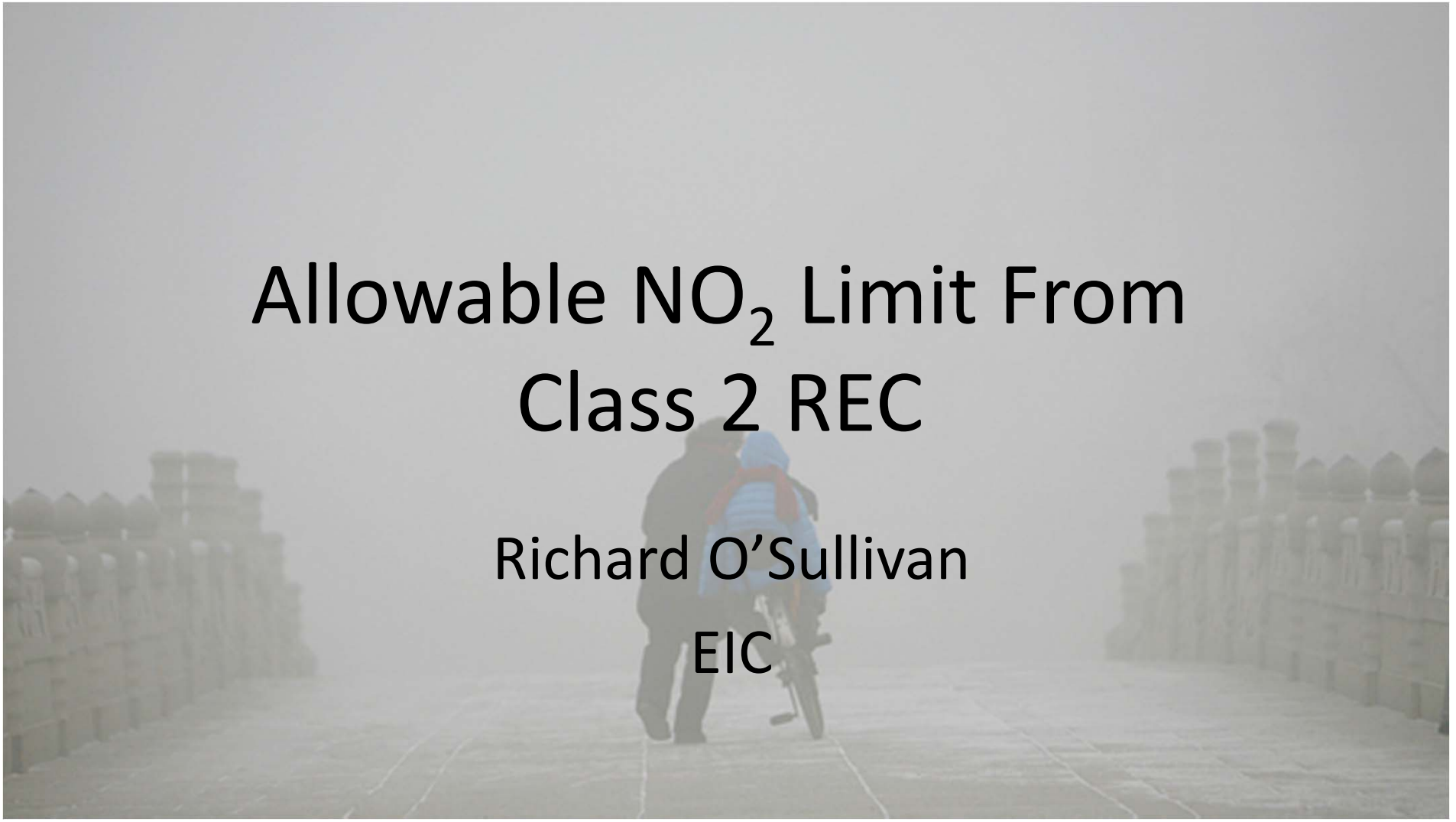


Allowable NO_2 Limit From Class 2 REC

Richard O'Sullivan

EIC

Background

- Retrofit strategy used successfully by Member States for 20 years
- Most widely used system based on NO_2 regeneration
  - Regeneration is biggest challenge
  - Pt/NO_2 based regeneration most reliable
  - All retrofit suppliers offer NO_2 based systems
- Recognise that NO_2 undesirable and is already optimised
  - To meet existing requirements for +30%
  - To maintain reliable PM filtration and regeneration
  - To reduce cost
- All truck OEMs use NO_2 based regeneration to meet EU VI requirements
  - Reliable regeneration under most conditions
  - Improves fuel economy

NO_2 In Context

- Diesel PM presents a more serious public health issue than NO_2
- Most primary NO_2 comes from existing Diesel passenger cars
- All NO is converted to NO_2 in the atmosphere in a matter of 10s of seconds
  - Depending on ozone level
  - Primary NO_2 increases level of oxidants
- NO_2 has a much greater focus in Europe because of difficulty in meeting EU requirements
- This regulation should allow other countries to assess importance of Diesel PM against NO_2

Quotes from 2013 WHO study funded by the EU

“The adverse effects on health of particulate matter (PM) are especially well documented. There is no evidence of a safe level of exposure or a threshold below which no adverse health effects occur. “

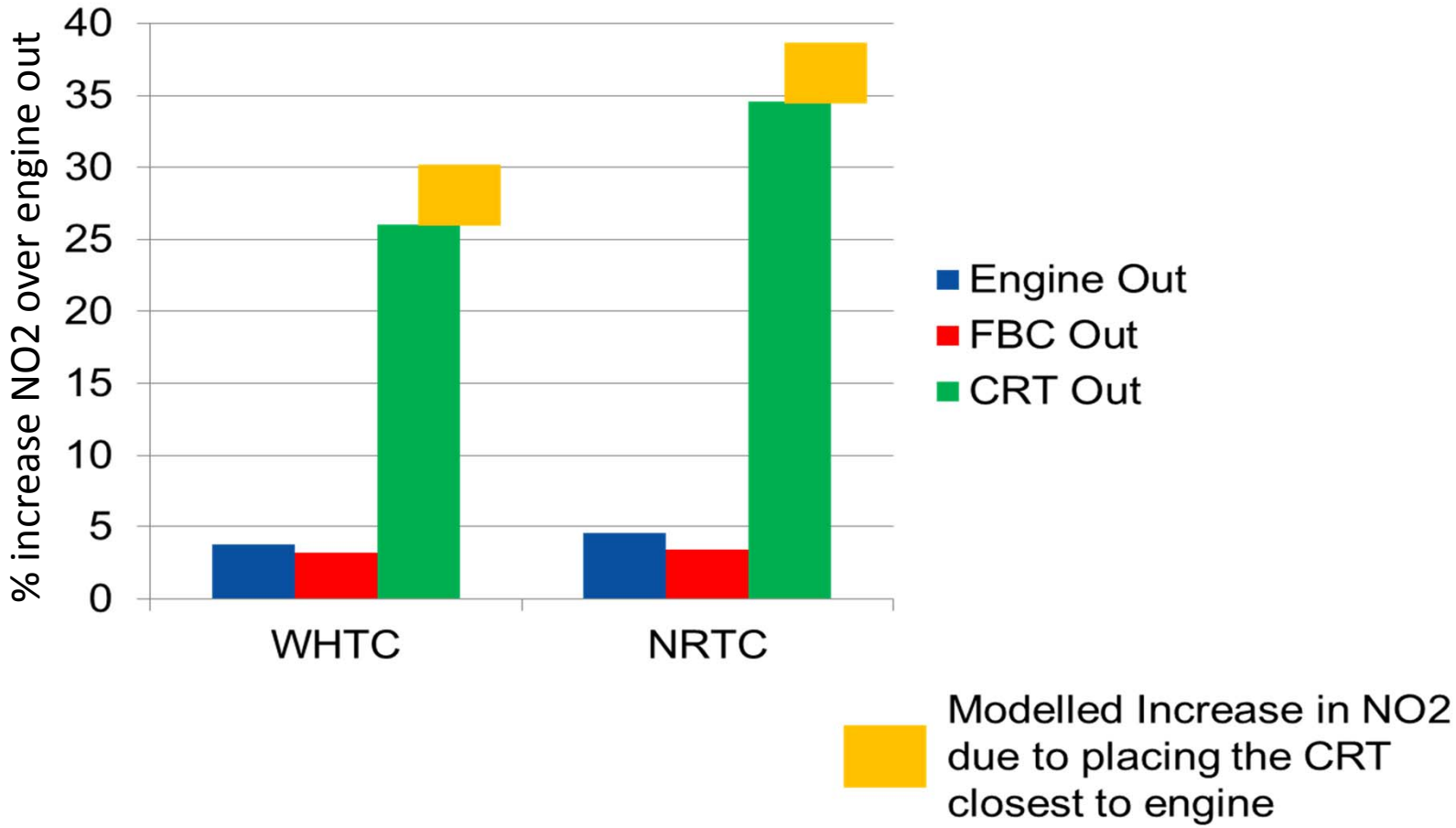
“Pollution from PM creates a substantial burden of disease, reducing life expectancy by almost 9 months on average in Europe. “

“some epidemiological studies do suggest associations of long-term NO_2 exposures with respiratory and cardiovascular mortality and with children’s respiratory symptoms and lung function that were independent of PM mass metrics.”

Why is +20% NO_2 a problem?

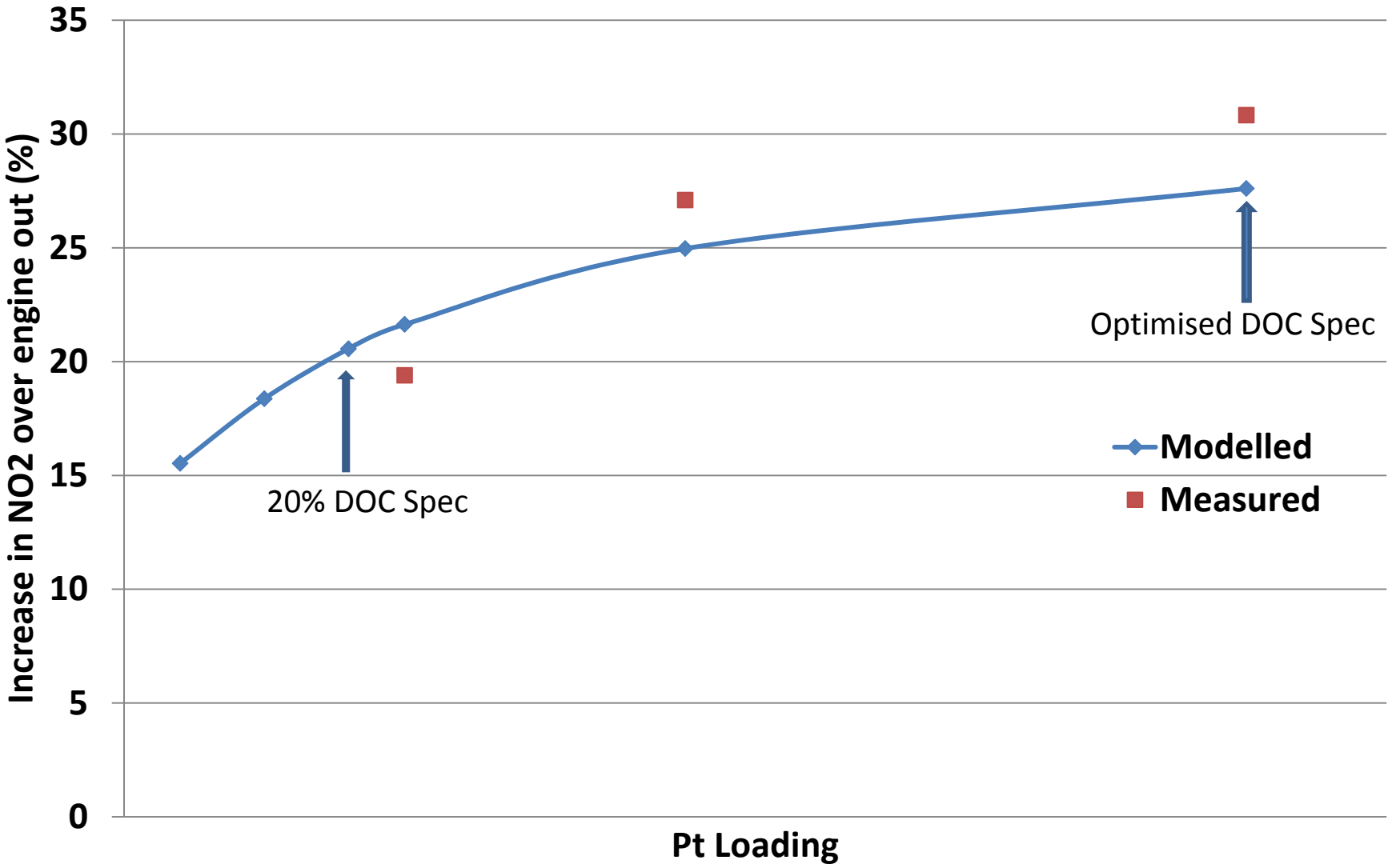
- We have very limited data but existing optimised systems can just meet +30% over WHTC and will not meet +30% NRTC
- Meeting +20% will result in
  - Higher failure rate/reduced reliability
  - More expensive/complex systems
- A system meeting 20% NO_2 requirement over WHTC was modelled
  - Did not regenerate over MLTB
  - Was marginal at regeneration over WHTC after mild conditioning
- Retrofit DPF needs to work after many years of service on old engines operating under difficult conditions

Increase in NO_2 For optimised CRT® System Positioned 2m From EU III Turbo Outlet



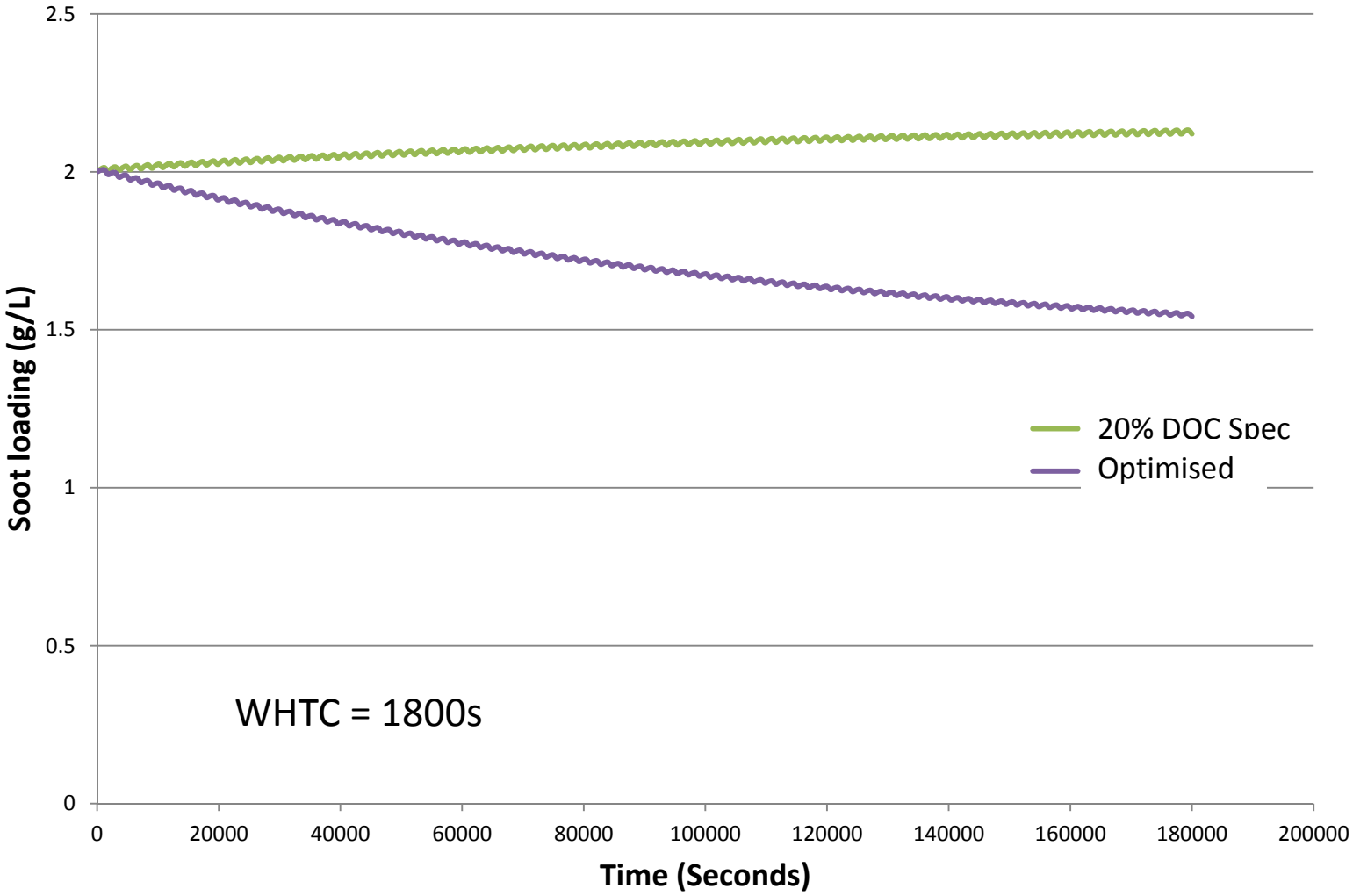
Effect of Pt Loading on NO_2 over WHTC

Modelled and Experimental

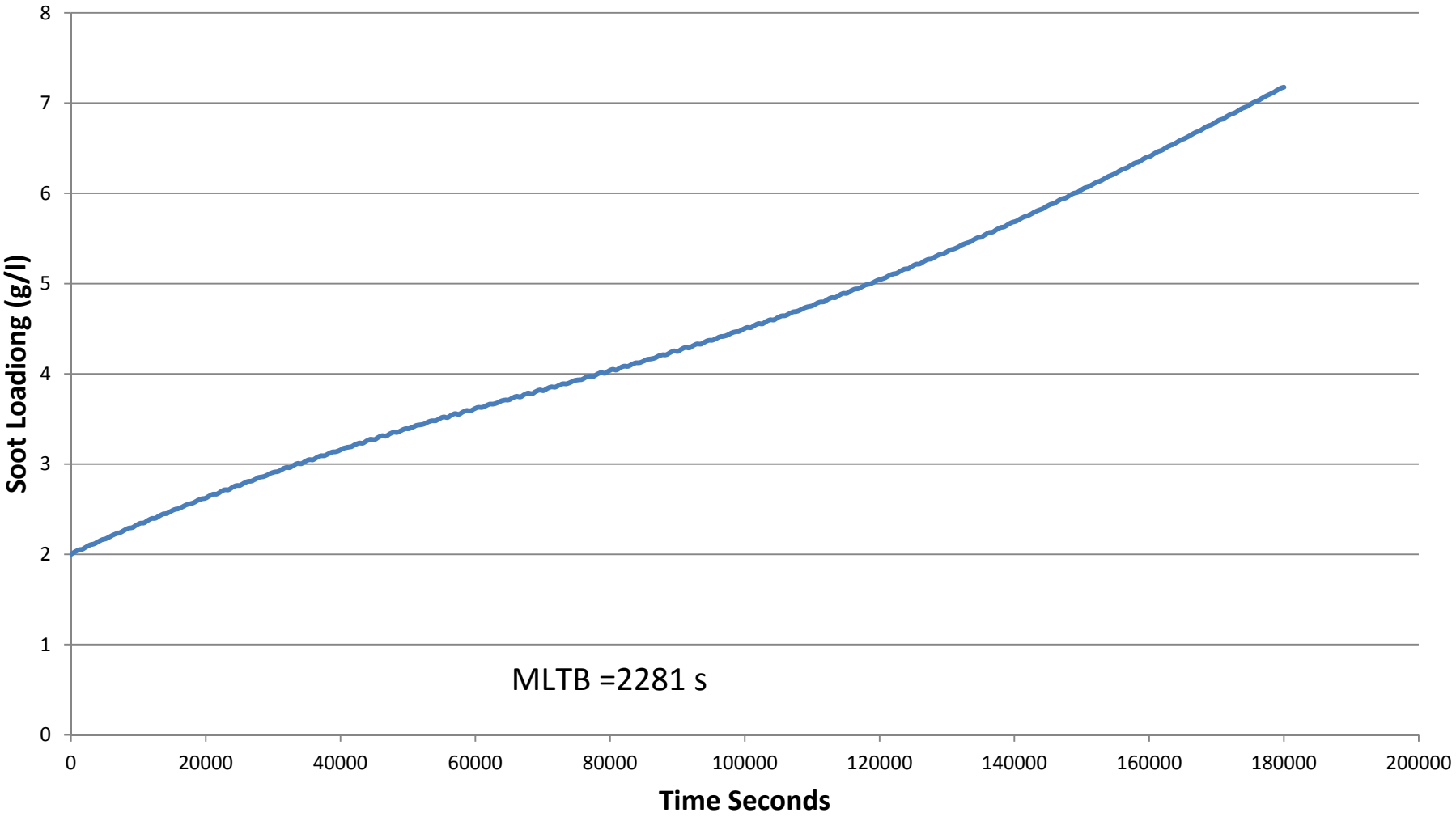


Optimised and 20% NO_2 Spec Pt DOC Loading

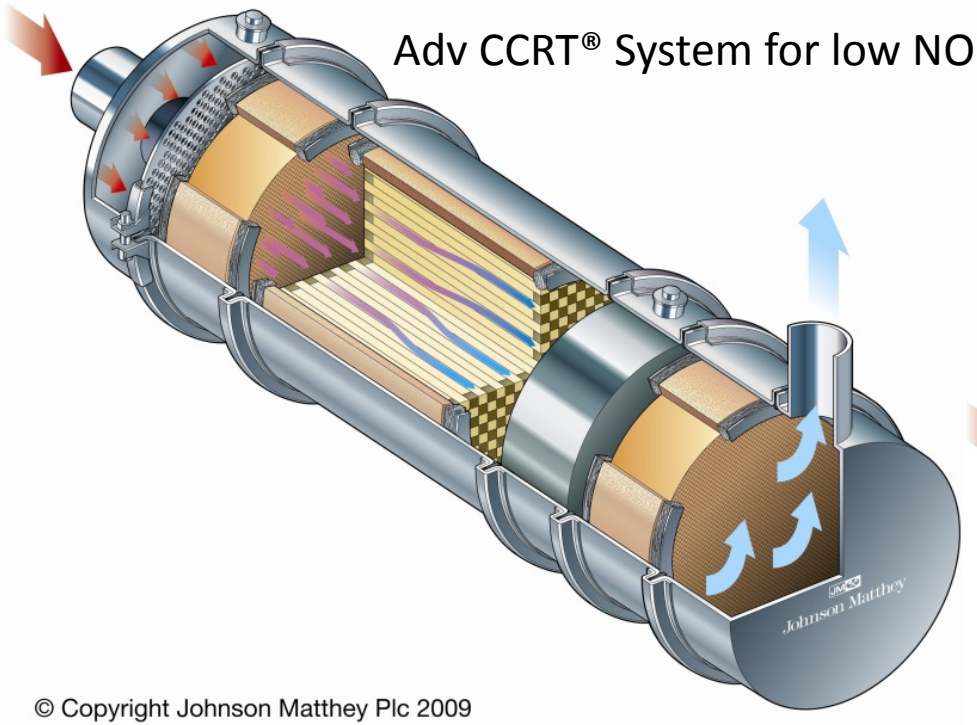
DPF Soot Loading Modelled over Repeat WHTC on EU III



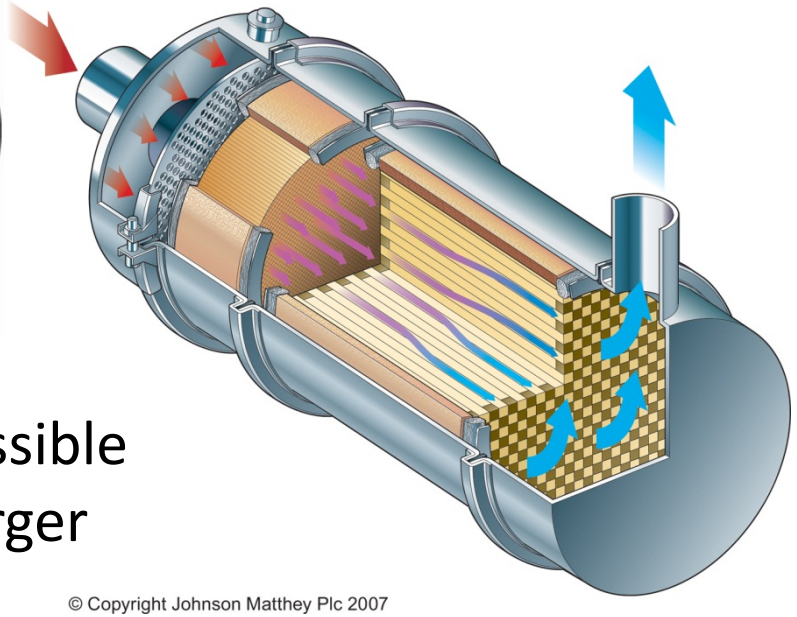
Accumulation of Soot in DPF for 20% NO_2 Spec DOC Over Repeat MLTB Cycles



Adv CCRT® System for low NO2



Regular CRT® System



Low NO_2 CRT® Systems Technically Possible but More Expensive, Complex and Larger

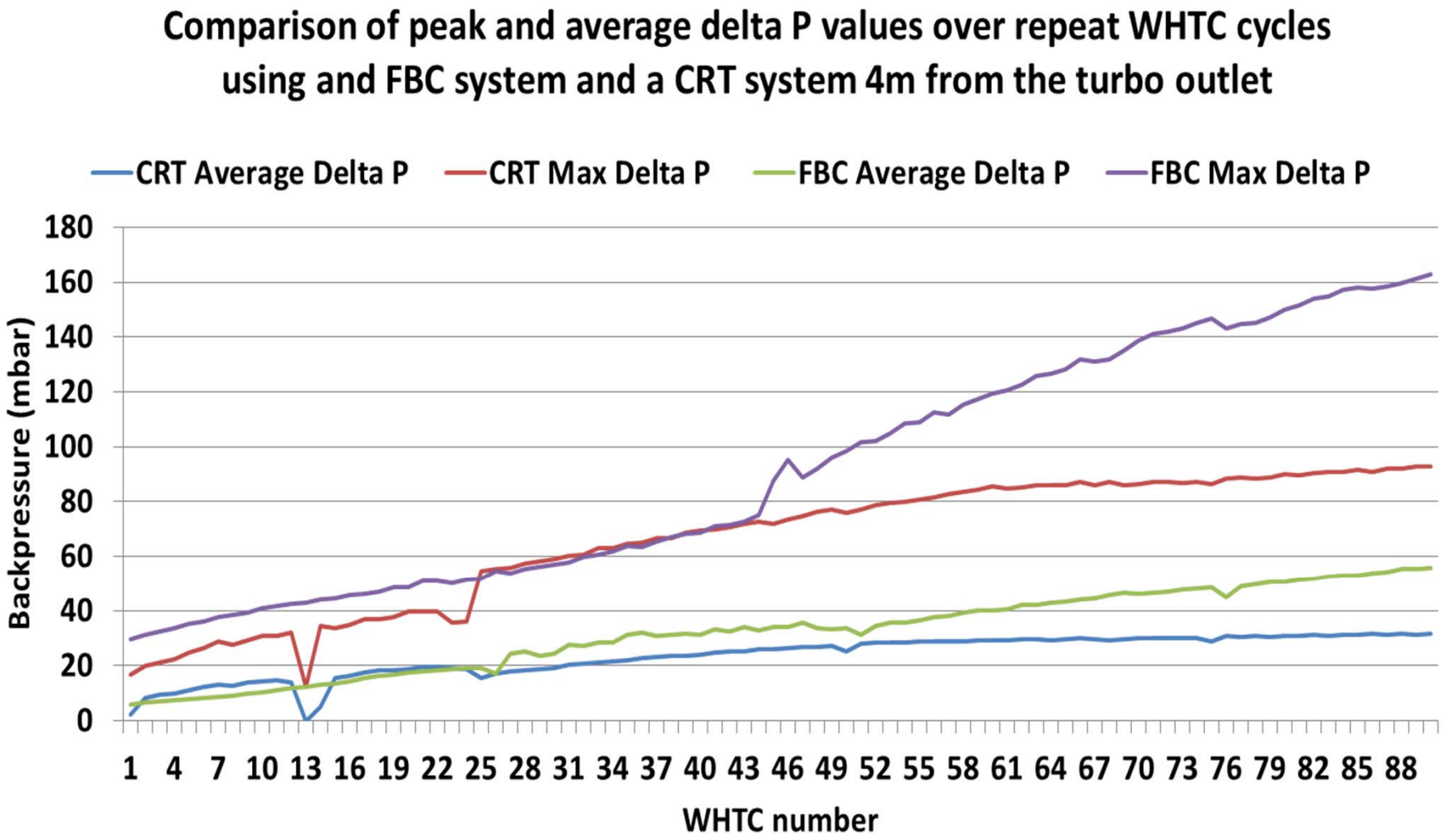
But They Have +20% In The US

- REC procedures are very much worst case
  - Largest catalyst
  - Closest to the engine
  - Highest concentration of PGM
  - Fresh system
  - No PM on filter
- In US 20% NO_2 requirement has led to reduced retrofit
  - Reduced reliability
  - More complex/expensive systems
- Engine out NOx:PM often better for US engines over a transient cycle
- Often higher temperature applications
- No 0% NO_2 requirement in the US

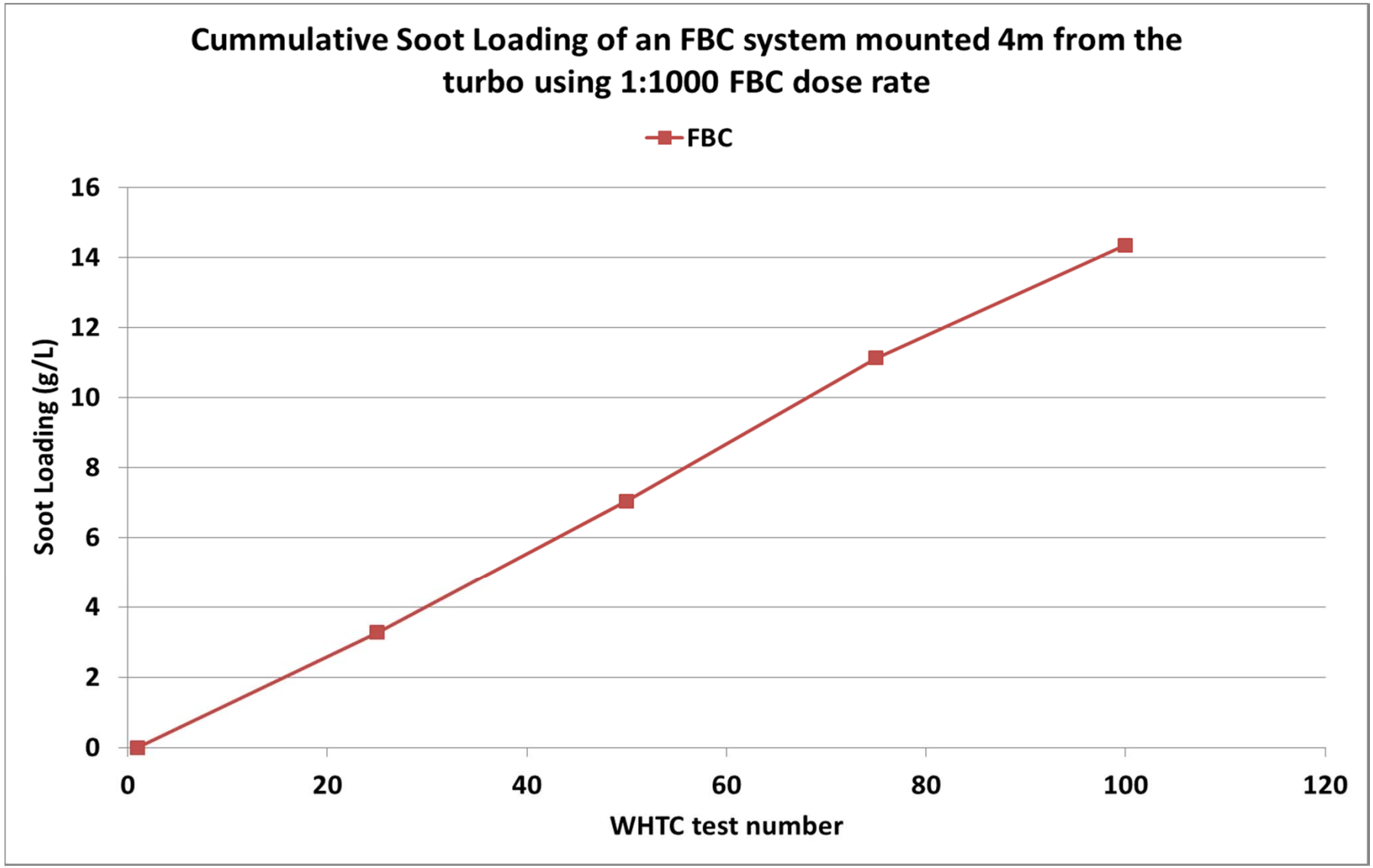
But What About Alternatives to NO_2 Based Systems?

- FBC need higher temperatures to regenerate (380^{o}C+ compared to 250^{o}C+ for NO_2-based)
  - Regenerate less often
  - Will be more likely to have high BP/CO_2
  - Will be more likely to suffer thermal events
  - When fail will also emit FBC products
- Electrical systems
  - Require external power and operator intervention
  - Higher BP/CO_2
- Burners and Fuel Injection
  - Complex and expensive
  - Difficult to calibrate/unreliable
  - Increase CO_2

Regeneration Performance of FBC System on EU III engine



Regeneration Performance of FBC System on EU III engine



Why Is Higher NO_2 Needed?

- Not all NO_2 reacts with PM on filter
  - Depends on temperature
  - Depends on amount of soot on filter
- Amount of NO_2 varies
  - Over time as catalyst deteriorates
  - With application and duty cycle
- Retrofit needs to work over all normal cycles, after many years in service and for different engine PM levels. Not just over WHTC, fresh under laboratory conditions
- Tough NO_2 limit will make retrofit less effective at reducing PM which should be the focus of the regulation

The Industry Will Rise To The Challenge?

- Retrofit is small compared to OE
  - Normally around 10,000 heavy duty retrofits/year in Europe
  - Normally around 400,000 new heavy duty vehicles/year in Europe
- NO_2 based retrofit systems have already been optimised over the last 30 years for balance between NO_2 emissions/cost and reliability
- Most companies specialising in retrofit are SME and do not have resources to make significant new development
- Some larger companies involved but retrofit represents a small part of sales (for JM <<1% of sales value)
- PM retrofit has been a declining market
- REC certification process already places major cost of compliance on industry without additional development costs

Conclusion

- Retrofit DPF has been used as an effective strategy in reducing Diesel PM in many European cities
- Most of these devices have used NO_2-based regeneration with Pt catalysts because they are simple to operate, reliable and cost effective
- The industry acknowledges that they increase tailpipe NO_2 and that this is undesirable
- Controls on NO_2 from Class 2 RECs are justified but
  - 20% NO_2 limit will affect reliability, cost and greatly restrict application of systems
  - 30% NO_2 limit will require system optimisation to control NO_2 but will allow these passive systems to continue to be an effective solution for PM reduction – especially in parts of the world where PM is the priority