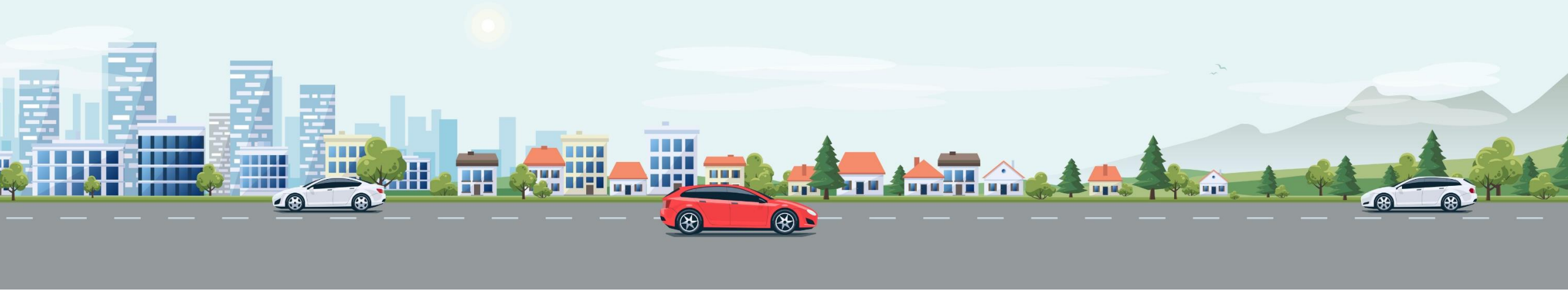
Thermal regimes during proving ground measurements using WLTP-Brake cycle



Carlos Agudelo

PMP IWG – Nov 8th, 2018

Sonya Collier, Seungju Yoon, Jorn Herner

Alan Stanard, Tim DeFries

Josh Bautell, Alejandro Hortet, Ravi Vedula

funded by CARB contract number 17RD016

updates to brake emissions factors

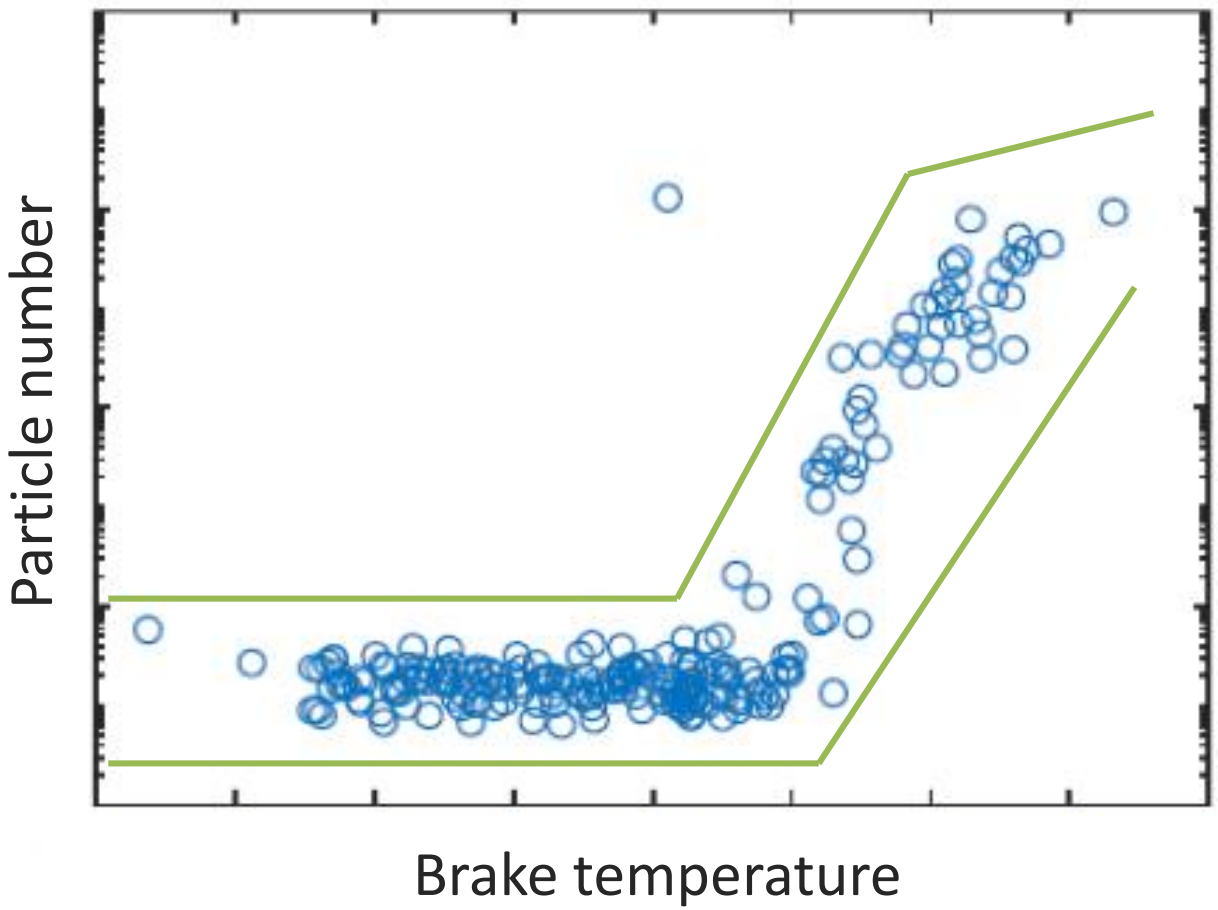
need to reflect vehicle population, driving activity, and current braking systems

Environmental Quality Act (CEQA). PM emission analysis results, particularly for analysis years of 2020 and beyond, reflect the growing importance of brake and tire wear as a fraction of total on-road vehicle PM emissions. However, there are important shortcomings in the way that brake wear and tire wear emissions are currently estimated, due in part to the introduction of advanced technology vehicles utilizing regenerative braking systems and the use of outdated emissions data in mobile source emission inventory tools such as Emission Modeling Factors (EMFAC) and Motor Vehicle Emission Simulator (MOVES). In addition, brake wear and tire wear modeling techniques were originally developed to support regional emissions analysis work and have important limitations (e.g., they are not sufficiently sensitive to reflect emissions variations by vehicle type, vehicles speed, and payload) when applied to transportation project-level assessments.

why assess the temperature on representative vehicles?

brake emissions levels

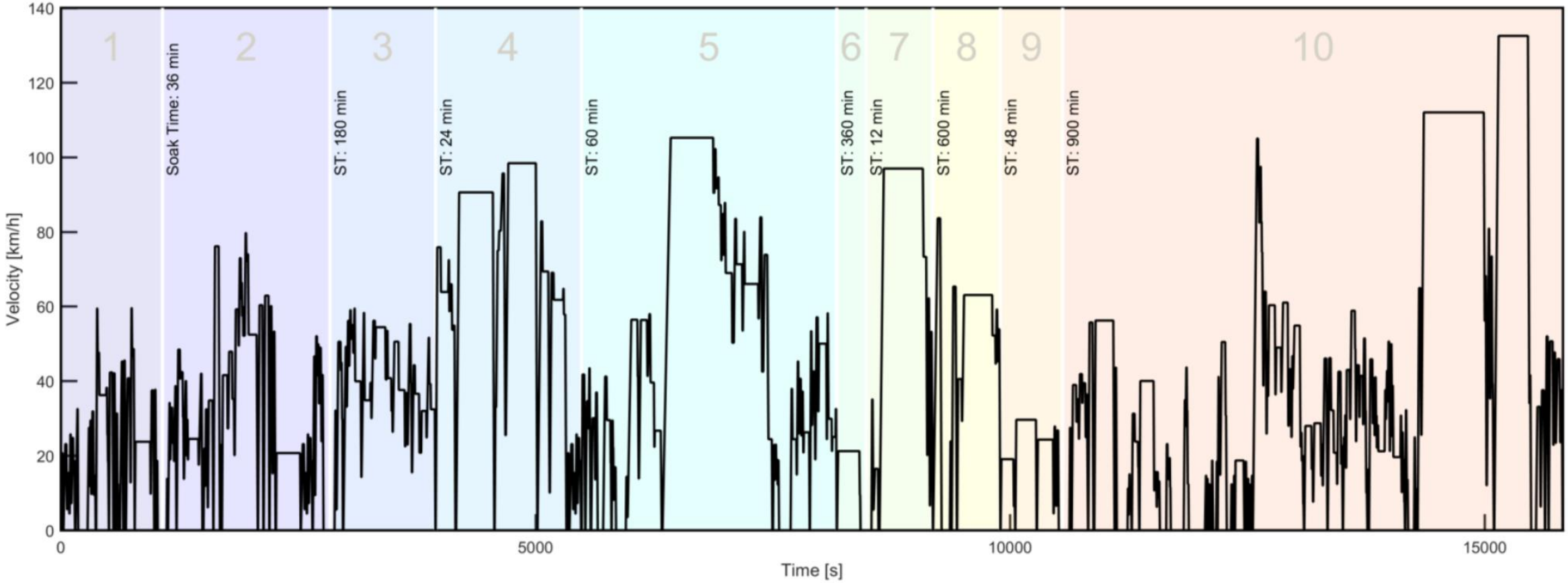
particle number is sensitive to brake temperature



Data courtesy of Ford Motor Co. – Europe – EB2018-VDT-027

WLTP-Brake dynamometer cycle speed trace

~310 brake events; 10 trips; ~6 hours; (40-130) km/h; (0.5-2) m/s²



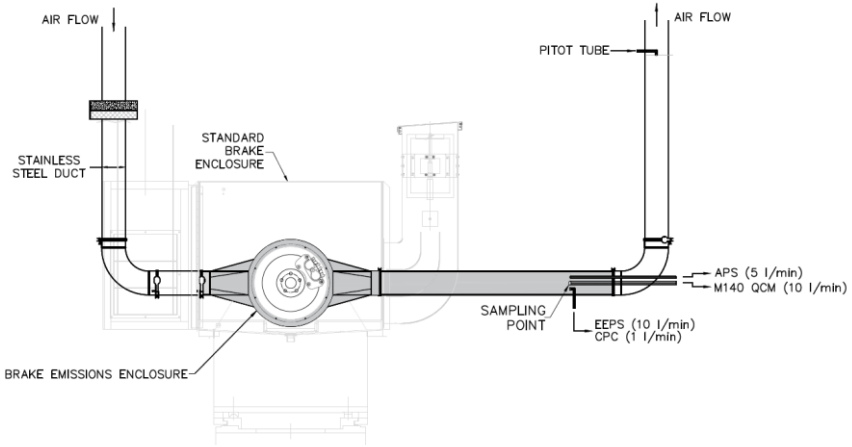
Mathissen et at., WEA102468 – *A novel real-world braking cycle for studying brake wear particle emissions*

vehicle class application

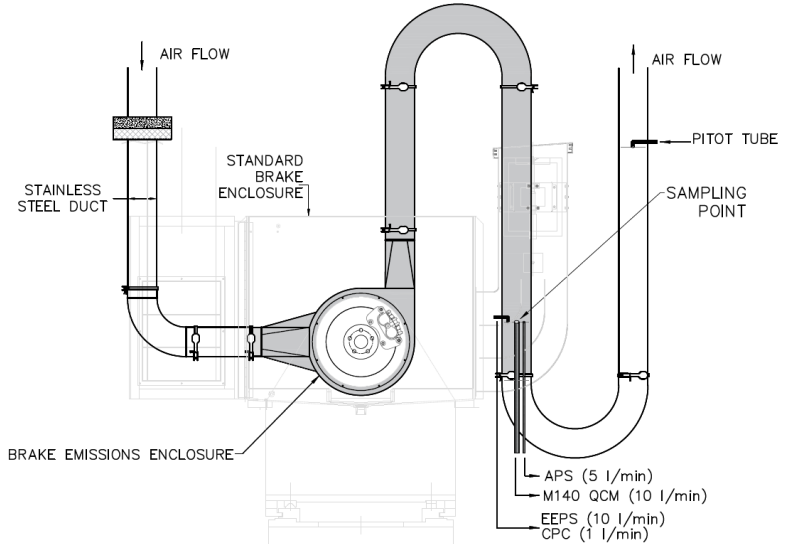
brake and wheel design, brake size, axle position, and vehicle type determine the thermal regime of the brake

WLTP-Brake cycle needs to be dyno agnostic

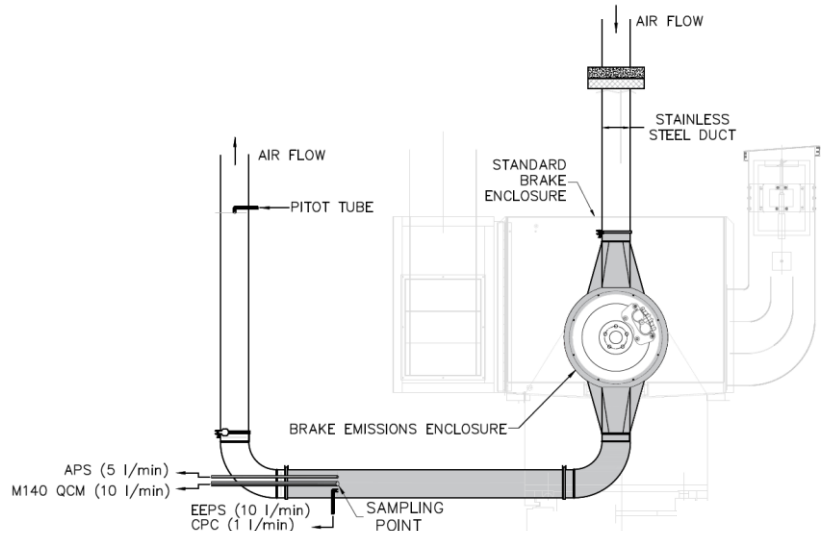
the cycle needs to run on different dyno designs and layouts



A



B



C

what process did we follow?

main steps utilized to select vehicles for PG testing

Brake Wear Index

for top 15+1 vehicles per VIO statistics

$$BWI = VIO \cdot Mass_{wear} \cdot \%_{replacement}$$

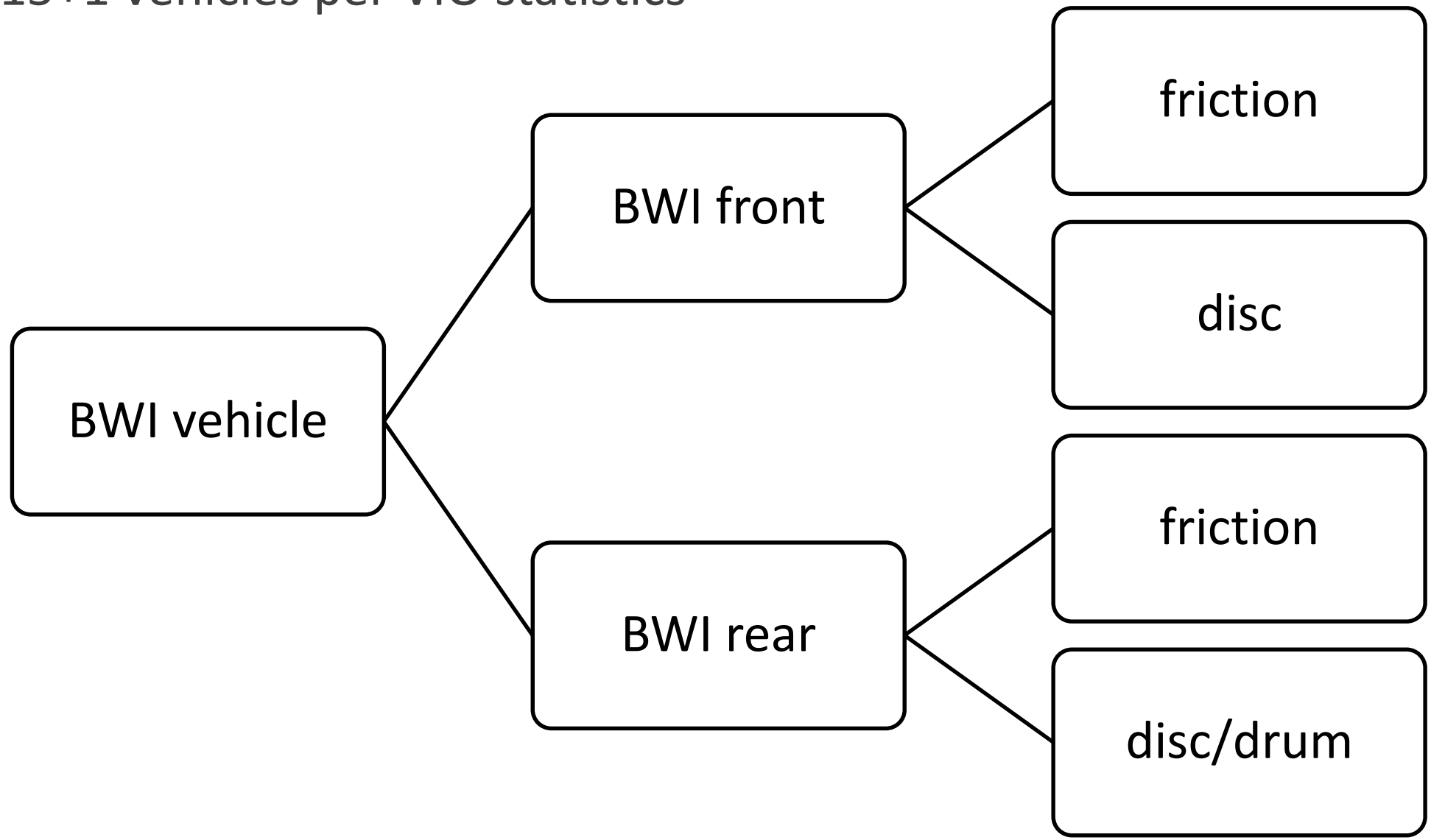
vehicles in operation

total wearable mass

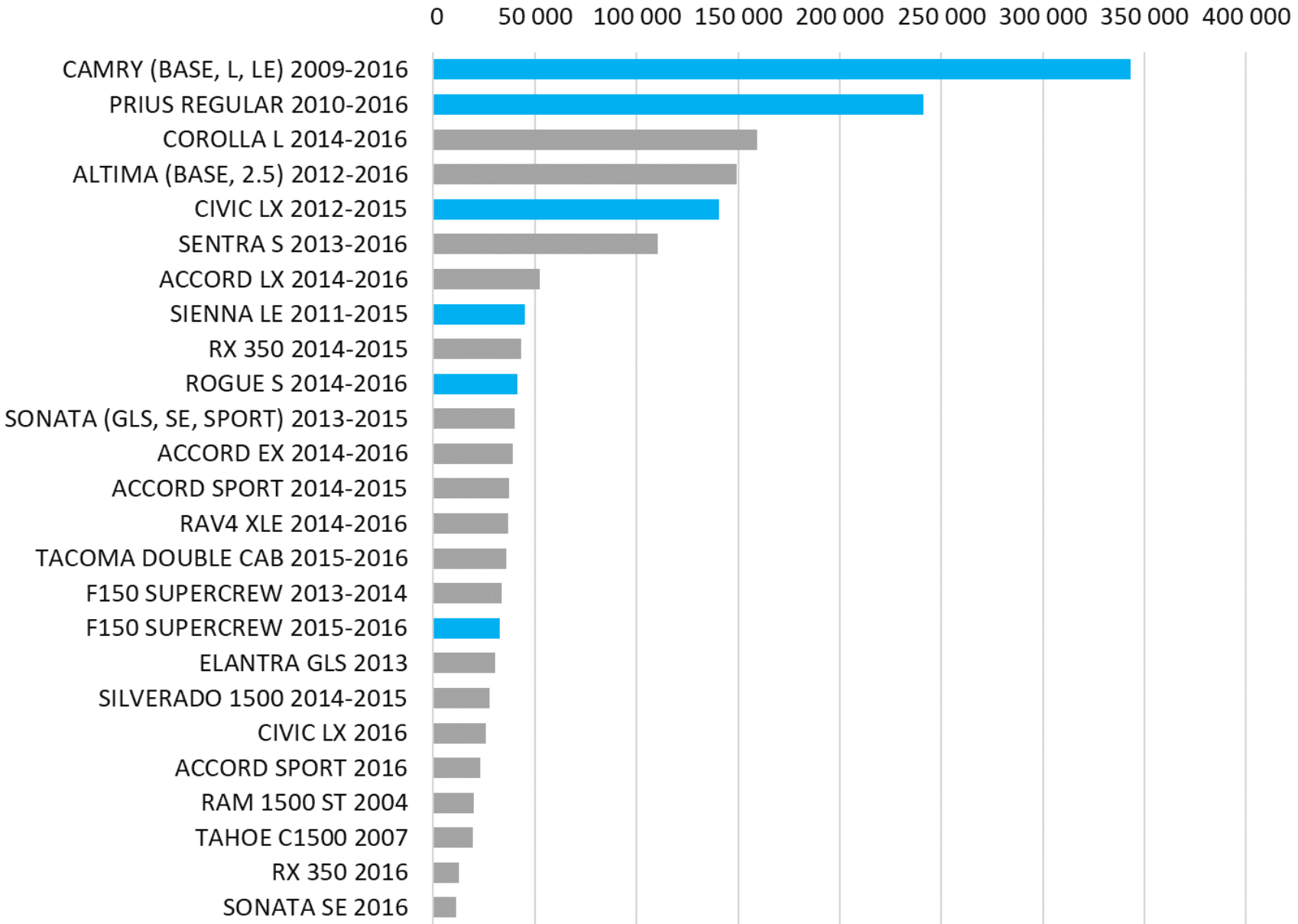
replacement rate

Brake Wear Index

for top 15+1 vehicles per VIO statistics



statistics for Vehicles in Operation in California



WLTP-Brake test procedure for Proving Ground testing

including vehicle preparation, instrumentation, speed error limits, burnish, WLTP cycle, heating and cooling, and coastdown

WLTP-Brake test procedure for Proving Ground testing

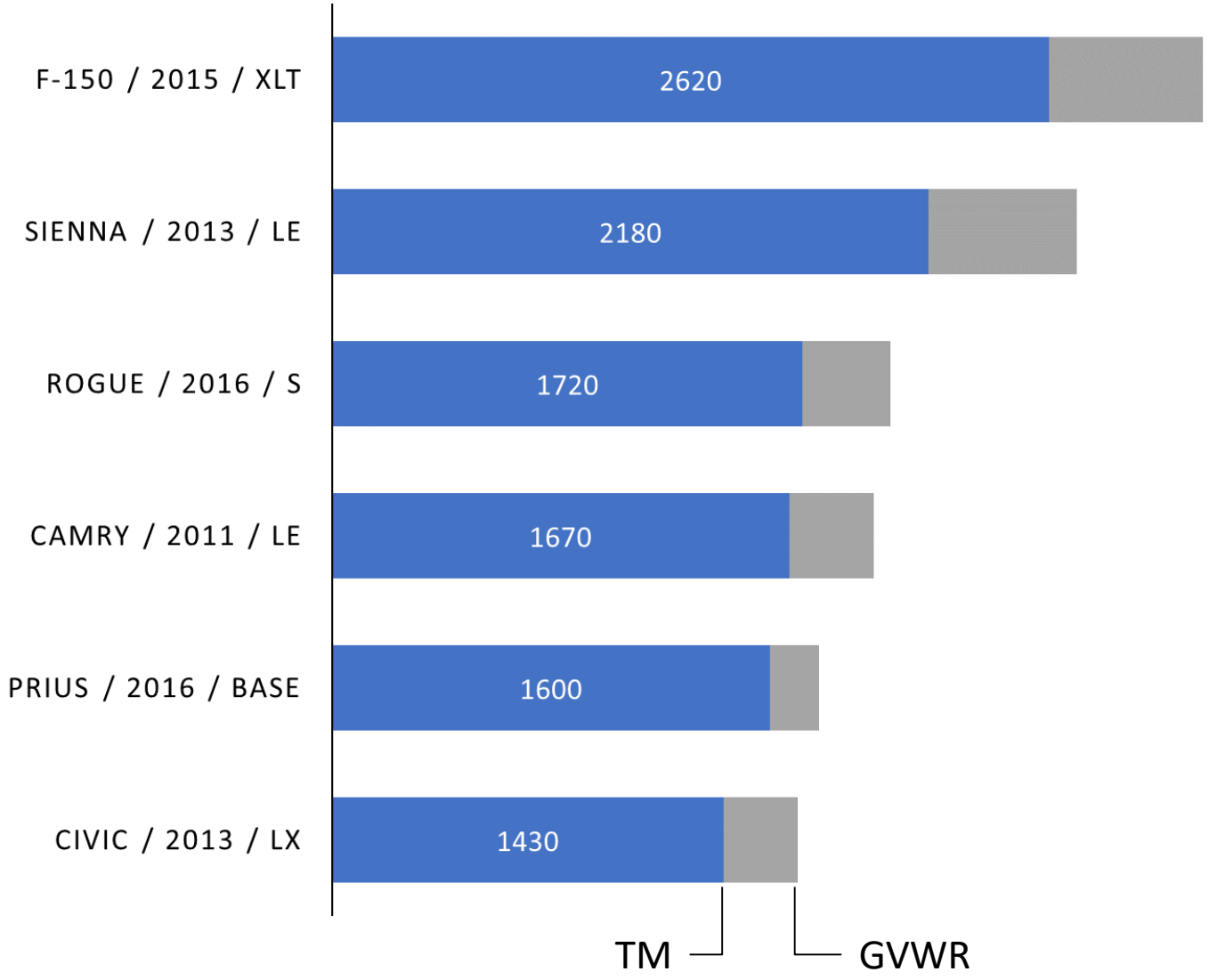
test mass comparable to EPA and WLTP cycles

Test mass = RM + 0.15(GVWR – RM)

RM = unladen + 100 kg

vehicle test masses / kg

per GTR 15 loading conditions



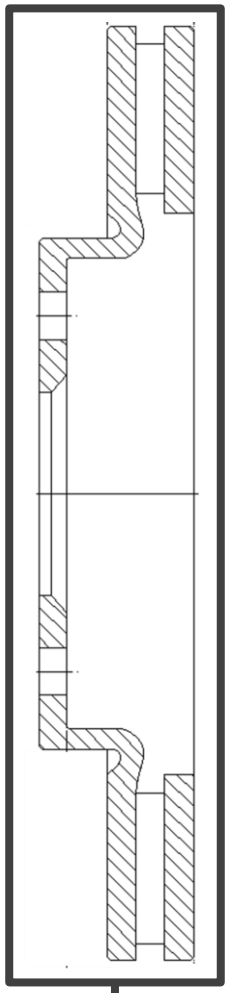
WLTP-Brake test procedure for Proving Ground testing

vehicle instrumented for temperature measurements and braking activity

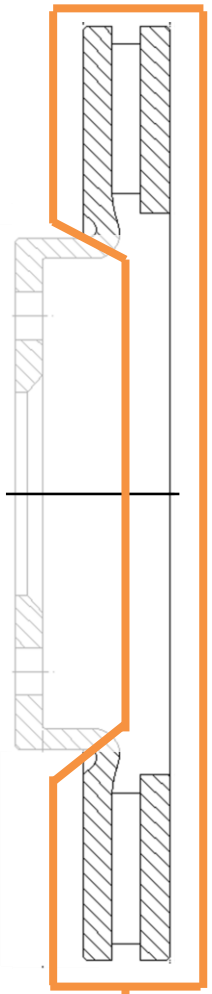
some initial results from the proving ground temperature measurements

rotor/drum thermal masses

the thermal model is more predictable after removing the mass not in the vicinity of the braking surface



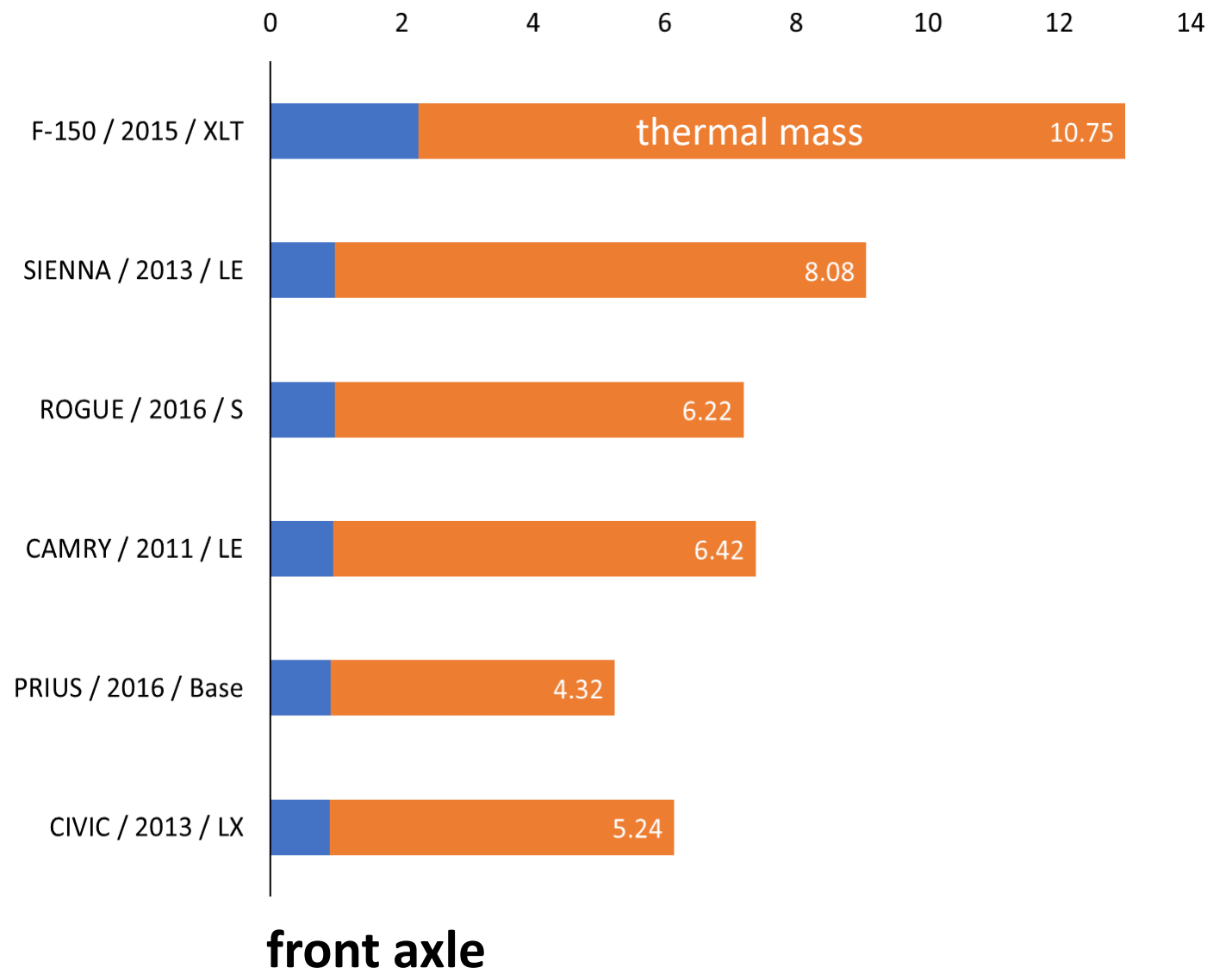
total mass



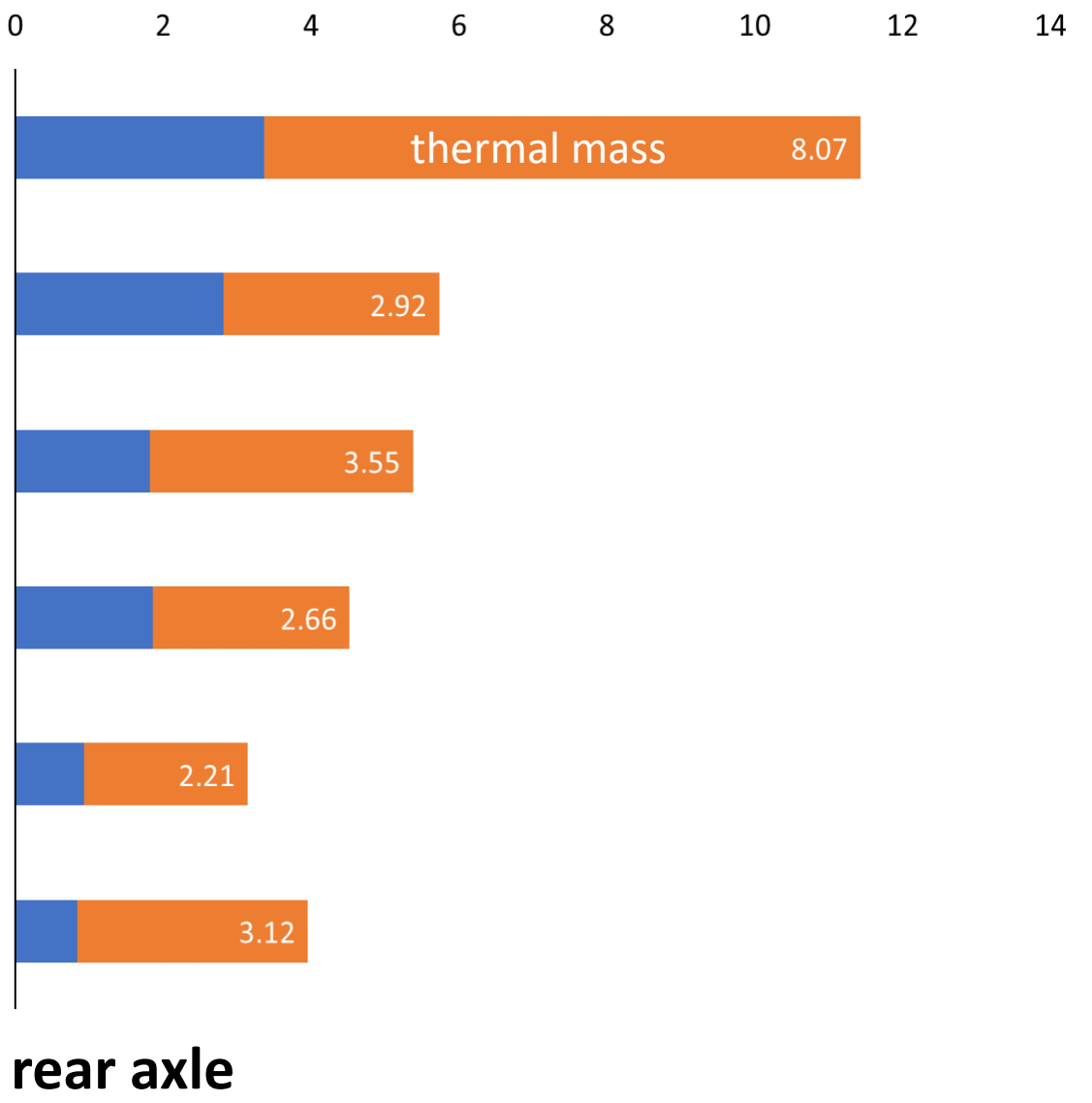
thermal mass

rotor/drum thermal masses / kg

reflect different design and sizing approaches



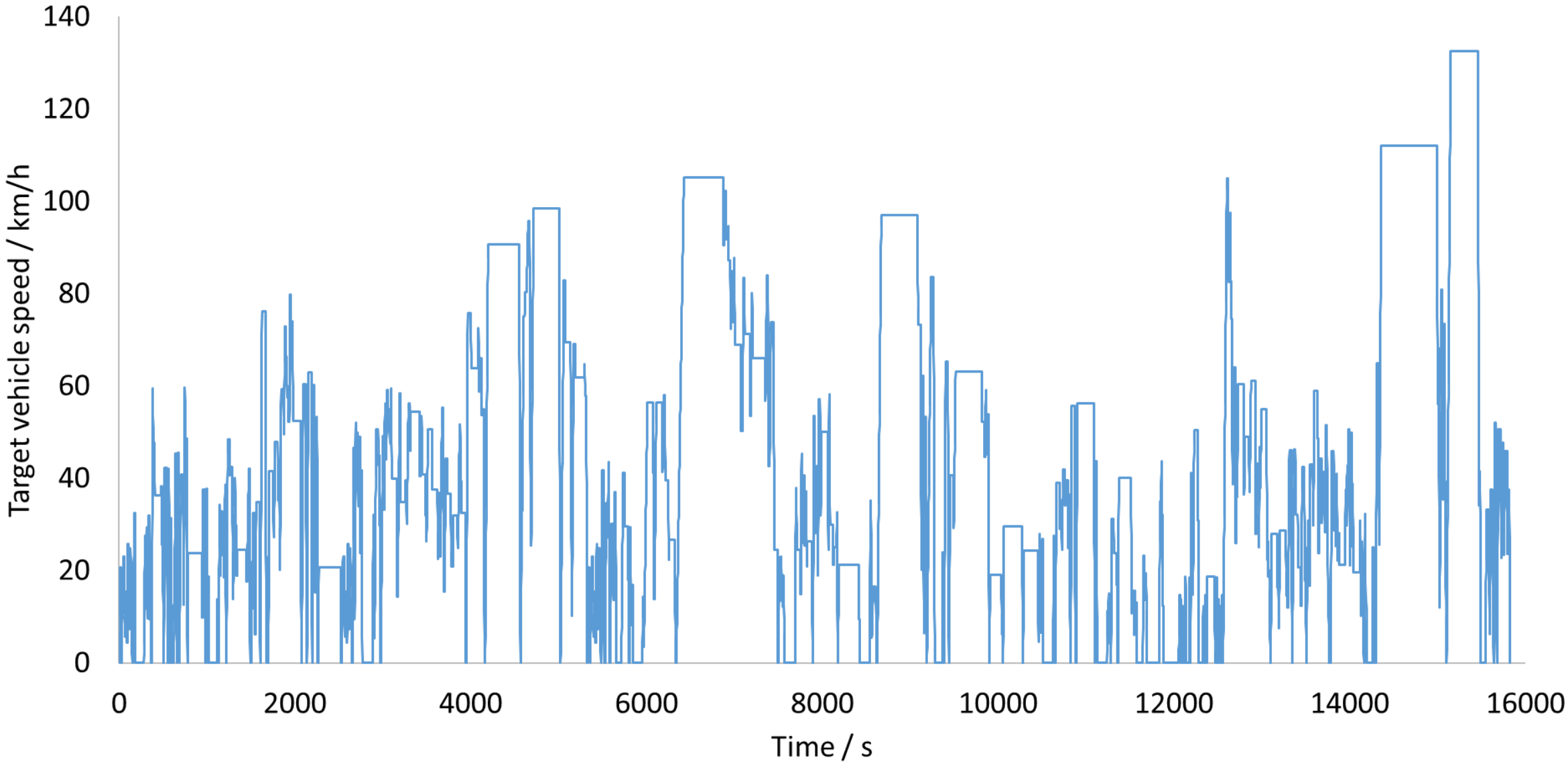
front axle



rear axle

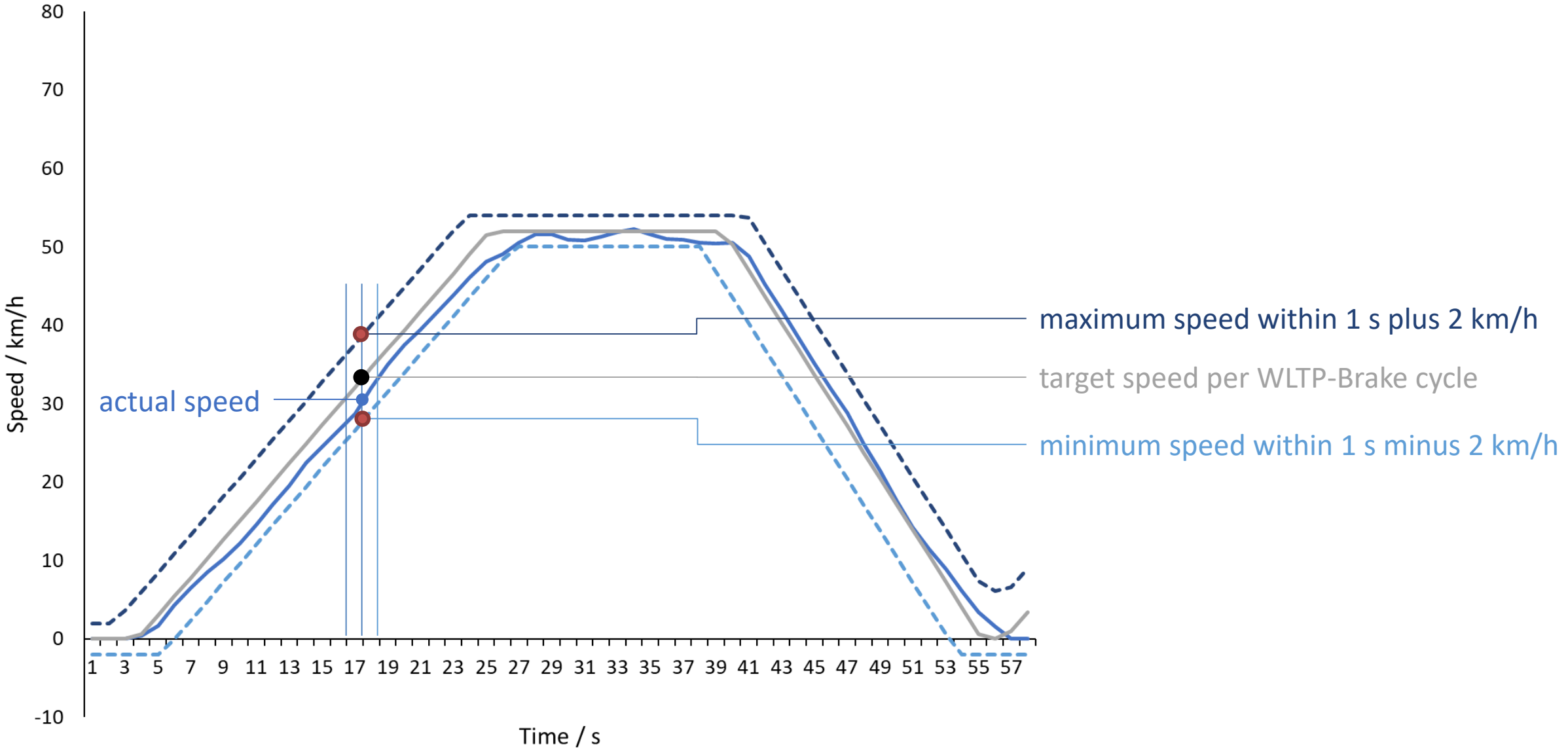
WLTP-Brake cycle

used to extract bedding cycles and entire cycle for temperature regimes



speed trace error tolerance for test driver

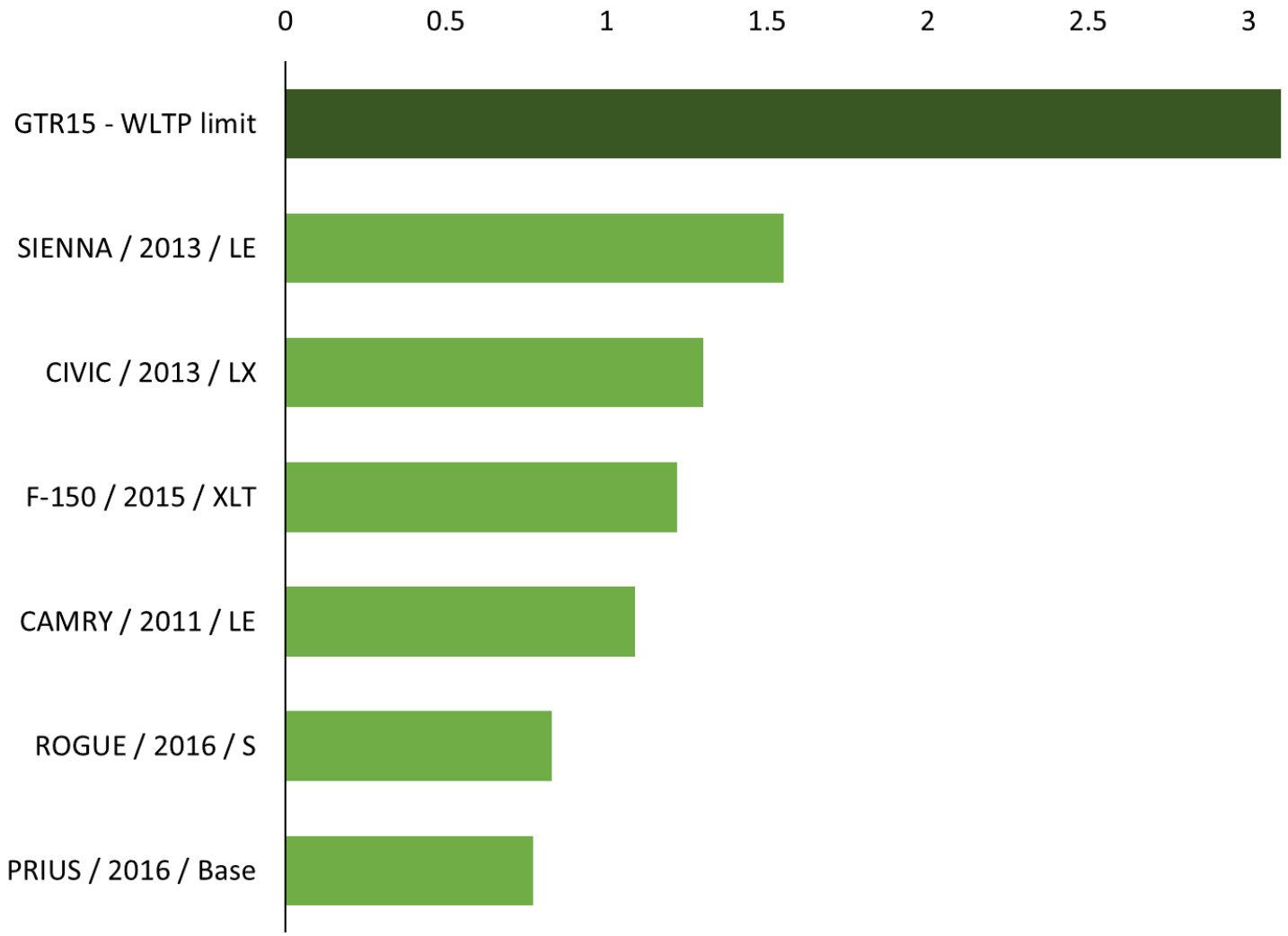
per GTR 15 – WLTP and programmed on vehicle Heads-up Display



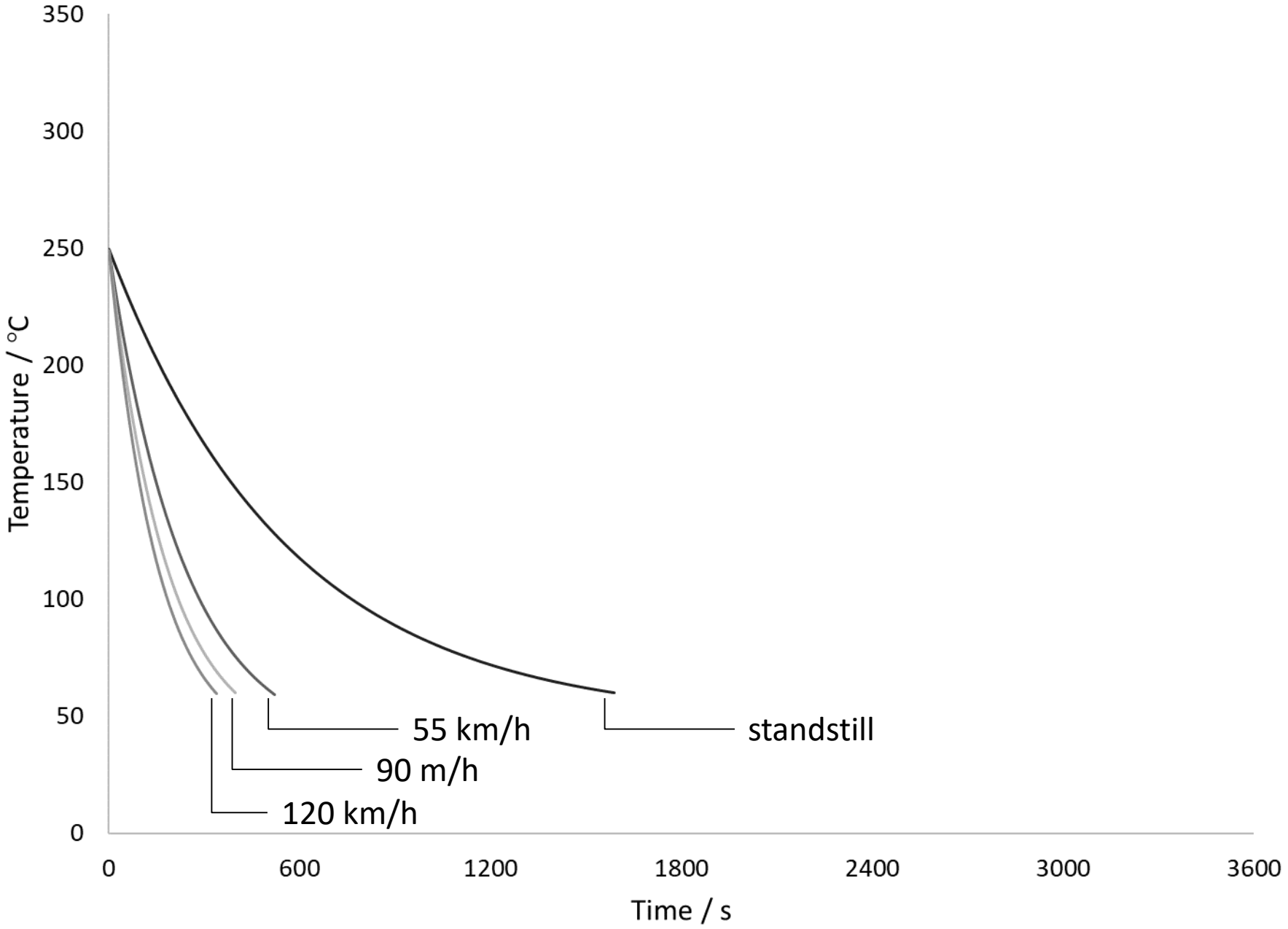
root mean square of speed error / km/h

per SAE J2951:2014 for drive quality evaluation

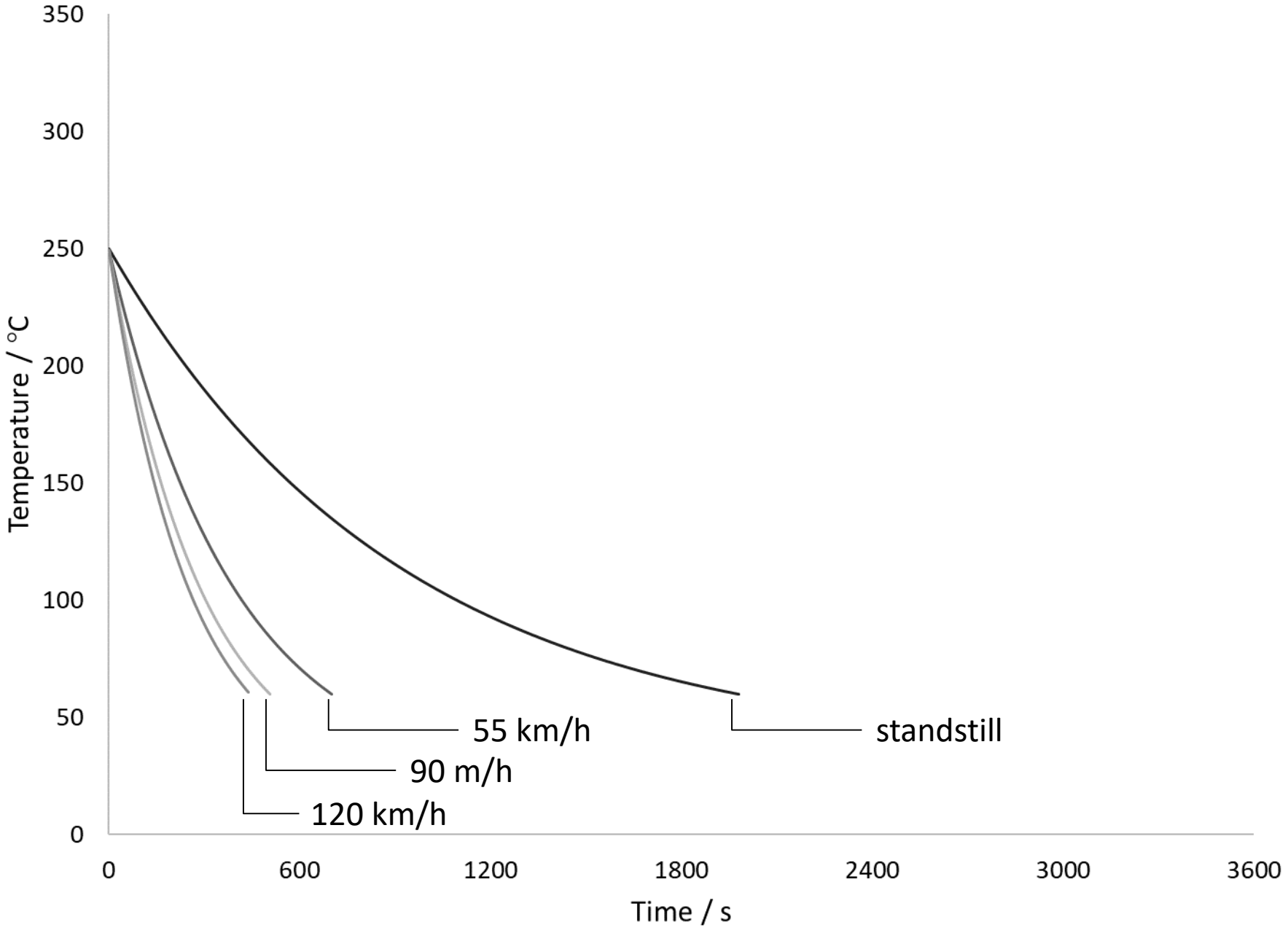
$$RMSSE = \cancel{2.237} \cdot \sqrt{\frac{\sum_{i=1}^{N} (V_{Di} - V_{Ti})^2}{N}}$$



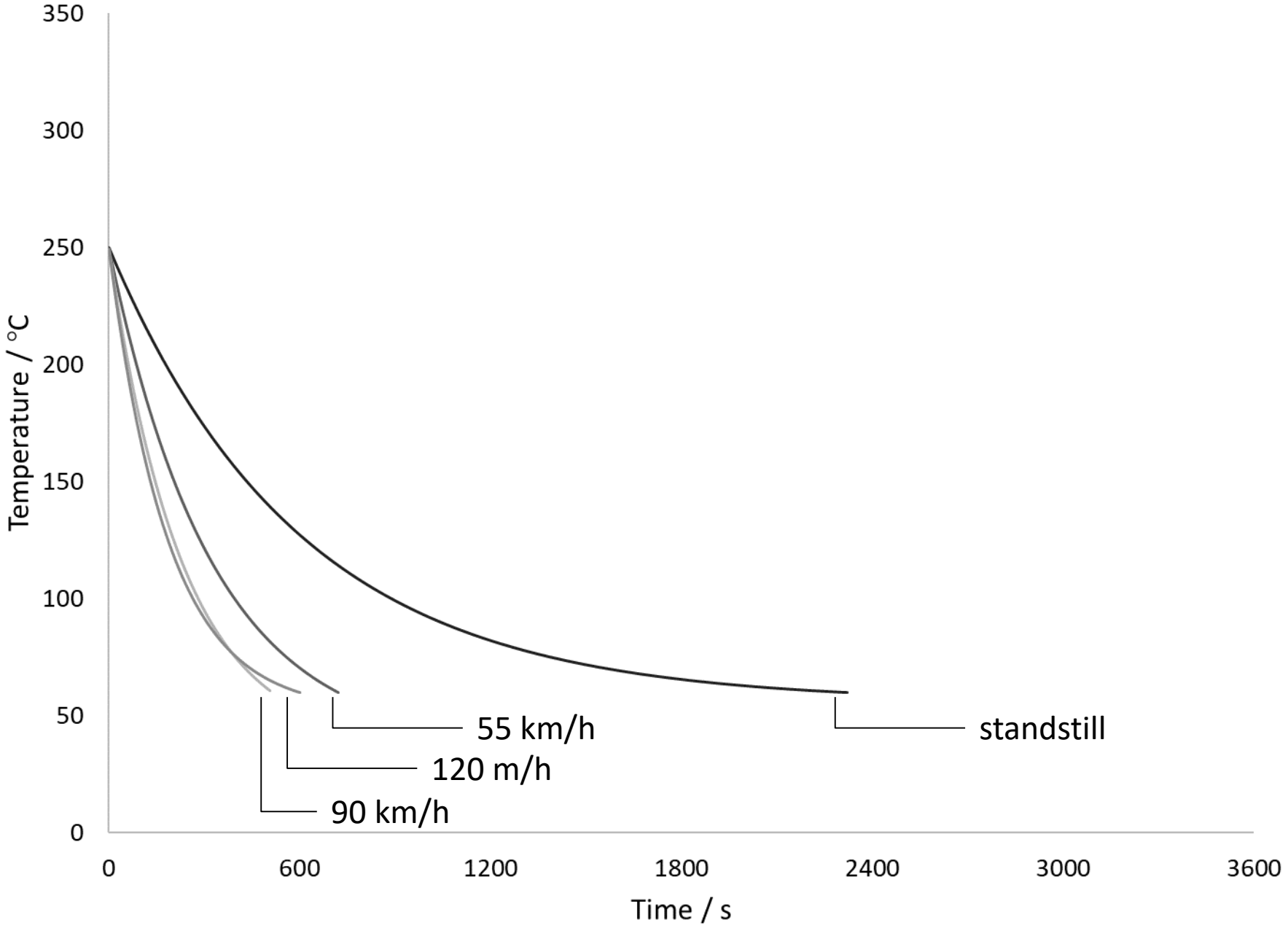
2016 Toyota Prius Base – cooldown time for front axle



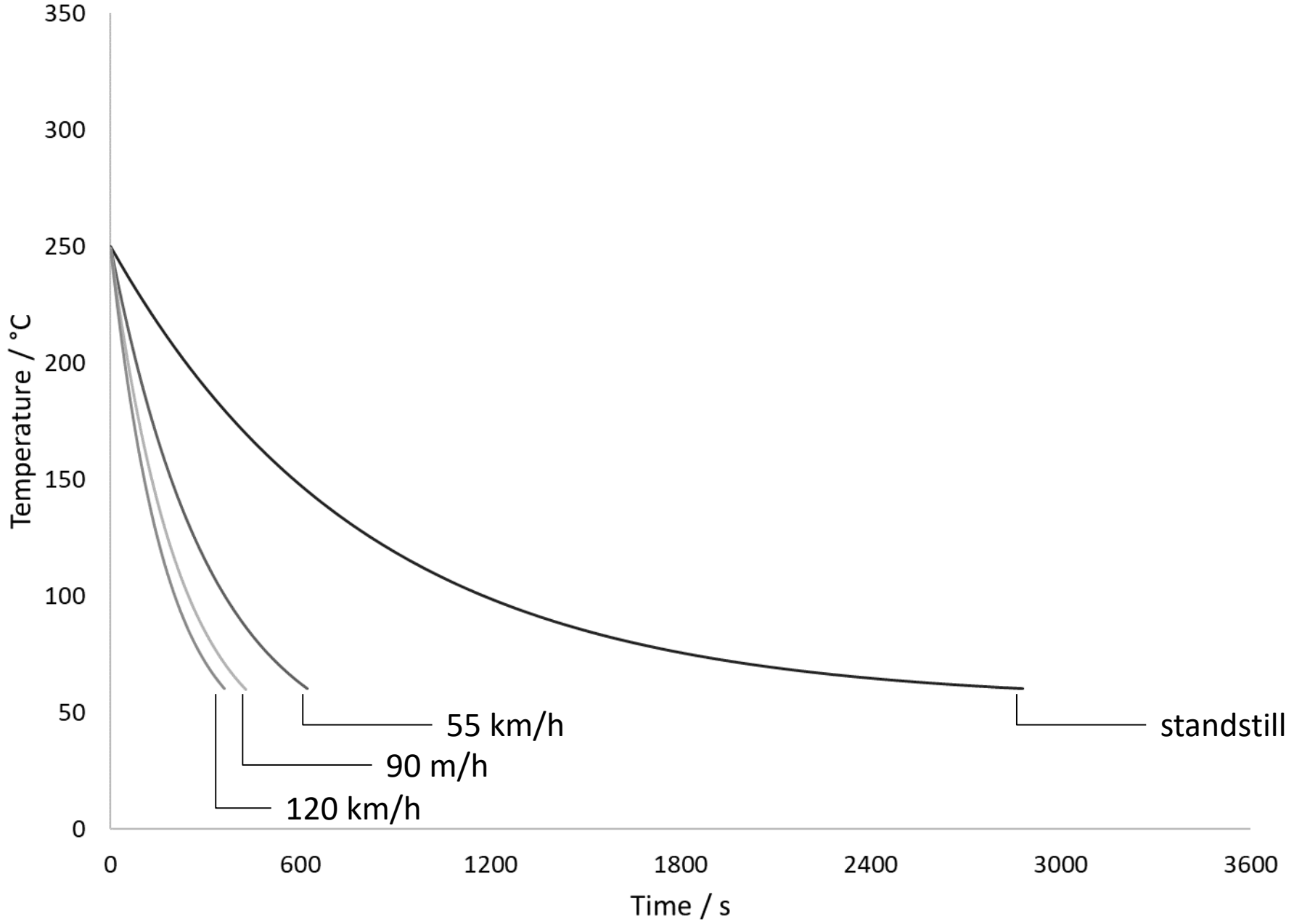
2015 Ford F150 XLT – cooldown time for front axle



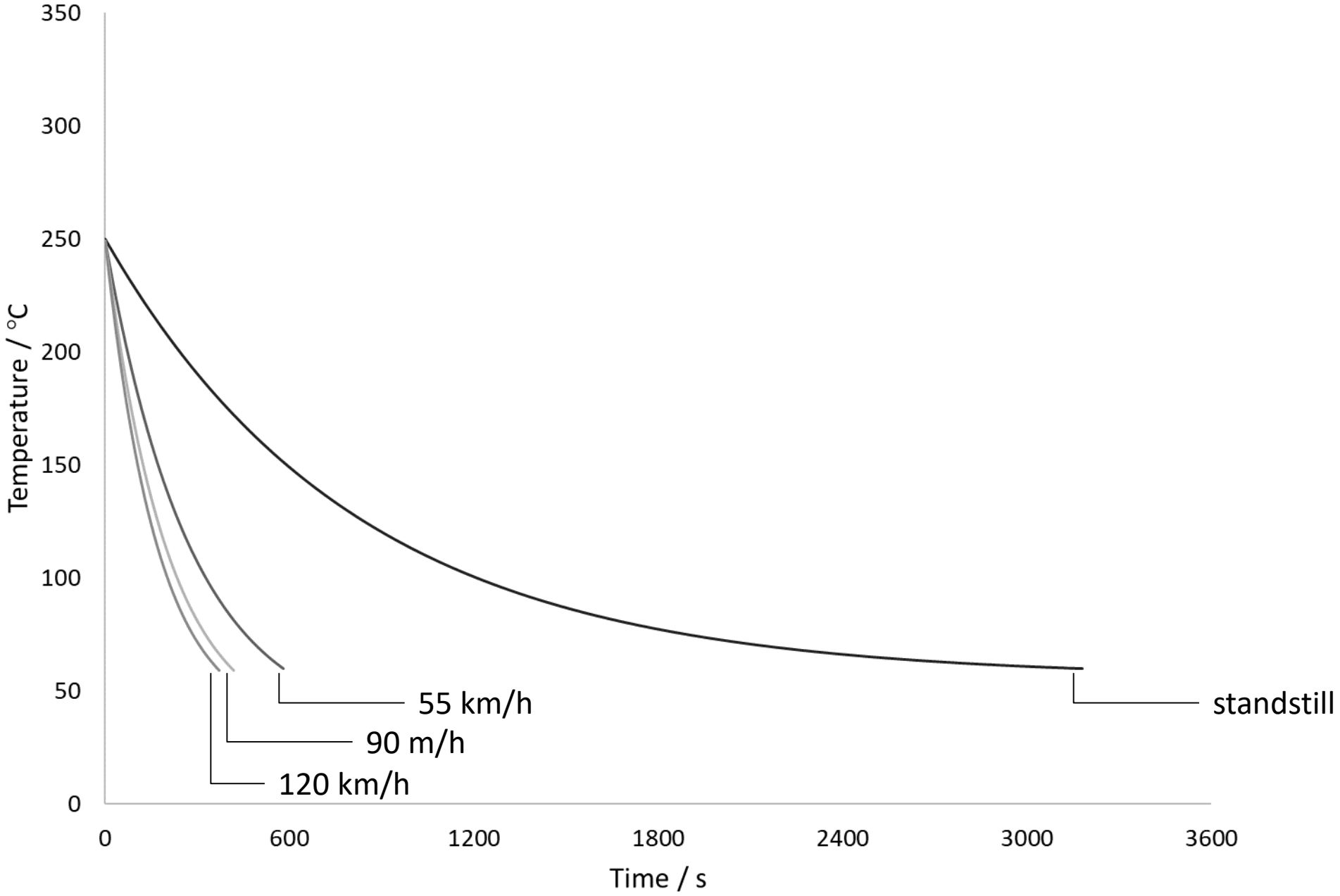
2016 Nissan Rogue S – cooldown time for front axle



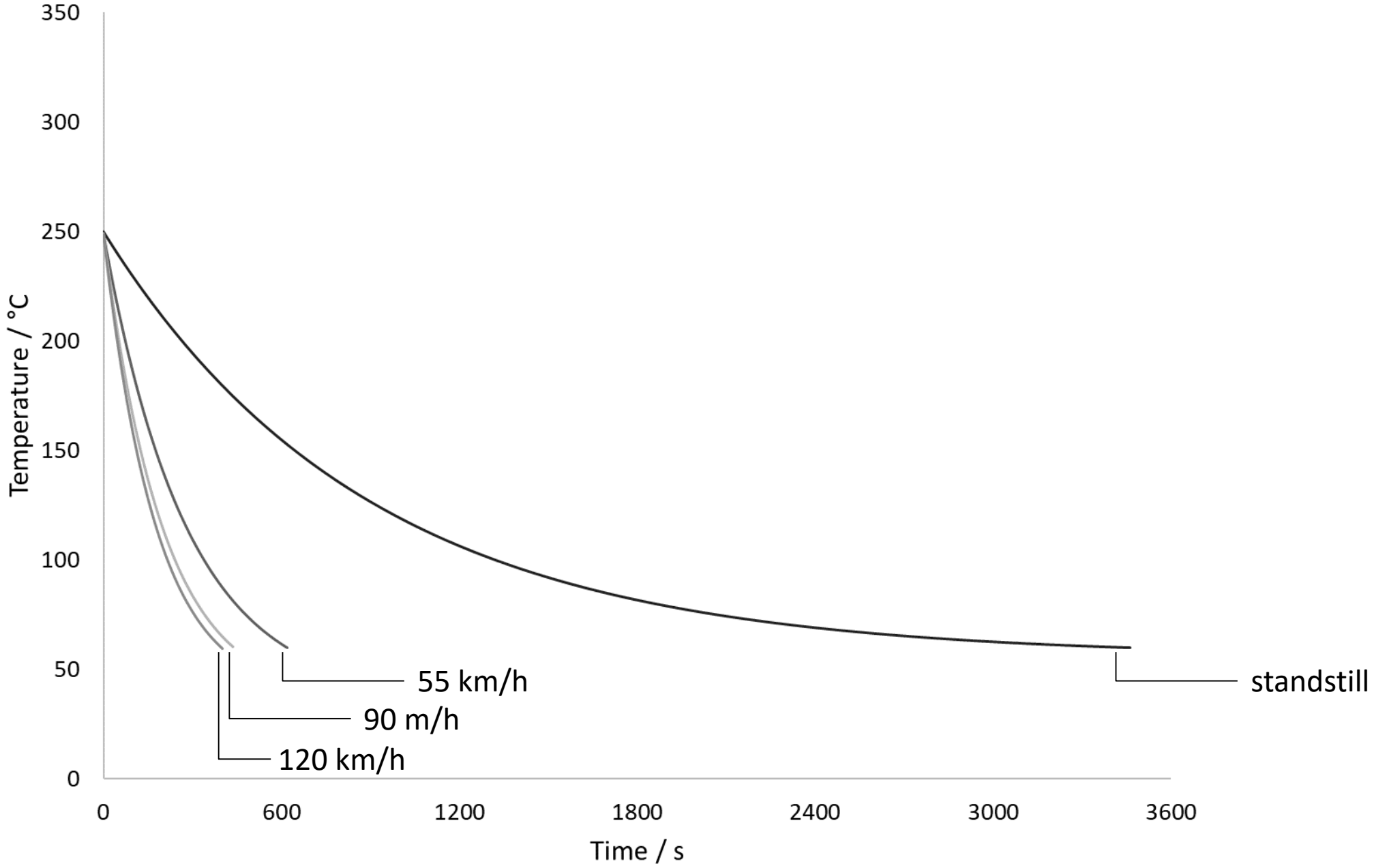
2013 Honda Civic LX – cooldown time for front axle



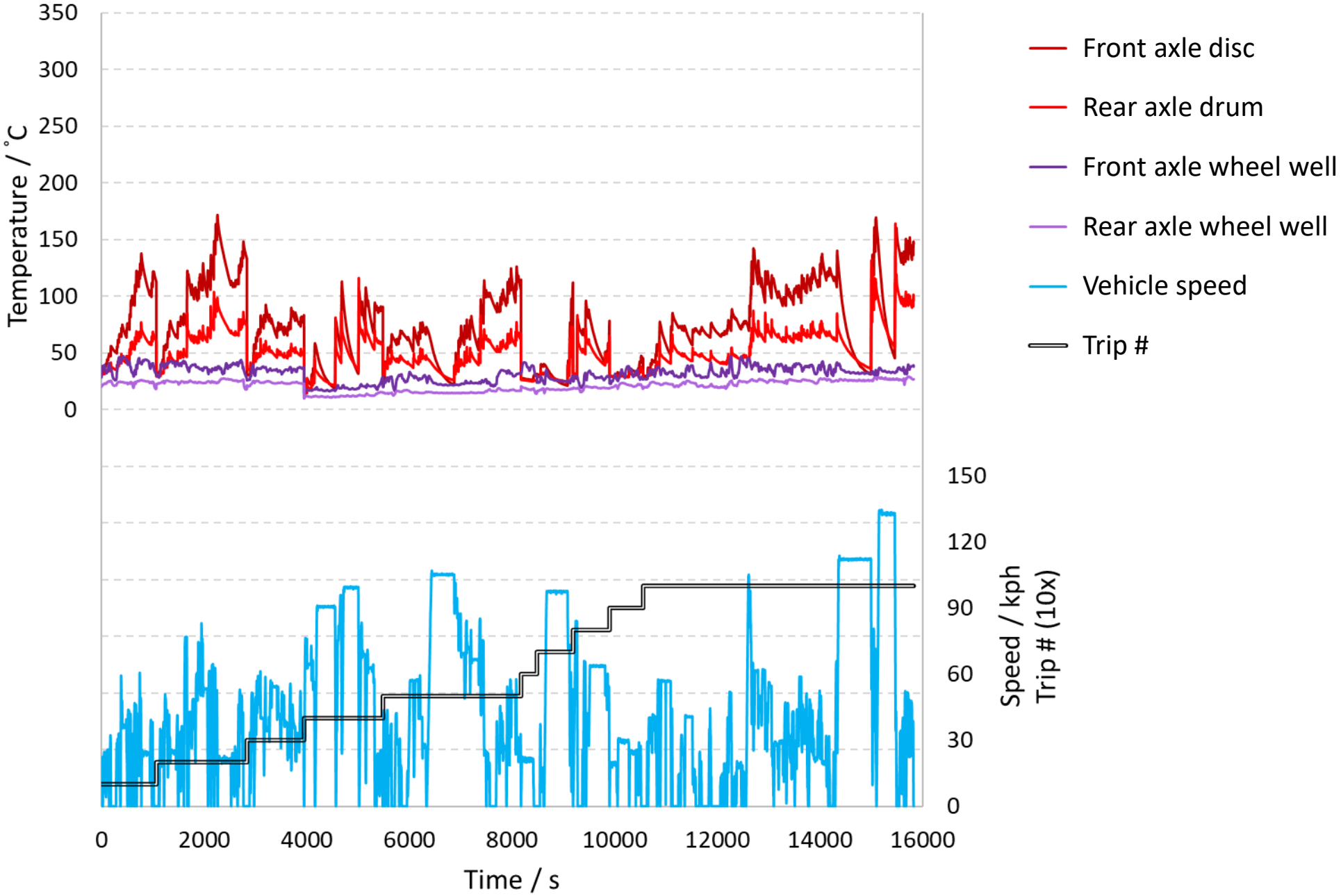
2011 Toyota Camry LE – cooldown time for front axle



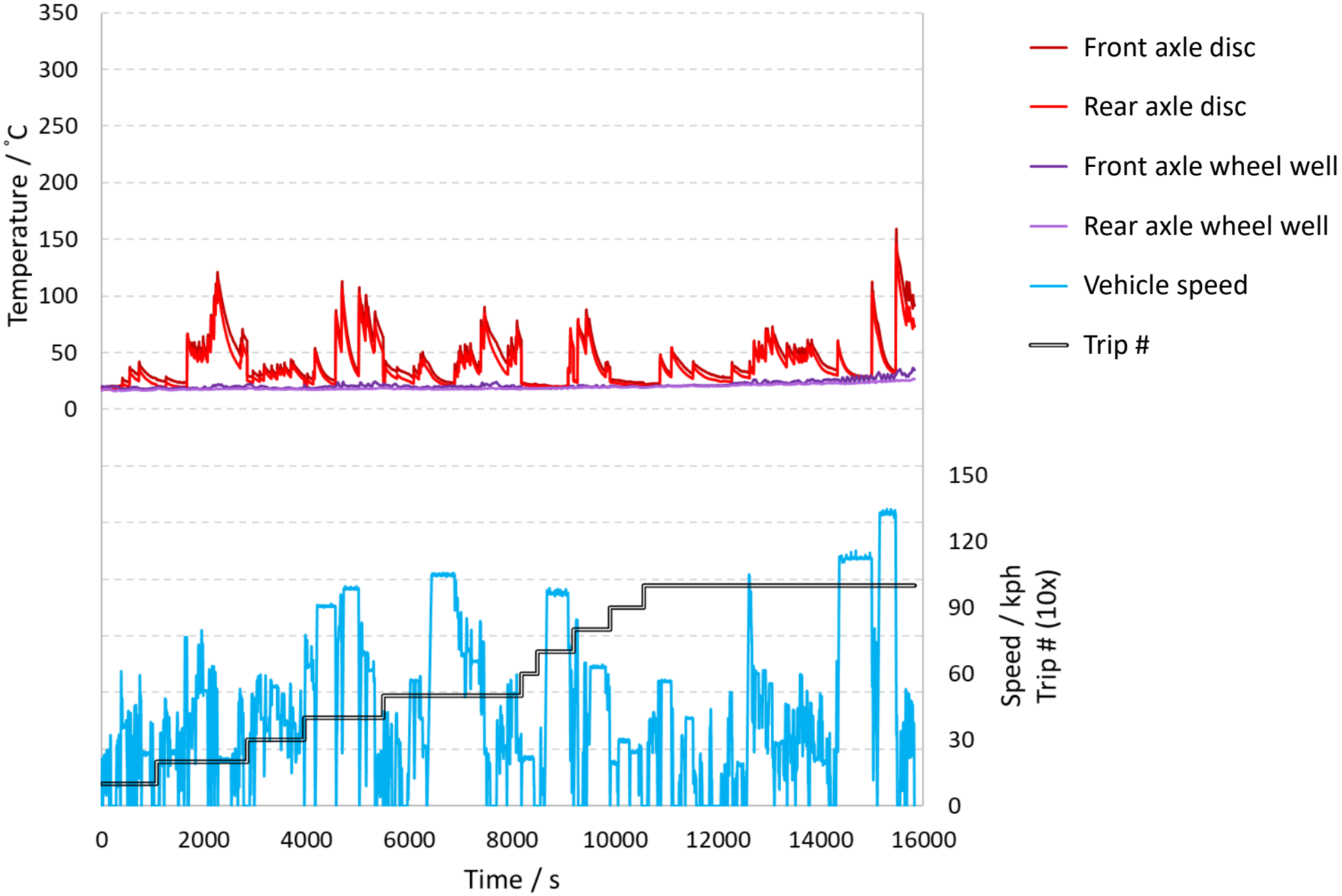
2013 Toyota Sienna LE – cooldown time for front axle



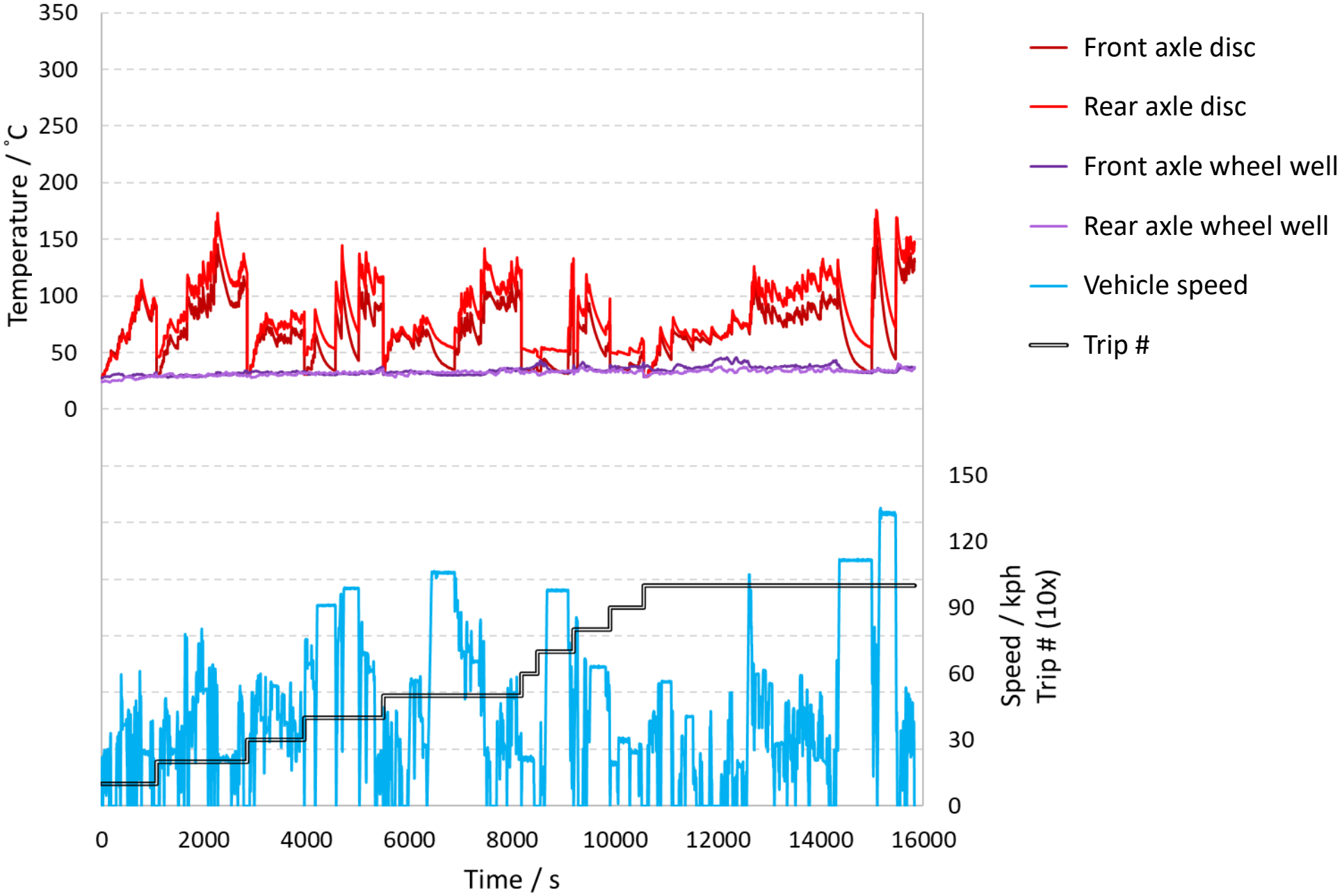
2013 Honda Civic LX



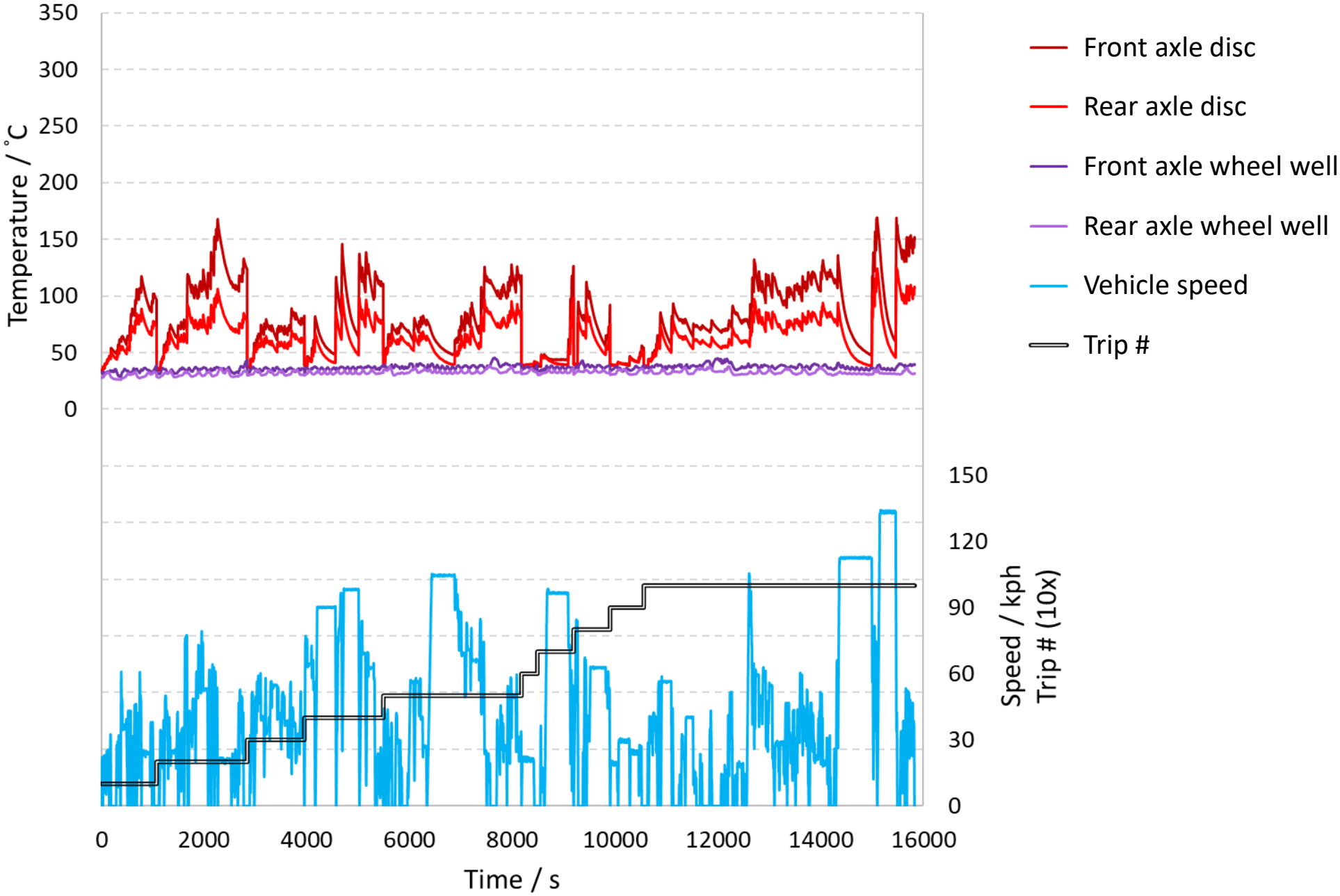
2016 Toyota Prius Base



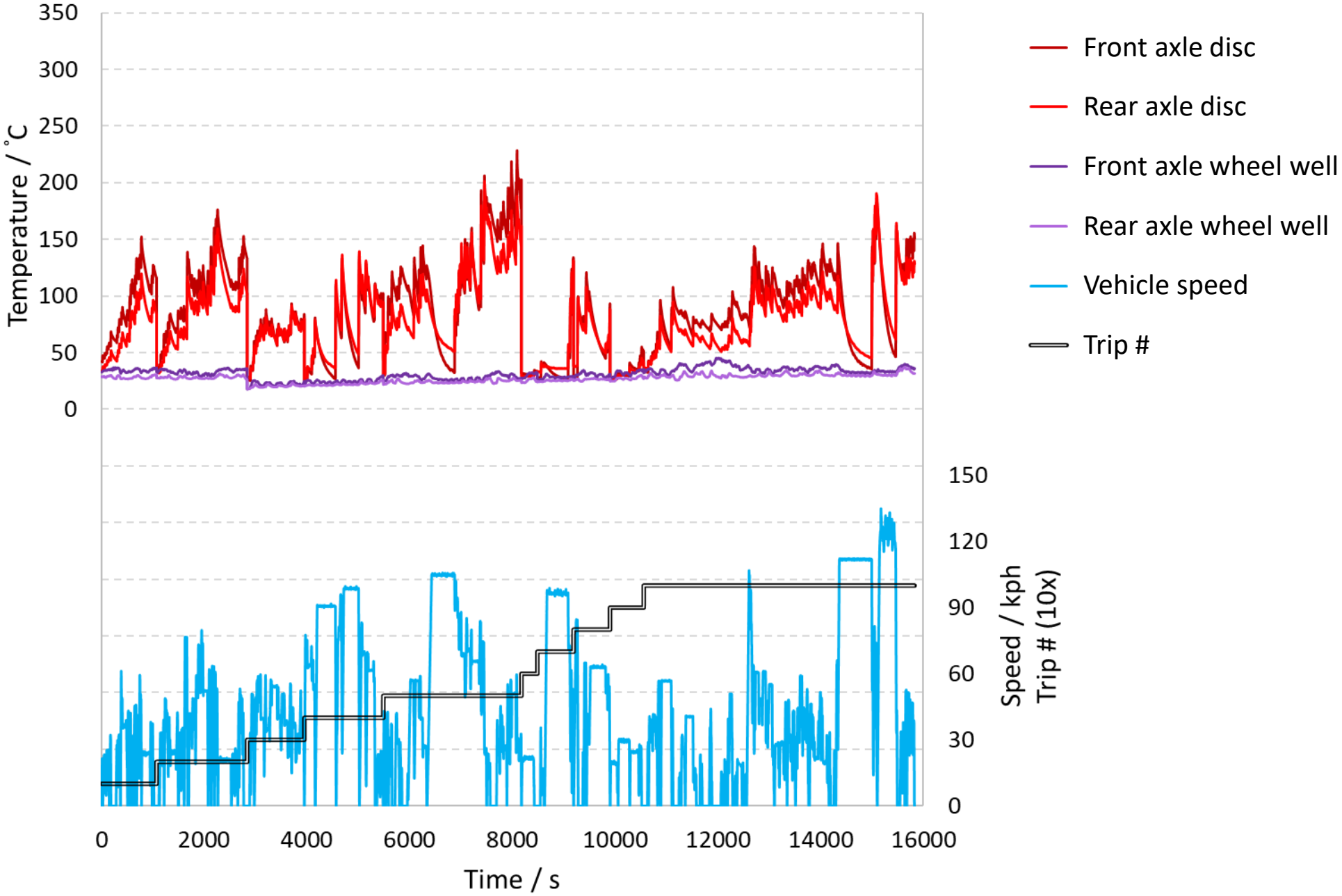
2011 Toyota Camry LE



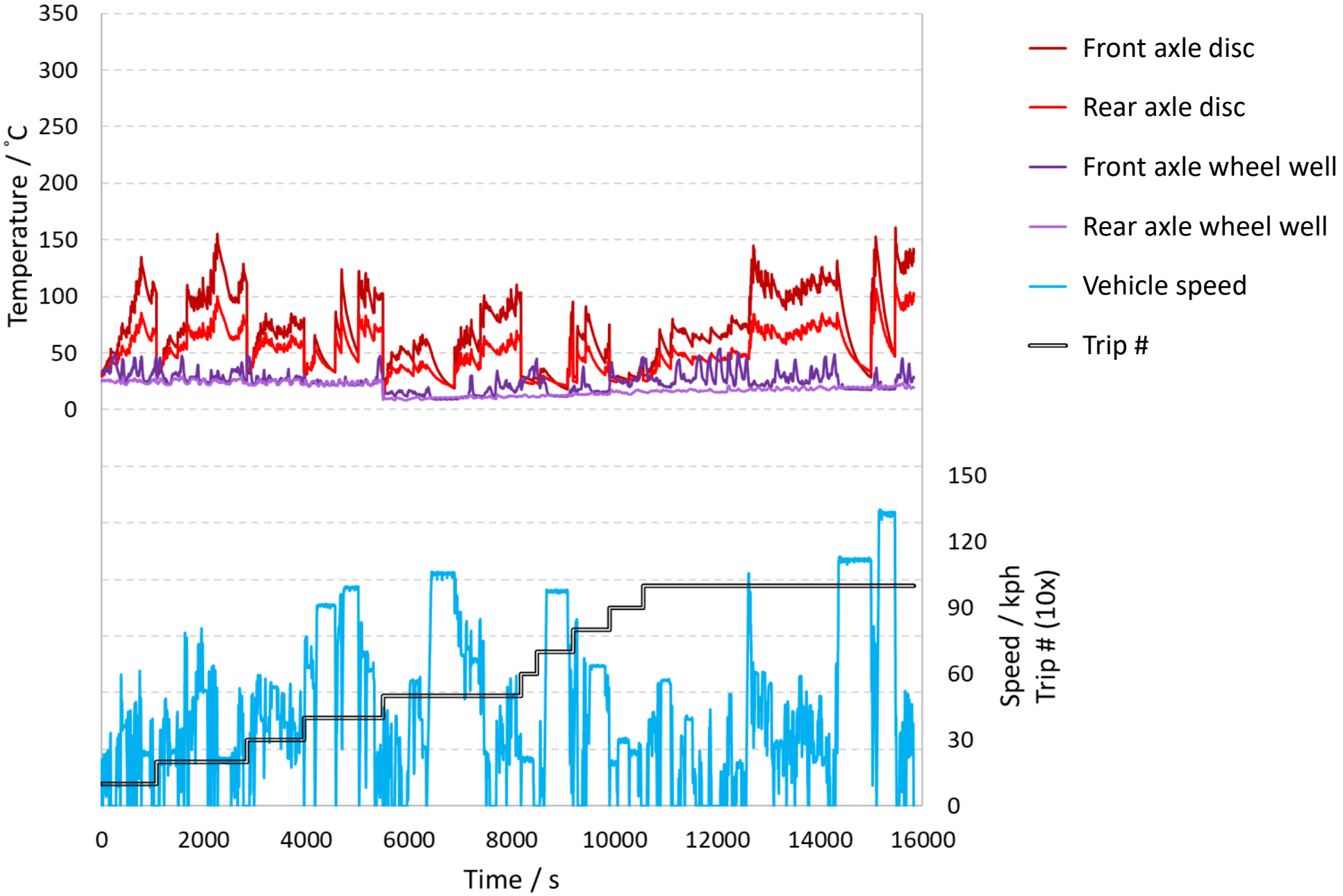
2016 Nissan Rogue S



2013 Toyota Sienna LE

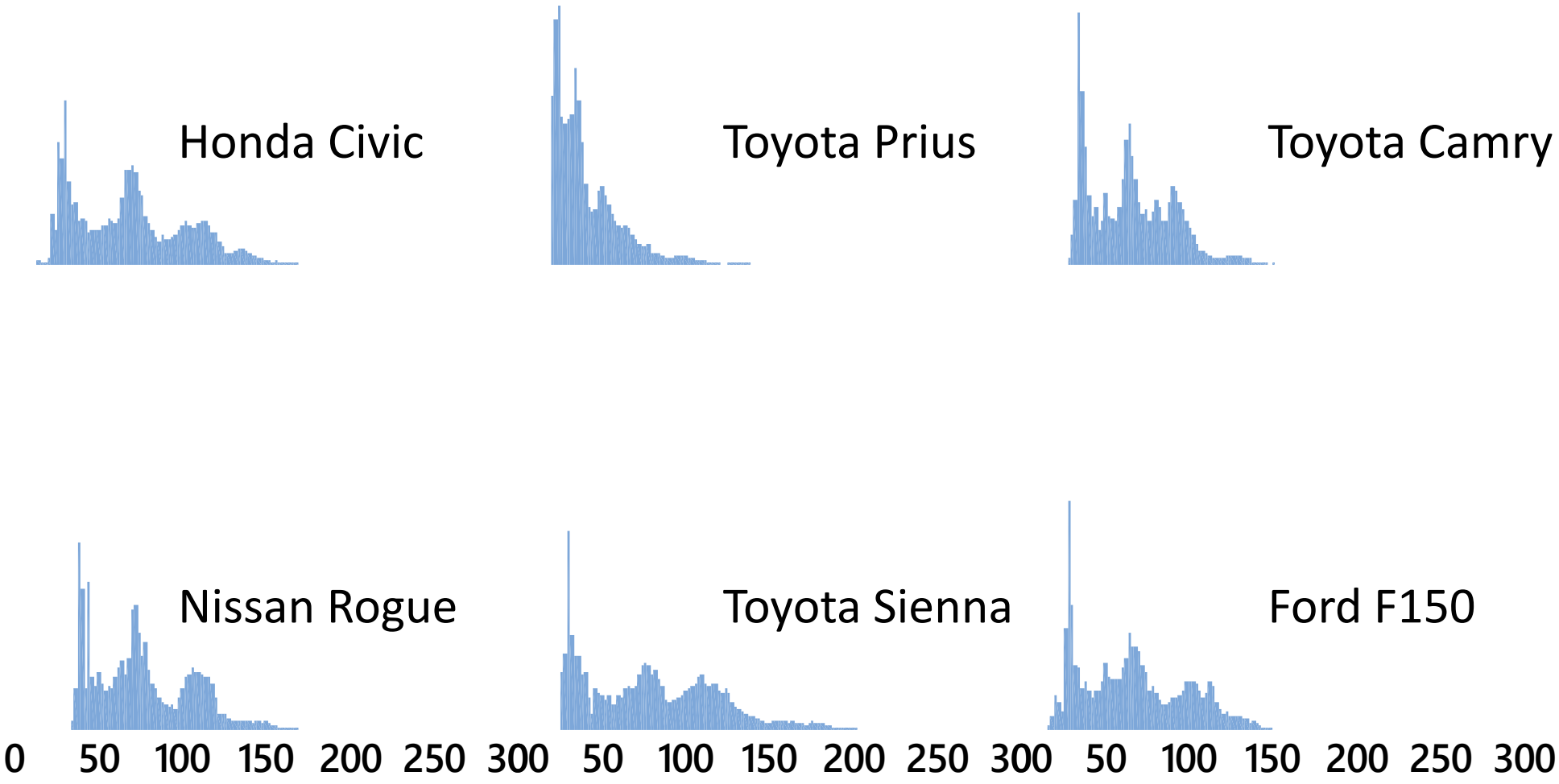


2015 Ford F150 XLT



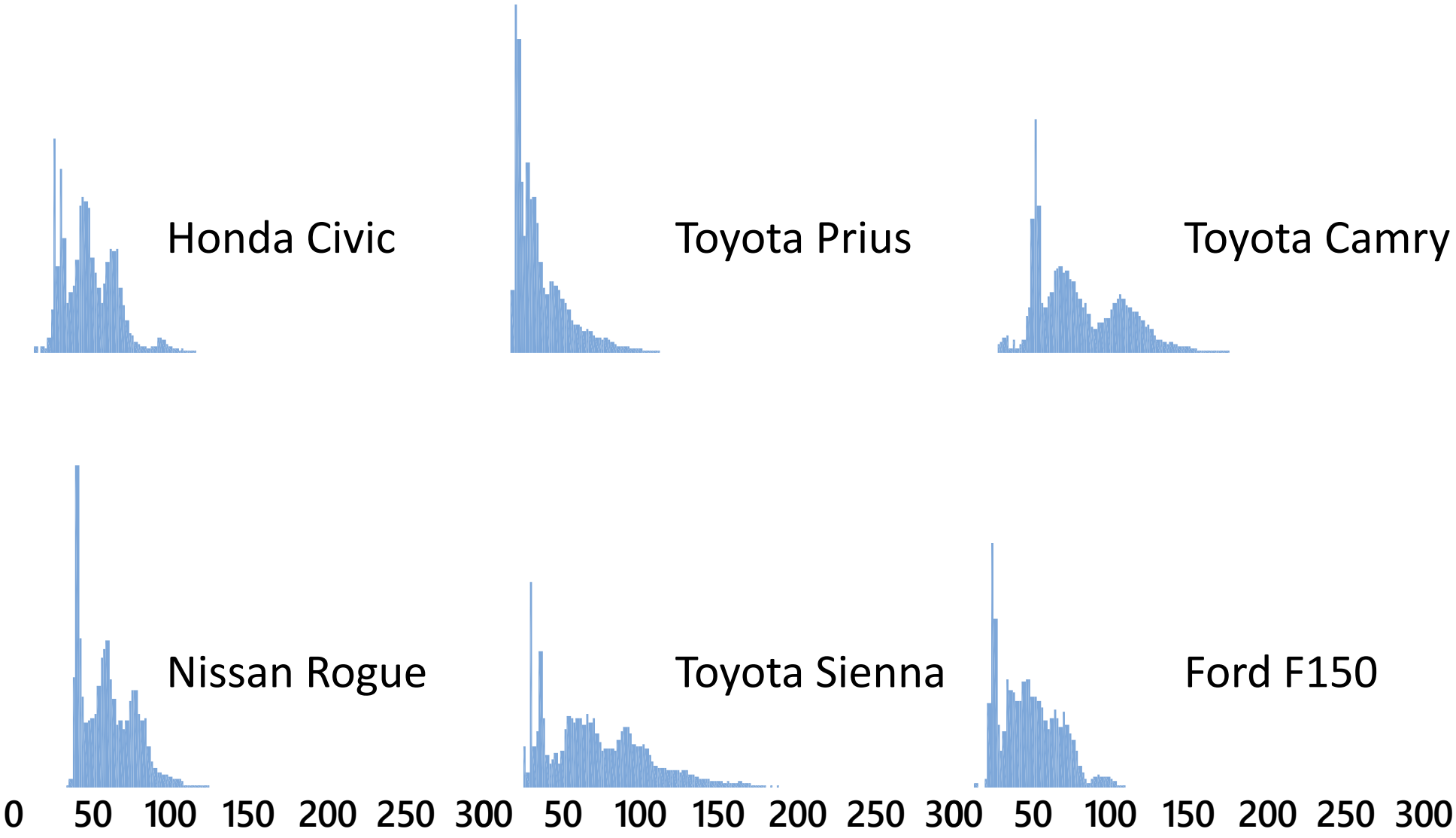
1 Hz average temperature front axle discs / °C

left side and right side brakes



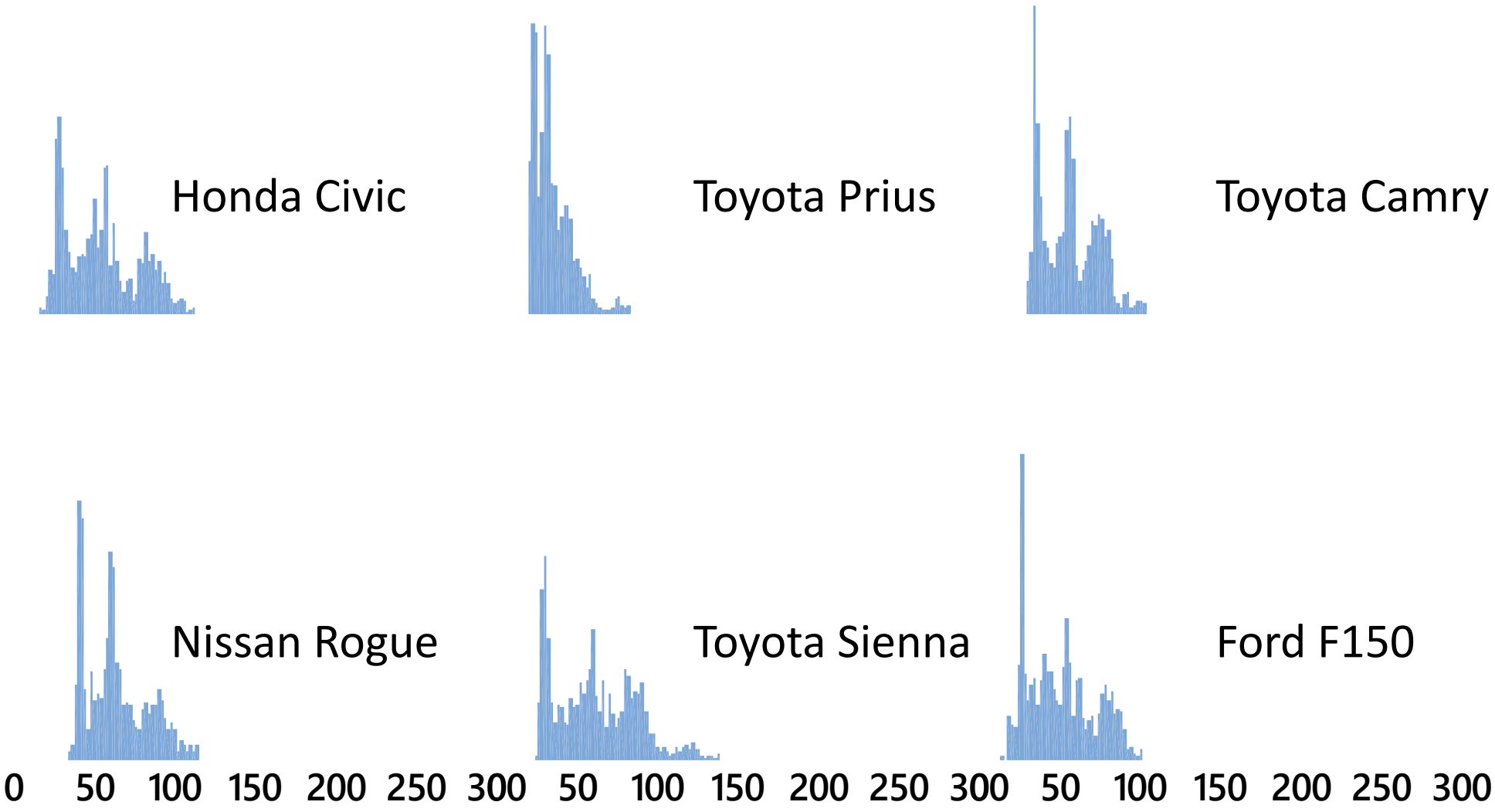
1 Hz average temperature of rear axle discs/drums / °C

left side and right side brakes



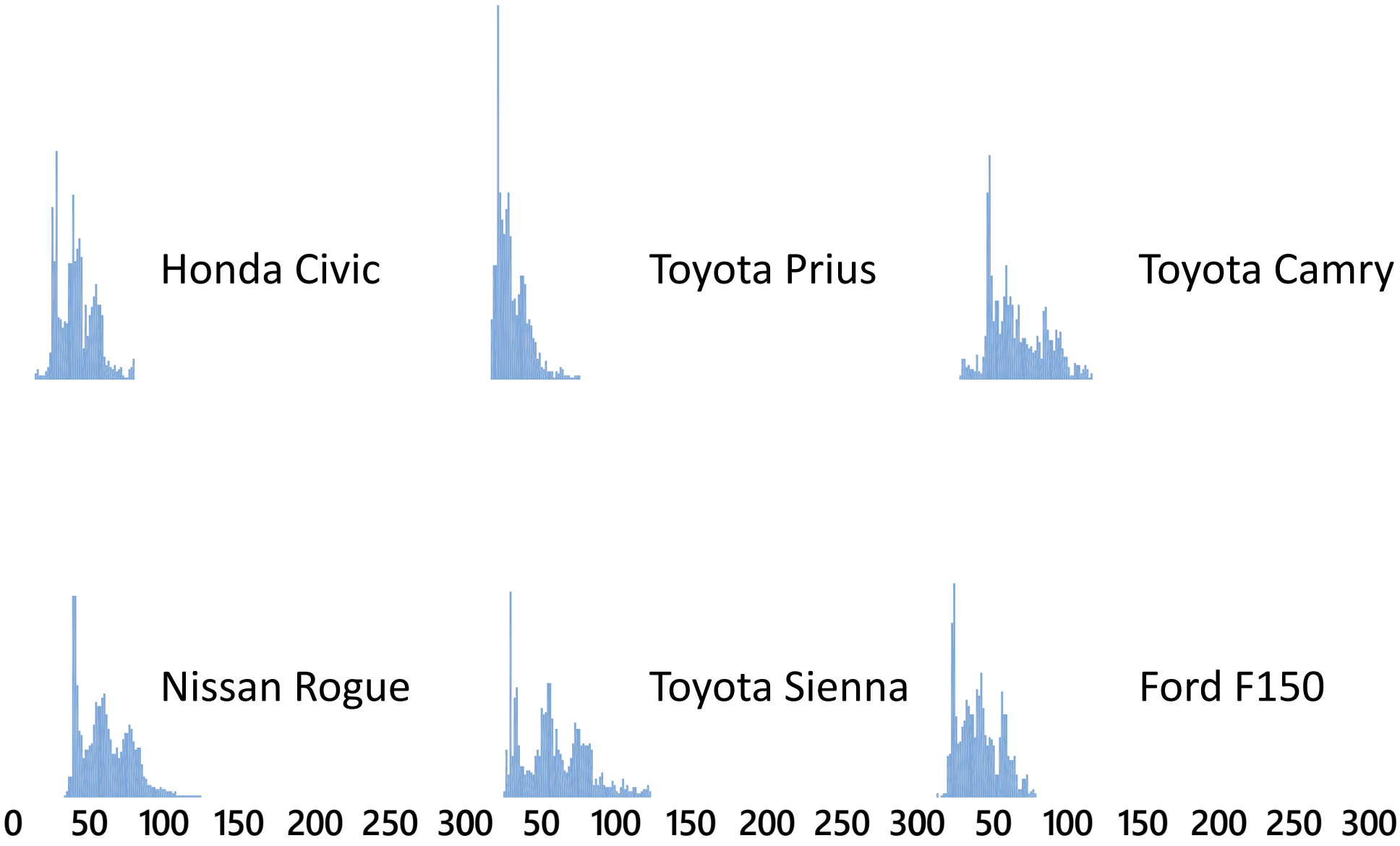
1 Hz average temperature of front axle pads / °C

left side and right side brakes



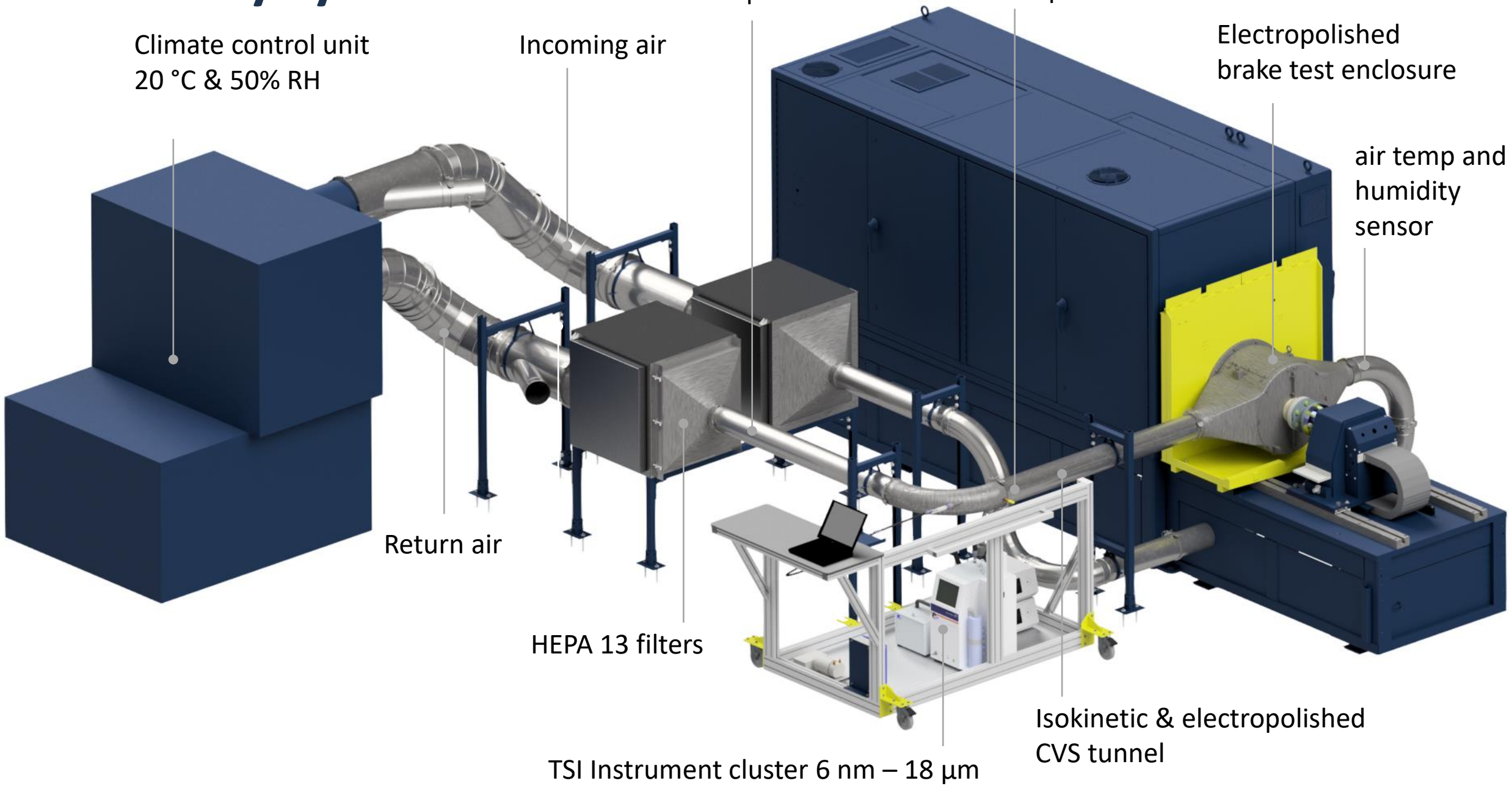
1 Hz average temperature of rear axle pads/shoes / °C

left side and right side brakes



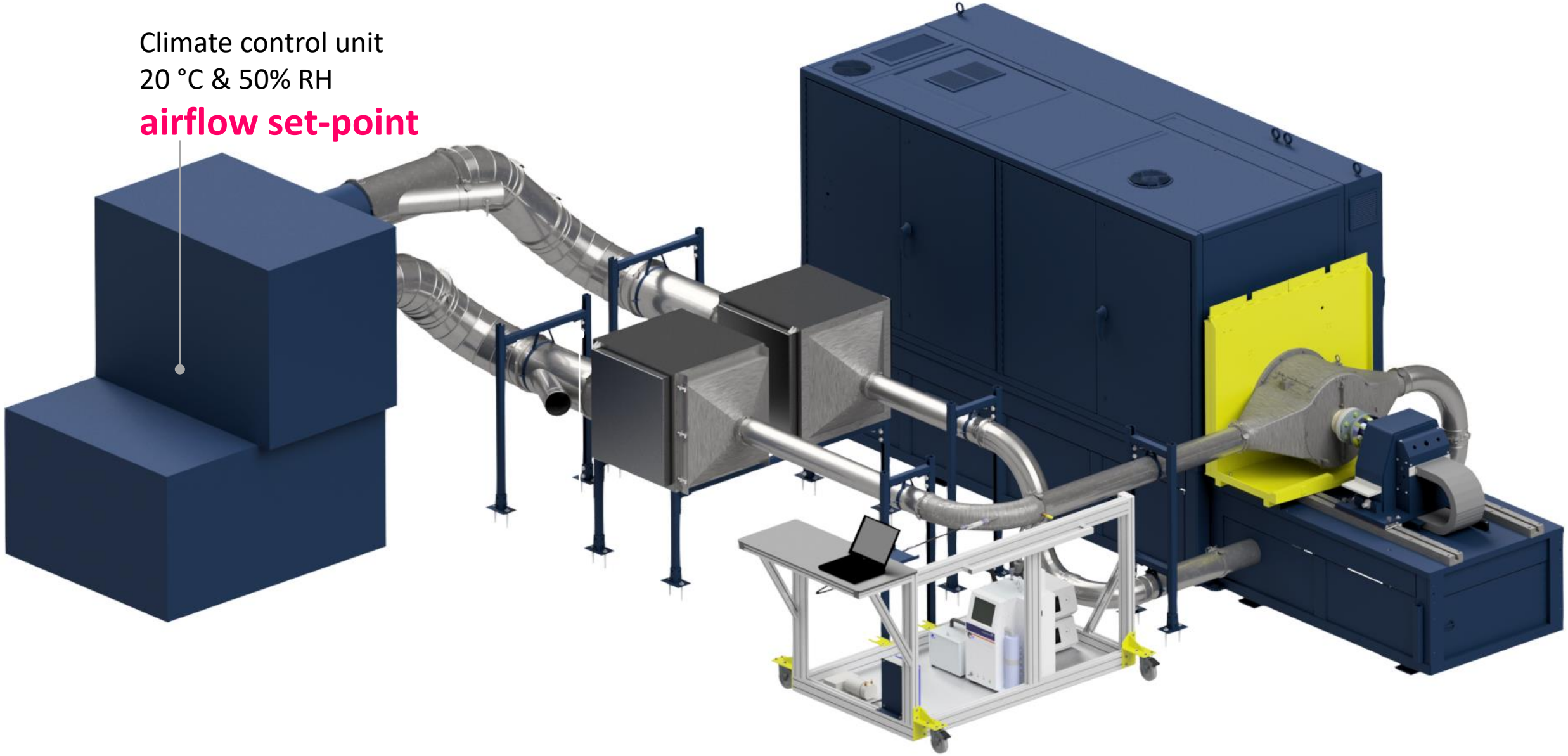
ultimate use of thermal regimes for vehicle, brake and dyno combination

laboratory system



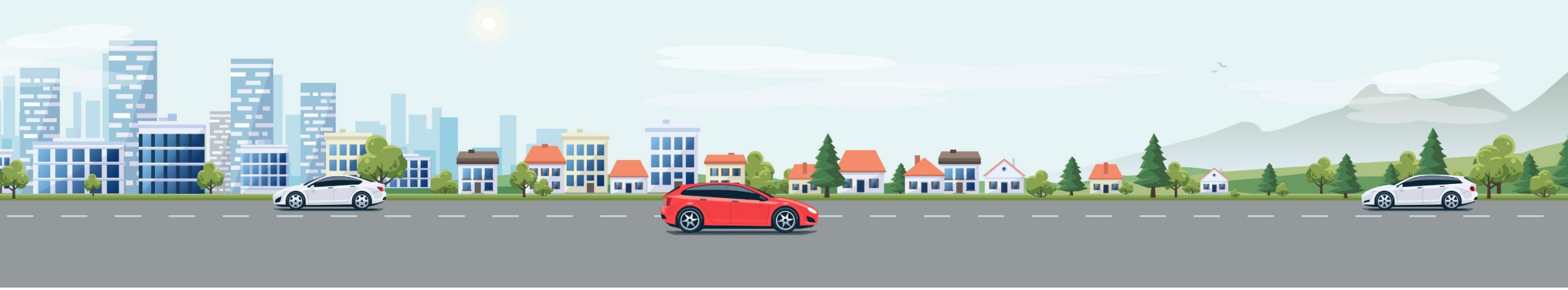
Climate control unit
20 °C & 50% RH

airflow set-point



next phases for the project

Thank you



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