A clear choice for the UK: Technology options for tackling air pollution

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Forewords

At the Environmental Industries Commission we and our member companies are involved in tackling a wide range of environmental issues. Many of these challenges pose risks to ecosystems and our quality of life. But only one issue - air pollution - is killing thousands of our fellow UK citizens each year.

For years air quality has been a marginal political issue, a victim of the understandable focus on the climate change/low carbon agenda and the sheer complexity of local atmospheric pollutant interactions and health impacts. But a combination of rising recognition of the health implications, growing media attention, legal proceedings and the widespread dismay over Volkswagen's cheating of emissions tests has led to a real opportunity for action.

Political will is part of the solution, but the challenge is so great that we also need innovative, thoughtful use of policies and technologies. EIC does not have all the answers, but through our members we know that there is a wide range of relevant pollution control technologies which could help make a difference in the short term, while we wait for longer term transformational technologies such as electrification of vehicle fleets and fuel cells to be rolled out.

This report shows the impact some of these technologies could make, and how policy might be reformed to enable this. I am grateful to consultancy Temple Group who undertook the modelling contained in the report, however I should emphasise that the policy conclusions are EIC's alone.

Matthew Farrow
Executive Director
Environmental Industries Commission

Effective policy-making requires a robust evidence base. As such, we are delighted to have worked with the EIC in understanding the potential costs and emissions benefits of a select range of pollution control options. Marginal Abatement Cost (MAC) curves have proved a compelling way to illustrate the relative costs and carbon reduction potential of different technologies and they can also play a useful role in the UK's air quality debate.

We have of course only looked at some of the many possible technologies and interventions - other options will also contribute. The study highlights how a range of different solutions could improve our air quality in the near term (by 2020), with further benefits accruing through to at least 2030. And most importantly it suggests that NO_x and PM_{10} emissions can be substantially reduced at no or little overall cost.

Chris Fry
Managing Director
Temple

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Air quality - the need for action

Air pollution is one of the biggest environmental challenges facing the UK. It is also unique in that it is the only environmental problem which is currently causing large numbers of premature deaths and serious illness amongst our fellow citizens. Estimates suggest 50,000 people a year die as a consequence of long term exposure to polluted air.

While overall levels of air pollution in the UK have fallen over recent decades, due to de-industrialisation, the use of emissions control technology on remaining industrial plants and on vehicles, and the phasing out of domestic coal burning, levels of harmful pollutants such as particulates and nitrogen dioxide (NO_2) have remained high in many urban areas. EU Directives have set binding limits for concentrations of these pollutants. Twenty years ago, most experts expected these targets would be met long before 2015. Limit values for particulate matter smaller than ten micrometres (called PM_{10}) should have been met by 2005, with NO_2 limits met by 2010. While PM_{10} targets have now largely been met, concerns are growing that the EU limits do not reflect the latest scientific research into the health risk posed both by PM_{10} and especially $PM_{2.5}$, while NO_2 levels are above the EU limits in 31 areas.

The UK's inability to meet these EU pollution limits has led to legal challenges against the Government, and earlier this year to a UK Supreme Court Judgement which required the Government to submit a revised plan to the European Commission by the end of 2015 – this plan must explain the measures the UK will take to become compliant in the 'shortest possible time'. It is clear then that there is now an overwhelming moral and legal need to significantly reduce harmful air pollution in the next few years.

The Government consultation

The Government has recently released a consultation document setting out how it proposes to respond to the Supreme Court judgement.

The consultation document has a number of welcome elements:

- An acceptance of EIC's long-made argument of the need for a national framework of Low Emission Zones (renamed in the document as Clean Air Zones)
- A recognition of the role of 'retrofit and alternative fuels' in reducing emissions alongside more high-profile technologies such as electric cars
- A recognition that there is no single solution but that a range of different policy measures and technologies will be needed.

From the modelling that has been prepared alongside the consultation, the Government concludes that all areas outside London will be compliant with the NO_2 limit and that London should reach compliance by 2025. It remains to be seen whether such projected timescales will satisfy the Supreme Court and the EU. Regardless of the legal process EIC believes that there is a strong public health need to achieve compliance earlier if possible and to reduce PM levels to well below EU limits.

Role of transition technologies – Our aim must be to create urban centres where we can all breathe air without any worry over its impact on our health or that of our families. In the medium term this will involve a wholesale switch to zero-emission vehicles. The Government has invested in supporting the development of electric vehicles and research into hydrogen fuel cells, and the number of electric cars on our roads is increasing steadily.

However it will be some years though before our road transport system is dominated by zero-emission vehicles yet we have to get the levels of harmful emissions down now. We must also recognise that many of the sources of urban emissions – diesel vans and buses, HGVs, construction machinery, generators and so on, are owned and used by businesses to serve their customers.

There may be cases where restricting or even banning the use of these assets in heavily polluted areas is unavoidable. But where we can find ways for businesses to extend the life of machinery or vehicles in an emissions restricted environment we can minimise the economic costs of cutting air pollution. Conversion to low emission fuel or duel fuel capability or exhaust system retrofits are examples of transitional technology that can help support business continuity and cost-effectiveness.

Liquefied Petroleum Gas (LPG) is a good example of a low emission fuel, producing less NO_x and PM emissions than standard diesel. In addition to converting older vehicles to LPG, in Continental Europe several manufacturers produce new left hand drive LPG cars. In the UK however its use has been limited despite LPG being available in 1400 petrol stations with industry commitment to expand on this demand. This is largely because car manufacturers do not produce LPG models for the UK market on the assumption that there is limited demand, while many consumers are not aware of the benefits of LPG. Breaking this self-perpetuating circle would help reduce emissions by exploiting existing infrastructure, without higher costs (LPG cars tend to have similar or slightly lower purchase price than the equivalent diesel versions and have lower refueling costs).

EIC research conducted by Temple Group

In considering how this might be achieved, EIC is aware of a wide range of air pollution reduction technologies. Some of these are mentioned in the consultation, albeit briefly and with little new detail, others are not covered. We have therefore commissioned environmental consultancy Temple Group to undertake some illustrative modelling of the cuts in air pollution (both in terms of NO_x and PM_{10}) that could be achieved by five different technologies. Options range from technologies which reduce overall pollutants at source, to those that remove pollutants from the atmosphere once they have already been emitted. The modelling was prepared on the following basis:

- Deployment scenarios were developed drawing on the expertise of EIC members with involvement in different technologies, taking account of supply chain constraints etc
- These deployment scenarios take place between 2016 and 2020 – the pollution impacts from these scenarios are then modelled for 2020 and 2030
- Temple Group were was given access to the latest technology cost and pollution abatement performance data from relevant EIC members to supplement existing academic research evidence
- The pollution reductions would take place in urban areas but are not linked to specific geographical locations – some technologies modelled can be targeted at specific roadside pollution hotspots whereas others cannot.

The five technology scenarios looked at were:

- **Electric vehicles:** Replacement of 300,000 diesel cars by electric vehicles as envisioned by Low Carbon Vehicle Patnership Roadmap.

- **Euro 6c diesels:** 90,000 old diesel cars replaced by new Euro 6c diesel cars in 2018/19
- **Bus retrofit:** 10,000 old buses in cities outside London retrofitted with DPF and SCR technology.
- **Renewable diesel:** 3,000 electricity generators on urban constructions sites switch from using red diesel to renewable diesel
- **Photo-catalytic treatment:** photo-catalytic treatment applied to 200km of the most polluted roads.

The main results are set out below – (please refer to the technical annex authored by Temple Group for the details of the methodology, scenarios and assumptions)

NOx results:

Technology option	Total impact to 2020			Total impact to 2030		
	Net cost (NPV)	NO_x savings	Cost of NO_x	Net cost (NPV)	NO_x savings	Cost of NO_x
	£m	tNO_x	£/tNO_x	£m	tNO_x	£/tNO_x
Electric cars	3,233	1,472	2,196,676	2,315	2,155	1,073,812
Euro 6c diesel cars	408	1,024	398,108	-56	1,451	-38,355
Bus retrofit	131	19,084	6,842	161	27,846	5,769
Renewable diesel generators	18	463	38,719	56	1,544	36,534
Photo-catalytic treatment	11	276	38,932	11	331	32,443

PM10 results

Technology option	Total impact to 2020			Total impact to 2030		
	Net cost (NPV)	PM_{10} savings	Cost of PM10	Net cost (NPV)	PM_{10} savings	Cost of PM_{10}
	£m	tPM_{10}	£/tPM_{10}	£m	tPM_{10}	£/tPM_{10}
Electric cars	3,233	77	42,235,116	2,315	110	21,011,638
Euro 6c diesel cars	408	74	5,499,833	-56	106	-526,898
Bus retrofit	131	481	271,697	161	575	279,245
Renewable diesel generators	18	17	1,080,046	56	55	1,019,096
Photo-catalytic treatment	11	36	297,296	11	43	247,747

Conclusions

EIC's conclusions from the data are:

- Electric vehicles have an important medium/long term role in both air pollution and carbon control, but are an expensive way to improve air quality in the short term.
- There is a range of more cost-effective technologies which could be deployed within 2-3 years and which could make a meaningful contribution to urban air quality.
- These and other related technologies have various strengths and weaknesses e.g. in terms of targetability and ability to contribute to CO_2 reduction alongside air quality improvement.
- There needs to be flexibility in how technologies are applied and combined in geographical areas to maximise impact where most needed and cost effective.

The Government consultation references some of the technologies Temple modelled on behalf of EIC (e.g. retrofit), and encourages local authorities to consider how they might be applied in the new Clean

Air Zones, but has little to say in terms of new policy initiatives at national level (beyond a reference to Government considering 'whether further incentives are needed').

From our modelling, and discussion with EIC members actively engaged in air pollution control, we believe that there is a case for proactive policies aimed at increasing the deployment of the more cost-effective technologies. We also believe such policies would drive the growth of the UK air pollution control industry.

Recommendations

Clean Air Zones

- We strongly support CAZs and have lobbied for such a scheme for some years.
- We will work with the Government and local authorities to help develop the detail of the framework and the national standards that will underpin them.
- We see additional bus retrofit schemes, especially outside London, as a cost effective way of ensuring CAZs deliver. Additional public funding will be needed for these.

Fuel taxation

- The planned erosion of the LPG duty differential should be reviewed. In addition any future change in fuel taxation should take account of the impact on local air pollution as well as CO_2.

Take up of cleaner cars

- A scrappage scheme should be introduced to incentivise the owners of Euro 4 and older diesel cars to replace them with new Euro 6c (once introduced and if real world emission targets are delivered) or LPG vehicles.
- Alternative fuel technology should be included in Government Buying Standards.
- Black cab drivers should be incentivised to convert diesel vehicles to LPG, and government should promote the benefits of LPG conversion for other existing fleets.

NRMM

- The London Non-Road Mobile Machinery registration scheme must be properly enforced, extended to include alternative fuel and duel-fuel options where these can be proven to deliver equivalent benefits to retrofit options and gradually be made more stringent.
- The London scheme should be rolled out to other UK cities.

Air Quality and Health – Defra estimates that NO_2 contributes to 23,500 early deaths annually in the UK and 29,000 due to particulate matter[2] . The UK government's Committee on the Medical Effects of Air Pollution (COMEAP) is currently undertaking further work to establish the true toll of UK air pollution.

While there are other air pollutants which impair human health, NO_2 and PM are currently thought to be the most significant contributors.

[2] Defra (September 2015), Draft Plans to Improve Air Quality in the UK

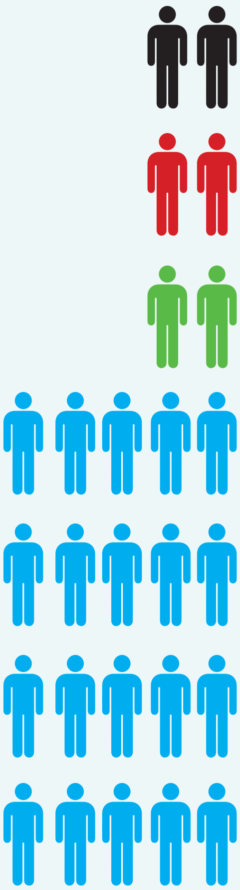
Innovation

- The investment in development of zero-emission vehicles such as electric vehicles should be balanced by funding for trials of innovative technologies which offer realistic prospects of cost-effective air pollution reductions – such as photo-catalytic surface treatments to road and/or pavements.

Other measures

- A statutory Air Quality Committee should be established based on the Climate Change Committee (CCC) created by the Climate Change Act. Like the CCC, the AQC would be independent of Government, and be required to report annually to Parliament on UK progress in meeting legal air pollution limits and on the effectiveness of government policies in delivering progress.
- Indicator boards displaying real time air pollution data (referenced to EU limits) should be set up in major urban centres.
- Transport planning should encourage walking, cycling and public transport.
- Dual carriageway speed limits should be reduced to 60mph where such roads pass through Air Quality Management Areas or the new Clean Air Zones.

Green jobs and air quality: Retrofit case study



Many of the technologies discussed in this report support UK jobs. For example, current UK employment in the diesel engine pollution control retrofit industry (including design, manufacturing, fitting and servicing) is about 500 people. Employment in the sector has been growing in recent years due to bus retrofit schemes and the London Low Emission Zone.

The bus retrofit scenario modelled for this report (10,000 bus retrofits over 5 years) would create around another 450 to 500 jobs.

Beyond this, requiring more commercial vehicles to be retrofitted through the roll out of Clean Air Zones to major UK towns/cities could lead to a further 250 to 500 jobs.

A stronger UK industry would then have a platform to secure a good proportion of the EU market. There are 360,000 EU busses without emissions filters and 300,000 commercial vehicles. If over time one half of the buses and one quarter of the commercial vehicles were retrofitted and the UK won 25% of this business an extra 5,000 jobs could be created with export sales of over £500m

Air pollution is a global problem and a scaled up UK industry would be in a good place to capture a share of the global market (Beijing alone has 30,000 buses), potentially leading to tens of thousands of UK jobs.

Key: = 250 jobs

Source: EIC estimates

Technical Annex – prepared by Temple Group

Research methodology

Scenarios for five different technology options have been modelled to determine the total costs and NO_x and PM_{10} emission savings. The scale of each scenario is based on what could realistically be implemented before 2020 if appropriate policies or incentives were in place. Each technology's impact has been calculated in comparison to a reference case (what would occur if the technology was not implemented). The cost and emission quantities have then been used to determine the cost per tonne of NO_x or PM_{10}.

Two impact timeframes have been explored:

- **2020** – to show what kind of emissions can be avoided in the near term; and
- **2030** – to show the full impact of introducing the technology scenario in terms of cost and emission reductions.

The data have been sourced from a range of places: interviews and information from EIC members validated through desk-based research, the latest UK government and other data sources (e.g. emission factors) and the most up-to-date future technology scenario research.

While many technologies presented are established technologies with well-known emissions savings and costs associated with them, some technologies require more real world large scale testing to verify air quality improvements. Where this is the case, conservative assumptions have been used. The cost of emissions savings may therefore turn out to be lower than that presented here.

The principal assumptions for calculating costs and abatement potential are listed below. A detailed list of technology specific assumptions can be found in at the end of this report.

Cost assumptions:

- A number of different costs have been taken into account, including capital costs of technologies or vehicles, cost of implementation, including staff time costs if relevant, fuel costs and maintenance costs.
- As far as possible, resource costs have been used, i.e. the costs of technologies without taxation such as value added tax (VAT) or fuel duty and without subsidies being taken into account. This means that all technologies are considered on a level playing field without current government support or duties which might favour some technologies over others.
- Government bureaucracy costs for setting up an incentive scheme for the technology options have not been included.
- Costs are shown as the net present value (NPV) of each technology scenario; if a measure has a negative net cost, this means that over the lifetime implementing the technology actually costs less than the alternative reference case.
- A discount rate has been applied to future costs (as social discount rate of 3.5% per annum[3])
- Cost projections including technology cost reductions (from efficiencies, improvements and economies of scale) and fuel price increases have been applied.
- While real-life driving has been taken into account for the emissions savings, this has not been possible for calculating fuel costs; instead the rated fuel economy (i.e. the manufacturer's stated fuel economy) has been applied, so fuel costs may be underestimates.

[3] This rate was chosen as it is recommended by HM Treasury, 2011, The Green Book: Appraisal and Evaluation in Central Government as the discount rate to use for costs to society as a whole

Emission assumptions:

- Only NO_x and PM_{10} in urban areas are assumed to have a significant impact on health. Emissions from rural driving have been excluded from the calculations.

- For the vehicle technologies, the emission factors used are those based on data available for real-life driving in urban areas.

It is assumed that emissions from electricity generation for the electric car option occur in rural areas, and are thus not included in the analysis.

The European COPERT database forms the basis of many emissions calculations in this report. COPERT is co-ordinated by the European Environment Agency (EEA) and was developed for road transport emission inventory preperation in EEA member countries. COPERT data are based on data that may not be representative of real-world driving conditions. The recent Volkswagen emissions scandal has highlighted this. While there will be errors in absolute emissions estimates compared to real world emissions, we have no reason to doubt the pattern of change: older vehicles, particularly diesels, produce far higher emissions than their modern counterparts.

NO_x – nitrogen oxides. NOx includes nitrogen oxide (NO) and nitrogen dioxide (NO_2). NOx is formed in combustion processes. NO also reacts in the atmosphere to form more NO_2 [1]. The most significant source of NO_x is road transport, accounting for just under a third of total UK NOx emissions (Defra, 2014).

There is good evidence that NO_2 is harmful to health. It can inflame the lung lining and reduce immunity to lung infections. It has been correlated with reduced lung function and growth and worsening of symptoms in asthmatic children (World Health Organisation (WHO), 2014).

[1] In this report, all NO_x figures are recorded as an equivalent mass of NO_2.

PM – particles (or particulate matter). Particles can originate from many sources, including combustion, brake and tyre wear, construction and industry. PM_{10} comprises particles smaller than ten micrometers. PM_{10} is too small to see with the naked eye. PM_{10} particles can settle deep in the lungs and cause health problems, including premature death and exacerbation of heart and lung disease.

Technology Options

Electric Cars

Replacing 300,000 older diesel vehicles with new electric cars by 2020

Wider pros and cons:

+ Reduction in CO_2 emissions (if electricity generation decarbonised)
+ Quieter than normal cars
– 'Range anxiety' so not ideal for long distance travel
– Current gaps in charging infrastructure

Scrapping 90,000 older diesel vehicles to be replaced with Euro 6c diesel cars when the standard is fully applied in 2018

Wider pros and cons:

+ Newer cars have improved safety features)
– Cars continue to emit CO_2

Euro 6c diesel cars

Bus retrofit

Retrofitting 10,000 Euro II-V standard buses outside London with diesel particulate filters, selective catalytic reduction (SCR) systems or ammonia generators (or a combination of the above) by 2020

Wider pros and cons:

+ Using existing vehicles saves resources
+ Proven technologies
– Buses continue to emit CO_2

Switching red diesel for renewable diesel in 3,000 electricity generators on UK construction sites by 2020

Wider pros and cons:

+ Reduction in CO_2 emissions
+ Easy to implement as same generators used
+ Can be combined with retrofitting to reduce emissions further
– Need to ensure fuel is sustainably sourced and production is not requiring space that would be used for food
– Only one current European producer of renewable diesel (as opposed to biodiesel which can increase NO_x emissions)

Renewable diesel to fuel construction site generators

Photo-catalytic treatments on roads

Applying treatment to 200km of UK roads in urban areas with a reapplication every two years to 2020

Wider pros and cons:

+ Can also be applied to other surfaces, e.g. pavements and buildings
+ Enables prioritisation of worst affected areas
+ Easily incorporated into existing road maintenance /cleaning operation
+ Immediate impact on apllication
– Large-scale trials have not yet been undertaken
– Effectiveness reduces over time so reapplication is necessary

Emissions in context

According to the National Atmospheric Emissions Inventory (NAEI), total NO_x emissions in 2013 were 1.02 million tonnes; total PM_{10} emissions in 2013 were 124 kilotonnes. Greater London Authority estimates of emissions across Greater London, taken from the London Atmospheric Emissions Inventory (LAEI) are as follows:

- NO_x, 2010, 50.6 kilotonnes
- NO_x, 2020, 33.6 kilotonnes
- PM_{10}, 2010, 4.86 kilotonnes
- PM_{10}, 2020, 4.17 kilotonnes

Calculated emissions savings for this study are not directly comparable, as they apply over different areas. These numbers, however, show that the emissions reduction potential from the measures considered is small in comparison with UK and Greater London totals.

NOx results:

Technology option	Total impact to 2020			Total impact to 2030		
	Net cost (NPV)	NO_x savings	Cost of NO_x	Net cost (NPV)	NO_x savings	Cost of NO_x
	£m	tNO_x	£/tNO_x	£m	tNO_x	£/tNO_x
Electric cars	3,233	1,472	2,196,676	2,315	2,155	1,073,812
Euro 6c diesel cars	408	1,024	398,108	-56	1,451	-38,355
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Renewable diesel generators	18	463	38,719	56	1,544	36,534
Photo-catalytic treatment	11	276	38,932	11	331	32,443

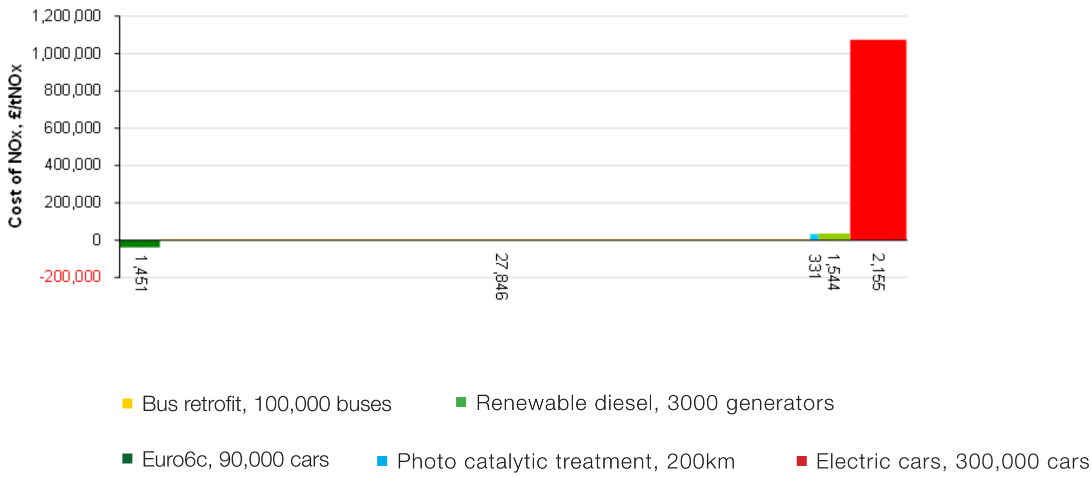
The most cost-effective technologies in the short term based on the scenarios are bus retrofit, renewable diesel generators and photocatalytic treatment. Stimulating the take up of Euro 6c diesel cars is more costly in the short term but costs less in the long run due to increases in fuel economy coupled with fuel price increases.

The greatest potential for NO_x reductions up to both 2020 and 2030 is from the bus retrofit programme, followed by electric vehicles.

While the costs shown here per tonne abated are high for renewable diesel generators, the costs actually faced by the consumer are much lower due to the tax regime and government incentives. The cost of renewable diesel faced by the consumer is similar to that of the red diesel/gas oil as a result of fuel duty exemptions and Renewable Obligation Certificates.

Electric vehicles implemented to 2020 are the least cost-effective technology. Again the costs actually paid by consumers are lower since there is a Plug-In Incentive of up to £5,000 on each car purchase in the UK. This, coupled with taxes which increase the price of petrol or diesel, make the price differentials less extreme.

With the current UK tax and incentive regime, therefore, both renewable diesel fuels and electric vehicles will seem much more attractive economically than the results presented here, especially if considering a wider set of factors including climate change.



PM10 results

Technology option	Total impact to 2020			Total impact to 2030		
	Net cost (NPV)	PM_{10} savings	Cost of PM_{10}	Net cost (NPV)	PM_{10} savings	Cost of PM_{10}
	£m	tPM_{10}	£/tPM_{10}	£m	tPM_{10}	£/tPM_{10}
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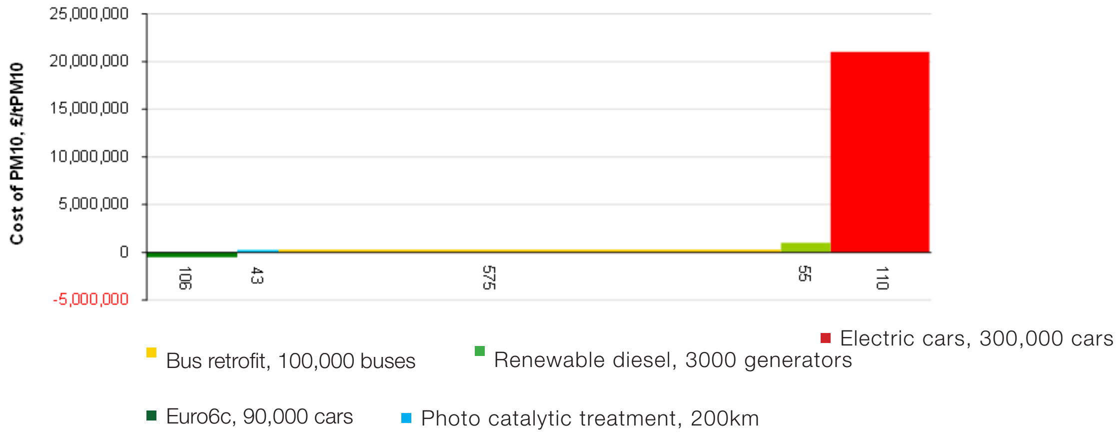
Renewable diesel generators	18	17	1,080,046	56	55	1,019,096
Photo-catalytic treatment	11	36	297,296	11	43	247,747

The emissions abatement potential is much lower and more expensive for PM_{10} compared to NO_x. In some cases, this is likely to be because standards for earlier vehicles were more stringent and the difference with new vehicle standards therefore less stark.

In spite of this, the abatement cost curve for PM_{10} (as shown in Figure 2) is markedly similar to NO_x. The main difference is that Euro 6c diesel cars are one of the least cost-effective to 2020 but become more attractive if looking to 2030, as the increase in fuel economy leads to cost savings.

Figure 2: PM10 abatement cost curve to 2030



Abatement cost curves – Abatement cost curves help to distil complex information visually to help policy makers and others prioritise different abatement options. Each technology is represented by a rectangular block. The width of the block is proportional to the emission saving arising from the technology over the time period, and the height of the block, the net cost per tonne of emissions saved. To date, they have been used to good effect to compare greenhouse gas abatement options (i.e. CO_2), but have yet to be properly applied to the topic of air quality.

The modelling of air quality abatement differs in one important respect to looking at greenhouse gases: for health impacts and compliance with limit values, it matters where air pollutant emissions occur. With this in mind, only emissions that are likely to occur in urban areas, where limits are being breached, are taken into account for the air quality abatement cost curves.

Abatement cost curves only look at two facets of performance – cost and effectiveness in reducing a particular pollutant. They should thus be used cautiously and considered in the context of wider environmental and social benefits or disbenefits. They also do not take into account the interconnectedness of different options. More detailed modelling would be required to understand the impact that introducing one measure might have on the effectiveness of another.

Detailed assumptions

Technology option	Details of option	Scale	Implementation trajectory	Reference case	Cost & emissions assumptions
Electric cars	Number of diesel cars (Euro 3 & 4 standards) to be scrapped and re-placed with electric cars.	300,000 cars	Assume cars replaced between 2016 and 2020 with increasing numbers replaced each year.	Diesel cars remain on road but replaced naturally to 2030 by latest diesel standard in line with projected replacement rates	Costs reductions of electric vehicles and battery hire of 5% per annum to 2020; range improvements of 10% per annum. Emission factors were calculated using the COPERT 4v11.3 software by Emisia for urban areas in the UK
Euro 6c diesel cars	Number of diesel cars (Euro 3 & 4) to be replaced with diesel cars of Euro 6c standard through new diesel engine filtration technology such as selective catalytic reduction	90,000 cars	Assume car scrappage scheme once Euro 6C standard comes fully in 2018, i.e. implementation in one year	Old diesel cars remain on road but replaced naturally to 2030 by latest diesel standard in line with projected replacement rates.	Emission factors were calculated using the COPERT 4v11.3 software by Emisia for urban areas in the UK.
Bus retrofit	Retrofitting 10,000 Euro II-V standard buses outside London with diesel particulate filters, selective catalytic reduction (SCR) systems or ammonia generators (or a combination of the above) by 2020.	10,000 buses	Max of 700 buses retrofitted in first year with capacity to retrofit increasing by 1000 each year between 2016 and 2020. Most polluting buses are retrofitted first. Retrofitting delays natural replacement for 5 years.	No retrofitting programme and fleet replaced by Euro VI buses between 2016 and 2030	Emission factors for reference and retrofitted buses came from real-life driving tests in urban areas tested by the Millbrook Vehicle Emissions Laboratory. When not available, they were calculated using the COPERT 4v11.3 software by Emisia for urban areas in the UK.

Technology option	Details of option	Scale	Implementation trajectory	Reference case	Cost & emissions assumptions
Renewable diesel to fuel construction site generators	Switching red diesel for renewable diesel in 3,000 electricity generators on UK urban construction sites by 2020.	3,000 generator sets	Equal numbers switched each year (600 each year) between 2016 and 2020.	Generators continue to be run on red diesel.	Future renewable diesel prices track projected red diesel price changes. Emission factors provided by the Energy Research Institute – University of Leeds, from a JCB diesel generator (G175QX) with a maximum capacity of 128 kW. Renewable diesel is compared to a standard petroleum gas oil that meets ASTM975 2-D standard.
Photo-catalytic treatments on roads	Photo-catalytic treatments applied to UK urban roads, prioritising treatment of roads with the high recorded pollution levels	200km road	All roads treated at implementation start (2016). Reapplication every 2 years (2018 and 2020).	No photo-catalytic treatments introduced.	No decay in abatement activity was considered between applications due to lack of full-scale long-term data.

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Pureti

Reference list

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Temple Group

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Temple's air quality team has extensive experience in air quality assessment. Team members have specialist expertise in vehicle emissions, policy development, infrastructure, industrial emissions, monitoring and construction air quality.

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The Environmental Industries Commission (EIC), founded in 1995, represents the businesses which provide the technologies and services that delivery environmental performance across the economy. In short, we are the voice of the green economy. Our members are innovative and the leading players in their field, and include technology manufacturers, developers, consultancies, universities, and consulting engineers.

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