate change itself on both indoor and outdoor air quality (Climate Change Committee, 2016), so this report does not attempt to look at future climate scenarios.

This report is produced specifically in response to Action CC1 in the strategy “Cleaner Air for Scotland” (Scottish Government, 2015b) which seeks to ensure that future updates to the publication ‘Low Carbon Scotland: Meeting our Emissions Reduction Targets’ (Scottish Government, 2013) take into account air quality impacts. The first two editions of this report have colloquially been known as the Report on Proposals & Policies versions 1 and 2 (RPP1 and RPP2). The timing of this investigation is intended to allow it to inform the drafting by Scottish Government of RPP3 in late 2016. It is worth noting that the RPP reports do not address some major GHG emissions in Scotland because they are captured under the EU emissions trading system and therefore are controlled by their own separate regulatory framework. That position is reflected in this report which also does not address some emissions from, for example, major combustion plants and aviation.

It is widely recognised that the co-benefits of climate change and air quality interventions greatly outweigh any adverse side-effects. However, there is much that is still unknown to a high degree of certainty and a major UK research collaboration is about to be launched by the RIDE Forum (Research & Innovation for our Dynamic Environment).

For example, very recent findings have discovered small particles of magnetite commonly lodged in the human brain and these are known to have originated from inhalation of air pollution. The health effects of this material are not yet known but the existence of such potentially important knowledge gaps suggests that it would be wise to adopt a precautionary approach (Sniffer, 2006).

However, recognition that we need to know more does not mean that action cannot be taken now. Indeed we certainly know sufficient to allow remedial actions to be taken against both climate change and air pollution. Both are urgent.

**References:**

**Climate Change Committee**, 2016. UK Climate Change Risk Assessment 2017. Technical Chapter 5. 140pp.

**Scottish Government**, 2013. Low carbon Scotland: Meeting the Emissions Reduction Targets 2013-2027. ISBN 9781782566595. 322pp.

**Scottish Government**, 2015a. Scottish Greenhouse Gas Emissions 2013. ISBN 97817854444500. 69pp.

**Scottish Government**, 2015b. Cleaner Air for Scotland – The Road to a Healthier Future. ISBN 9781785446177, 88pp.

**Sniffer**, 2006. Practical Guidance on Applying the Precautionary Principle. 12pp. http://www.sniffer.org.uk/files/6613/8202/4944/Precautionary_Principle.pdf

## 3. Transport

The transport sector in Scotland produced 13 $MtCO_2e$ in 2011, 25% of total Scottish emissions. The majority, approximately 75%, of these emissions derived from road transport; although international aviation and shipping also contribute.

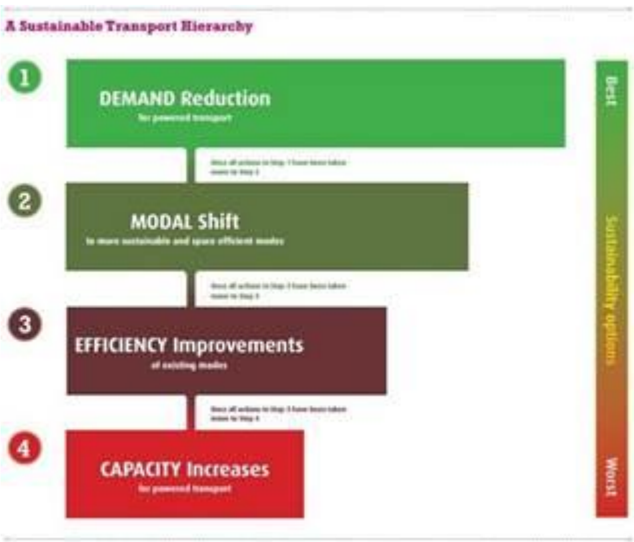
Also attributable to transport sources are 38% of $NO_x$, 16% of $PM_{10}$, and 3% of $SO_2$ emissions (Scottish Government, 2015).

There are several key concepts of fundamental importance when considering transport emission impacts on both air quality and climate change:

- Transport is essential in a modern society and economy (HR Wallingford *et al.*, 2012) and climate change has the potential to disrupt the infrastructure significantly. This is recognised in Scotland's National Transport Strategy
- Climate change is a global issue and GHG emissions have a cumulative impact, no matter their specific source or their temporal behaviour
- Adverse air quality impacts are predominantly on people. Proximity to source increases impact and so location and timing are critical
- Emissions from transport ($CO_2$, $NO_x$) are proportional to transport demand
- Air quality impacts from transport can be dependent on fuel type: for example, diesel fuel is a relatively high source of $NO_x$ and PMs
- The emissions caused in moving people and the emissions caused in moving goods may need rather different approaches and incentives
- Transport is a derived demand, driven by consumers wishing to access other services.

The following infographics illustrate the sustainable transport hierarchy, a conceptual framework for transport mode in relation to the movement of people and services:

Sustainable Transport Hierarchy



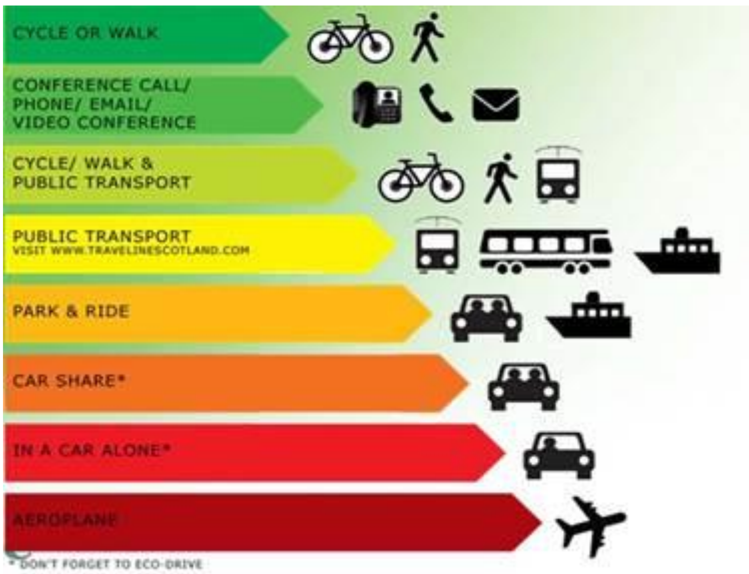
MORE SUSTAINABLE

| | | |
|---|---|---|
| **Priority 1** | Minimise demand | Manage the reasons why transport is needed and the context in which transport demand is derived, to deliver the same access to services and activities with less powered/motorised transport. |
| **Priority 2** | Enable modal shift | Enable the choice of transport modes with the lowest environmental impacts, and enable easier changes between modes. |
| **Priority 3** | Optimise system efficiency | Increase all efficiency measures of transport modes and their use, particularly in terms of $gCO_2/km$ for passengers and $gCO_2/tkm$ for freight. |
| **Priority 4** | Increase capacity | After optimisation of the first three steps, any capacity increases that are required should be prioritised to the most efficient and sustainable modes. |

LESS SUSTAINABLE

Spatial planning (see Section 8 of this report, p.53) offers a particular opportunity where policy may be able to deliver long term improvements - by helping to avoid the need for long distance commuting or excessive freight movement.

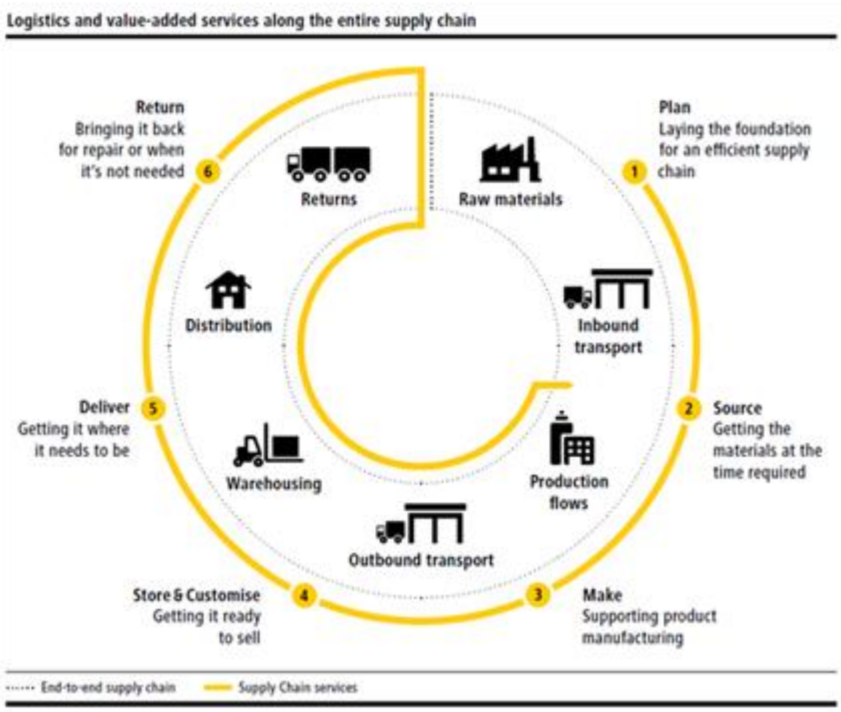
Movement of People and Services



**Road user hierarchy**

| Priority | Road user group |
|---|---|
| 1 | emergency vehicles |
| 2 | children, elderly people, people with sensory or mobility impairments |
| 3 | other pedestrians |
| 4 | cyclists |
| 5 | public transport |
| 6 | public services |
| 7 | local business collection and deliveries |
| 8 | residents' cars |
| 9 | non-local motor traffic |

Changing the transport patterns of people predominantly involves personal behavioural change, which may take a very long time to achieve significant uptake. However, a shift in investment towards, for example, active travel infrastructure and away from road transport will certainly encourage a more rapid cultural transformation. Price signals will also have some effect, particularly in supply chain management.




For example:

- Changing transport patterns for goods can be significantly influenced by pricing and procurement policies
- Clear signals based on the type of access regulation schemes defined in the CAFS national low-emission framework will have significant and fairly fast-acting effect.

London, for example, is linking air quality and climate change action in its proposed ultra-low emission zone for 2020 (Transport for London, 2016)
- Public sector procurement can be a key enabler for change
- Businesses are already adopting new logistics approaches to improve efficiency, this reduces travel and emissions.

**Health impacts**

It is clear that climate change emissions and air pollution have very direct long and short-term deleterious impacts on population health, particularly in relation to circulatory and respiratory disease (Royal College of Paediatrics and Child Health, 2016) and recently nitrogen oxides have been associated with increased dementia risk (Killin, *et al.*, 2016). In contrast, investments to support more active modes of transport have the potential to deliver multiple health and social benefits, over and above being more sustainable and less polluting. These benefits include:

| |
|---|
| People being more active is associated with both physical and mental health benefits |
| Reduced noise pollution and less stress |
| More children playing safely and walking and cycling to school |
| People spending less on transport |
| Stronger neighbourhoods and local economy with attractive local shopping streets & amenities |
| Less stressful commutes and easier/quicker to get to where you need to be |
| Fewer pedestrians and cyclists being injured (assuming investment in safer infrastructure) |

One study (Department for Food, Environment & Rural Affairs, 2013) has shown that the cost of air pollution across the UK from all sources, but based on 29000 premature deaths from fine airborne particulate matter alone, was £16Bn per year. Scaling up to include deaths from other pollutants, and scaling down for the likely impact in Scotland, provides an estimate cost in Scotland of around £1.5Bn per year.

**Policy Context**

Scotland's ambition is for almost complete decarbonisation of road transport by 2050, with set milestones to 2020:

- a mature market for low carbon cars resulting in achievement of an average efficiency for new cars of less than 95 $gCO_2e$/km
- an electric vehicle charging infrastructure in place in Scottish cities
- personalised travel planning advice provided to all households
- effective travel plans in workplaces with more than 30 employees
- at least 10% of all journeys made by bicycle.

This was later enhanced by the Scottish Government (2013) with six elements necessary to achieve a transition to a low carbon economy:  "long term legal and institutional certainty; expanding renewable energy production; improvements in energy and resource efficiency in households and industry; transition of transport to a lower carbon basis; expansion of renewable sources of heat; and sustainable land use".

Four sub-packages were identified for addressing transport emissions:

- **decarbonising vehicles** EU legislation on vehicle emissions standards and biofuels; and Scottish proposals that involve: fleet conversion to electric vehicles in the public sector, supporting electric vehicle charging infrastructure, the E-cosse Partnership, a Green Bus Fund and supporting hydrogen bus projects
- **road network efficiencies** congestion management and efficient driving. Intelligent Transport Systems including variable speed limits and ramp metering, complemented by deployment of average speed cameras
- **sustainable communities including modal shift to walking, cycling and public transport** a behaviour change model 'to help people understand their options and use more carbon friendly modes of travel, for example travel planning, walking and cycling, and the use of car clubs'.  The Climate Challenge Fund to provide funding opportunities for communities to progress local cycling projects.  Improvements in integrated public transport, such as smart ticketing and park-and-ride facilities. Bus quality contracts and statutory bus partnerships are important aspects of this approach
- **business engagement around sustainable transport** a range of measures including the provision of support for workplace travel planning and advice to encourage fleet efficiency improvements, including fuel-efficient driver training.

The Climate Change Committee (2016) has recently strongly encouraged Scotland to do more on mitigating the transport sector's contribution to GHG emissions, stating the next Scottish climate change plan "needs to go further" than its predecessor.

**Trends**

*i. Transport emissions*

In 2011, transport emissions amounted to 13 Mt$CO_2$e or 25.3% of total Scottish emissions, and the majority were from road transport.

Overall transport emissions, which include international aviation and shipping, have increased 0.1% since 1990. In 2011, emissions from domestic transport were 0.2% lower than 1990.  Emissions from international aviation and shipping in 2011 were 2.49 Mt$CO_2$e, up very slightly on 1990; underlying this, aviation emissions rose significantly while shipping emissions fell.

Land-based transport emissions in 2011 were slightly lower than in 2010, giving four consecutive years of reductions. In 2011, road traffic distances fell 0.2% compared to 2010, attributable mainly to a fall in HGV kilometres. The economic recession, and the subsequent faltering recovery, clearly continue to play a significant part in the recent reduction in reported transport emissions. However, the current business–as-usual projection for transport emissions suggests that they will increase by 11% between 2013 and 2027.

Emissions from cars currently account for around 55% of land-based transport emissions. Average vehicle emissions per kilometre are falling steadily, as a consequence of improved engine efficiencies, and currently stand at 159 $gCO_2e/km$, but these gains have been offset by increased car travel. The Society of Motor Manufacturers and Traders calculated that average new car emissions in the UK fell by 27% between 1997 and 2011.

ii. *Trends in vehicle registrations*

Scottish Transport Statistics (Scottish Government, 2016: Tables 1.1 and 1.2) show that, after a 4 year period of reductions, related to the financial crisis, new registrations of private and light goods vehicles rose from 159200 in 2011 to 217400 in 2014, an increase of 36%.

New registrations of hybrid-electric vehicles have risen by 73%, to 2000, in the period 2011 to 2014, but still only represent 0.7% of all newly registered vehicles, while registrations of electric vehicles have also risen in the same period by 93%, to 1600, representing 0.6% of all newly registered vehicles.

In 2014, 2369000 cars were registered in Scotland, representing 84% of all registered vehicles. The overall number of registered vehicles in Scotland has increased steadily over the last 11 years.

iii. *Distances driven*

There was a 5% increase in vehicle-kilometres driven on all roads in the period 2004 to 2014. Distances driven on motorways rose by 22%, while there was no increase on urban roads, and a 4% rise on rural roads. There was a reduction in vehicle-kilometres driven after 2007, but an upward trend re-emerged after 2011 (Scottish Government, 2016: Table 5.1).

iv. *Commuting trends*

Trends in mode of travel to work in Scotland can be followed over a 45-year period (1966-2011) using census data.

In this period, the use of a car to commute to work has risen significantly, from 21% in 1966 to 69% in 2011. In contrast, commuting on foot and by bus has reduced dramatically. In 1966, commuting by bus, at 43%, was the most popular method of travelling to work but by 2011 only 11% of commuters used this method. The proportion of employed people commuting on foot halved in the period from 24% to 11%. Train use, including use of the Glasgow underground, increased slightly between 1991 and 2011 from 3% to 4.5% of commuters. Bicycle use has remained low over most of the period, with only a very marginal increase from 1.5% in 2001 to 1.6% in 2011 (Understanding Glasgow, 2016).

## Transport Sectors

### Active travel – Walking and Cycling

Exercise has been described as a best-buy ‘health’ initiative (Morris, 1994) and increasing levels of walking and cycling would have multiple benefits. As noted earlier, investment in active travel will deliver improved population health beyond the beneficial impacts on climate change emissions and air quality.  Increasing walking and cycling will increase physical activity and help combat obesity, boost mental health, and is likely to be beneficial for social connectedness of communities and for local economies.

**Active travel synergies**

**(i) Significant increase in long-term investment in active travel and reduced investment in road building**

Essentially there should be effort to attain two linked outcomes: 1) shifting the spend in the transport budget towards active travel in towns and cities and away from road building to create a step-change in travel patterns and modal share; 2) road traffic volumes being reduced if more people are encouraged not to travel at all, or to walk and cycle more, or to use public transport, thereby reducing the need to drive.

Road building is much more expensive than building or repairing walking and cycle paths and there may therefore be opportunities, in the long term, to reduce the overall transport budget.  There is evidence that investment in 'smarter choices' (travel planning, car-reduction policies), road safety and cycling schemes and public transport represents by far the best value for money in transport interventions (Goodwin, 2010).

However, as active travel accounts for only 1.9% of transport budget currently (£39.5 million in 2015/16) out of a budget of £2.1 billion, the challenge is to increase investment in active travel to a level that will significantly increase levels of active travel (Glasgow Centre for Public Health, 2015). Edinburgh provides an example in which the Council has increased the proportion of its transport budget committed to cycling from 5% in 2012/13 to 8% in 2015/16 (City of Edinburgh Council, 2015). Correspondingly, trends in commuting in the city reflect the Council's commitment: between 2001 and 2011 use of train and bus rose, car driving and being a passenger declined, cycling increased further from a relatively high base (3% to 4.3%) and walking increased marginally, to 28.6%.  Edinburgh now has a higher proportion of people who walk, cycle and take a bus to work than anywhere else in Scotland and the number of people with access to a car has also reduced between 2001 and 2011 (Glasgow Centre for Public Health, 2015).

Building new infrastructure for active travel would provide economic benefits for local communities through jobs in the construction phase and through increased footfall in local shops in the long-term (Living Streets, 2014). The Place Standard (2016) has a role in encouraging the design of neighbourhoods that prioritise walking and cycling, restrict traffic speed and promote safe travel to school.  The design of urban environments has the potential to contribute substantially to increased physical activity (Sallis, *et al.,* 2016).

If less people are driving a car then air pollution and carbon emissions would be reduced.

Actions (ii) and (iii) are intrinsically linked with action (i).

**(ii) Increased investment in walking infrastructure and behaviour change initiatives to encourage more walking for utilitarian purposes in local communities and for commuting**

Capital investment needs are not great since there already exist a lot of serviceable pavements and paths, although improvements and repairs to the public realm would be needed to make walking a more attractive option. If successful, this intervention would likely impact on more people than an equivalent cycling investment. More people can walk, and indeed walk already; cycling is not for everyone. Targeted improvements to paths, pavements and the public realm could also be achieved more quickly in general than for cycling-based infrastructure, which needs time to bed-in and get used, and may be subject to lengthy consultation in the planning stages.

Increasing levels of walking would contribute to better physical and mental health, help tackle obesity (Dept.of Health, 2016; Martin *et al*., 2015) and if, as a direct consequence, less people were driving a car then it would also contribute to lowering air pollution and to reducing carbon emissions. It is worth considering, however, that the health gains from new initiatives are often seen most among more affluent, middle class groups and this may lead to widening health inequalities. Therefore efforts to increase walking need to be applied across the whole population, but may need specific targeting to avoid exacerbating inequalities.

**(iii) Increased investment in building cycling infrastructure, cycle hire schemes and behaviour-change initiatives to encourage more cycling for utilitarian purposes in local communities and for commuting**

It is cheaper and more cost effective to build cycle paths (DfT, 2014; Gu, *et al.,* 2016) which also require less maintenance, than roads. However a repair and maintenance programme and gritting should be carried out in winter – to keep routes open and to avoid a seasonal reversion to motorised transport use. Investments in these types of schemes demonstrably lead to greater levels of cycling and a shift towards more sustainable modes of travel.

Cycling infrastructure can take time to design and get through the planning process. Cycle hire schemes appear to be relatively easy to set up, do not require very much new infrastructure and are relatively cheap to run. Barcelona's bike sharing scheme has increased cycling by 30% (Rojas-Rueda, *et al.*, 2011).

Positive health economic benefits of cycling have been calculated in Glasgow (Glasgow Centre for Population Health, 2013) and at a country level (Fishman, *et al*., 2015), and can provide substantial population health benefits in addition to climate change mitigation.

Along with better and safer infrastructure, lower road speeds are needed to make cycling a safer and more attractive activity, both in perception and in reality (Cairns, *et al*., 2015). For example there is evidence that 20 mph limits, or the introduction of limit-zones, not only increase the likelihood of people cycling but bring down the level and severity of casualties, especially pedestrian and cyclist casualties.

The introduction of new cycling infrastructure has occasionally been met with significant opposition, perhaps reflecting the level of car dependency in some local, especially middle-class, communities. To gain more widespread support, effective community engagement is necessary in order fully to explain the benefits but also to allow concerns to be expressed.

### (iv) Promoting modal shift away from car

A pilot project in Edinburgh has been led by Living Streets to restrict motor vehicle use around schools, aiming to reduce the number of children being dropped off/picked up outside school by private car and to increase the level of walking and cycling to school.

Many benefits have been identified during this project: a reduction in vehicle speeds on both school streets themselves and also surrounding streets; a reduction in vehicles outside the school gates; a net reduction in traffic volumes in the immediate neighbourhood; air quality improvements with associated reductions in $NO_x$; improved perceptions of safety associated with the restrictions; and improved perceptions of motorist compliance, especially amongst residents (City of Edinburgh Council, 2015).

Many other mechanisms are being trialled in various communities:

- Reducing need to travel, through several different social changes, such as internet shopping, mobile/flexible/remote working, spatial planning and digital technology
- Public and private sector support for car clubs, cycle-to-work schemes, car sharing, for example NHS Greater Glasgow and Clyde operate a Liftshare scheme
- Encouragement for multi-modal journeys through oyster-card type schemes. Other suggestions include taxis to carry bike racks, as in Copenhagen, and bike racks on buses
- Promotion of electric bikes as a way of reducing car use and encouraging modal shifts to more sustainable modes of travel. This approach encourages those who feel less confident about their fitness to cycle; promotes travelling further; supports cycling in hilly locations; facilitates cycling without getting too tired or sweaty; and maximises the use of existing cycle paths (Bikeplus, 2016)
- Odd-even car traffic-reduction schemes, whereby vehicles with licence plates ending in odd or even numbers are allowed on the road on alternating days, have been used in Beijing, Delhi, Rome, Paris, Athens, and Mexico City. In Beijing a range of measures, including this scheme, resulted in short-term improvements in air quality during the Olympic Games, reducing daily concentrations of $SO_2$ by as much as 60%; CO by 48%; $NO_x$ by 47%; $PM_{10}$ by 55% and $PM_{2.5}$ by 27% (SPICE, 2016).

- Car-free days as exemplars of a different use for our streets and of potential solutions to the problems of congestion and air pollution. Aberdeen held its second car-free day in September 2016 as part of European Mobility Week. This ‘gives people the chance to experience car-free streets and encourages them to consider concrete solutions to tackle challenges like traffic congestion, road safety, air pollution, climate change, the decline of public spaces and the many health issues caused by sedentary lifestyles’ (Paths for All, 2016).

**Road Demand Management**

There are a number of potential interventions:

(1) **Review of policy position on road-building**: the aim should be to control the upward trend in road building and road use in Scotland. If a new road was built then equivalent older infrastructure could be decommissioned, or equivalent active travel or public transport infrastructure be implemented. This type of regulatory approach could be implemented relatively quickly and could inject funding for cycle routes, pavements and footpaths.

(2) **Intelligent Traffic Systems:** ITS technologies collect traffic data and control traffic lights to create energy-efficient junctions which improve traffic flow and reduce congestion, which can result in significant reductions in $NO_2$ and PM emissions. A project in Newcastle found that using ITS resulted in 15% reductions in fuel consumption, 66% reductions in vehicles travelling at 5mph or less, and reduced congestion.

(3) **Public Procurement Contracts:** Use public procurement contracts to incentivise reductions in carbon footprint and pollutant emissions.

**Buses**

Buses account for 6% of Scotland's surface transport emissions.

The Scottish Green Bus Fund**,** launched in 2010, is helping the Scottish bus industry invest in the latest emission reducing technology. A market penetration of 50% low-carbon buses by 2027 is thought to be achievable, provided the technology improvements continue to remove the price differential with diesel vehicles.

A revision to the Bus Service Operators Grant methodology increases incentives for fuel efficiency and thus rewards environmentally efficient operations, as well as supporting the extent of the bus network. Low-carbon vehicles receive double the standard rate. Local authority actions around permitted vehicle types in air quality zones could further encourage low-carbon transformation.

Public finance support has been provided to the Aberdeen Hydrogen Project, led by Aberdeen City Council and SSE plc, which will see ten hydrogen buses operate on routes within central Aberdeen.

**Co-benefits between air quality and climate change mitigation**

(i) Increase investment in publicly-funded bus services to increase their use and decrease car use

Bus usage in Scotland for commuting purposes has more than halved over a 45-year period, from 43% in 1966 to 11% in 2011. In contrast, in Edinburgh, commuting by bus, to work or to study, rose from 26% in 2001 to 28% in 2011. There is evidence, from the Edinburgh experience, that public-sector bus services can be run efficiently with low fares and can increase their modal share. The Barcelona bus and metro system is also operated by a publicly owned company and is another positive exemplar which embodies social and environmental principles. There is, however, evidence from Sweden that bus services commissioned to private operators can also be run efficiently with low fares - if the financial model is right.

An additional benefit is that more people will also be slightly more physically active, as bus journeys usually require people to walk at either end of their trip.

A potential related benefit would be that the introduction of low emission zones may trigger investment in electrifying bus fleets.

(ii) Hydrogen fuel buses

The Aberdeen Hydrogen Bus Project http://aberdeeninvestlivevisit.co.uk/Invest/Aberdeens-Economy/City-Projects/H2-Aberdeen/Hydrogen-Bus/Hydrogen-Bus-Project.aspx provides a long-term test-bed, given that the Aberdeen project is a demonstration of hydrogen fuel cell buses funded by Europe. Such action helps position Scotland to be a lead player in the development of a new fuel source.

(iii) Bio-fuel buses

The Bio-Bus, introduced in Bristol, is fuelled by human and household waste (Guardian, 2015). This bus emits less greenhouse gases than a conventional diesel engine, specifically 20 to 30% less $CO_2$ but also 80% less $NO_x$ and is almost completely free of harmful particulates emission. The technology itself is nothing new since Oslo already employs 100 so-called ‘poo buses’.

(iv) ECO Stars Fleet Recognition Scheme for HDV Fleet Operators & Taxis & Private Hire Vehicle

This scheme encourages fleet operators of all sizes to improve efficiency and reduce fuel consumption and emissions from their fleet. It originated in South Yorkshire and has since been adopted by other areas in the UK, including 12 schemes in Scotland. This free scheme can help to improve local air quality and, at the same time, reduce the carbon footprint and make cost savings. ECO Stars is just one example as there are other similar schemes in existence.

(v) Other Initiatives

There are many opportunities to accelerate the capture of co-benefits between air quality and climate change. For example:

- Driver awareness education with a new section in the UK driving test
- Freight/Bus Quality Partnerships and Car Clubs, especially if the vehicles are low emission
- Contracts that stipulate that evidence must be provided of reduced emissions, with a requirement to ensure such schemes focus on reducing not only on $CO_2$, but also $NO_x$ and PMs.

(vi) Electric vehicles

Continued action to decarbonise the transport sector focuses on an intensified effort to encourage the widespread adoption of electric vehicles and, of course, the accompanying infrastructure to support them (Transport Scotland, 2013). Substantial funding is required to subsidise the purchase of electric or plug-in hybrid vehicles by the public sector and by private individuals. Given only 1469 electric vehicles were registered in Scotland by the end of 2014, and only 55% of charging points were used in August 2014 (SPICE, 2016), this would require substantial extra funding to achieve a significant rise in electric vehicles on Scottish roads. An additional benefit, of course, is that electric vehicles are cheaper to run. There remain some challenges – for example the growing demand for transport and the resulting congestion needs to be addressed, electricity supplies need to become increasingly low carbon intensity, and emerging evidence suggests that the introduction of electric vehicles will do little to address particulate air pollution since their heavier weight, due to current battery technology, causes greater emission of particulates from tyre and brake wear.

(vii) Aviation

The EU is responsible for the main policy lever for addressing aviation emissions, through the EU ETS, under which emissions from both domestic and international aviation are capped. In 2012, emissions were capped at 97% of average annual emissions from 2004-2006, and from 2013 to 2020 they will be capped at 95%.

Biofuels have been used on a number of commercial flights and have the potential to deliver a step-change in the environmental performance of aviation. However, this is a long-term ambition, possibly not achievable until 2050, and so not available in the short to medium term.

(viii) Shipping

Efficient powering of vessels, while they are in port, through connection to shore-side power sources, can reduce polluting air emissions which may affect parts of nearby urban areas, such as Aberdeen. Improved vessel design, using hybrid diesel-electric engines, has become a feature of the building of ferries by the Ferguson yard in Port Glasgow and can deliver both air quality and climate change benefits.

(ix) Rail

The electrification programme for the Scottish rail network is very expensive, forming part of an overall £5Bn investment package in Scotland's railway infrastructure. It would probably not be justifiable as a priority on climate change mitigation alone but it delivers significant other economic, social and environmental benefits – especially in reducing air pollution hot-spots at major rail termini. So far, of the 2776 km of rail track in Scotland, 25% is electrified.

There are recent and interesting developments in building and running hydrogen-fuelled trains that may be worthy of considering in terms of cost-benefit comparison.

**Tensions between air quality and climate change mitigation**

(i) Real driving emissions (RDE) testing

This new test is to replace the now-discredited laboratory-based testing. However, the test will only be fully enforced across Europe from 2019. In addition, to allow car manufacturers some leeway in adapting to the new regime, $NO_x$ emissions standards will be temporarily relaxed from 2019 to 2021, setting them twice as high as the current limit set by Euro 6 standards, and 50% thereafter (SPICE, 2016) .

(ii) Modern fuels/exhaust treatment

Experiments have shown that the most modern exhaust treatment technologies may exacerbate vehicle $NH_3$ exhaust emissions, which in any case have shown no decline over the past decade (Suarez-Bertoa, *et al*., 2014).

(iii) Airports

Improvements in fuel-efficiency and aviation emissions are being negated by increased air travel, which will clearly be accelerated by any reduction in air passenger duty. At least half of the anticipated expansion of air travel is expected in the domestic market, where journeys could be made more sustainably by rail.

Ground level emissions of $NO_x$ from airports are already significant (Heathrow Airport Ltd., 2011). With the expansion of air travel at Scotland's major airports, Edinburgh and Glasgow in particular, ground level $NO_x$ emissions are likely to increase and potentially exacerbate existing road traffic-related pollution hot spots.

(iv) Shipping

Shipping is becoming more efficient with the introduction of lower-emission engines, but there is a rise in shipping journeys due to growing leisure/tourism and also due to an expansion of services on Scottish island ferry routes. Emissions from shipping at major ports, like Aberdeen, could contribute to further raising existing background levels of pollutants caused predominantly by road transport.

(v) Road building

Nearly 1400km of new road infrastructure has been added to the overall road network in Scotland over the period 2004 to 2014 (Scottish Government, 2016). There is clearly a conflict of policy interests which needs to be overtly addressed and resolved. Road user charging can be brought in by local authorities in Scotland, but to date only one attempt has been made in Edinburgh in 2005, which was rejected in a referendum with a vote of 74% against. It seems unlikely to be any more acceptable now - although the introduction of low emission zones from 2018 onwards and enhanced active travel and public transport infrastructure may increasingly encourage the Scottish public to look more favourably on road-pricing schemes or simpler alternatives like a variable MoT levy linked to location/emissions/mileage.

**References:**


**Bikeplus**, 2016. http://www.carplus.org.uk/project_page/electric-bikes-a-summary-of-existing-research/)

**Cairns J, Warren J, Garthwaite K, Greig G & Bambra C**, 2015. Go slow: an umbrella review of the effects of 20 mph zones and limits on health and health inequalities. *Journal of Public Health* 2015;37(3):515-520. http://jpubhealth.oxfordjournals.org/content/37/3/515.abstract?etoc (accessed September 2015)

**City of Edinburgh Council**, 2015. Budget commitment to cycling Item no 7.3. *Edinburgh: Transport and Environment Committee.* Available at: http://www.edinburgh.gov.uk/download/meetings/id/46498/item_73_-_8_budget_commitment_to_cycling (accessed March 2015)

**Committee on Climate Change**, 2016. Reducing emissions in Scotland: *2016 Progress Report .*

**DfT**, 2014. *Value for Money Assessment for Cycling Grants.* August, 2014. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/348943/vfm-assessment-of-cycling-grants.pdf

**Department of Health**, 2016. Start Active, Stay Active. *A report on physical activity for health from the four home countries Chief Medical Officers. Report updated March 2016.* https://www.gov.uk/government/publications/start-active-stay-active-a-report-on-physical-activity-from-the-four-home-countries-chief-medical-officers (accessed September 2016)

**Department for Environment, Food & Rural Affairs**, 2013. Impact Pathway Guidance for Valuing Changes in Air Quality. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/197900/pb13913-impact-pathway-guidance.pdf

**Fishman E, Schepers P & Kamphuis CBM**, 2015. Dutch Cycling: Quantifying the Health and Related Economic Benefits. *American Journal of Public Health*. 105(8): e13 - e15. Available at: http://ajph.aphapublications.org/doi/abs/10.2105/AJPH.2015.302724 (accessed September 2015)

**Flint E, Cummins S & Sacker A**, 2014. Associations between active commuting, body fat, and body mass index: population based, cross sectional study in the United Kingdom.

*BMJ 2014.* 349: g4887 http://www.bmj.com/content/349/bmj.g4887

**Glasgow Centre for Population Health**, 2013. *Briefing Paper Findings Series 37: Cycling is good for health and the economy*. Available at:

http://www.gcph.co.uk/publications/431_findings_series_37-cycling_is_good_for_health_and_the_economy (accessed June 2015)

**Glasgow Centre for Public Health**, 2015. Seminar report: Creating liveable cities – the role of active and sustainable travel*.* http://www.gcph.co.uk/events/154

**Glasgow Centre for Population Health**, 2015. Trends in Pedestrian and cyclist road casualties in Scotland. 2015. Available at: http://www.gcph.co.uk/latest/news/573_trends_in_pedestrian_and_cyclist_road_casualties_in_scotland

**Goodwin P**, 2010. Transport and the Economy. Submission of evidence to the House of Commons Transport Select Committee*.* The Centre for Transport & Society, University of the West of England, Bristol; 2010 https://eprints.uwe.ac.uk/13130/2/Goodwin_Transport_Committee_Transport_and_the_Economy_sub mission.pdf

**Guardian**, 2015. https://www.theguardian.com/uk-news/2015/mar/15/uk-first-poo-bio-bus-bristol-regular-service

**Gu J, Mohit B & Muennig PA**, 2016. The cost-effectiveness of bike lanes in New York City. *Inj Prev*, Published Online First 9 September 2016

**Heathrow Airport Ltd.,** 2011. Heathrow Air Quality – together towards sustainability.

http://www.heathrow.com/file_source/Company/Static/PDF/Communityandenvironment/air-quality-strategy_summary-document_LHR.pdf#

**HR Wallingford, *et al*.**, 2012. The UK Climate Change Risk Assessment: Evidence Report: Transport Sector.

http://ccra.hrwallingford.com/CCRAReports/reportviewer.html?sector=transport&link=LinkTarget

**Killin LOJ, Starr JM, Shiue IJ & Russ TC**, 2016. Environmental risk factors for dementia: a systematic review. *BMC Geriatrics,* 201616:175 http://bmcgeriatr.biomedcentral.com/articles/10.1186/s12877-016-0342-y

**Living Streets**, 2014**.** The pedestrian pound: the business case for better streets and places. https://www.livingstreets.org.uk/media/1391/pedestrianpound_fullreport_web.pdf

**Martin A, Panter J, Suhrcke M & Ogilvie D**, 2015. Impact of changes in mode of travel to work on changes in body mass index: evidence from the British Household Panel Survey. *Journal of Epidemiology and Community Health*.

Available at: http://jech.bmj.com/content/early/2015/04/05/jech-2014-205211.abstract?sid=d3ab14f2-9104-45f1-a3a1-7c791bac7e1e (accessed September 2015)

**Morris JN**, 1994. Exercise in the prevention of coronary heart disease: today's best buy in public health. *Med Sci Sports Exerc.* 26(7): 807- 814.

**Paths for All**, 2016 http://www.pathsforall.org.uk/pfa/news/car-free-day-success.html

**Place Standard**, 2016. http://www.placestandard.scot/#/home

**Pucher J, Dill J & Handy S**, 2010. Infrastructure, programs, and policies to increase bicycling: an international review. *Prev Med,* 50:S106–S25

**Rojas-Rueda D, de Nazelle A, Tainio M & Nieuwenhuijsen MJ**, 2011. The health risks and benefits of cycling in urban environments compared with car use: health impact assessment study. *BMJ.* 343:d4521 http://www.bmj.com/content/343/bmj.d4521

**Royal College of Paediatrics and Child Health,** 2016. Every breath we take: The lifelong impact of air pollution. *Report of a working party, Royal College of Physicians* https://www.rcplondon.ac.uk/projects/outputs/every-breath-we-take-lifelong-impact-air-pollution

**Sallis JF, Cerin E, Conway TL, Adam MA, Frank LD, Pratt M, Salvo D, Schipperijn J, Smith G, Cain KL, Davey R, Kerr J, Lai P-C, Mitáš J, Rodrigo Reis R, Sarmiento OL, Schofield G, Troelsen J, Van Dyck D, De Bourdeaudhuij I & Owen N,** 2016. Physical activity in relation to urban environments in 14 cities worldwide: a cross-sectional study. *The Lancet*. DOI: http://dx.doi.org/10.1016/S0140-6736(15)01284-2.

http://www.thelancet.com/journals/lancet/article/PIIS0140-6736(15)01284-2/fulltext

**Scottish Government**, 2013. Low carbon Scotland: Meeting the Emissions Reduction Targets 2013-2027. ISBN 9781782566595. 322pp.

**Scottish Government**, 2015. Cleaner Air for Scotland – The Road to a Healthier Future. ISBN 9781785446177, 88pp.

**Scottish Government**, 2016. Scottish Transport Statistics No. 34, 2015 edition, ISBN 9781909948648. http://www.transport.gov.scot/report/j415388-00.htm

**SPICE**, 2016. http://www.parliament.scot/ResearchBriefingsAndFactsheets/S5/SB_16-35_Air_Quality_in_Scotland.pdf

**Suarez-Bertoa R, Zardini AA, Astorga C**, 2014. Ammonia exhaust emissions from spark ignition vehicles over the New European Driving Cycle. *Atmospheric Environment*. 97: 43–53 Link: http://www.sciencedirect.com/science/article/pii/S1352231014005809)

**Transport for London,** 2016. Ultra Low Emission Zone.

https://tfl.gov.uk/modes/driving/ultra-low-emission-zone#on-this-page-1

**Transport Scotland**, 2013. Switched On Scotland: A Roadmap to Widespread Adoption of Plug-in Vehicles http://www.transport.gov.scot/sites/default/files/documents/rrd_reports/uploaded_reports/j272736/j272736.pdf

**Understanding Glasgow,** 2016. Trends in modes of travel to work in Scotland, 1966-2011. http://www.understandingglasgow.com/indicators/transport/travel_to_work/trends/scottish_trends

## 4. Agriculture and Land Management Sector

Just over 70% of the land area of Scotland is used for agricultural purposes. Emissions from agriculture and related land use were about 11 MtCO2e in 2014. Agriculture accounts for 23% of Scotland's GHG total, and is the third-largest emitting sector, behind energy and transport. Emissions from the agriculture sector are largely non-$CO_2$ gases, with nearly half due to nitrous oxide ($N_2O$) and a little more than a quarter due to methane. Enteric emissions make up 30% of agricultural emissions, followed by soil emissions (27%) (Scottish Government, 2015; Committee on Climate Change, 2016).

Emissions for agriculture were 25% lower in 2014 compared to 1990 levels. This fall is mostly attributable to three reductions:

- livestock numbers
- use of fertiliser, due to increasing costs
- grassland being ploughed for arable production, due to market forces

Agricultural emissions stem from biological processes. Emissions are therefore hard to measure and also are difficult to eliminate. The main measures that could be implemented to reduce emissions from farming practices include improving livestock health, adjusting livestock diets and breeding, manure management, farm fuel efficiency, and crops and soil management. Note that the Scottish Government and the UK Committee on Climate Change use slightly different figures since the latter excludes land use and land use change.

Despite being a leading source of ammonia, methane and nitrous oxide emissions, the policies and controls surrounding emissions from the agricultural sector are considered to be weak (O'Brien, 2015). The Gothenburg Protocol (2012) and the EC's Clean Air Policy Package (2014) both recommend several agricultural measures to reduce agricultural $NH_3$ emissions, relating to: manure storage, animal housing, livestock feeding strategies, low-emission manure spreading techniques and storage systems, and nitrogen management.

### Fertiliser management

Fertiliser input is essential on Scottish farms. Nitrogen usually has a very beneficial effect on crop growth, yield and quality. Most agricultural soils contain too little naturally-occurring, plant-available nitrogen to meet the needs of a crop, so supplementary nitrogen applications must be made each year.

Around 129000 tonnes of manufactured nitrogen fertiliser is applied annually to Scottish farmland, and this figure has shown little variation for several years (Scottish Government, 2016). Producing and applying this fertiliser generates around 475000 tonnes in $CO_2$ emissions. There can also be nitrous oxide emissions from the soil as a result of spreading fertiliser and manure. This accounts for a further 2.7M tonnes of $CO_2$e. Nitrogen fertiliser use therefore accounts for at least 5% of Scotland's GHG emissions.

Nitrous oxide arises from the denitrification of nitrogen applied to the soil, particularly when N is applied in excess of plant requirements. Denitrification in heavy textured soils during wet conditions is the main source of $N_2O$ emissions.

Nitrous oxide makes the biggest single contribution to agricultural GHG emissions. There is a large body of research that shows that $N_2O$ emissions depend on the wetness of soil, the amount and type of N available, the timing of N application, the crop type and the cultivation method. Fertiliser applications to grassland are the largest single source of Scottish emissions, and both the rate of application and soil conditions influence the magnitude of the flux (Rees, *et al.*, 2015).

Measures to reduce $N_2O$ emissions include:

- Ensuring soils are not poorly drained or compacted, and applying N only when the crop needs it, and then only as much as the crop requires
- Ensuring that the crop-available N in organic manures is fully taken into account when deciding on N fertiliser application rates
- Delaying mineral N application to a crop that has already had slurry applied, because applying N fertiliser and slurry at the same time increases emissions of $N_2O$. Separating the applications of the two materials by a few days should reduce emissions
- Optimising the timing and reducing the amount of nitrogen fertiliser or manure applied to land. Avoiding nitrogen application to wet soils, or just before heavy rain is forecast
- Maintaining soil pH at suitable levels for crop/grass production. Keeping pH at an optimum level for crop growth has the potential to reduce $N_2O$ emissions because it assists in the efficient use of N fertiliser since low pH makes N less available for uptake
- Including clover in grass mixes. This saves mineral N costs and has the additional benefit of saving GHG emissions from fertiliser manufacture and spreading.

**Livestock management and methane**

Methane emissions from ruminants are responsible for just over a quarter of the GHG emissions associated with agriculture in Scotland. Around 85% of methane generated by the agricultural sector arises from enteric fermentation, mainly by ruminant livestock, with the remainder from manure.

Enteric $NH_3$ emissions from ruminant livestock are controlled by the quantity of dry matter intake and the proportion of digestible carbohydrate that it contains. Methane emissions are an inevitable by-product of production, but efficiency measures can be adopted. Reducing the emissions intensity (i.e. the amount of GHG emitted per unit of meat or milk produced) of ruminants is, therefore, key to reducing agricultural emissions in Scotland (Skuce, *et al.*, 2016).

Good management of livestock is key to reducing enteric emissions, with measures such as dietary manipulation proven to give a 10% reduction in enteric $NH_3$ emissions. There is evidence to show that genetics also influences emissions (Roehe, *et al*., 2013).

Eradicating or controlling major livestock diseases in Scotland will also reduce the intensity of GHG emissions. Three diseases, one from each of the major livestock sectors, were considered more cost-effective and feasible to help control GHG emissions (Skuce, *et al*., 2016).

**Livestock management and ammonia**

Livestock sources (manure and slurries) account for approximately 85% of $NH_3$ emissions in Scotland, with the remaining 15% coming mainly from fertilisers (Sutton, *et al.*, 2004). These $NH_3$ emissions represent a loss of nitrogen from agriculture, thereby reducing the nitrogen efficiency of the farms. Concentrations of $NH_3$ emissions vary widely, with hotspots found in areas with intensive livestock production.

Local differences in agricultural activities result in a wide range of $NH_3$ emissions, ranging from less than 0.2 kg N ha/yr in the Scottish Highlands to over 100 kg N ha/yr in areas with intensive poultry farming.

$NH_3$ can undergo chemical reactions in the atmosphere to produce ammonium $NH_4$+ aerosol which can then be transported over thousands of miles, before being deposited mainly as acid precipitation (O'Brien, 2015). It can also react with other pollutants from traffic and industry ($NO_x$ and $SO_2$) to form secondary $PM_{2.5}$ (ammonium sulphate and ammonium nitrate) to the extent that several studies have claimed that reducing $NH_3$ emissions is the most effective way to reduce $PM_{2.5}$ under present-day conditions (O'Brien, 2015). A study, conducted in Auchencorth Moss in Scotland, found that ammonium was the single largest contribution to $PM_{2.5}$ in all seasons (Twigg, *et al.*, 2015).

**Organic manure management**

Around 16 million tonnes (wet weight) of organic materials are spread on land in Scotland each year, with 95% of this being manures and slurries from agriculture. The remaining 5% is derived from residues from food and drink production, sewage sludge from the water industry, and small amounts of organic materials derived from other industrial processes.

Spreading organic materials on land may result in the release of various gases, including $NH_3$, $CH_4$ and $N_2O$, to the atmosphere. The extent of release depends on the type of organic material and the timing and method of application. Emissions may also occur during handling and storage.

Air emissions from the spreading of organic waste on land do not have significant direct effects on human health, although offensive odour can certainly be an important issue. There are, however, significant concerns about the indirect effects associated with the formation of secondary air pollutants, such as ground-level ozone and secondary particulate matter.

In terms of air quality, the most environmentally significant emission from organic materials applied to land is $NH_3$. Ammonia emissions are mainly derived from spreading manures and slurries, and also from some sewage sludges, depending on their pre-treatment.

The methods to reduce $NH_3$ emissions from manures include:

- Using slurry bandspreading or shallow soil-injection techniques. Trailing hose slurry application reduces $NH_3$ emissions by about 30% compared with surface broadcast application. Shallow injection of slurry reduces $NH_3$ by about 70%, although this method won't be feasible on many of Scotland's soils
- Rapidly incorporating manures into tillage land. Ideally, slurry applications should be incorporated into the soil within six hours of spreading, and farmyard manure within 24 hours, to ensure that worthwhile reductions in $NH_3$ emissions are achieved, although this is not often practical
- Covering manures during storage. This can include fitting rigid covers to above ground slurry stores, and covering farmyard manure heaps with sheeting. Slurry tanks fitted with rigid covers can result in $NH_3$ being reduced by around 80%. However, practically all above ground stores were not constructed or designed to have a cover, and the costs of retrofitting would be immense to an individual farm
- Dietary manipulation offers considerable potential for reducing $NH_3$ emissions, but there are challenges to implementing strict dietary control in forage-based feeding systems
- Washing down hardstanding areas can be very effective in reducing $NH_3$ emissions, but will increase volumes of slurry/dirty water and therefore adversely impact water pollution risks.

Despite promotion of these mitigation measures, reductions in $NH_3$ emissions in Europe have generally been minor. The exceptions are Denmark and the Netherlands, which have both demonstrated that $NH_3$ emissions can be successfully cut by actively implementing mitigation policies (O'Brien, 2015).

Scotland's anaerobic digestion (AD) industry grew by more than two thirds between 2014 and 2015 although little of the feedstock was animal waste, so AD has considerable potential to improve the utilisation of farm manures and other organic materials. The Anaerobic Digestion and Bioresources Association confirms that there are 27 AD projects operational in Scotland, with a further 43 in planning approval. Issues that have occurred from AD on farms in recent years have been due to lack of knowledge and expertise in maintaining the systems (Committee on Climate Change, 2016).

**Soil management**

An often overlooked value of soils is their potential to mitigate greenhouse gas emissions. Gaseous fluxes from soils are only partially recorded in the GHG Inventory, which is primarily concerned with man-made changes. It is evident that losses from degraded soils could be significant relative to overall reported net GHG emissions.

Soils are the main terrestrial store of carbon in Scotland containing over 3000 M tonnes of carbon. This represents about 60 times more than is stored in all of Scotland's trees and plants. Cultivated soils gain or lose carbon in the course of farming operations and can also be a source of $N_2O$ and $CH_4$ emissions.  Peatlands hold most of Scotland's soil carbon store (53%).

Although proven practices exist, the implementation of soil-based greenhouse gas mitigation activities remains at an early stage.  Accurately quantifying emissions and reductions presents a substantial challenge (Paustian, *et al*., 2016).

Arable reversion to grassland may lead to carbon sequestration, although if the grass is then used for grazing there will be other GHG releases.  Similarly, measures such as enhanced buffer strips, designed for biodiversity and for watercourse protection, can help conserve organic/carbon-rich soils.  Good soil and nutrient management practices will reduce GHG emissions, and improve soil quality, as well as reducing nitrate, phosphorus and sediment loads in watercourses.

A wide range of materials, including farm manures and slurries, sewage sludges, composts and other non-agricultural wastes are used in farmland, forestry, land restoration, landfill reclamation, landscaping and domestic gardens.  Application of organic materials to soil has the potential to increase the carbon stock of Scottish soils.

**Peatlands**

Peatlands cover 1.7 M hectares, approximately 23% of Scotland's land area, and contain up to 1700 M tonnes of carbon.  Undisturbed and active peatlands accumulate about 0.25 tonnes of carbon per hectare per year. This is broadly equivalent, for example, to around 10% of the amount of carbon accumulated over the duration of a forest crop.

Peatlands can be damaged through a range of land management practices such as draining, burning, overgrazing, pollution, afforestation, extraction, establishment of windfarms and access paths.  Whereas functioning peatlands can act as net carbon sinks and be resilient to climate change, damaged sites are net sources and will degrade further under climate change pressures.

Restoration of degraded sites can lower emissions and improve likely resilience, with cost-benefit analysis suggesting that it is generally justifiable (Moxey & Moran, 2014). While peatlands are threatened by current activities in some locations, more damage has been caused by historic activities.  Even where these have been abandoned, damaged peat will continue to cause substantial net emissions of $CO_2$ into the atmosphere.

Peatlands restoration aims to re-establish peatland function and secure the storage of carbon held within the peat. It can also help peatlands adapt to climate change. The Peatland Action project is led by SNH to deliver restoration. Restoration work was carried out on 5580 hectares of peatland between 2013 and 2014.  Further funding was announced in 2015 to enable the project to undertake restoration of another 3000 hectares.

Net potential abatement benefits from peatland restoration, given the wide span of values for near-natural and damaged sites, could provide up to 9 t $CO_2$e ha/yr. This figure is subject to large uncertainties and, in less damaged areas, much smaller emissions savings may be provided by restoration.  The upper end of the annual abatement range is likely to be achievable in severely damaged sites from the point that the restoration process has resulted in a near-natural state (Artz, *et al*., 2012).

**Forestry**

Woodland and forest covers over 1.3 M ha in Scotland, or around 16% of the land area. Growing trees is a key measure to increase the natural carbon reservoir. The forestry sector in Scotland is a net emissions sink.

The amount of carbon sequestrated by forests depends on the species of tree and the duration of the crop rotation. It can vary between 700 to 800 tonnes of carbon per hectare. Young forests grow rapidly and soak up carbon more quickly than mature forests. In mature forests the carbon balance may reach a steady-state as carbon storage is matched by decomposition. Growing wood to use as a fuel is carbon-neutral and provides a sustainable alternative to the burning of fossil fuels.

Scotland has adopted a policy to increase the average afforestation rate to 10000 hectares per year by creating 100000 hectares by 2022. The 10000 hectare pa target has yet to be achieved although around 8300 hectares of new forest were planted in 2014; this fell to 7600 hectares in 2015. Rates will have to rise substantially to meet the target of 100000 hectares by 2022 (Committee on Climate Change, 2016).

It is very probable that moderate and high productivity forests, planted on shallower peats (<50 cm deep) with limited disturbance, provide a net C-uptake over the forest cycle, because uptake of $CO_2$ by the forest exceeds emissions from soil decomposition. In addition, there is likely to be a substantial reduction in $CH_4$ emissions with afforestation. On deep peats, forestry will result in increased GHG emissions and it is probable that the net GHG balance would be negative. A Practice Guide on deciding future management options for afforested deep peatland has been published by Forestry Commission Scotland (2015).

The Woodland Carbon Code is a voluntary standard initiated in 2011 to pay land-managers for the carbon sequestered by woodland creation projects. It provides independent verification, validation and assurance about the levels of carbon sequestration from managed woodland and their contribution to climate change mitigation. The Woodland Carbon Code project generates Woodland Carbon Units, which once verified can be used by UK businesses to help compensate for their gross emissions.

Air pollution, in the form of $NO_x$, is a precursor to ozone production. It has been found that ozone can seriously damage both trees and plants (Felzer, *et al.,* 2007). Although the interactions are complex, crop production in Scotland may be reduced by around 10% due to ozone damage, therefore also reducing carbon sequestration. For temperate forests, associated nitrogen-deposition can act as a fertiliser and compensate for the ozone damage. However, ozone damage is cumulative and can exacerbate other negative impacts from pests and diseases.

**On-farm technologies**

Eory, *et al.* (2016) assessed various on-farm technologies for the reduction of GHG emissions in Scotland. The mitigation options selected for assessment were:

- Agroforestry
- Precision farming technologies
- Low emission N spreading technologies
- Legumes in rotations
- Reduced tillage
- Land drainage
- Loosening compacted soils
- Feed additives in total mixed ration
- Precision and multi-phase feeding
- Improved livestock health: John's disease prevention
- Precision livestock farming
- Covering slurry and farmyard manure
- Slurry acidification
- In-house poultry manure drying
- Anaerobic digestion of livestock waste
- Capital investment in fuel efficiency
- More efficient heating and ventilation
- More efficient crop drying
- More efficient milking and milk handling

Mitigation options could reduce emissions by between 9 and 150 kt $CO_2$e annually, if they were implemented to their fullest potential extent across the country (Eory, *et al.,* 2016). Their cost-effectiveness is between - £112 and + £302 t $CO_2$e where negative values indicate financial savings to the farmer.

The technologies differed in terms of cost, complexity, market availability and acceptability to farmers. Some well-established technologies are readily acceptable and the main barrier to uptake is cost while others either require familiarisation and acceptance by farmers, or pose additional challenges that impede easy implementation. For example, slurry injection can increase water pollution risks, if carried out on unsuitable sites, while slurry acidification has significant health and safety risks, due to the production of hydrogen sulphide, in addition to other environmental risks.

**Energy consumption and production on farms**

Some farming systems use lots of energy and, therefore, the emissions of $CO_2$ can be high. Systems that have a significant requirement for heating or cooling such as glasshouses, vegetable production, and intensive livestock systems, are energy-intensive. The cultivation of some field crops, such as root crops that require a lot of soil movement, is also energy-intensive as is the use of irrigation which requires energy for water application, and some energy-intensive harvest and transport technologies.

Famers could reduce GHG emissions and save money by monitoring energy use per operation to determine informed management on good practices. Renewable energy options should also be considered by farmers, such as biomass, geothermal energy, solar and wind energy.

**Biofuels**

Biofuels are fuels that have been extracted from plants and crops. Sources of biofuels include manure, wheat, rapeseed oil and other plant oils, and waste from crops and plants. The most commonly extracted biofuels are bioethanol, ethanol and biodiesel. Plant-based fuels are from renewable sources and have lower carbon emissions compared to fossil fuels. However, biofuels are produced from crops which require fertilizers to grow better. Unless carefully managed, the production of crops for biofuels may result in emissions. Competition for land between crops grown for food and crops for biofuels is another issue to be considered.

**Muirburn**

Burning is used on some managed moors with the aim of removing older, less productive vegetation and litter to encourage regeneration of young heather, which is more palatable to grouse and sheep. Large effects on carbon storage are seen if burning is poorly managed particularly if the peat itself catches fire (Towers, *et al*. 2012). Wildfires on peatbogs are a serious concern as, once established, they are difficult to extinguish and can release significant amounts of carbon. The effects of prescribed burning on wildfires is unclear (Marsden & Ebmeier, 2012). It seems, however, the release of detrimental gaseous $NH_3$ during muirburn is relatively limited, being estimated as <1% of total UK emissions (DEFRA, 2008). There is some evidence that carefully managed muirburn, on a lengthy cycle of around 30 years, may provide a small benefit to carbon sequestration (Clay, *et al*., 2010).

The Scottish Government is currently revising the Muirburn Code and a key issue for the revision will be to consider the implications of burning on soil and carbon storage (Marsden & Ebmeier, 2012).

**Advice to farmers on reducing emissions**

A key requirement for encouraging good practices and behaviour change across farms in Scotland is the provision of good quality advice. The Farming for a Better Climate initiative (FFBC) was launched by the Scottish Government and Scotland’s Rural College in 2009. It is designed to encourage voluntary uptake of win-win actions in five key action areas:

- Using energy and fuels efficiently
- Developing renewable energy
- Locking carbon into soil and vegetation
- Optimising application of fertilisers and manures
- Optimising livestock management and storage of waste

Agricultural consultants offer practical advice to help farmers choose the most relevant measures to improve both farm performance and resilience to future climate change effects. The nine Climate Change Focus Farms offer open-days and discussion groups. It has been estimated that good advice and practical guidance can deliver significant GHG savings (Rees, *et al*., 2015).

There is also a need to review how future funding support for agriculture is targeted so that farmers can be supported to implement appropriate advice and actions which are over and above basic good environmental practice.

**Wildfires**

Wildfires can be major events, having air quality impacts extending some hundreds of kilometres. They release both particulate matter, containing numerous individual organic compounds which age/aggregate in transit, and also ozone-precursors such as $NO_x$, VOCs, and carbon monoxide. The particulates are often very fine, being over 80% at <1micron and hence, potentially, very detrimental to human health. A severe wildfire season in Europe can contribute as much $PM_{2.5}$ loading to the atmosphere as all the anthropogenic sources over the same period (Hodzic, *et al.,* 2007). This serves to emphasise that the expanded planting of trees in Scotland, intended to act as a carbon sink, must be accompanied by close attention to the reduction of wildfire risk.

**Rewilding**

Rewilding, or management intervention to allow an area to return to a near-natural state, has been shown to enhance the capacity of ecosystems to supply regulating and cultural ecosystem services, such as carbon sequestration and recreation. These enhanced services also encompass a greater capacity to capture and remove certain air pollutants, for example more rapid deposition of $NO_x$ (Cerquiera, *et al.,* 2015). It seems advantageous for rewilding and ecosystem defragmentation to be features of Scotland's approach to promotion of biodiversity.

**Urban trees**

Urban trees are able to reduce the need for heating and cooling of neighbouring buildings and, especially if planted in urban pollution hotspots, are very effective at improving air quality while, of course, also sequestering carbon as they grow. For example, PMs are reduced 20% immediately downwind of a tree. It has been shown that there are significantly lower rates of asthma in children where there are more street trees. However, some trees emit significant biogenic VOCs which lead to increased ozone pollution. An urban tree quality score has been devised which helps identify the most appropriate urban trees across a number of variables: favourites would include alder, hawthorn, laurel and birch (Woodland Trust, 2012). There may, however, be some issues with allergies induced by certain urban trees which need to be recognised as a limited concern for communities (Schroeder, *et al.,* 2006).

**References:**

**Artz RRE, Chapman SJ, Donnelly, D and Matthews RB**, 2012. Potential abatement from peatland restoration. ClimateXChange Briefing Note to Scottish Government**.**

**Bell M, Rees RM, Cloy J, Topp K, Bagnell A & Chadwick D**, 2015. Nitrous oxide emissions from cattle excreta applied to a Scottish grassland: effects of soil and climatic conditions and a nitrification inhibitor. *Science of the Total Environment*, 508, 343-353.

**Cerquiera Y, Navarro LM, *et al*.**, 2015. Ecosystem services: the opportunities of rewilding in Europe. Ch.3 in Rewilding European Landscapes. Ed. Pereira & Navarro, *Springer*, ISBN 978-3-319-12038-6.

**Clay GD, Worrall F, *et al*.**, 2010. Carbon budgets of an upland blanket bog managed by prescribed fire*. J. Geophys. Res*. **115:** doi:10.1029/2010JG001331.

**Committee on Climate Change**, 2016. Reducing emissions in Scotland: 2016 Progress Report .

**DEFRA**, 2008. An appraisal of unknown sources/sinks of GHG, ammonia and other emissions from UK land management. Project AC0108.

**Eory V, *et al*.**, 2016. On-farm technologies for the reduction of greenhouse gas emissions in Scotland. ClimateXChange Briefing Note to Scottish Government**.**

**Felzer BS, Cronin T, Reilly JM, Melillo JM & Wang X**, 2007. Impacts of ozone on trees and crops. *Geoscience*, 339, 784-798.

**Forestry Commission Scotland**, 2015. Deciding future management options for afforested deep peatland. Forestry Commission Scotland Practice Guide.

**Hodzic A, Madronich S, *et al*.**, 2007. Wildfire particulate matter in Europe during summer 2003: meso-scale modelling of smoke emissions, transport and radiative effects. *Atmos. Chem. & Phys*.: **7**, 404-4064.

**Marsden K and Ebmeier S**, 2012. Peatlands and Climate Change. SPICe Briefing12/28.

**Moxey A & Moran D**, 2014. UK peatland restoration: Some economic arithmetic. *Science of the Total Environment*, **484,** 114-120.

**O'Brien F**, 2016. Air Quality in Scotland, SPICe Briefing 16/35.

**Paustian K Lehmann J, Ogle S, Reay D, Robertson G & Smith P**, 2016. Climate-smart soils. *Nature,* 532, 49–57.

**Rees, *et al*.**, 2015. Reducing emissions from the agriculture and land use sector. Evidence presented to the Committee on Climate Change, 22 January 2015.

**Roehe R, Duthie CA, Rooke J, Wallace RJ, Hyslop J, Ross D, & Waterhouse A**, 2013. The association between growth and methane emissions of finishing beef cattle using an experimental trial designed to estimate breed and sire differences. 4, 376. 2013. Dublin, Cambridge University Press. Advances in Animal Biosciences: Proceedings of the 5th Greenhouse Gases and Animal Agriculture.

**Schroeder H, Flannigan J, *et al***., 2006. Residents' attitudes toward street trees in the UK and US communities. *Arboriculture & Urban Forestry:* **32,** 236-246.

**Scottish Government**, 2015. Scottish Greenhouse Gas Emissions 2013. ISBN 97817854444500. 69pp.

**Scottish Government**, 2016. Scottish Greenhouse Gas Emissions 2014.

**Skuce PJ, Bartley DJ, Zadoks RN & MacLeod M**, 2016. Livestock Health & Greenhouse Gas Emissions. ClimateXChange Briefing Note to Scottish Government**.**

**Sutton, MA, *et al.*,** 2004. Ammonia emission and deposition in Scotland and its potential environmental impacts. *The Scientific World Journal*, 4, p.795-810.

**Towers W, Hester A, Chapman S, Pakeman R, Littlewood N, Art R & Legg C**, 2012. Review of muirburn impacts on soil carbon and biodiversity.

**Twigg MM, *et al*.**, 2015. Water soluble aerosols and gases at a UK background site – Part 1: Controls of PM2.5 and PM10 aerosol composition. *Atmospheric Chemistry and Physics*, 15, p.8131-8145.

## 5. Industry, Business and the Public Sector

The Scottish Pollution Release Inventory (SPRI, 2016) provides details of the major licensed industrial emissions in Scotland. The latest available data are from 2014, and there are example numbers quoted in this summary. Longannet power station, previously a very large contributor, has been excluded from this analysis as it closed in March 2016. The following description provides the annual metric tonnage released by industry of the major air pollutants, along with a summary of the types and locations of principal sources. Where appropriate and for comparison, an equivalent estimated annual tonnage produced by vehicles in Scotland is also provided (assumptions: 3M vehicles, 8000 miles per year, Euro 5 standard).

**Total particulates:** A total of about 7500 tonnes pa is released from a range of industry sources. The main point sources include Lockerbie dairy with 2644 tonnes pa, Lochaber aluminium smelting at 237 tonnes pa, and poultry farms up to 100 tonnes pa. Grangemouth refinery is 63 tonnes pa.

- $PM_{10}$ emissions from industry sites include Lockerbie dairy with 639 tonnes pa, the Glensanda superquarry with 192 tonnes pa, Lochaber aluminium smelter at 158 tonnes pa, and several poultry farms each with up to 30 tonnes pa.
- $PM_{2.5}$ emissions from industry sites include Lockerbie dairy with 494 tonnes pa, Lockerbie biomass power plant with 7 tonnes pa, and just two quarries with 2 tonnes pa each (of course there will be many other smaller, unlisted, quarries which may have localised intermittent air quality impacts).

Some exotic pollutants are attached to air-borne particulates (Visschedijk *et al*., 2013). For example, 0.3 tonnes pa of vanadium is emitted from Grangemouth and WHO has identified vanadium as an element of concern for air quality and human health.

Road Vehicles emit around 200 tonnes pa of total particulates, but much of this is $PM_{10}$, $PM_{2.5}$, and 'black carbon' which can have much more significant health impacts.

Out of the 34 designated Air Quality Management Areas (AQMAs) in Scotland, a large number result from high $PM_{10}$ levels found in Scottish towns and cities, mostly due to traffic emissions, but background PM levels will also be contributing to poor local air quality.

**Ammonia:** A total of 500 tonnes pa is released from about 100 sites, mainly related to livestock and waste water treatment. Most poultry and pig rearing units are located in rural or less populated areas, and with point sources of up to 35 tonnes pa of $NH_3$. Waste water treatment plants are often located on city outskirts, but the largest is under 4 tonnes pa. The only significant industry process source of $NH_3$ is from glass insulation manufacturing in Stirling, with 39 tonnes pa.

Road vehicles emit small amounts of $NH_3$, estimated at between 4mg and 70mg per km for light vehicles. With about 50 billion vehicle kilometres annually in Scotland, at 10 mg/km of $NH_3$, this would result in 500 tonnes pa from road vehicles.

There is the potential for this to increase as consequence of 'AdBlue' urea addition used to control $NO_x$ emissions in diesel engine exhausts.

**Non-methane volatile organic compounds:** Industrial emissions amount to 17500 tonnes pa from a very wide range of businesses including oil terminals, petrochemicals whisky production, pharmaceuticals, pigments, and card/board manufacturing. Significant point sources include 5696 tonnes pa from Grangemouth complex, and emissions from oil storage sites of 2833 tonnes pa at Flotta and 2000 tonnes pa from Dalmeny. Whisky production accounts for 4300 tonnes pa from the Girvan distillery, 942 tonnes pa from the Cameronbridge distillery, and 596 tonnes pa from the North British distillery. A very significant source of distributed release of ethanol vapour is the maturation process for whisky (HSL, 2003). Using the estimates of Mascone (1978), it could be that around 64000 tonnes pa of ethanol is released to the air in Scotland.

Road vehicles emit around 2700 tonnes pa of non-methane volatile organic compounds in Scotland. Annual emissions in the UK are estimated at around 1 million tonnes per year, with transport accounting for a relatively small proportion. Other major sources include widely distributed use of solvents, and extraction and distribution of fossil fuels. (NAEI, 2016).

**Sulphur Dioxide:** An industrial total of about 7000 tonnes pa is released. The main point sources include Grangemouth oil refinery and petrochemical plants (4351 tonnes pa), Dunbar cement works (822 tonnes pa), Lochaber aluminium smelter (576 tonnes pa), and glass bottle production at both Alloa (487 tonnes pa) and Irvine (238 tonnes pa). With the closure of the Longannet and Cockenzie power stations there is now very little sulphur emitted from electricity generation in Scotland although there are reported emissions from SSE Lerwick power station in Shetland (529 tonnes pa) and the Ineos power station in Grangemouth (128 tonnes pa).

There is currently one AQMA for $SO_2$, in Grangemouth, which is possibly the only designation directly attributable to industrial emissions. The only other $SO_2$ AQMA, for Pathhead in Midlothian, was due to the use of domestic coal and was revoked in April 2014 after the village was connected to mains gas and burning of coal for heating declined significantly.

The National Atmospheric Emissions Inventory (NAEI, 2016) indicates that UK $SO_2$ emissions from transport in 2014 were 13000 tonnes, so in Scotland it may amount currently to around 1000 tonnes pa.

**Nitrogen oxides:** Industrially around 12500 tonnes pa is released, from combustion processes for heat and power generation. The main industry source locations include Grangemouth (3167 tonnes pa), Lerwick power station in Shetland (2567 tonnes pa), Dunbar cement works (1147 tonnes pa), Peterhead gas plant and power station (1060 tonnes pa) Irvine glass and paper mill (870 tonnes pa), and Alloa glass (750 tonnes pa). There are about another 10 sites with $NO_x$ emissions of between 100 to 700 tonnes pa.

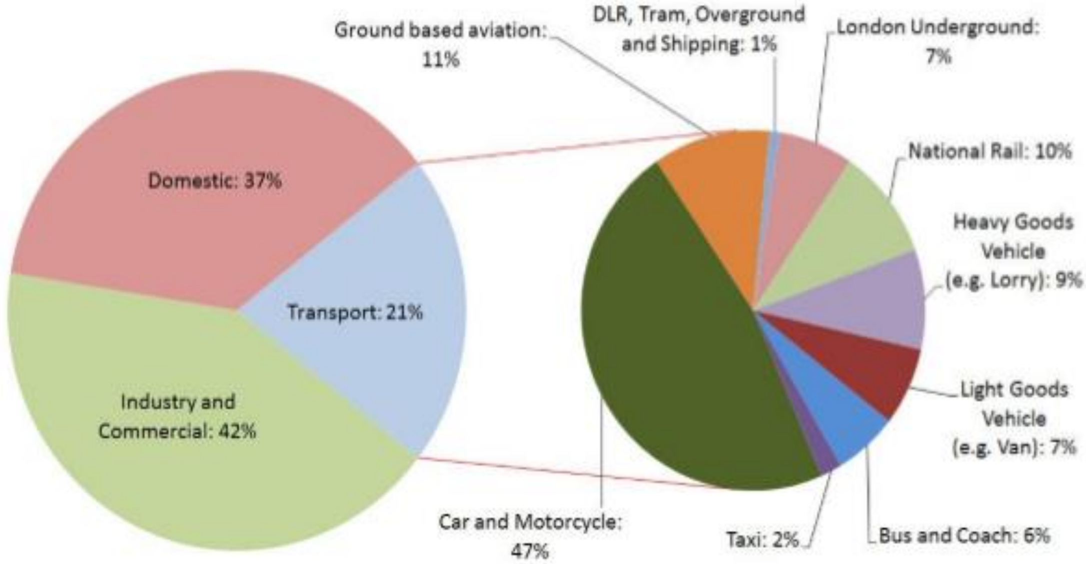
Road vehicles emit around 5000 tonnes pa of nitrogen oxides.

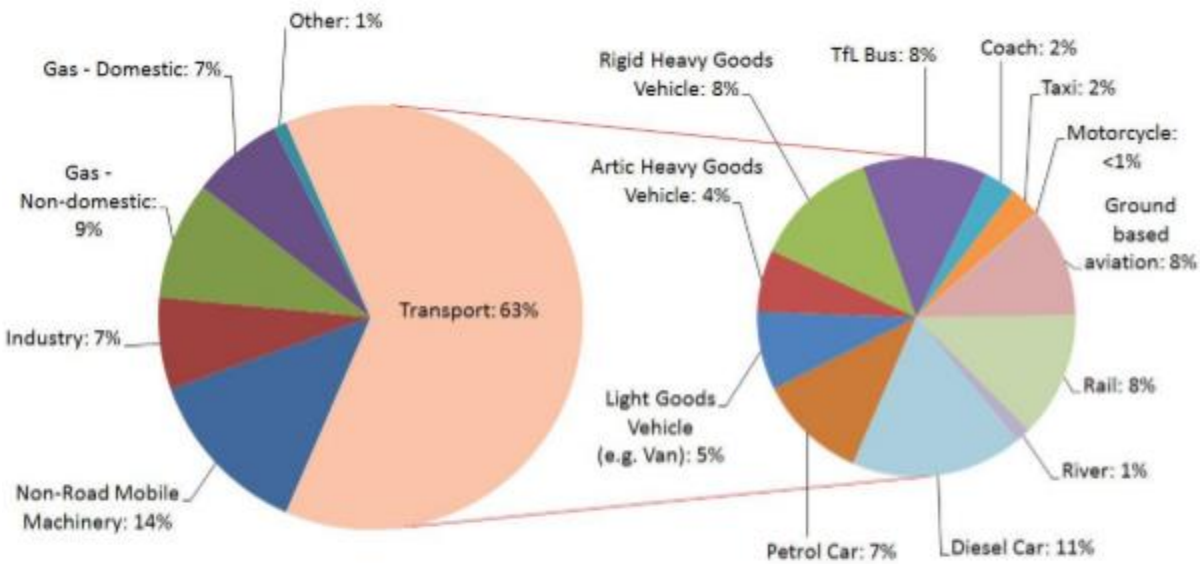
There are a large number of AQMAs resulting from high $NO_x$ levels in Scottish towns and cities, most due to traffic emissions, but background $NO_x$ levels will also be contributing to poor local air quality.

These major industrial emissions will be controlled by the application of best available techniques required under the Pollution Prevention and Control (Scotland) Regulations

2012. These regulations also require consideration of energy efficiency which will often help reduce $CO_2$ emissions. Equally, industry is regulated under the Water Environment and Water Services (Scotland) Act 2003 which requires efficient use of water by industry, thereby reducing sewerage demands and its associated air pollution emissions but also the energy consumption and associated $CO_2$ emissions of both water supply purification and waste water treatment. Scotland's environmental regulator, SEPA, has recently announced that it will seek to encourage all businesses to go beyond minimal compliance with environmental legislation and make every effort to create a more sustainable, or one-planet, Scotland (SEPA, 2016).

These three plots (Fig. 5.1) show that, for London, industrial sources are very significant for overall carbon emissions, but much less so for the air pollution component of $NO_x$, and insignificant for $PM_{10}$.



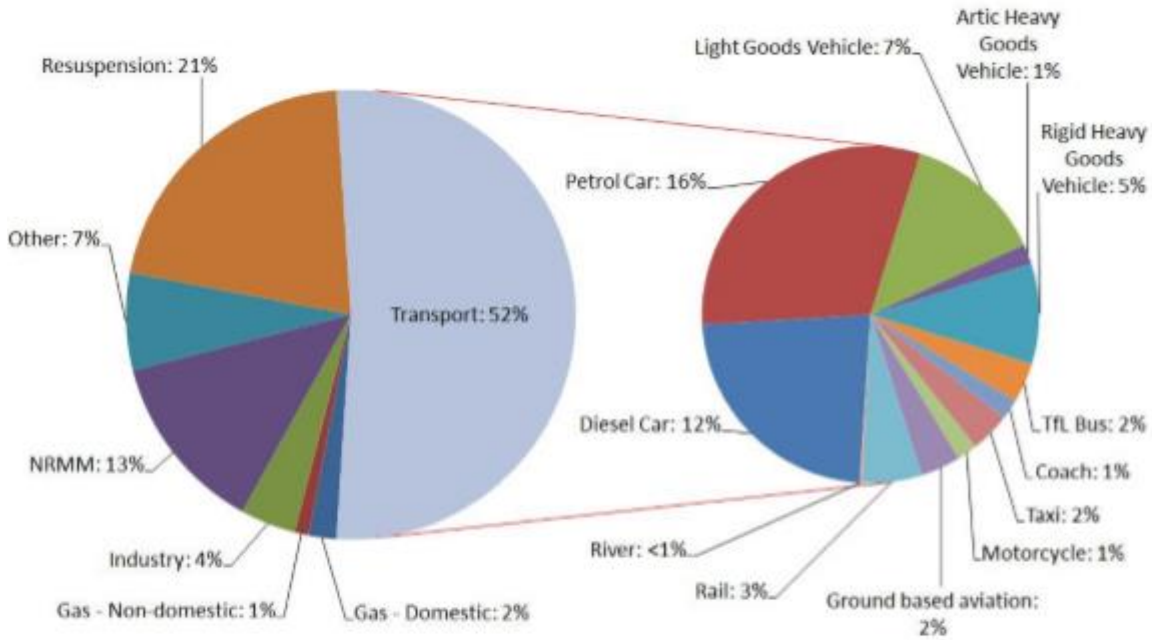



Figure 5.1. Comparison of sources for $CO_2$, $NO_x$ and $PM_{10}$ in London (Transport for London, 2014) with further breakdown for the transport sector only. This is purely illustrative: for example, London does not have an agricultural sector whereas Scotland does.

**Space Heating in Business and Public Sector**

Much space heating and hot water supply in business premises is provided by gas boilers, primarily on the basis of lowest cost. Gas boilers emit $NO_x$ gases at a rate between 30mg/kWh and 200mg/kWh depending on the type and efficiency of the equipment. Oil and biomass boilers will be around 3x and 10x higher in $NO_x$ emissions respectively, and may also result in $PM_{10}$ and $PM_{2.5}$ emissions.

It has been calculated that 5,500 tonnes pa of $NO_x$ is emitted in London for space heating and hot water supply (Cleaner Air for London, 2013). It can be estimated that a comparable figure for Scotland might be between 2000 and 3000 tonnes pa. Both $CO_2$ and $NO_x$ emissions can be reduced if there is encouragement to move away from gas (or oil or biomass) heating to electric heating since the Scottish Government has a published target of carbon intensity of the Scottish grid supply to be 50g/kWh by 2030, with continuing decarbonisation beyond that date.

**Indoor Air Quality**

The effort to reduce the costs of space heating, along with reduction in $CO_2$ emissions, requires high thermal efficiency buildings. This can often lead to the antagonistic situation of colloquially-known ‘sick building syndrome’ where high concentrations of indoor air pollutants can arise due to much reduced air circulation.

It has been shown that new buildings are more prone to poor indoor air quality, especially elevated levels of total VOCs – including halogenated compounds (greenhouse gases themselves), acetone, styrene, and benzene compounds. Major sources include solvent-based waxes and detergents, deodorisers, as well as fittings like vinyl flooring, and construction materials like solvent-based adhesives and paints (Brown, *et al.,* 1994).

There is a significant opportunity to enhance indoor air quality, reduce its health impacts, and reduce embedded carbon and upstream $CO_2$ emissions by adopting more natural fixtures and fittings in buildings – including zero-carbon/recycled carpet tiles, water-based natural paints, textile and natural wood finishing, natural soft-furnishings. Increasing investment in such products would help build the circular economy (also see Section 7: Synergies, p.50).

**References:**

**Brown, SK, Sim MR, *et al.***, 1994. Concentrations of volatile organic compounds in indoor air – a review. *Indoor Air*. **4:** 123-134.

**Cleaner Air for London**, 2013. Manual A – minimising air pollution during building us: Factsheet A4> Par Hill research. 17pp.

**Health & Safety Laboratory**, 2003. Potential explosion hazards due to evaporating ethanol in whisky distilleries. *HSL/2003/08*, 9pp.

**Mascone DC**, 1978. Cost and Engineering Study – Control of Volatile Organic Emissions from Whiskey Warehousing, *EPA Report No. EPA-450/2-78-013*, United States Environmental Protection Agency, Research Triangle Park, North Carolina.

**NAEI**, 2016. http://naei.defra.gov.uk/overview/pollutants?pollutant_id=8 (consulted 8/8/2016)

**SEPA,** 2016. One Planet Prosperity – our regulatory strategy. https://www.sepa.org.uk/media/219427/one-planet-prosperity-our-regulatory-strategy.pdf

**SPRI**, 2016. http://www.sepa.org.uk/environment/environmental-data/spri/ (consulted 7/8/2016)

**Transport for London**, 2014. Transport emissions roadmap. 48pp.

**Visschedijk AHJ, Denier van der Gon HAC, *et al*.**, 2013. Anthropogenic emissions to air and ambient air concentrations in North-West Europe. *E3S Web of Conferences*. DOI 10.1051/e3sconf/20130103004.

## 6. Domestic and Communities Sector

Residential emissions of GHGs in Scotland account for 12% of total figures and have reduced by 26% since 1990, compared to a 39.5% reduction in the overall national inventory (Scottish Government, 2014). However energy consumption to heat and cool homes and businesses is very significant and accounts for approximately half of Scotland's GHG emissions (Scottish Government, 2016). There are conflicting trends in household energy use: an ageing population, increasing numbers of households due to increased single-person living, and growing demand for electrical appliances, all result in increases in demand, while improvements in housing stock reduce it.

The majority of air quality pollutants in the domestic sector arise from transport and energy generation. Other sources are particulates from burning coal, wood and solid fuels.

Local air pollutants, such as ozone and black carbon from solid fuel heating, are themselves significant climate change drivers. Ways of reducing energy consumption and shifting towards clean energy usage will have benefits for climate change targets and for improving air quality. Benefits can be realised if GHG emissions and clean air are tackled in an integrated way with policies and proposals that simultaneously reduce both emissions of GHGs and the pollutants that contribute to poor air quality. Defra's recent 'Air Pollution: Action in a Changing Climate' (2010) document sets out how policies could be aligned at a national level; however, integrating policy at a local level is also strongly desirable.

**Potential co-benefit actions**

**Policies and plans to encourage energy efficiency**

Reducing energy usage is a key win-win for air quality and climate targets. Energy efficiency has been designated a national priority, being key to meeting Scotland's ambitious climate change targets and to tackling fuel poverty. Homes with poor energy efficiency, challenging weather and reduced heating options, especially in rural areas, can make fuel bills unaffordable - resulting in fuel poverty.

Enabling mechanisms include Scotland's Energy Efficiency Programme (SEEP), and local authority Sustainable Energy Action Plans (SEAPs). SEEP will help local authorities to pilot new and innovative approaches to energy efficiency with community groups and businesses, helping reduce costs and improving warmth in homes, schools, hospitals and businesses. The SEAP provides a universal framework for strategies and actions for reducing carbon emissions across a region. The Plans are developed by local authorities, with the intention of transforming energy-use by reducing demand, encouraging more efficient transmission, and promoting local generation. The City of Edinburgh Council has produced a skills demand document focussed on low carbon, linked to their SEAP and there is scope for others to do the same, and also to consider air quality in parallel.

Links could usefully be made between policy measures to encourage energy efficiency and to improve air quality, particularly in relation to public messaging and behaviour change, identifying the multiple benefits of reduced energy consumption and improved air quality.

**Designing and retrofitting energy efficient sustainable housing**

Studies have shown that, in the UK, we spend about 90% of our time indoors, and that about 66% of that indoor time is at home (Public Health England, 2015), so new buildings clearly should be designed to minimise the use of fossil fuels, which contribute to both climate change and poor air quality, and to address associated potential health effects.

Scotland has committed to a range of measures such as smart-metering, a national retrofit programme for older homes, new-build domestic energy standards, regulation of energy efficiency, a retrofit programme for insulation and heating, and low carbon heat.
New buildings, and retrofit of old buildings, need to make more use of low-carbon energy sources incorporating technologies that help reduce energy use, and therefore the overall impact of the built environment on our climate. New-build also needs to be designed using materials that don't create adverse air quality. The typical approach to building design addresses many aspects of building performance in distinct silos: for example energy-efficiency standards, indoor air quality and ventilation, and thermal comfort standards, with limited coordination or consideration of how buildings are designed to accommodate future changes in climate (e.g. warmer, damp conditions; extreme weather events).

The recent planning review (Beveridge, *et al*., 2016) suggests the need for new approaches to low carbon infrastructure planning and delivery, taken forward through a programme of innovation. This includes decarbonising and future-proofing infrastructure with a more ambitious and innovative approach by planning authorities. It also involves working together to achieve the aims and objectives set out in the 'Making Things Last – A Circular Economy Strategy for Scotland'. Retrofitting of existing infrastructure with energy-efficient and low carbon technologies is also of paramount importance, as the vast majority of infrastructure that will be present in 2050 is already in place now.

Legislative drivers could be used to encourage greater update of renewable technologies with higher quality homes, where new-builds include renewable technologies and energy efficiency and consideration given to use of new technologies when retrofitting.

Sustainable design principles can also be applied to the outdoor environment to mitigate against the impacts of climate change. Green roofs and green walls can have a cooling effect on buildings, as well as the greening of streets and the provision of shading, which can minimise the potential impacts of the urban "heat island" effect.

**Community and Locally-Owned Renewables**

The Scottish Government has set a target to increase the capacity of community and locally-owned renewable energy in order to maximise the benefits for communities from renewable energy, with communities gaining from renewables projects over and above the energy generated and the financial returns. This includes increased community cohesion and confidence, skills development, and support for local economic regeneration. Air quality could certainly be another aspect that would promote greater community engagement.

Community renewables will reduce greenhouse gas emissions and improve air quality.

**Urban / infrastructure planning**

Good urban planning and infrastructure planning can have the dual role of improving domestic air quality and reducing carbon emissions through the consideration of new development and transport routes. This can have direct benefits in terms of health and wellbeing while contributing to the United Nations Sustainable Development Goals to make cities inclusive, safe, resilient and sustainable.

Infrastructure and other developments need to be sensitively planned to ensure they do not add to, or cause, significant additional air quality issues. The layout of buildings and roads can have substantial impacts on air pollution. Many of the UK's pollution hotspots are located on streets lined with tall buildings, so-called "street canyons", which impede air circulation, thereby preventing the dissipation of emissions from vehicle exhausts.

Place-making is important in creating attractive green places that encourage people to use active travel rather than drive. The Scottish Government 'Designing Streets' document recommends integration of streets with blue and green infrastructure and such networks improve the sense of place and also air quality and health and wellbeing.

Scottish Planning Policy requires that planning authorities consider the need for buffer zones which will protect all sensitive receptors from unacceptable risks at distances which meet the approval of the Scottish Government. The creation of "green spaces" in urban areas is a relatively easy and cheap way to reduce air pollution which will also have the added benefits of reducing emissions from transport by encouraging active travel. Greenspace and good quality permanent, or temporary, growing space can also have a valuable role in providing local food-growing opportunities, thereby reducing imported food miles and local freight transport.

Local Authorities and Regional bodies have a clear leading role to play in improving their local air quality and building resilience in the face of climate change, however they require to be given adequate powers and resources to deliver effective air quality and climate change improvements. Single Outcome Agreements and Local Outcome Improvements could be ideal vehicles for this, however Local authorities and Community Planning Partnerships are often dealing with conflicting priorities such as poverty, health inequalities and deprivation and, without adequate support and resources, climate change and air quality interventions can become secondary.

There are benefits of including consideration of air quality in Local Outcome Improvements and including in Community Planning Partnerships.

The Place Standard can be used as a tool in helping communities and local authorities and developers consider place-making options.

Decision making tools are needed to assist local authorities in taking a systems approach to allocation of resources at a local level, to include emissions and improve air quality as part of broader place-making agendas.

## Behaviour change and greener campaigns

Scotland's current climate change plan (Scottish Government, 2013) offers little mention of behaviour change, other than reference to the low carbon framework and to the Climate Challenge Fund as an enabling mechanism for households and for empowering communities to come up with their own projects to reduce emissions. It is anticipated that the updated plan will include greater reference to behaviour change, presumably linking to the ISM model. There are multiple benefits to addressing both low carbon and air quality in Government behaviour-change programmes and interventions, with joined-up consistent messaging.

Visioning materials such as the Low Carbon 2030 narratives (ClimateXChange, 2015) currently consider low carbon in isolation from other environmental factors. Future scenarios could usefully include the achievement of the best possible air quality for Scotland, as well as other environmental and social factors. Such visions should take account of social and environmental justice considerations. Those with least responsibility for emissions may often be most impacted by climate change and by poor air and environmental quality. Greener campaigns could, and should, be more sensitive to the needs of disadvantaged communities.

The recent Community Empowerment (Scotland) Act 2015 provides powerful mechanisms for communities to have a role in local decision making about how local air quality and climate change policies are implemented. It is important to raise awareness and build capacity within local communities and Local Authorities could build more meaningful and lasting relationships with the communities they serve. There is a need to consider how communities can access knowledge and tools, and develop ability to contribute to policies. Communities need support to increase their confidence and skills so they are better able to engage and implement actions.

Behaviour change initiatives and greener campaigns could usefully address multiple objectives – low carbon, cleaner air, active travel and community empowerment.

The means of building community capacity in relation to place and emissions requires greater consideration.

## Potential tensions

### Domestic biomass and heating systems

Scottish Government policy is to promote the use of biomass plants for heat or for combined heat and power, with new plants being relatively small in scale. This is to optimise local supply, serve localised heat markets, and maximise efficient use of a limited fuel source. Wood fuel use for energy production has more than tripled in the last five years (Scottish Government, 2013) and while biomass (organic matter used as fuel) currently remains a relatively small energy source, if the rate of uptake continues as forecast, then its contributions will become increasingly important especially in urban areas (Environmental Protection UK, 2009).

However biomass burning boilers can emit a number of pollutants including $NO_2$, particles PMs and $SO_2$. The mix and amounts of pollution produced will depend on the size and design of the boiler, the quality of the fuel used and the presence of any emissions abatement equipment.

**References:**


**Beveridge C, Biberbach P, Hamilton J**, 2016. Empowering Planning to Deliver Great Places – an independent review of the Scottish planning system. http://www.gov.scot/Resource/0050/00500946.pdf

**ClimateXChange**, 2015. http://www.climatexchange.org.uk/files/7014/1892/0471/Low_carbon_narratives_2030.pdf)

**DEFRA**, 2010. Air Pollution Action in a Changing Climate. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/69340/pb13378-air-pollution.pdf

**Environmental Protection UK**, 2009. Biomass and Air Quality Information for Developers. http://www.iaqm.co.uk/text/guidance/epuk/biomass_developers_leaflet.pdf

**Public Health England,** 2015. https://publichealthmatters.blog.gov.uk/2015/11/26/home-is-where-the-climate-risks-could-be/

**Scottish Government**, 2013. Low carbon Scotland: Meeting the Emissions Reduction Targets 2013-2027. ISBN 9781782566595. 322pp.

**Scottish Government**, 2014. http://www.gov.scot/Publications/2016/06/2307

**Scottish Government**, 2016. https://beta.gov.scot/policies/home-energy-and-fuel-poverty/

## 7. Waste Management and the Circular Economy Sector

More than two thirds of all GHG emissions in Scotland are associated with the production, manufacture, distribution and retail of food and consumer goods, and the extraction of raw materials and construction. A more circular Scottish economy could reduce territorial emissions by 11 million tonnes $CO_2e$ per year by 2050 and help to reduce air pollution, while still providing continued economic growth. Nearly 1 in every 5 tonnes of material flowing through the Scottish economy is waste (Zero Waste Scotland, 2015).

The Scottish Government (2013a) has presented a blueprint for a circular model of resource use. This model can be used to assess the implications of changing waste management practices on GHG and air pollutant emissions in Scotland. The report focuses on Reuse-Refurbish-Remanufacture-Recycle, on Energy and Organic Waste, and on Leakage (Energy Recovery and Landfill). Key waste policies include Scotland's Zero Waste Plan (Scottish Government, 2010) and Safeguarding Scotland's Resources (Scottish Government, 2013b). Figures for the carbon metric impacts of waste, targets and performance are published by Zero Waste Scotland (2016).

There was a very substantial reduction in the emission of GHGs from the waste management sector in Scotland between 1990 and 2014. This reduction, estimated at 77% (equivalent to 7.6 $MtCO_2e$), was the largest percentage fall of any sector over this period. This was achieved through the progressive introduction of landfill-gas capture and its use for energy generation, and through a reduction in the amount of biodegradable municipal waste going to landfill. Other factors, such as improvements in the standards of landfill and changes to the types of waste going to landfill, are also thought to have contributed to this reduction. The GHG emissions from the waste sector fell by 13% (equivalent to 0.3 $MtCO_2e$) between 2013 and 2014 and the sector contributed some 5% of the total Scottish GHG emissions in 2014. Almost all of the GHG emissions from this sector are in the form of methane $CH_4$ (Scottish Government, 2016a).

The UK Committee on Climate Change recently reviewed Scotland's progress towards meeting GHG emission reduction targets (Committee on Climate Change, 2016) and recognised that good progress had been made in the waste sector, with emissions falling 13% in 2014 and with the introduction of a circular economy strategy and a Scottish Food Waste Reduction target. It recommended that Scotland focus on (i) encouraging recycling and introducing separate food-waste collections in rural and island communities; and (ii) ensuring that structures are in place to handle the municipal biodegradable waste ban and to reduce emissions from non-municipal waste sent to landfill.

Scotland's current climate change plan reported that more than 92% of the GHG emissions from the waste sector in Scotland in 2011 came from landfill (Scottish Government, 2013a). This contribution fell to 85% in 2014 (Scottish Government, 2016a) and is expected to decrease further with the continued diversion of waste away from landfill and the drive towards a circular economy (Scottish Government, 2016b). However, it is important to recognise that many of the existing landfills are emitting gas now and will continue to do so for many years to come. The key is to collect and treat/use the gas generated by landfill, not just by flaring but for the generation of energy. It has been estimated that if landfill gas from closed/inactive sites is captured it would save 22kt$CO_2$e in 2013 to 144kt$CO_2$e in 2026.

The waste sector is a small contributor of air pollutants in Scotland. This is evidenced by the work of Salisbury *et al.* (2015) who have published inventories for seven air quality pollutants ($NH_3$, Carbon Monoxide, $NO_x$, non-methane VOCs, $PM_{10}$, $SO_2$, and Lead) for the period 1990-2013. Furthermore, most of the complaints that SEPA has received about landfill sites concern odour, and not air quality *per se*.

The quantity of waste produced in Scotland is decreasing (SEPA, 2016a) and will continue to do so, while there will also be a change in emphasis in the way in which this waste is processed. Reducing consumption and waste generation, and increasing reuse and recycling will reduce GHG emissions. There will be an increasing quantity of materials recovered through Materials Recovery Facilities and less waste disposed to landfill. A ban will be introduced for the disposal of biodegradable waste to landfill with effect from 2021, so this source of GHG and air pollutant emissions will continue to decrease. There has been some investment in infrastructure for the capture and use of gas from closed landfills and the generation of combined heat and power. This has been very successful and the work should be extended. Furthermore, in future, a greater proportion of waste arisings will be processed by incineration, composting and anaerobic digestion.

The outlook for the waste generated by each waste-source in Scotland is variable, and is dependent on sector. The waste management industry is generally short of meeting the standards required for the circular economy and some sectors are more challenging than others. There is a move towards increasing materials recovery and decreasing waste arisings, with much less waste going to landfill and more waste being incinerated, composted, and treated by anaerobic digestion.

It is important to understand more about these trends, and how they will affect the emission of GHGs and air pollutants, in order to identify where there is scope for achieving win-wins and win-losses through intervention (Defra, 2010).

For example, the trend towards increasing incineration (generation of energy from waste) will reduce the emission of $CH_4$, but increase the emission of $CO_2$. It may also lead to an increase in the emission of air pollutants such as particulate matter. Composting and anaerobic digestion are also sources of GHG emissions and air pollutants, including bioaerosols. However, these industrial processes are tightly regulated by SEPA and compliance should ensure that the energy value of materials is realised and the emission of pollutants reduced so that they do not present a significant risk to the environment or human health. It is widely recognised that well-run and regulated modern municipal waste incinerators do not present a significant risk to public health (HPS & SEPA, 2009) (Air Quality News, 2016) (Font *et al.,* 2015).

Furthermore, SEPA plans to work with the waste industry to help them go beyond compliance and achieve social and economic success through improved environmental performance (SEPA, 2016b). This will deliver further reductions in the emissions of GHGs and air pollutants from this sector.

**Assessment of synergies and tensions**

It is important to consider spatial and temporal scales and direct and indirect effects in assessing the co-benefits of actions for climate change and air quality (Defra, 2010). It is also useful to consider the scale of the benefit/dis-benefit for these two drivers. Some examples are presented below. These help to illustrate the approach and recognise that the assessment of benefit/dis-benefit and the scale of them are subjective.

The **collection and burning of landfill gas for energy generation** is of benefit to climate change, albeit converting $CH_4$, a potent GHG, to $CO_2$, a less potent but more persistent GHG. This action might have a small negative impact on local air quality but this needs to be put into perspective and balanced against the impact of other practices used to generate energy. It is better to collect and burn this gas in a controlled way than allow it to be released fugitively from landfill. Such fugitive release of gas may also have a negative impact on local air quality. The generation of energy from the controlled combustion of the gas still results in the release of carbon to atmosphere, as $CO_2$ rather than $CH_4$, but this does help to meet our energy demand in a more sustainable way, by not having to import gas from other sources.

**Anaerobic digestion** plants are used to treat degradable waste and produce$CH_4$, which is captured and used to generate renewable energy through combined heat and power plants. This action may have a small negative impact on local air quality but, as with the first example, this needs to be considered in a wider context. The digestate, produced by anaerobic digestion, is a valuable fertiliser that is applied to agricultural land and this reduces the demand for more energy-intensive industrial production of fertilisers.

The **generation of energy from waste by incineration** (EFW) contributes to the achievement of Scotland's renewable energy and electricity targets. The process of incineration to generate heat and electricity results in the emission of particulates, dioxins, potentially toxic elements (PTEs) and gases to atmosphere. However, EFW plants are tightly regulated, under the PPC Regulations 2012, and the emission of these pollutants should not present a significant risk to the environment. There are currently 16 EFW plants operating in Scotland and these cover a wide range of industries such as paper mills, kilns, laboratories and hospitals (SEPA, 2016c). There may be pressure on feedstock supply in the future as Scotland moves towards a circular economy and less material is available.

The quantity of household waste incinerated in Scotland more than doubled between 2011 and 2014. However, the contribution of incineration to Scotland's total GHG emissions is negligible (less than 0.01%) (Scottish Government, 2016a). Incineration is also a very minor source of air pollutant emissions (e.g. 0.02% of total $NH_3$ emissions to air; 0.5% for $NO_x$; 0.07% for $PM_{10}$; and 1.8% $PM_{2.5}$). $PM_{2.5}$ emissions may however present a problem in areas where ambient levels are nearing the air quality objective value (SEPA, 2016d).

**Synergies**

(i) **Promote High Quality Recycling** as specified in The Waste (Scotland) Regulations 2012 and defined in the "Duty of Care – A Code of Practice" as a mainstream activity, where high quality and high capture of the key recyclables supports the foundation of a circular economy, and minimises the potential for harmful emissions as a result of Energy from Waste or landfill. Section 82 of the Climate Change (Scotland) Act 2009 allows Government Ministers, by regulation, to stipulate the recycled content of items procured or constructed in Scotland. If used appropriately, this could support targeted development of high quality recyclate feedstock and also promote targeted indigenous businesses.

(ii) **Capture and use of landfill gas for energy generation** It is estimated that if landfill gas from closed or inactive sites is captured it would save 22kt$CO_2$e in 2013 to 144kt$CO_2$e in 2026.

(iii) **Anaerobic digestion of degradable waste (e.g. food waste) for energy generation** This diverts waste from landfill and produces $CH_4$ that is used (normally via a combined heat and power plant) to generate energy. The digestate (PAS110 compliant) is a valuable fertiliser that can be applied to agricultural land.

(iv) **Incineration of (residual) waste for energy generation** This is a tightly controlled process and the emission of air pollutants should not present a significant risk to the environment. It reduces Scotland's demand on fossil fuels. Most, if not all, waste incinerators in Scotland are used to generate usable energy.

**Tensions**

(i) **Materials Recovery Facilities (MRF)** MRFs will divert waste from landfill. However, the increased use of HGVs to deliver waste and remove recyclates has the potential to increase the emission of air quality pollutants, particularly if older vehicles are used. A MRF that accepts 150000 tonnes of waste annually can have more than 7000 vehicle movements per year, or approximately 25 vehicle movements per day. This may have an adverse impact on local air quality. It is therefore important that MRFs are situated near other waste management facilities, like waste transfer stations, to minimise vehicle movements and air quality impacts.

(ii) **Composting of degradable waste (*eg* green and food waste)** Composting is an aerobic process so does not generate $CH_4$. It does, however, generate $CO_2$ and heat, but neither of these is collected. The process is much less energy-intensive than anaerobic digestion and the heat generated by composting can be used to optimise and sustain the process. Composting diverts biodegradable waste from landfill and the resulting compost (PAS 100 compliant) is a valuable product with a wide range of applications. Composting generates bio-aerosols and these can be potentially hazardous and present a risk to local air quality. Bio-aerosol emissions can be minimised if a site is well regulated and composting plants are generally located in rural areas with a low population density.

**References:**

**Air Quality News**, 4th March 2016. Incinerator health study findings expected in 2016.

**Committee on Climate Change**, 2016. Reducing emissions in Scotland. 2016 progress report.

**Defra**, 2010. Air Pollution: Action in a Changing Climate.

**Font K, de Hoogh K, *et al.***, 2015. Using metal ratios to detect emissions from municipal waste incinerators in ambient air pollution data. *Atmospheric Environment* **113**: 177-186.

**HPS & SEPA**, 2009. Incineration of Waste and Reported Human Health Effects. ISBN: 9781873772294.

**Salisbury E, Thistlethwaite G, *et al.***, 2015. Air Quality Pollutant Inventories for England, Scotland, Wales and Northern Ireland: 1990-2013. Report for Defra, Scottish Government, Welsh Government, and North Ireland Department of the Environment. ISBN: 9780957354999.

**Scottish Government**, 2013a. Low Carbon Scotland: Meeting our Emissions Reduction Targets 2013-2027. The Second Report on Proposals and Policies. ISBN: 9781782566595.

**Scottish Government**, 2013b. Safeguarding Scotland's Resources - Blueprint for a More Resource Efficient and Circular Economy. ISBN: 9781782568704.

**Scottish Government**, 2010. Scotland's Zero Waste Plan. ISBN: 9780755983063.

**Scottish Government**, 2016a. Scottish Greenhouse Gas Emissions 2014. ISBN: 9781786523099.

**Scottish Government**, 2016b. Making Things Last - A Circular Economy Strategy for Scotland**.** ISBN: 9781786520630.

**SEPA**, 2016a. Waste data for Scotland. Last accessed on 1 September 2016.

**SEPA**, 2016b. One Planet Prosperity – Our Regulatory Strategy.

**SEPA**, 2016c. Energy from waste sites; http://www.sepa.org.uk/regulations/waste/energy-from-waste/energy-from-waste-sites/; accessed 16/09/2016

**SEPA**, 2016d. Scottish Pollutant Release Inventory).Last accessed on 30th September 2016.

**WRAP**, 2016. List of energy from waste sites; http://www.wrap.org.uk/content/list-energy-waste-sites; Accessed 16/09/216; Last updated Feb 2013

**Zero Waste Scotland**, 2015. The Carbon Impacts of the Circular Economy. Technical Report. June 2015. 33pp.

**Zero Waste Scotland**, 2016. Scotland's Carbon Metric Impact.

## 8. Land-Use Planning System

An independent planning review was announced in September 2015. The review, undertaken by Crawford Beveridge, Petra Biberbach and John Hamilton (Beveridge, *et al.,* 2016), focused on six key themes: development planning, housing delivery, infrastructure, development management, community engagement and leadership, resources and skills. The Scottish Government (2016) provided a subsequent response.

The key purpose of the review was to simplify and strengthen the planning system to ensure it better serves all of Scotland's communities. Scottish Government's response is that they do not plan to open the debate on what should be done but to focus, instead, on how process improvements can be delivered. The Scottish Government will consult on a white paper in autumn/winter 2016, with a Planning Bill proposed for 2017. The White Paper is likely to seek views on proposals for:

- A reconfigured system of development plans. This will link with proposals to extend the role and scope of the National Planning Framework and Scottish Planning Policy
- New tools to assist housing delivery and diversification of types of housing
- An approach to infrastructure delivery which recognises the development planning process
- Changes to the development management process to improve efficiency and transparency; a renewed approach to performance improvement which links with an enhanced fee structure and more innovative resourcing solutions
- More meaningful and inclusive community engagement
- Embedding IT and innovation to achieve a digitally transformed planning system.

Many of the recommendations, if taken forward, could be relevant for greenhouse gas emissions and air quality in Scotland. A short summary of the review and implications for the next Scottish climate change plan and for the Cleaner Air for Scotland Strategy is outlined below. This is not a comprehensive summary, but is presented for information purposes with a particular focus on relevant aspects.

| Key themes from the review | Short overview of recommendations and key points in the review (not comprehensive) | Comments on relevance for RPP3 and CAFS |
|---|---|---|
| **Strong and flexible development plans.** | • Strong and flexible local development plans, updated regularly with a "20-year vision", and an enhanced national planning framework<br>• Primacy of development plans retained but strategic development plans replaced by an enhanced National Planning Framework.<br>• Strategic development planning authorities repurposed with planners proactively co-ordinating development with infrastructure delivery at the city-region scale.<br>• National Planning Framework more fully integrated with wider government policies and strategies including *National Transport Strategy, Strategic Transport Projects Review, Land Use Strategy, National Marine Plan, Infrastructure Investment Plan, climate change programme and the national housing strategy and action plan*<br>• Scottish Planning Policy (SPP) expanded to avoid the need for policy to be repeated in development plans<br>• IT task force to explore how information technology can make development plans more accessible and responsive to 'live' information. Digital innovation, such as the use of big data, specialist systems (such as for minerals and aggregates), GIS and 3D visualisations, actively rolled out across all authorities. | Linkages of the various strategies referred to (transport, land use, infrastructure investment and climate change and housing) are all relevant in terms of air quality and carbon emissions<br><br>Use of IT/technology will help to address energy use minimisation |
| **The delivery of more high quality homes.** | • A focus on delivering more, better housing, and improving infrastructure. Housing supply needs to match changing needs, *eg* for living with disabilities/elderly people. A focus on place making.<br>• National Planning Framework to define regional housing targets as the basis for setting housing land requirements in local development plans<br>• A programme of innovative housing delivery progressed and aligned with local development plans | Opportunities to think about low carbon approaches as part of innovate housing |
| **An infrastructure first approach to planning and development.** | • A national infrastructure agency or working group with statutory powers, involving all infrastructure providers and planning representatives, bringing together all relevant infrastructure agencies<br>• A national or regional infrastructure levy to be defined and consulted upon.<br>• A development delivery infrastructure fund<br>• A corporate structure requiring all key infrastructure providers to co-operate in delivering the local development. To include the existing key agencies, and extend to other bodies including those responsible for delivering | The national focus on infrastructure provides impetus for more efficient design, energy use and exposure to pollutants |

| | | |
|---|---|---|
| | electricity, heat, telecommunications and digital networks. Linking with external infrastructure providers, a corporate partnership established which commits to delivering plans at all scales from the National Planning Framework and its proposals for city-regions to local development plan action programmes.<br>• A review of transport governance to address the gap between this key aspect of infrastructure and development planning. Transport agencies at the national and regional scales be given a clearer mandate to directly support the delivery of development in accordance with the development plan<br>• Local authorities and their partners to be bolder in their approach to infrastructure investment<br>• New approaches to low carbon infrastructure planning and delivery taken forward through a programme of innovation. Decarbonising and future proofing of our infrastructure with a more ambitious and innovative approach by planning authorities. Work together to achieve the aims and objectives set out in the 'Making Things Last – A Circular Economy Strategy for Scotland'.<br>• Planning to innovate and lead the way into embedding new infrastructure into development to ensure that climate change targets are met. | |
| **Efficient and transparent development management.** | • Efficient, fair and transparent management process. Smarter about how information is managed within the system and more open to simplification and integration of consenting regimes. Consistency, transparency and predictability essential for all concerned. | |
| **Stronger leadership, smarter resourcing and sharing of skills**. | • Planning services aspiring to become leaders and innovators within the context of public service reform and the Scottish Government and key agencies should lead by example. A planning service viewed as a central function of a local authority that is of direct relevance to a wide range of other services | Opportunities for Planning to mainstream climate and air quality across Councils |
| **Collaboration rather than conflict – inclusion and empowerment** | • Continuing commitment and improvement to early engagement in planning,<br>• Planning authorities and developers to promote innovation which empowers communities to get actively involved in planning their own places. Much smarter use of information technology, including 3D visualisation and social media could support a step change in the transparency of planning decisions.<br>• Communities empowered to bring forward their own local place plans, forming part of the development plan. Communities are best placed to define the future of their place and this may emerge from community planning as locality | The review has a strong focus on meaningful engagement with diverse communities, and for communities to have voice. This provides opportunity to work with communities to think about place, energy use and air quality in a joined up way |

| | | |
|---|---|---|
| | plans, or be driven by land reform or charrettes.<br>• Communities supported to go beyond plan preparation to actively enable their delivery. Community development trusts, community councils and other community groups will play an increasingly important role in this.<br>• Community councils given a statutory right to be consulted on the development plan, with a responsibility to demonstrate that the wider community, including young people, has been involved.<br>• A working group to identify barriers to greater involvement in planning, taking account of measures contained in the Community Empowerment Act and the Land Reform Act.<br>• More effective and continuous engagement in the planning system is required. with disabled people, young people, minority ethnic groups, or disadvantaged communities involved.<br>• Significant and substantive shift towards local empowerment recognising that communities can be based on shared interests as well as geography.<br>• A strong movement of community development trusts and similar delivery focused local bodies with frontloaded engagement prioritised over involvement in development management decisions.<br>• Community Empowerment Act 2013 providing impetus for planning authorities and developers to establish a more mature and positive relationship with communities.<br>• A new statutory right for young people to be consulted on the development plan.<br>• A mechanism for direct engagement between young people and elected members which focuses on place, with training and a measure for monitoring inclusion. | The suggestion for training and mechanisms for engaging young people, elected members *etc* could play a vital role in influencing behaviour and place making |

**References:**


**Beveridge C, Biberbach P & Hamilton J**, 2016. Empowering Planning to Deliver Great Places – an independent review of the Scottish planning system. http://www.gov.scot/Resource/0050/00500946.pdf

**Scottish Government**, 2016. Planning Review: Scottish Government response. https://beta.gov.scot/publications/planning-review-sg-response/

## 9. Postscript

The authors recognise that the understanding of the drivers and implications of climate change is demanding while the understanding of the sources, dynamics and impacts of poor air quality is equally demanding. So, it is a stretching task to investigate and report on the interface between these two modern and urgent human challenges.

The authors reiterate that this report should not be regarded as comprehensive or definitive. It should be used more as a screening tool – potentially preferentially directing interventions to those areas where there are co-benefits to be readily gained, but also raising awareness where there may be tensions. These tensions may often be resolvable with good management and innovative thinking. Even where this is not possible, interventions should perhaps not be abandoned but additional interventions may be considered to compensate for any adverse side-effects.

The authors firmly believe that comprehensive and integrated action is urgently required to address both climate change and air quality in Scotland.

"The changes that would be important in contributing to reducing air pollution have multiple benefits"
Lord Krebs, UK Climate Change Committee and Chair of the Climate Change Adaptation Sub-committee
Scottish Parliament, 27 September 2016

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