Project BREATHE retrofitting

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Buses in Leicester's AQMA

- AQMA declared for NO_2 exceedances
- **Key equation: $NOx = NO + NO_2$**
- Reducing NOx reduces primary (tailpipe) NO_2
- Traditional exhaust gas treatments (developed for trucks) not designed for the stop-start drive cycle of the urban bus
- In congested conditions exhaust gas temperatures may not be hot enough to achieve higher rates of NOx conversion

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Leicester Bus Emissions Study 2013

Route	Percentage contribution to NOx emissions by direction Buses/Coaches
A426	
North	10%
South	24%
A607	
North	33%
South	40%
A47 East	
North	28%
South	23%
A5460	
North	19%
South	16%

- Study included modelling work to **estimate** the percentage contribution from different vehicle categories to NOx emissions
- The highest contribution from buses/coaches was found to be the A607 radial running through the north of the city
- Following the study, emissions from buses was added to the ongoing council/bus company dialogue
- The need to address the issue was initially met with some scepticism
- However, the Council has a statutory duty to improve air quality, and this includes reducing emissions from our privately operated bus services.

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Retrofitting - Project BREATHE 1/2/3

(**B**us **RE**trofit: **AT**tenuating **H**armful **E**missions)

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Retrofitting - Project BREATHE 1/2/3

- In partnership with Arriva and Centrebus, the Council has made successful bids to all three of the DfT's national funding programmes for retrofitting with technologies achieving > 50% NOx reduction in tailpipe emissions
- PB1 (2013) – 32 Arriva Euro 3 buses retrofitted to Euro 5+ standard
- PB 2 & 3 (2014 & 2015) – 11 Centrebus Euro 3 buses – to Euro 5+ standard
- All projects have a five year duration
- PB 1 & 2 target services on the A607 corridor, where the contribution from buses to NOx emissions is estimated to be highest
- Swap hydraulic engine fans for electric versions

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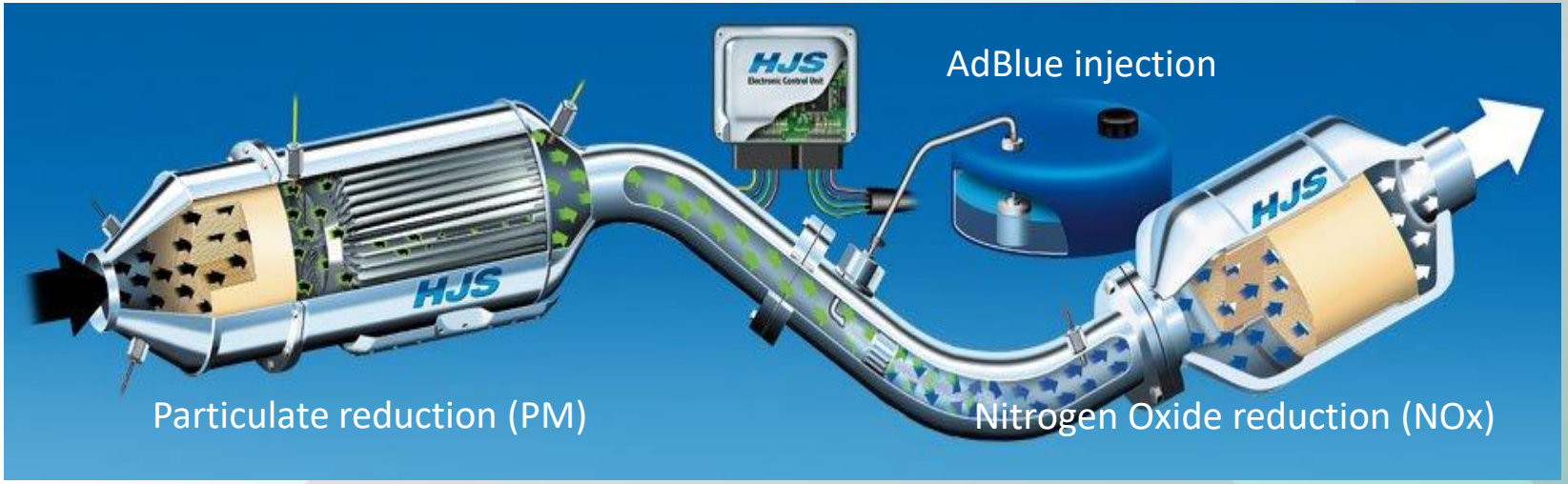
Exhaust system retrofitting



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Retrofit with DPF and Selective Catalytic Reduction

- To reduce particulates as well as NOx
- Choice based on London's positive experience with such systems; which when deployed at scale have led to sustained **reductions in ambient NO_2** at the property line – the holy grail!
- Some ingenuity is required to install the kit in the available space, and provide robust fixings to cope with vibration
- **Key lesson –** refurbish engine before retrofitting; or 'Vehicle off Road' risk. Trouble free running from retrofitted vehicles with refurbished engines

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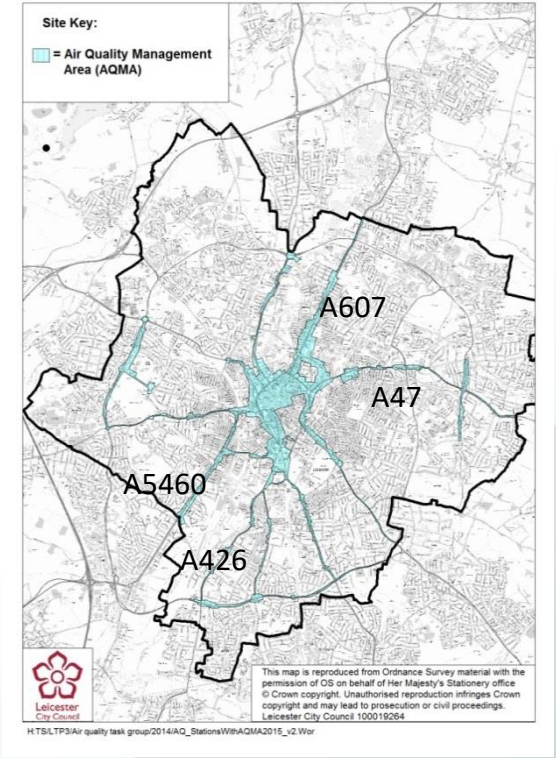
Project BREATHE routes through Leicester's AQMA



- PB 1 & 2 – A607 corridor
- PB 3 – A47 corridor
- Retrofitting and air quality's higher profile have helped encourage Arriva & First to expedite the introduction of Euro 6 buses in Leicester
- Arriva have replaced some of the PB1 buses with Euro 6 vehicles. The retrofits have been cascaded to Arriva routes in other parts of the AQMA; namely the A5460 corridor

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Procurement and Payments

- The Council leads on procurement in close collaboration with the operators. When equipment and supplier have been chosen, the Council transfers the required capital grant to the operator, to place the order
- In addition to the DfT's capital grant, the Council provides revenue support to cover extra, project related operating and maintenance costs; i.e maintenance of the retrofitting kit, and the cost of the extra AdBlue.
- The allocation for the 32 PB1 buses is almost £300k, over 5 years.
- The Council also funds tailpipe and roadside emissions monitoring

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Project BREATHE: emissions testing results

Arriva – PEMS tests

Pollutant	Unmodified vehicle Baseline	Target emissions reduction	Actual emissions reduction
NOx	18.9g/km	70%	78%
NO_2	1.3g/km	50%	15%
Particulate mass (PM)	279.6g/km	90%	43%

Centrebus – NOx sensor data

Reduction between engine out and tailpipe
88% at 275°C
89% at 251°C
90% at 269°C
91% at 278°C

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Project BREATHE: emissions testing results

- Autumn 2015 Council commissioned Emissions Analytics Ltd to conduct on-bus emissions tests on two PB1 buses, using Portable Emissions Monitoring equipment
- Buses ballasted for average load, driven over actual route sections 6 times
- Big learning exercise re: exact technical condition of the vehicle, exact configuration of the SCR system, time between testing the buses in unmodified and retrofitted states
- One bus gave useable results; and for this vehicle we are pleased to have exceeded the 70% target reduction for our key objective; reducing NOx pollution.

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Project BREATHE: emissions testing results

- Now understand that it is hard to get a 50% reduction in NO_2, and that NO_2 production is very sensitive to the set up of the SCR system
- The lower than expected results for particulates may have been due to a blockage in the DPF
- The engines of the PB1 buses were not refurbished ahead of retrofitting, which is likely to have had a negative impact on the test outcomes.
- NOx sensors fitted upstream and downstream of the NOx abatement kit on the Centrebus vehicles indicate higher NOx reductions; 89.5% average
- Effect on CO_2 and fuel economy was ambiguous

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Summary and Looking Forward

- Did we achieve our target of retrofitting Euro 3 up to Euro 5 standard?
- Professional judgement required, as Euro standards and emissions tests are done in different units; but a 78% NOx reduction well meets the Euro 5 standard for NOx
- retrofitting delivers this at fraction of the cost of a new bus - vfm
- Still to see reduction in NO_2 annual mean at AQ monitoring stations on PB routes

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Summary and Looking Forward

- PB 2&3 PEMS emission tests set for Spring 2018. Buses to be driven to a drive cycle, for better results repeatability
- Leicester not mandated to produce a CAZ; but we expect to sign an agreement with our buscos for a CAZ by January 2018.
- Badging low emission projects 'Healthier Air for Leicester'; helps public awareness
- All outlined in Leicester's AQAP
- CBTF 2017 bid

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http://www.leicester.gov.uk/media/180653/air-quality-action-plan.pdf

Thank-you

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