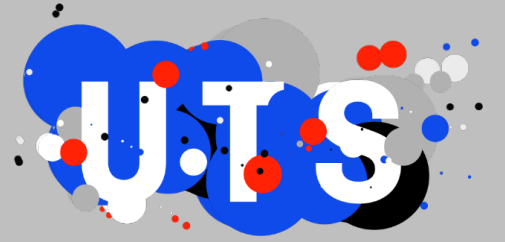


# Real driving solid particle number emissions from a hydraulic hybrid heavy commercial vehicle and diesel sports utilities vehicles in Australia



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Results based on: R. Smit, et al. 2022. *Transport. Res. D-Tr. E.*, 107, Article Number: 103286  
N. C. Surawski et al. Under Review.

# Funding Acknowledgements



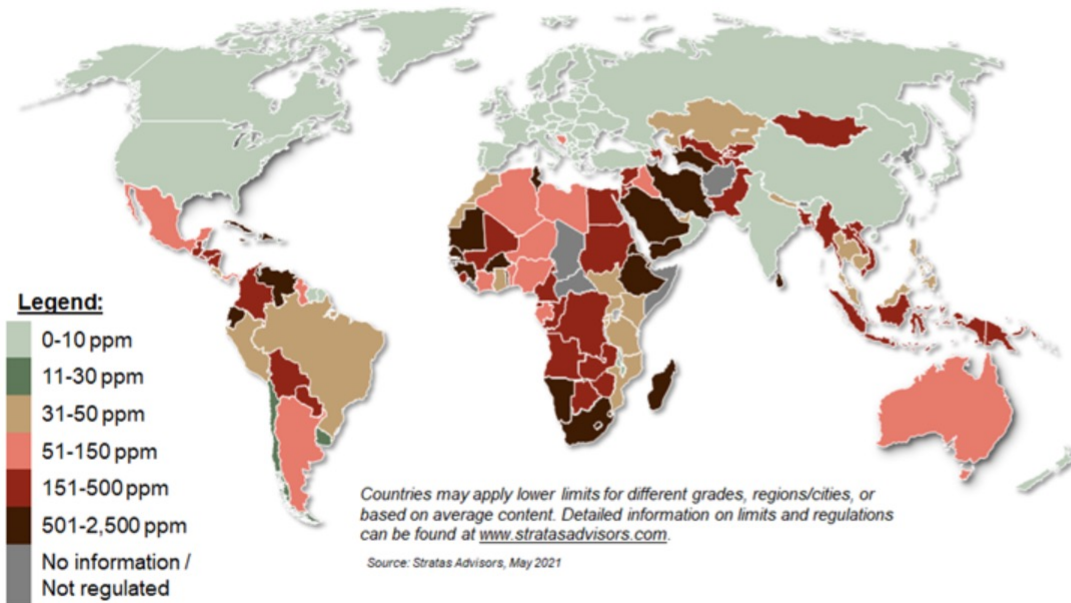
Automotive Innovation Lab Access Grant Scheme – Department of Industry,  
Innovation and Science

Queensland Department of Environment and Science

# Vehicle Emissions: The Australian Way ...

## Maximum Sulfur Limits in Gasoline, 2021

Only Fiji switched to 10 ppm since January



<https://stratasadvisors.com/Insights/2021/05272021-Global-Gasoline-Quality-Outlook>

**Australia:** a global laggard that decided to make some progress with vehicle emissions

- Euro VI diesel legislation being introduced<sup>1</sup>
- Real driving emissions testing program under way<sup>2</sup>
- Euro 6 standard for light duty vehicles being introduced<sup>3</sup>
- Mandatory fuel efficiency standards being introduced<sup>4</sup>
- Petrol fuel quality was amongst the worst in the world (until 2025)

<sup>1</sup><https://tinyurl.com/4p38syn2> <sup>2</sup>Real-World Testing delivering for motorists - Australian Automobile Association ([aaa.asn.au](http://aaa.asn.au))

<sup>3</sup><https://tinyurl.com/4vrtnfpn> <sup>4</sup><https://tinyurl.com/yrun6nab>

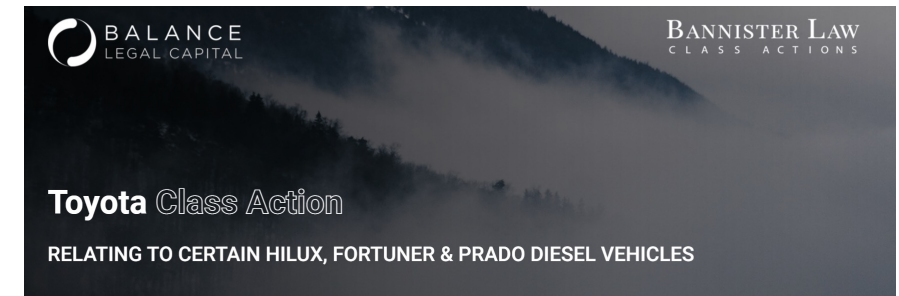
# Two sports utility vehicles (SUVs) tested



Parameter	Vehicle A	Vehicle B
Make/model	Toyota Land Cruiser Prado GXL	Isuzu MU-X LS-U
Year of manufacture	2019	2018
Odometer	18041	50634
Engine Specifications	4 cylinder, turbocharged, diesel	4 cylinder, turbocharged, diesel
Engine Capacity	2755 cm <sup>3</sup>	2999 cm <sup>3</sup>
Rated power	130 kW @ 3400 rpm	130 kW @ 3600 rpm
Rated torque	420 Nm @ 1400 rpm	430 Nm @ 2000 rpm
Aftertreatment	DPF-EGR-DOC	Catalysed DPF - EGR
ADR Compliance	ADR 81/02	ADR 81/02
Type Approval Emissions Limit	Euro 5	Euro 5

**Diesel Particulate Filter (DPF) regenerations:** Vehicle A under idle possible, Vehicle B under steady speed of ~ 60 km/h

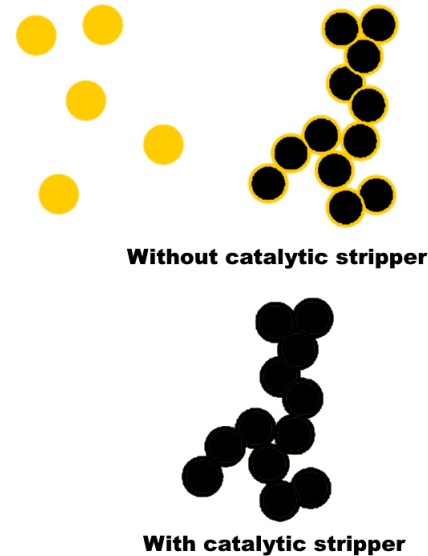
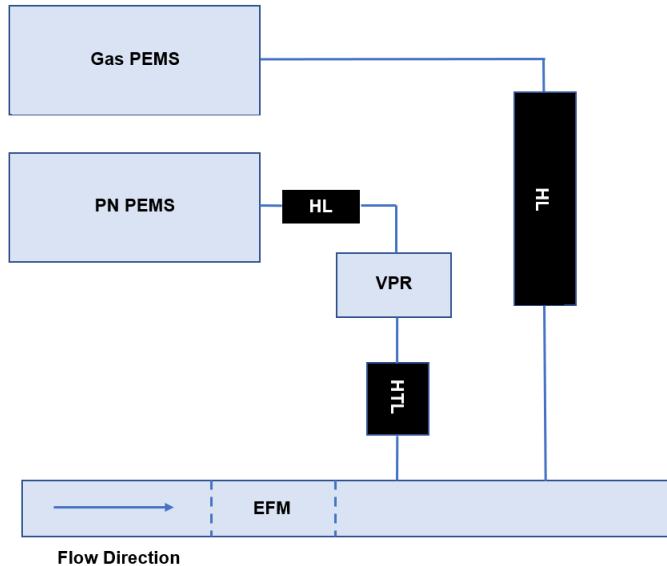
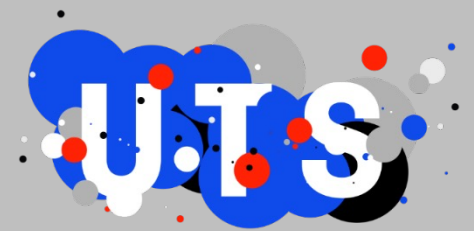
Class action lawsuit initiated against Toyota for potentially faulty DPF technology



<https://www.toyotaaction.com.au/>

Euro 5 vehicles with malfunctioning/removed DPFs likely on the rise (more later)  
(sensu Smit et al. 2021. Atmos. Environ. 252, Article Number: 118317)

# Particle number (PN) testing with a Portable Emissions Measurement System (PEMS)

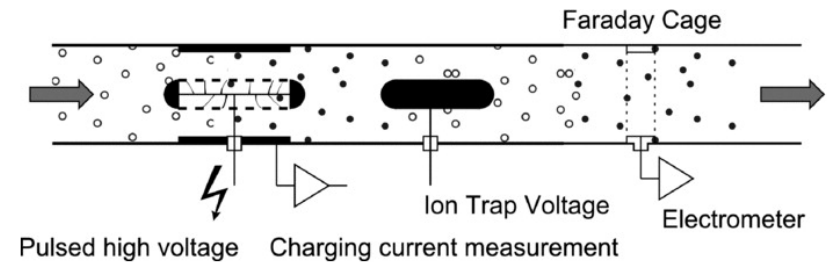


- Primary Carbon Particle
- Adsorbed HC (SOF)
- HC (SOF) Particle



PN sensing with an Automotive (Naneos) Partector

<https://www.naneos.ch/>

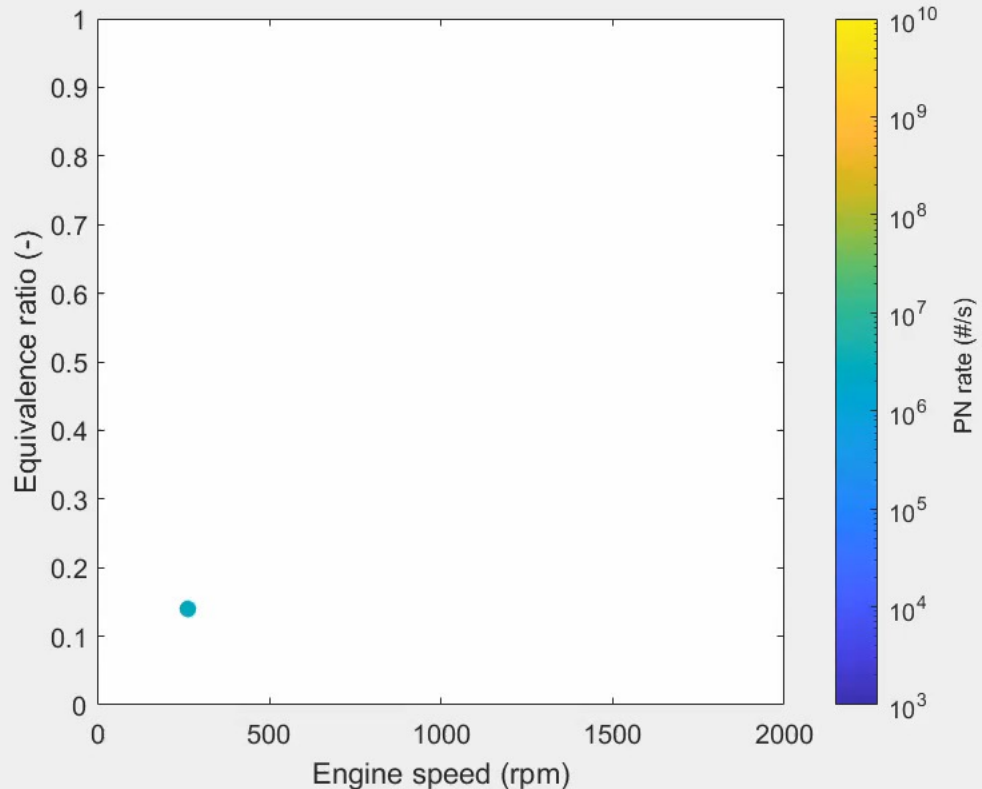
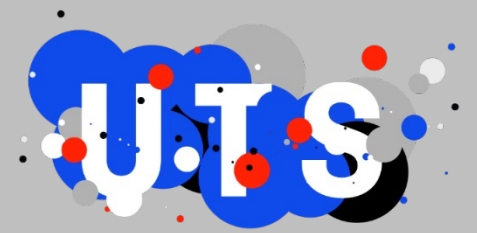


Partector combines 1) unipolar charging 2) precipitation 3) current measurement with an electrometer

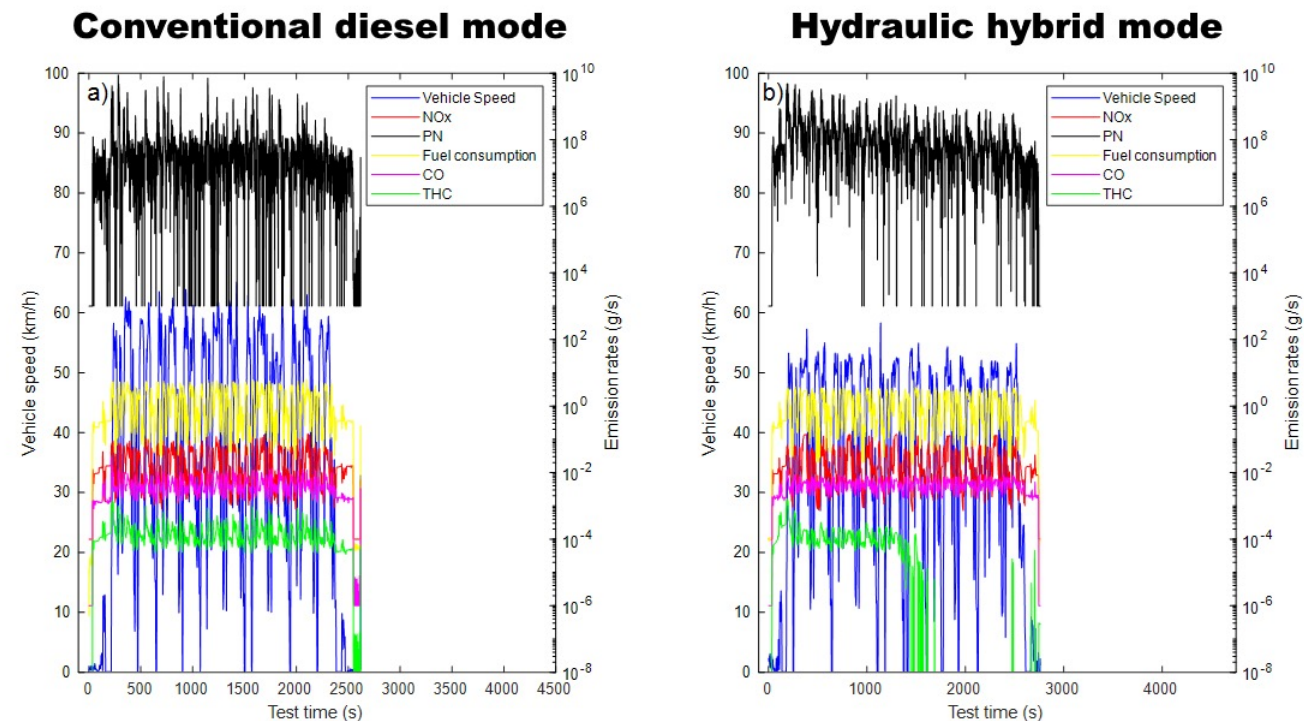
## System architecture

HL = Heated Line, VPR = Volatile Particle Remover

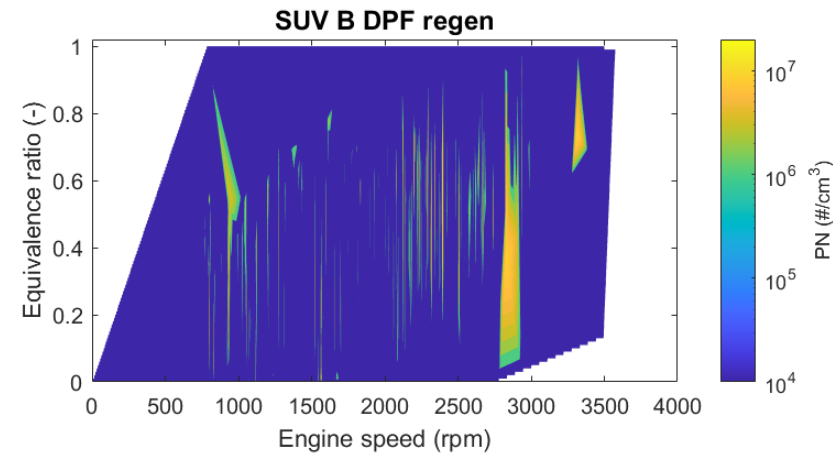
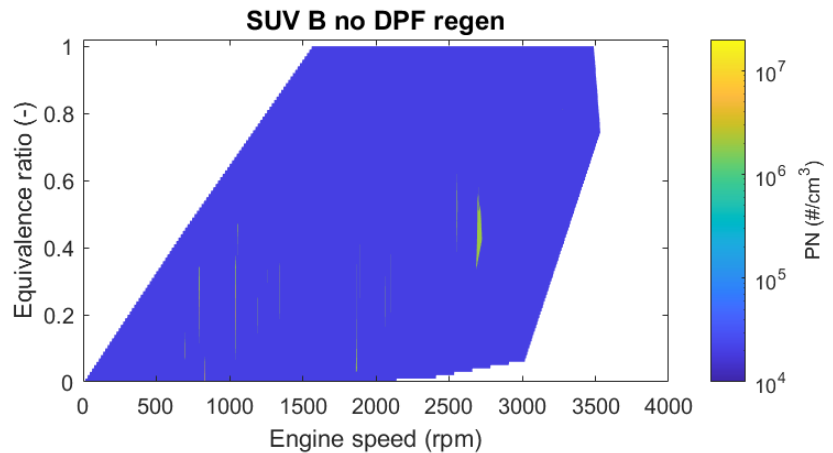
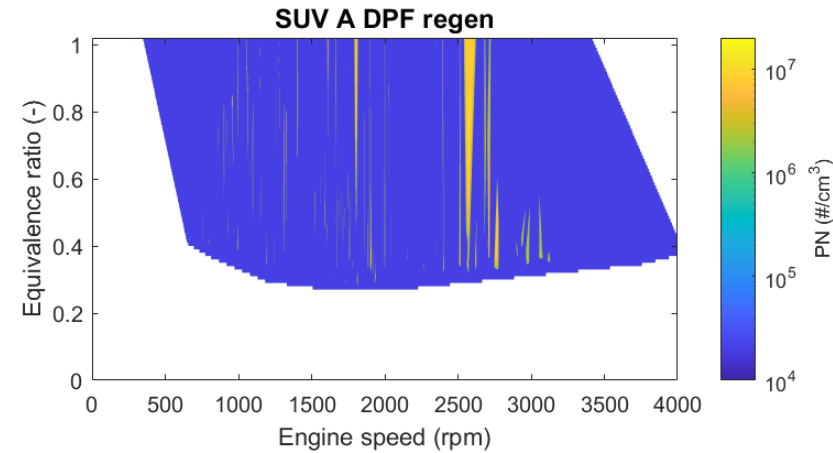
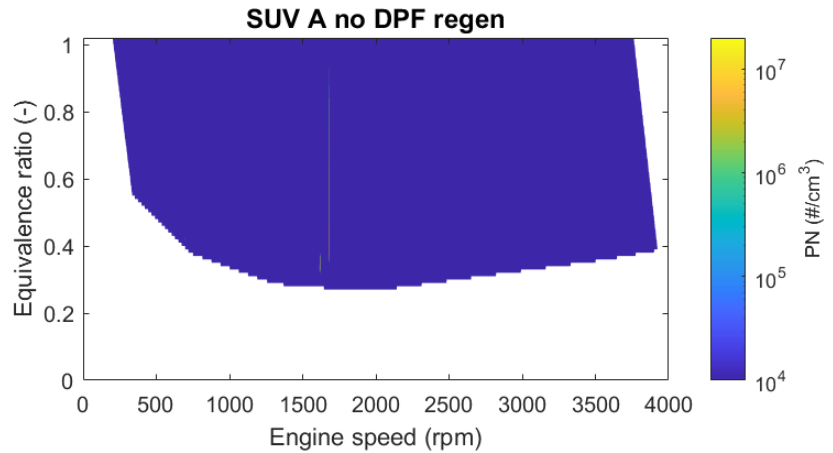
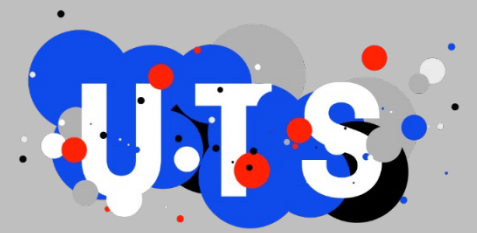
# Engine Performance Maps



- Performance maps used widely in engine dynamometer studies but not so much in real driving emission studies
- Easier to see trends compared to time series graphs

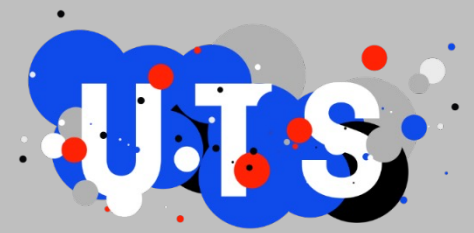


# SUV PN Performance Maps

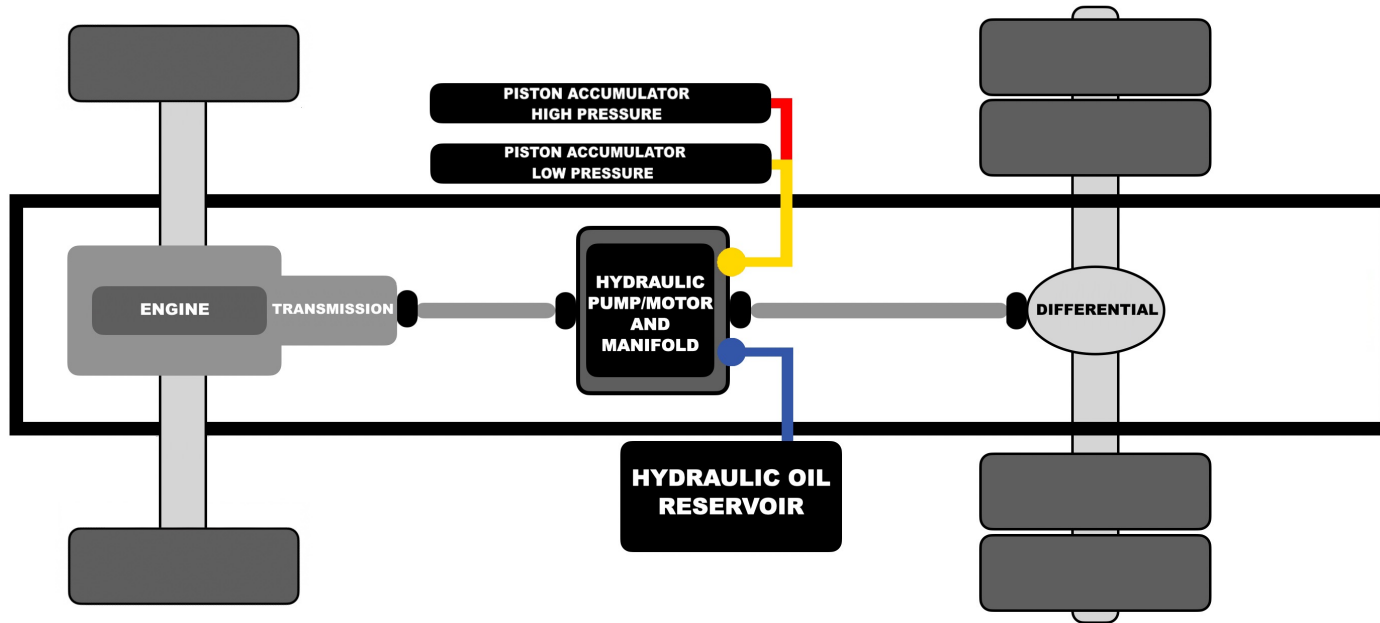


- Euro 5 PN limit met  
with the DPF  
regenerations (more  
later)

# Parallel hydraulic hybrid truck architecture



## Hydraulic hybrid driveline architecture and specifications



What PN reductions are possible in hybrid mode?

Item	Specification
Hydraulic pump type	Axial piston, variable displacement, hydraulic motor
Hydraulic pump capacity (cm <sup>3</sup> )	210
Hydraulic pump maximum power/speed (kW/rpm)	480/3000
Accumulator uncompressed volume (L)	32
Accumulator maximum pressure (MPa)	35
Oil reservoir volume (L)	120
Control system	Programmable logic controller with the engine throttle position in a closed loop



# Parallel hydraulic hybrid truck architecture II



## Base truck specifications

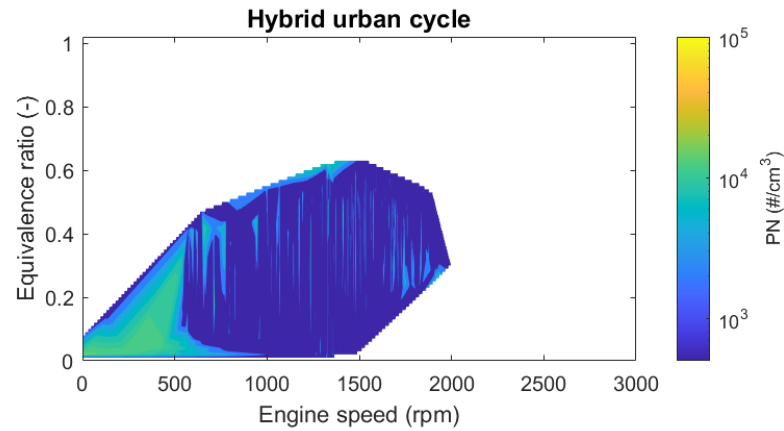
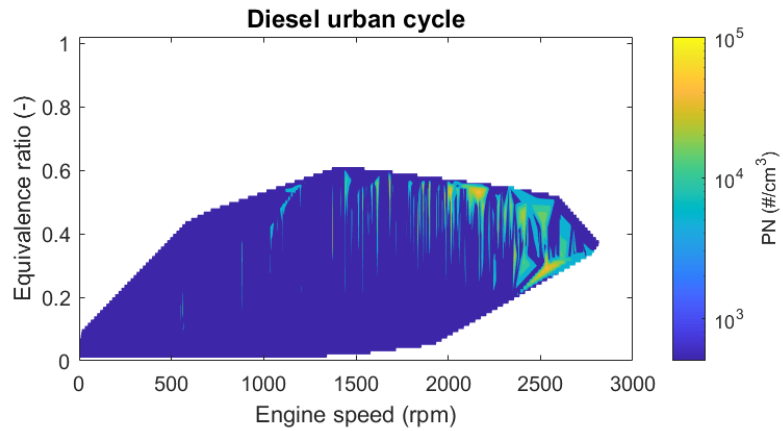
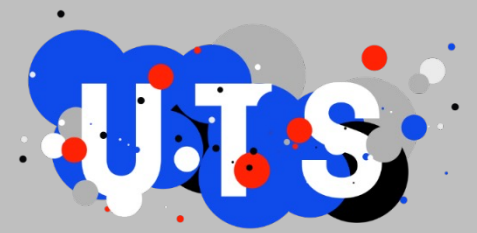
Item	Specification
Model	Isuzu NPR 400
Gross Vehicle Mass (kg)	7500
Cylinders	4
Capacity (L)	5.193
Bore × stroke (mm)	115 × 125
Maximum power (kW/rpm)	114/2600
Maximum torque (Nm/rpm)	419/1600
Compression ratio	17.5
Fuel injection	Common rail
Aspiration	Turbocharged
Emissions certification	Euro IV
After-treatment	Exhaust gas recirculation and catalysed diesel particulate diffuser <sup>1</sup>
Australian Design Rule	80/02



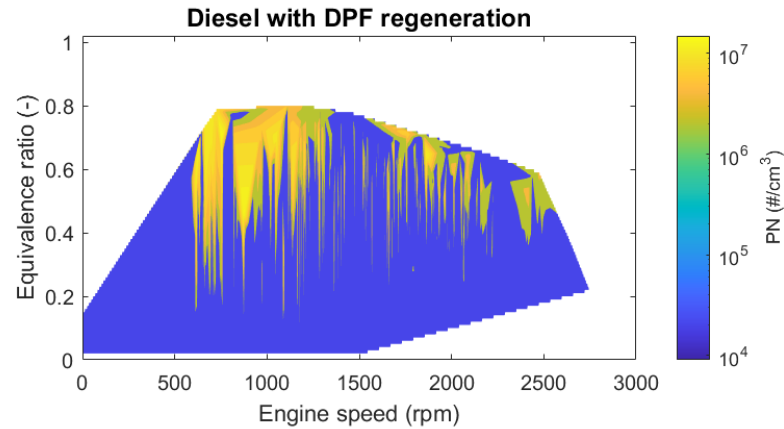
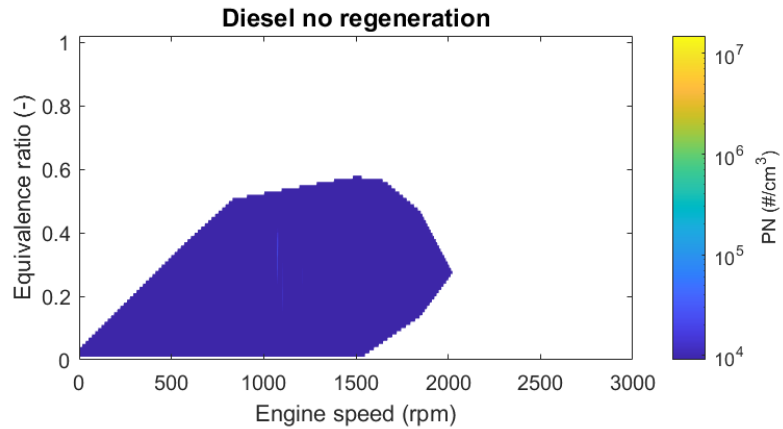
RDE testing in partnership with HRDS Technologies

<https://www.hrdstech.com.au/>

# Hybrid truck PN performance maps

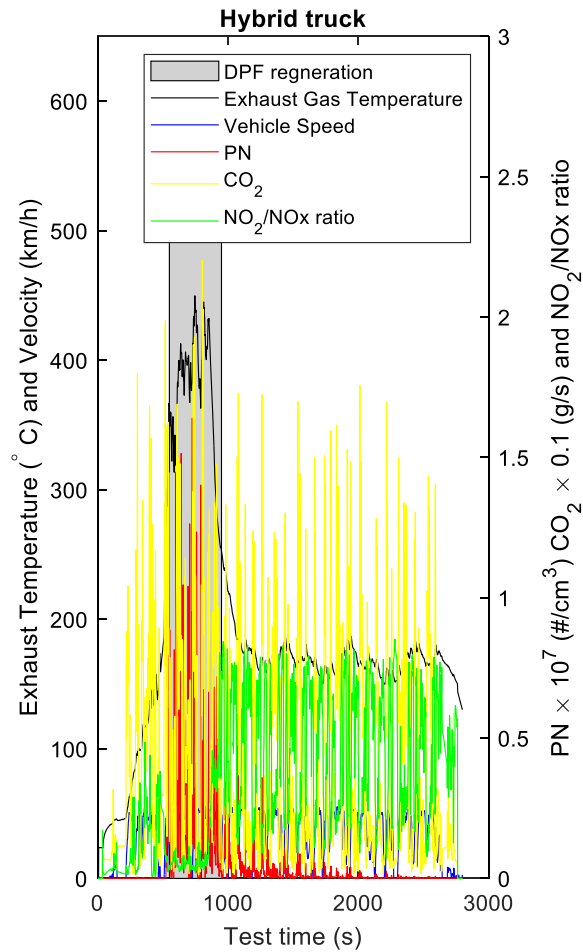
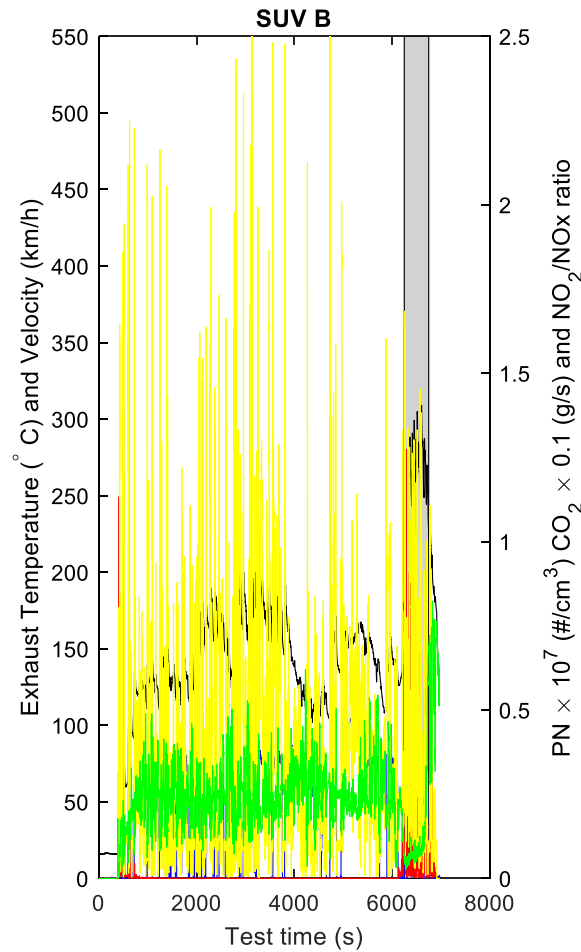
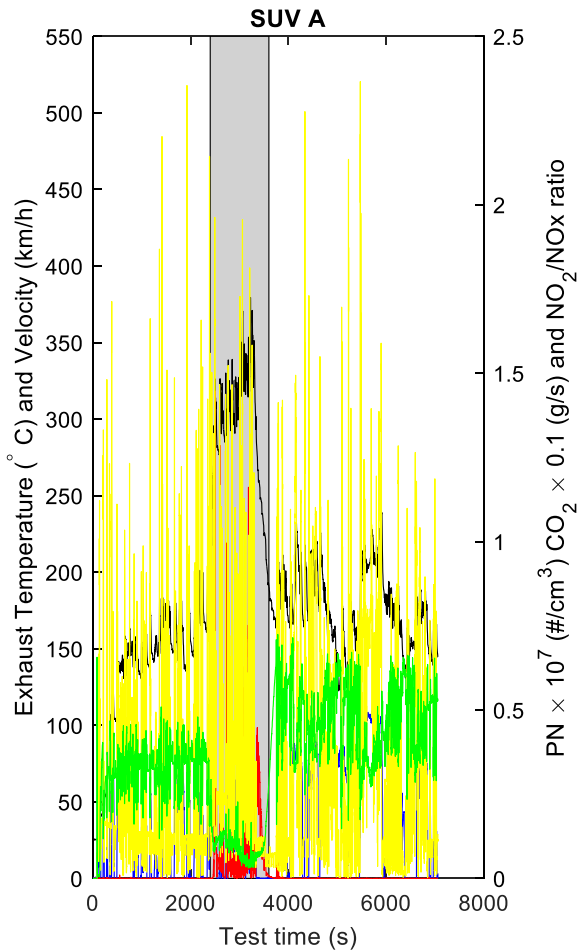
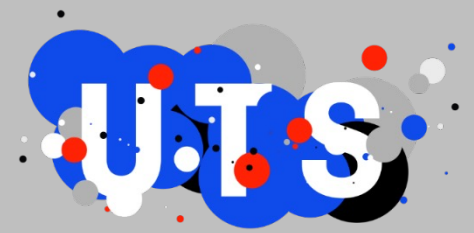


- 40% reduction in solid PN with hybrid technology in an urban cycle



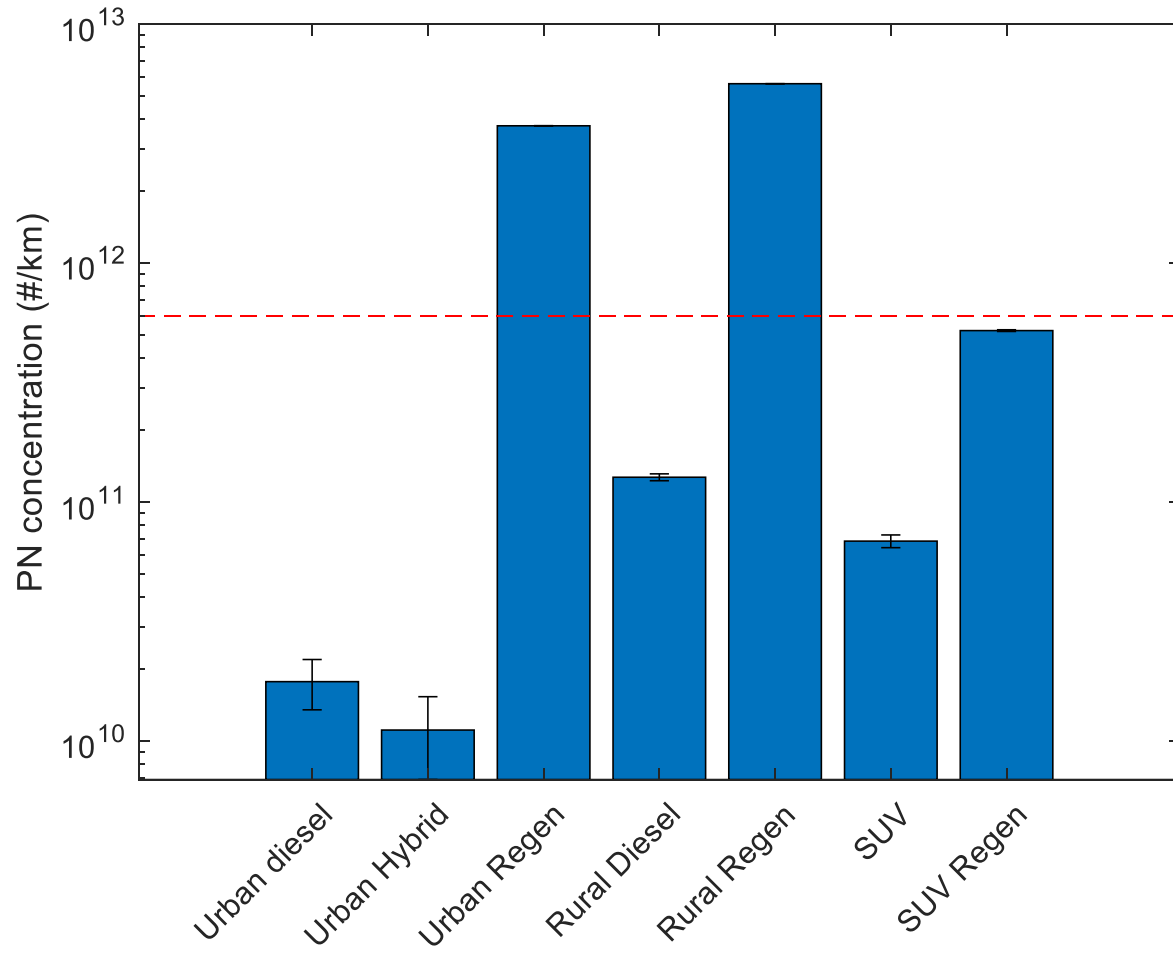
- DPF regeneration from the urban cycle

# Detecting DPF regeneration events



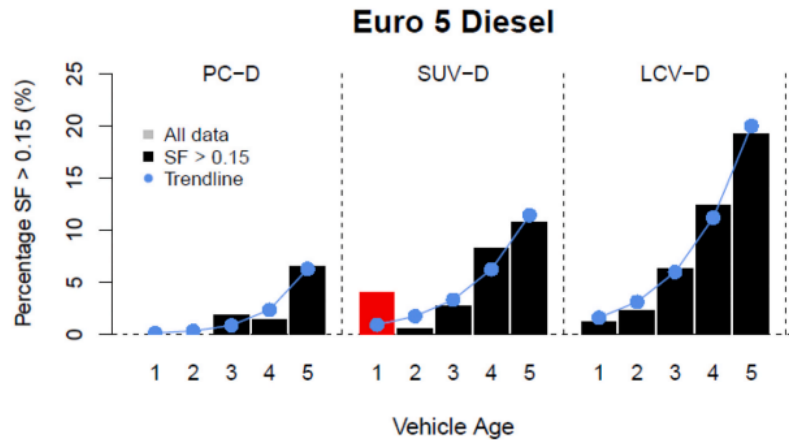
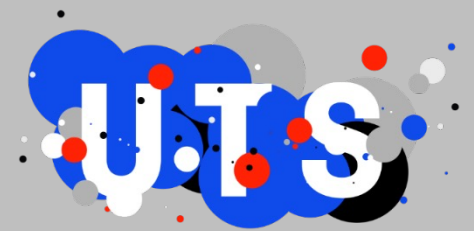
- NO<sub>2</sub>-based DPF regenerations observed for all three vehicles

# PN results summary



- SUV data below the PN type approval limit with regenerations
- Heavy commercial vehicle 6-9 times above PN limit with regenerations

# Some comments on DPFs down under



Possibility of DPF performance issues with Euro 5 diesel technology (Smit et al., 2021)

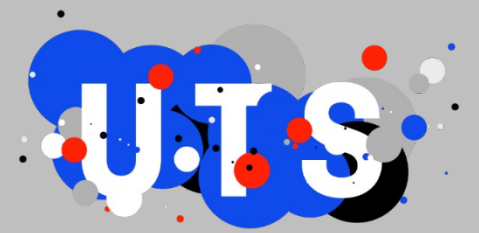
**Problem diesel filters 'widespread' as VW, Subaru owners report similar problems to Toyota drivers**

<https://www.abc.net.au/news/2019-11-08/diesel-filter-problems-in-australian-cars-widespread/11655040>

DPFs: a newer technology that drivers need education with (in some cases)

**Future work:** aiming to get the hydraulic hybrid truck working better

# Thanks – contact details



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