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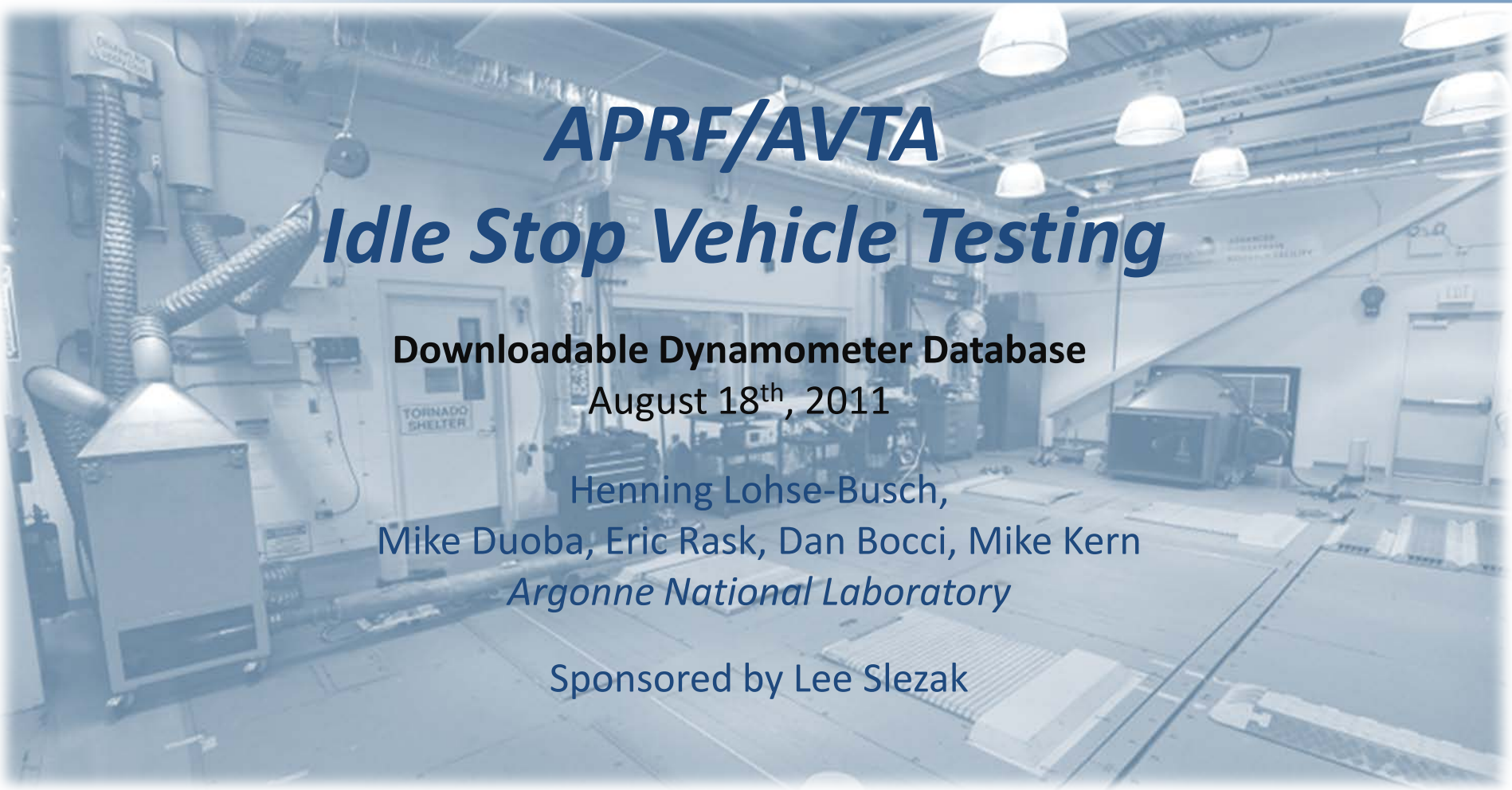

APRF/AVTA
Idle Stop Vehicle Testing

Downloadable Dynamometer Database

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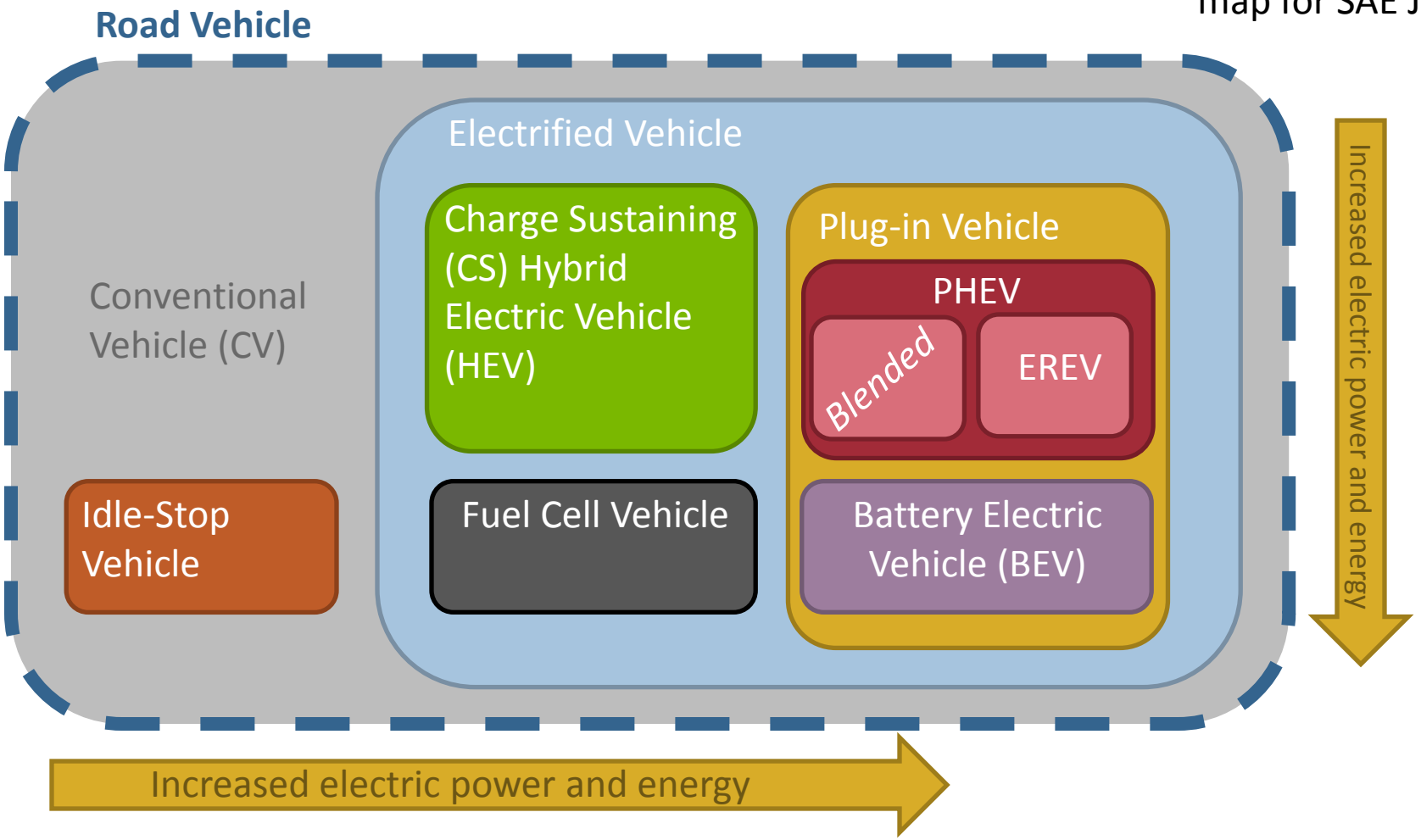
Overview

- SAE Idle stop definition
- 3 different approaches to the idle stop technology
  - Smart MDH (automatic)
    - Operation
    - Idle stop enable and disabled comparison
  - Mazda 3 iStop (manual)
  - Golf TDI Bluemotion (manual)
- Vehicle to Vehicle comparison
  - Vehicle technology comparison
  - Benefits of idle stop technology
  - Comparison of benefits between US cycles and European cycles
  - Impact for Air Conditioning

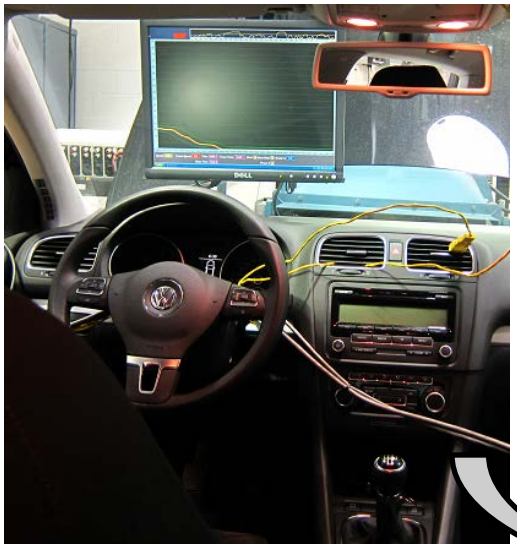
Categorizing Electrified Vehicles

SAE/ANL proposed vehicle terminology map for SAE J1715

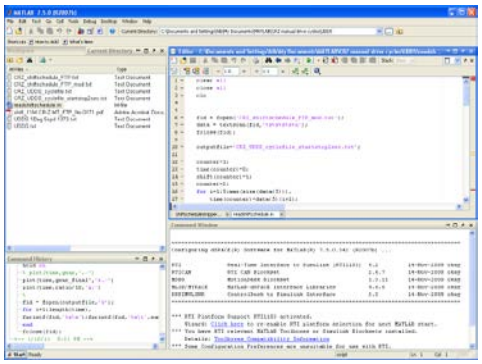


Note: Manual Transmission Vehicle Shift schedules for Dynamometers

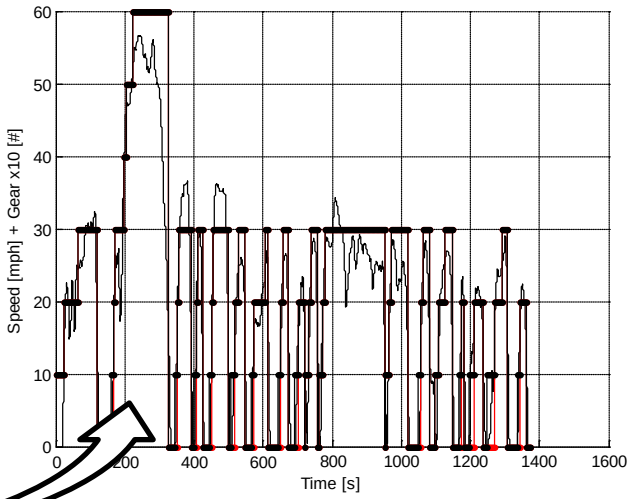
- Most cars in the US use automatic transmission, thus for most APRF test vehicles the shifting is ‘taken care of’, except for manual transmission powertrains
- We developed our own shift schedule using the shift indicator light
  - Mazda 3 i-Stop
  - Golf TDI
- Smart MHD uses an automated manual which does not require a shift schedule



Driven iterations of shifting



Translation program



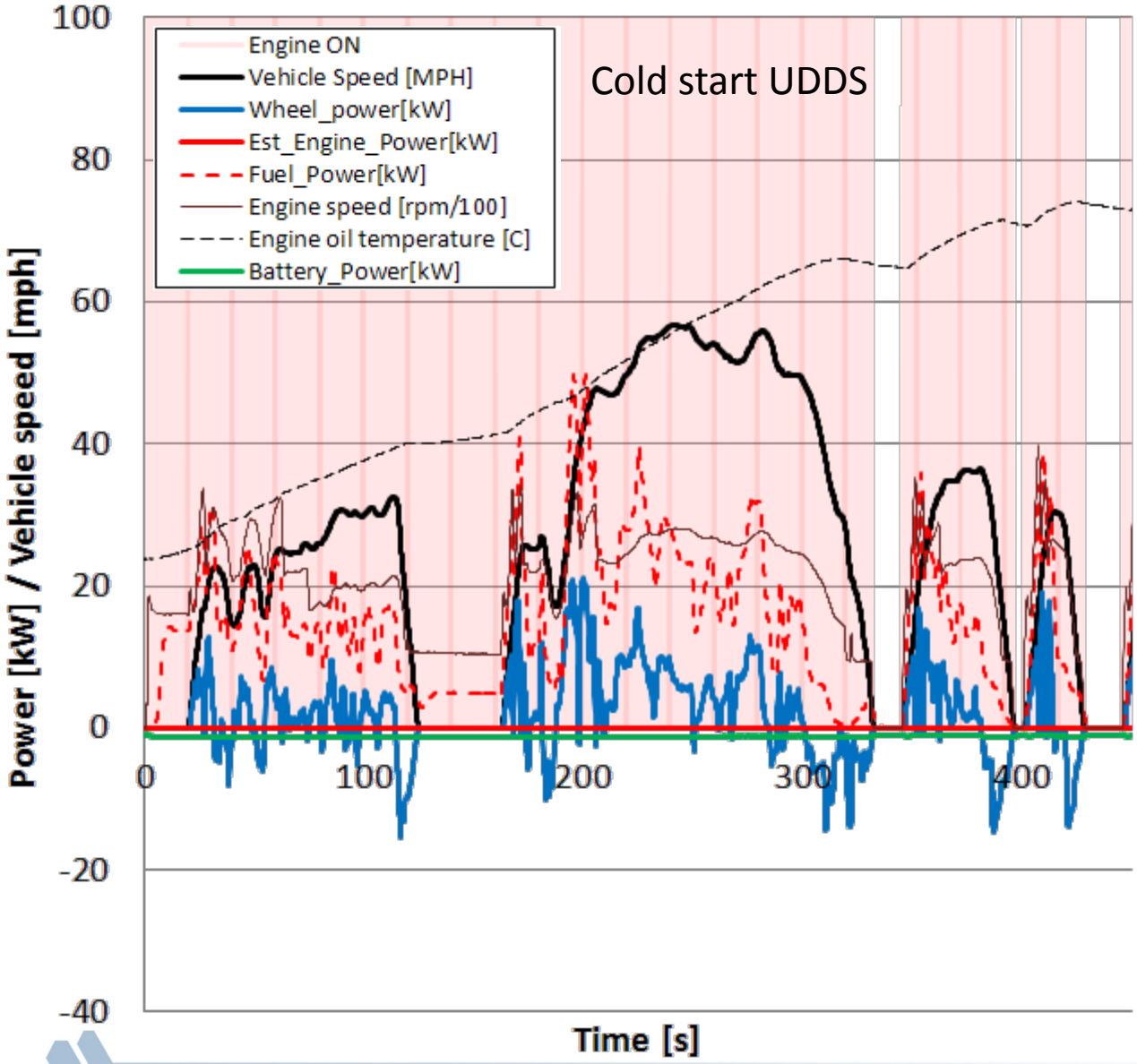
Shift schedule ready for dyno testing

Smart MHD (Micro Hybrid Drive) Benchmark goals

- FY2011 Level 1 Benchmark Test Vehicle
- Part of the AVTA program
- Part of the vehicle idle stop study

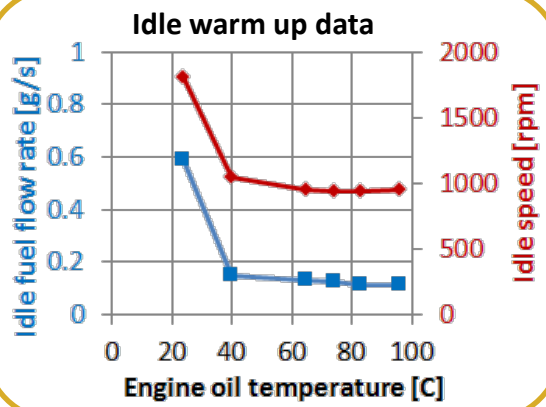
Smart MHD	
Vehicle architecture	Idle Stop Vehicle
Curb weight	750 kg (1650 lb)
Power plant	Gasoline 1.0 liter 3 cyl 52 kW @ 5800 rpm 92 N.m @ 4500 rpm 5 speed automatic
Performance (0- 62 mph)	13.3 s
Battery	Standard 12V battery
Fuel economy	55 / 70 mpg NEDC (C/H)
Idle stop features	Engine start-stop function: BAS Valeo system using the 12V battery
Additional fuel efficiency factors	Small and light vehicle 2 seat vehicle Engine ON trigger: Brakes

Smart MHD - Operation

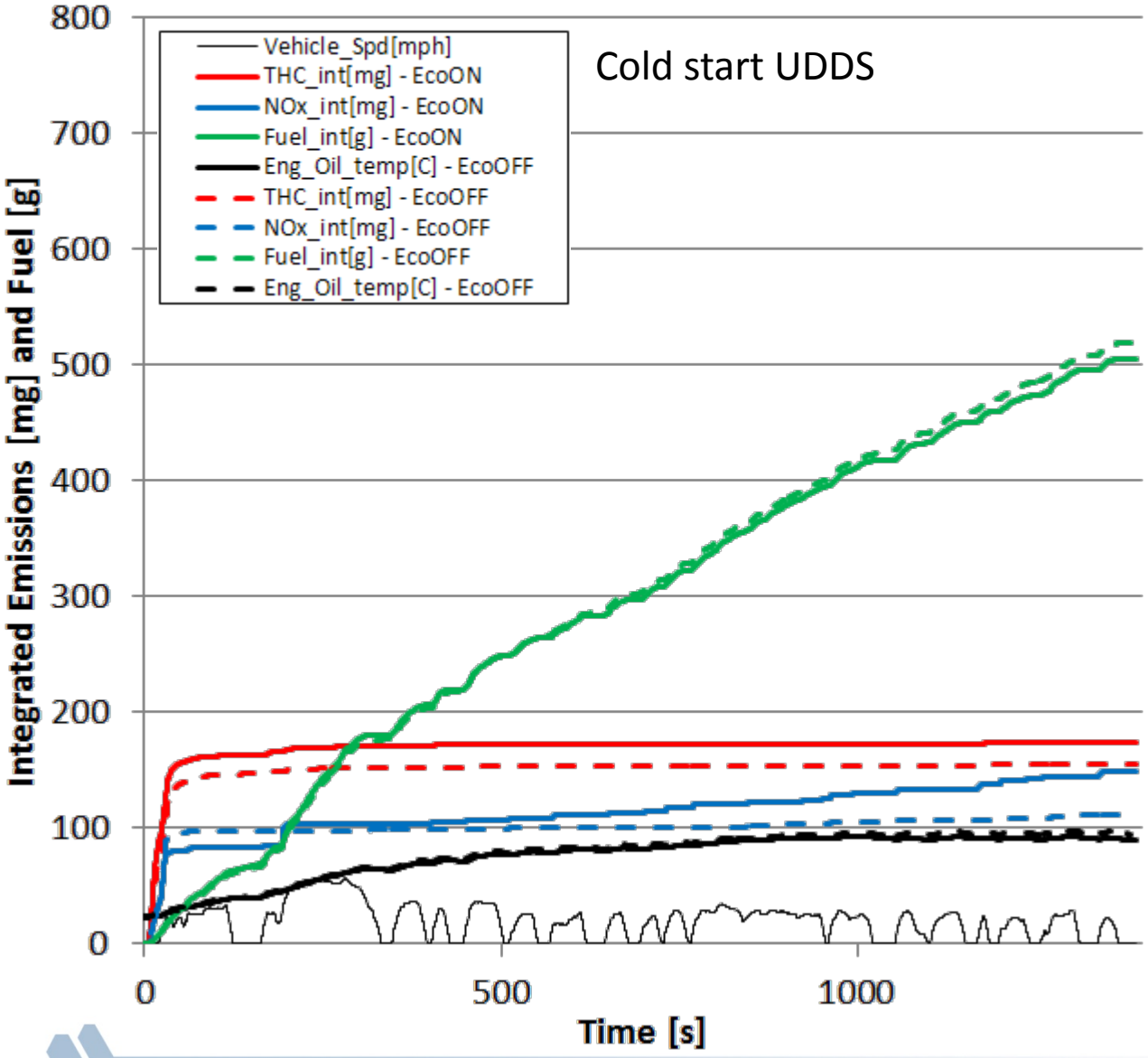


Operation

- Engine OFF
  - Below 5 mph
  - Engine warmed up
- Engine ON
  - Foot off brakes
  - AC ON may turn engine ON based on cabin temperature
- Idle stop disable switch



Smart MHD – Idle stop enabled vs. disabled



- The idle stop function decreases fuel consumption while causing NOx spikes during most engine starts

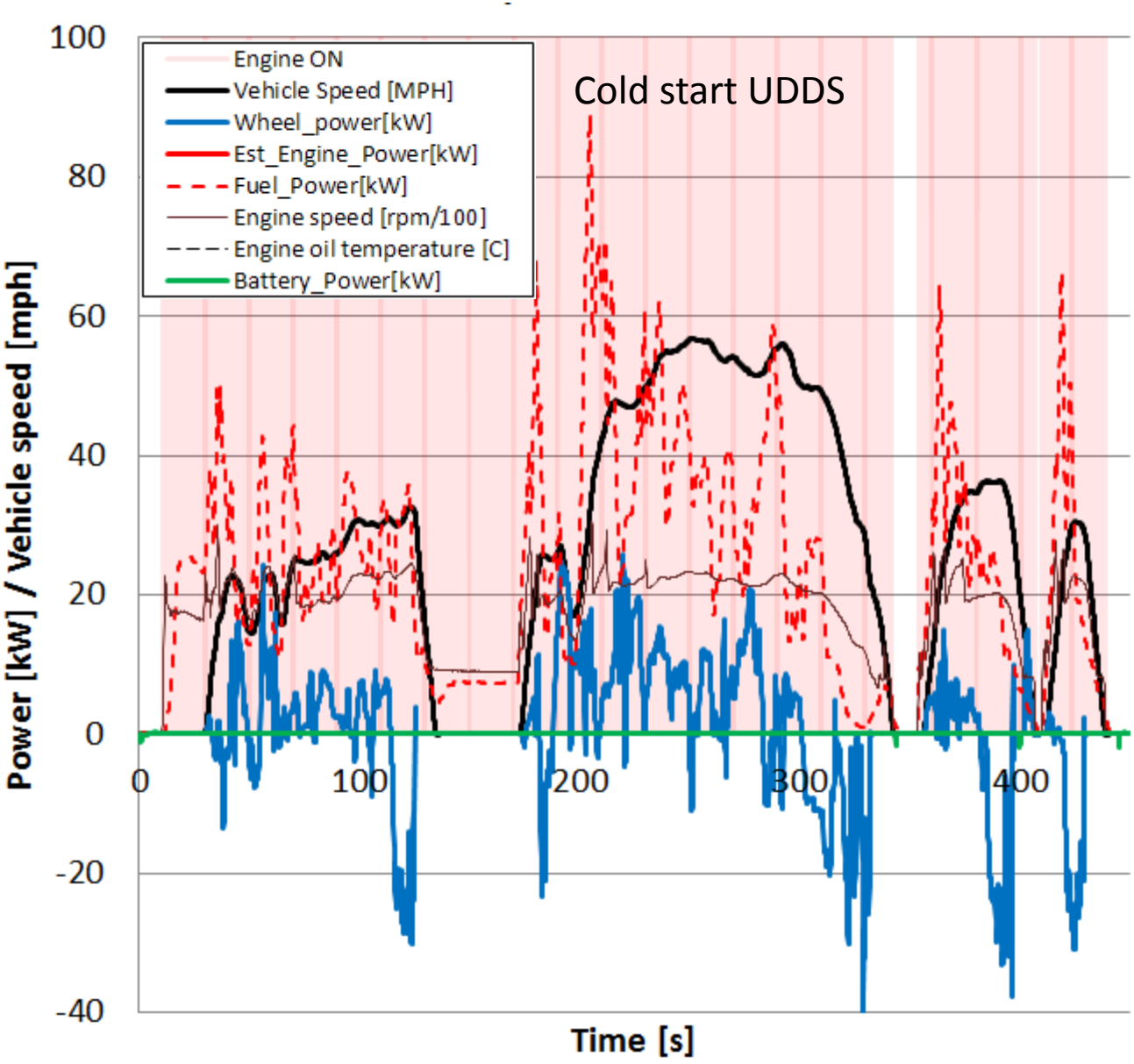
Eco:	ON	OFF
FE [MPG]	41.6	40.5
THC [mg/mi]	21.9	19.6
NOx [mg/mi]	19.3	14.4

Mazda 3 i-Stop Benchmark goals

- FY2011 Level 1 Benchmark Test Vehicle
- Part of the AVTA program
- Part of the vehicle idle stop study

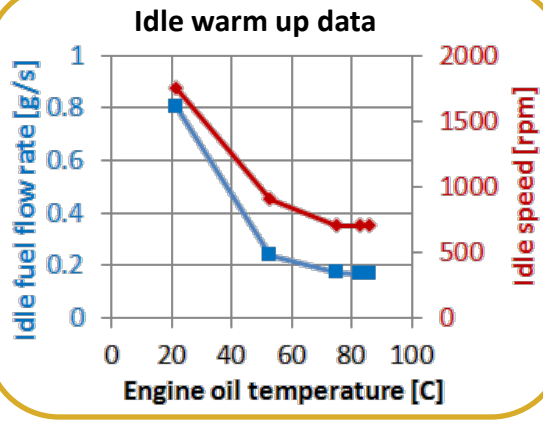
Smart MHD	
Vehicle architecture	Idle Stop Vehicle
Test mass	1475 kg (3250 lb)
Power plant	Gasoline 2.0 liter 4 cyl DI (11.2:1) 111 kW @ 6200 rpm 191 N.m @ 4500 rpm 6 speed manual
Performance (0- 62 mph)	10.4 s
Battery	Secondary 12V power battery for engine start
Fuel economy	25 / 44 mpg NEDC (C/H)
Idle stop features	Engine start-stop function: engine assisted combustion start with 12V starter (0.35 sec to start compared to 0.7 sec)
Additional fuel efficiency factors	Engine ON trigger: Clutch pedal

Mazda 3 operation

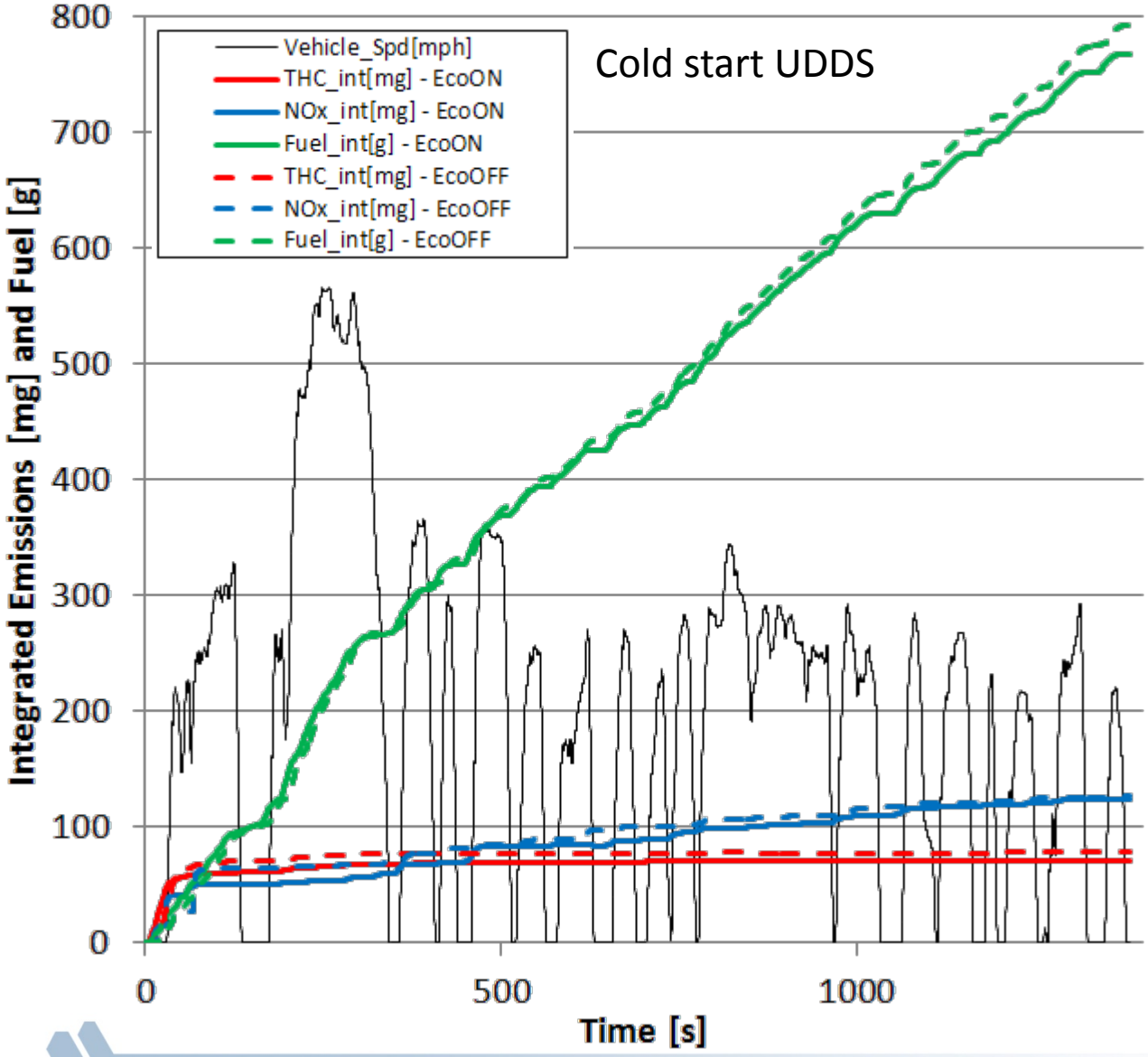


Operation

- Engine OFF
  - Below 3 mph
  - Engine warmed up
- Engine ON
  - Push clutch pedal in
  - AC ON may turn engine ON based on cabin temperature
- Idle stop disable switch



Mazda 3 i-stop – Idle stop enabled vs. disabled



- The idle stop function decreases fuel consumption but for this vehicle the emissions are not increased
- The combustion assisted engine start process (controlled engine stop position and igniting start sequence) help provide a clean engine start

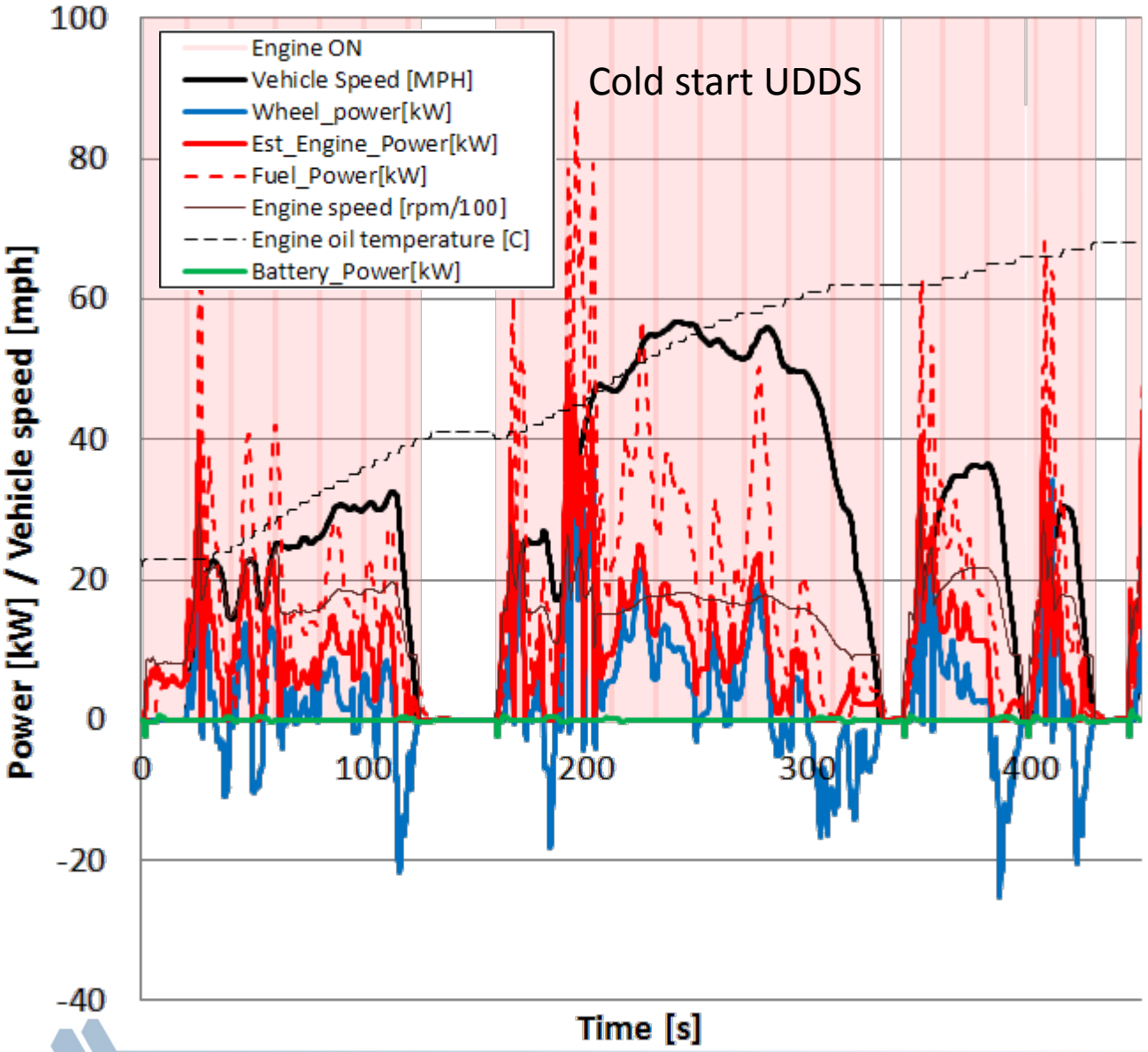
Eco:	ON	OFF
FE [MPG]	27.3	26.5
THC [mg/mi]	9.6	10.6
NOx [mg/mi]	16.8	16.4

Golf TDI Bluemotion Benchmark goals

- FY2011 Level 1 Benchmark Test Vehicle
- Part of the AVTA program
- Part of the vehicle idle stop study

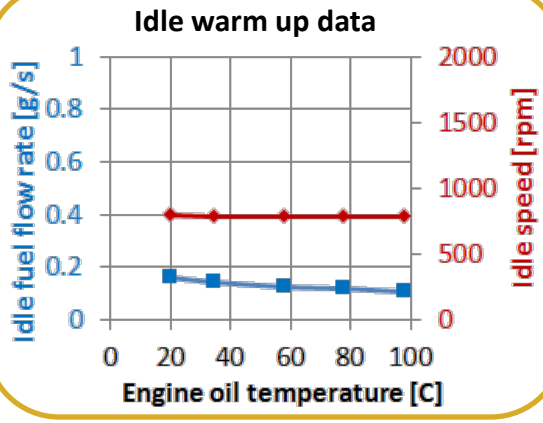
Smart MHD	
Vehicle architecture	Idle Stop Vehicle
Test mass	1645 kg (3625 lb)
Power plant	Diesel 2.0 liter 4 cyl TDI (11.2:1) 103 kW @ 4200 rpm 236 N.m @ 1750 rpm 6 speed manual
Performance (0- 62 mph)	9.3 s
Battery	Standard 12V battery
Fuel economy	44 / 62mpg NEDC (C/H)
Idle stop features	Engine start-stop function
Additional fuel efficiency factors	Engine ON trigger: Clutch pedal Aero tweaks Tall final drive

Golf TDI Bluemotion – Operation

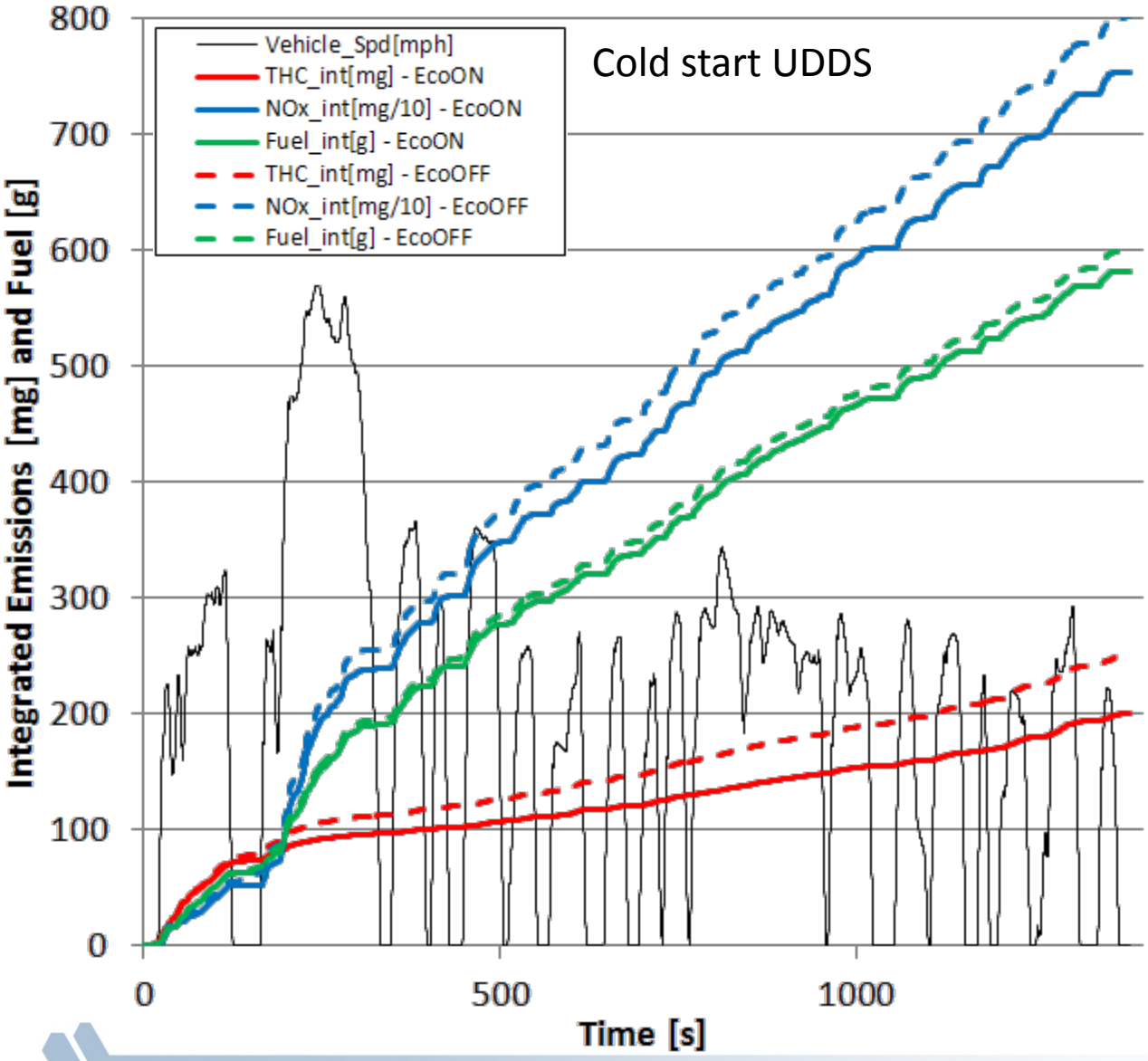


Operation

- Engine OFF
  - Almost a complete stop required
  - No engine warm up required from 23 C
- Engine ON
  - Push clutch pedal in
  - AC ON may turn engine ON based on cabin temp
- Idle stop disable switch



Golf TDI Bluemotion – Idle stop enabled vs. disabled



- The idle stop function decreases fuel consumption while decreasing emissions
- For this diesel the emissions always increase during the drive cycle independent of engine and exhaust operating temperature

Eco:	ON	OFF
FE [MPG]	41.7	40.6
THC [mg/mi]	25.4	31.3
NOx [mg/mi]	1034	1104

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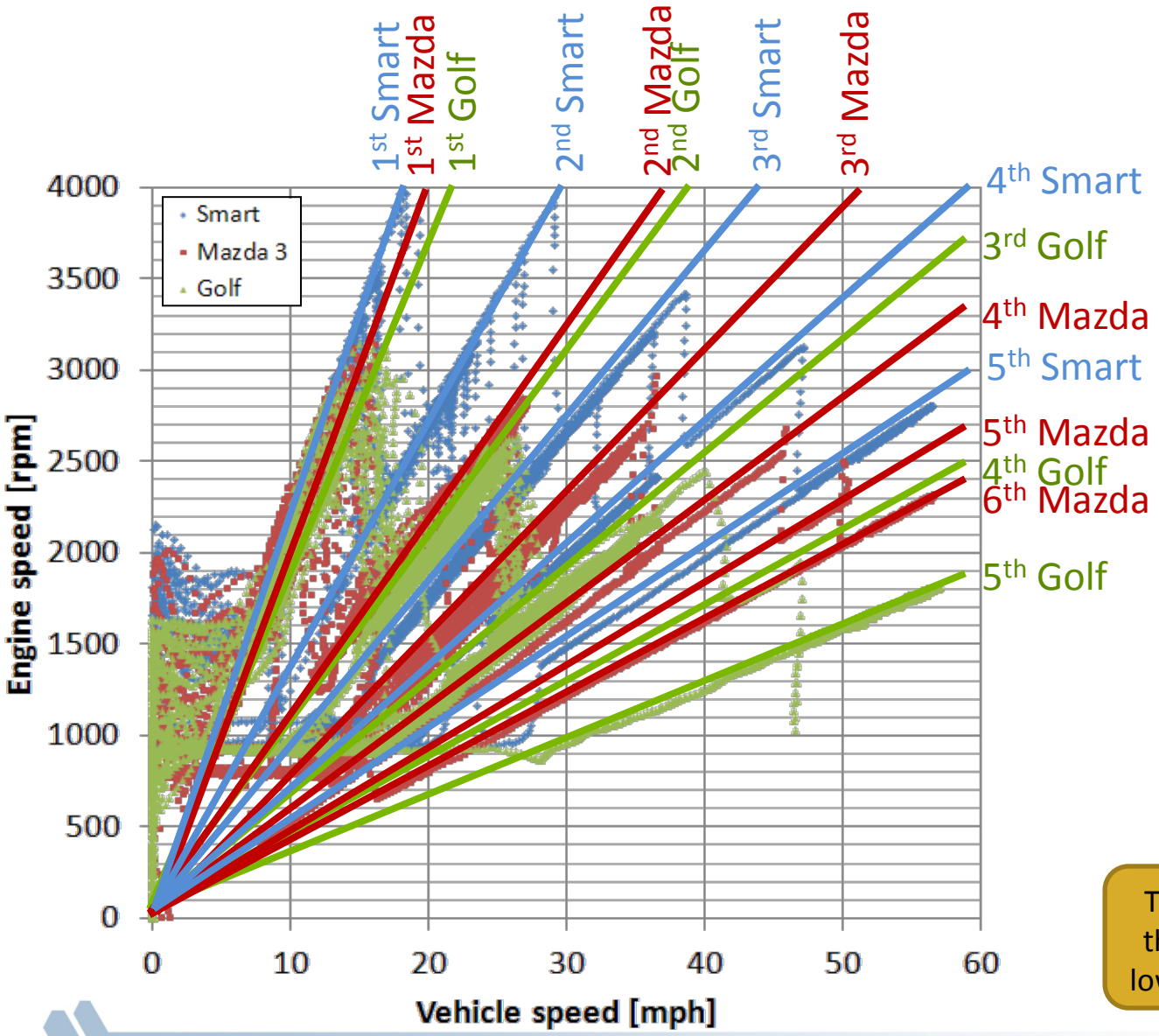
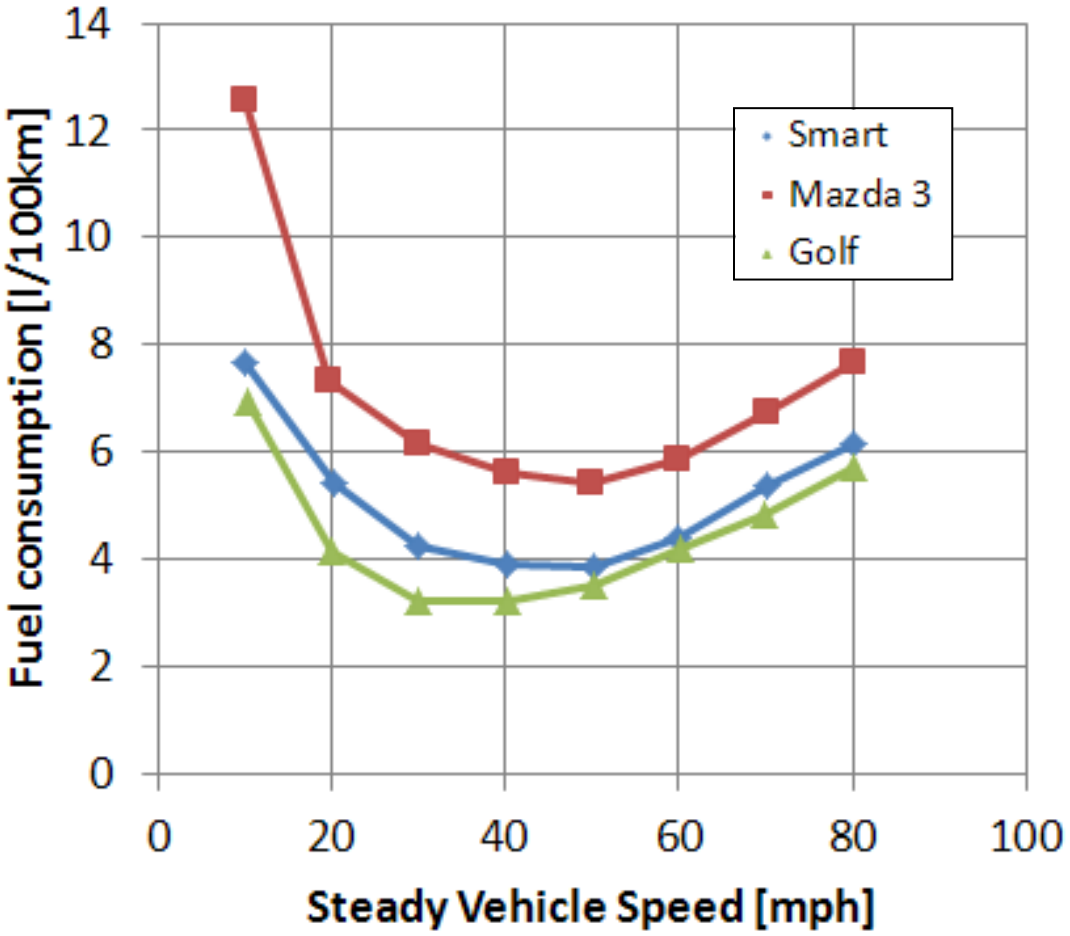
Comparison of final drive ratios



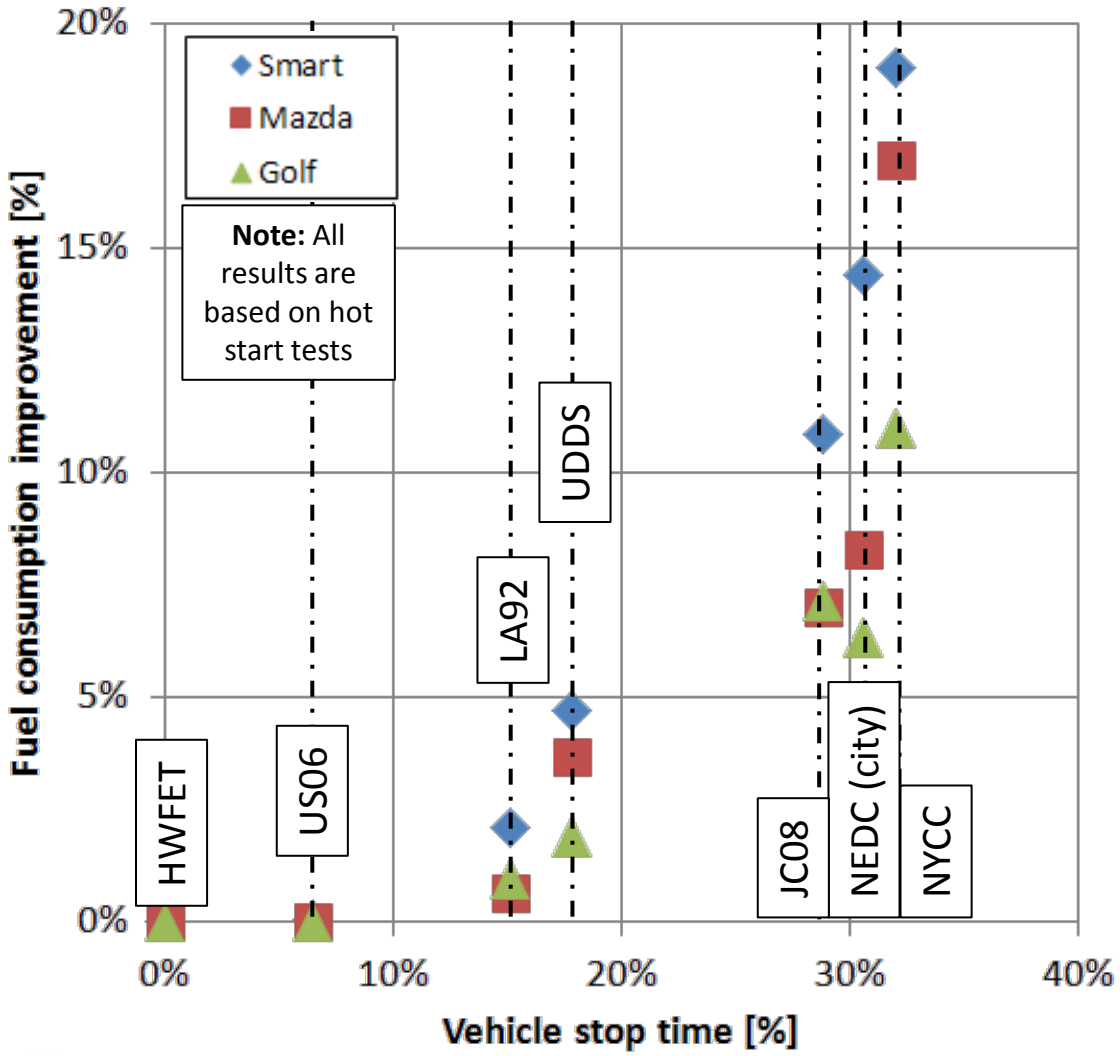
Increasing max engine torque

The higher the final drive the higher the average engine efficiency due to lower engine speed and higher torque

Steady State Speed Fuel Consumption

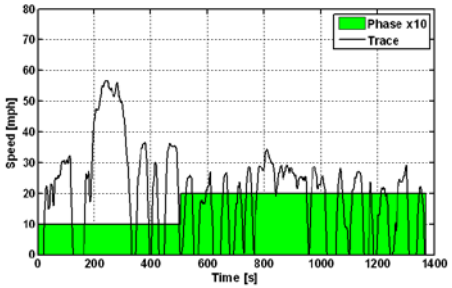


Fuel Consumption Improvement as a Function of Vehicle Stop Time for Different Cycles



- Start stop technology can provide a significant improvement in fuel consumption for a vehicle in city type driving with vehicle stop periods of over 20%.
- For those vehicle the idle stop technology can be a cost effective alternative to HEVs to improve fuel efficiency

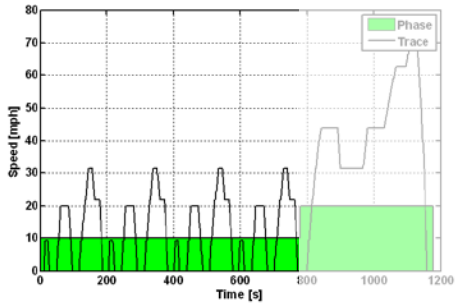
Idle Stop Vehicle Benefits in US and Europe



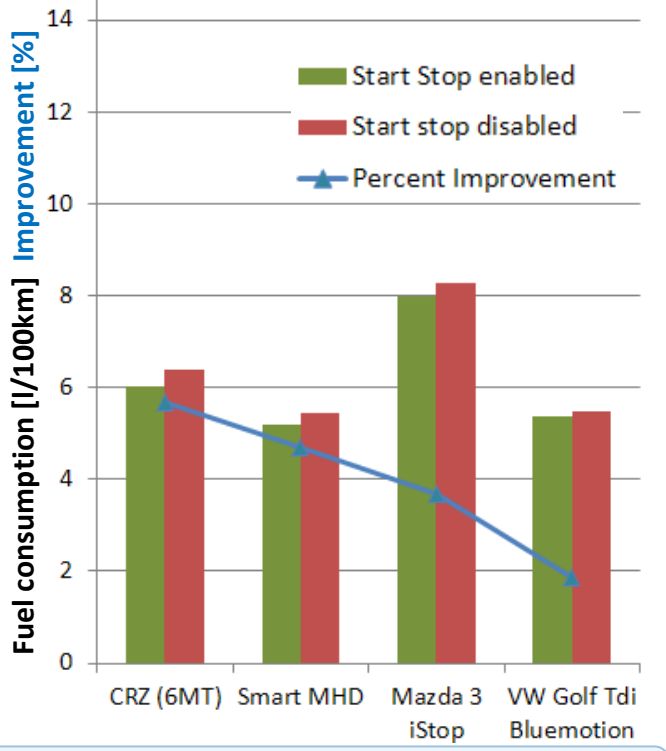
UDDS

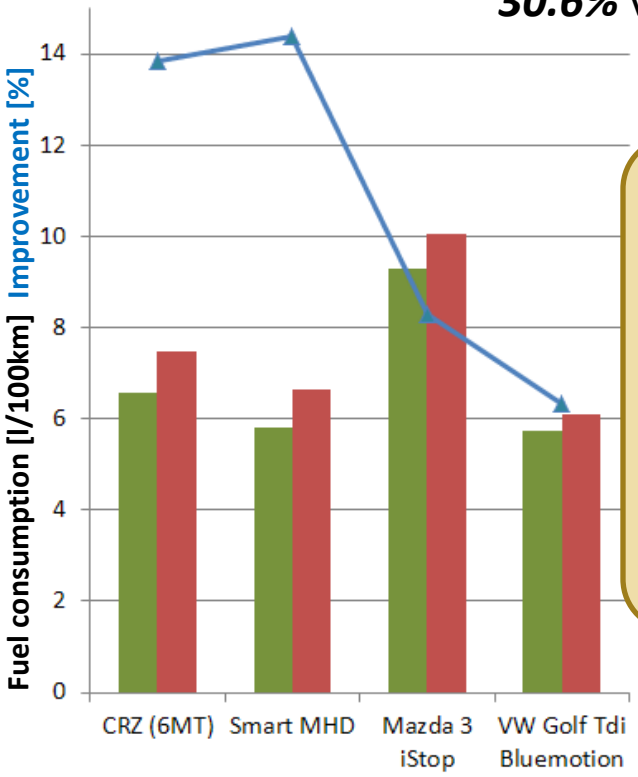
17.6% vehicle stop

NEDC (City)



30.6% vehicle stop





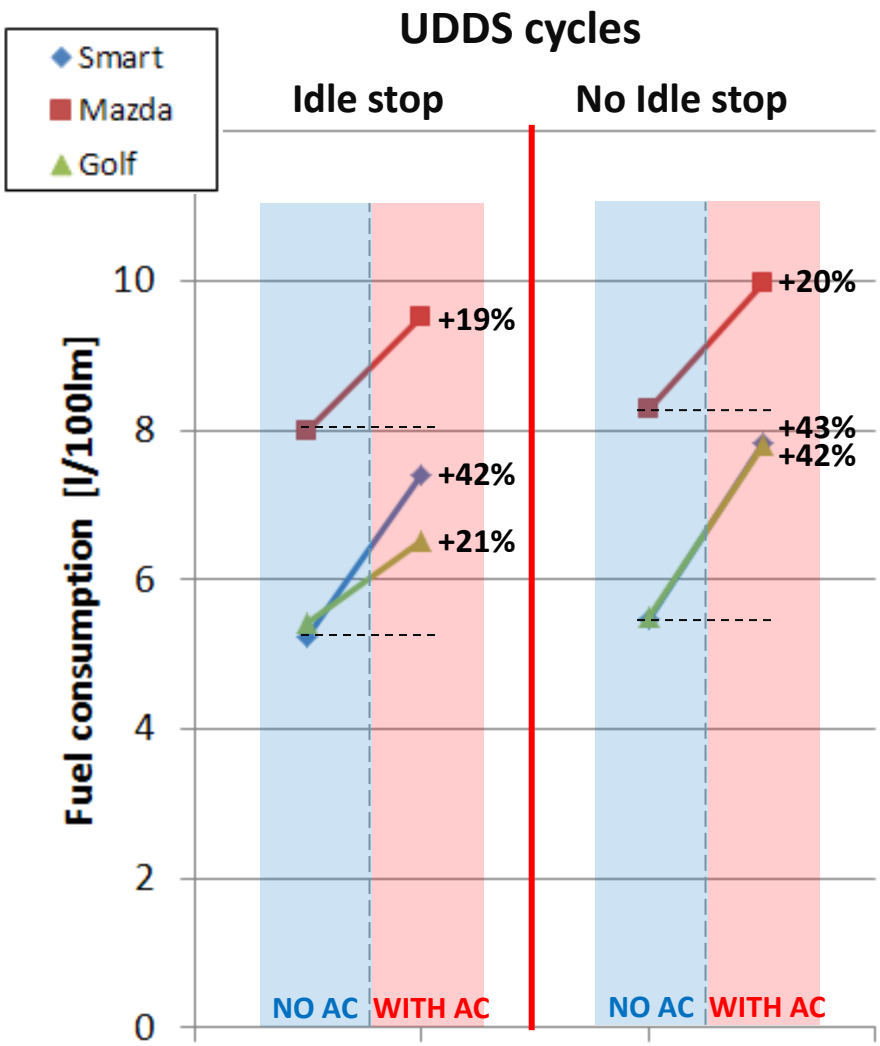
Notes:
- All tests here are hot start tests
- Average start stop improvement is based on the 4 test cars

Start stop vehicles are more popular in Europe, as the fuel efficiency gain is higher on the European certification cycles

→ Average start stop improvement ***4%***

→ Average start stop improvement ***10%***

Impact of Air Conditioning on Fuel Consumption



- The impact of Air Conditioning far outweighs the idle stop fuel savings

Idle stop vehicle summary

- Start stop technology can provide a significant improvement in fuel consumption for a vehicle in city type driving with vehicle stop periods of over 20%
- Tailpipe emissions may suffer from the idle stop technology
- The impact of Air Conditioning outweighs the idle stop fuel savings