



Environment and
Climate Change Canada

Environnement et
Changement climatique Canada



Transport
Canada

Transports
Canada



Natural Resources
Canada

Ressources naturelles
Canada

Office of Energy Research and Development
Bureau de recherche et de développement énergétiques

Canada

Real World Gaseous and Particulate Emissions from 2018 PHEVs

Contact: Aaron Loiselle-Lapointe (Aaron.Loiselle@Canada.ca)
Team: Kieran Humphries, Jonah Veenendaal and Vinay Sharma
(613)949-0918
Emissions Research and Measurement Section
Environment and Climate Change Canada

Photos: Michel Jovenier

Canada

Inception

- Why look at emissions from PHEVs?
 - Off-cycle driving results in much higher exhaust emissions than in-lab compliance testing due to cold start effects during aggressive start-ups
 - Need for characterization of particulate emissions from PHEVs from a number and size perspective, not mass
 - These vehicles may emit higher numbers of particulates than originally thought



Environment and
Climate Change Canada

Environnement et
Changement climatique Canada



Transport
Canada

Transports
Canada



Natural Resources
Canada

Ressources naturelles
Canada

Office of Energy Research and Development
Bureau de recherche et de développement énergétiques

Canada

Inception

- Who would benefit from the information produced by this study?
 - Regulators: ECCC, USEPA, CARB, EU
 - MECA (Manufacturers of Emission Controls Association)
 - International regulatory community (for example, IEA-HEV)



Environment and
Climate Change Canada

Environnement et
Changement climatique Canada



Transport
Canada

Transports
Canada



Natural Resources
Canada

Ressources naturelles
Canada

Office of Energy Research and Development
Bureau de recherche et de développement énergétiques

Canada

Project Overview

- Answer the questions:
 - What levels of regulated gaseous emissions and particulate number are emitted, if any, during electric mode testing of different PHEVs?
 - What difference is there between electric mode and charge-sustaining mode emissions?
 - What effect does multiple engine Stop-Start modes have on these emissions?
 - How are these emissions affected by driving patterns and ambient temperature?



Environment and
Climate Change Canada

Environnement et
Changement climatique Canada



Transport
Canada

Transports
Canada



Natural Resources
Canada

Ressources naturelles
Canada

Office of Energy Research and Development
Bureau de recherche et de développement énergétiques

Canada

Test Plan Overview

- Mileage accumulate four 2018 PHEVs to 1600km
- Conduct on-road tests over the ERMS 5-mode (COMBO) route and if time, an EU-RDE compliant route in summer and winter months
- Collect gaseous emissions and particulate number, battery power, cabin heating/cooling power, 14V module power, on-board charger power, and if possible, battery thermal management power



Environment and
Climate Change Canada

Environnement et
Changement climatique Canada



Transport
Canada

Transports
Canada



Natural Resources
Canada

Ressources naturelles
Canada

Office of Energy Research and Development
Bureau de recherche et de développement énergétiques

Canada

Test Vehicles

Vehicle ID	TC2018-023	TC2018-015	TC2018-016	Not yet Assigned
Make	Chrysler	Toyota	Mitsubishi	Hyundai
Model	Pacifica	Prius Prime	Outlander PHEV	Ionic PHEV
Curb Weight (lbs)	5021	3365	4292	3353
Drivetrain	FWD	FWD	AWD	FWD
Fuel	Electric (AC Level 2)	Electric (AC Level 2)	Electric (AC Level 2)	Electric (AC Level 2)
	Gasoline	Gasoline	Gasoline	Gasoline
Range (km)	53	40	35	47
Battery Description	96 cells, 360V	Series-Parallel 351.5V	300V	Parallel 240V
Battery Capacity (kWh)	16	8.8	12	8.9
Engine	3.6L Pentastar V6	1.8L i-4	2.0L i-4	GDI 1.6L i-4
Power (hp @ rpm)	287 @ 6400	95 @ 5200	117 @ 4500	139 @ 5700
Torque (lb-ft @ rpm)	262 @ 4000	105 @ 3600	137 @ 4500	109 @ 4000
Fuel Economy (L/100km) (City / HWY / Combined)	12.4 / 8.4 / 10.6	4.3 / 4.4 / 4.3	9.4 / 9.0 / 9.2	4.2 / 4.0 / 4.1



Environment and
Climate Change Canada

Environnement et
Changement climatique Canada



Transport
Canada

Transports
Canada



Natural Resources
Canada

Ressources naturelles
Canada

Office of Energy Research and Development
Bureau de recherche et de développement énergétiques

Canada

Preparation

- Accumulate to 1600km
- Purchase technical service manual and determine how to access required component cabling and safely deactivate battery
- Complete instrumentation process and ensure all vehicle systems operate normally
- Use different available scantool technologies to determine which one works with the vehicle and offers the most realtime data
- Instrument vehicle with Sensors LDV PEM unit
- Shakedown



Environment and
Climate Change Canada

Environnement et
Changement climatique Canada



Transport
Canada

Transports
Canada



Natural Resources
Canada

Ressources naturelles
Canada

Office of Energy Research and Development
Bureau de recherche et de développement énergétiques

Canada

On-Road Route

- COMBO Route
 - Artery (S1) + City (S2) + Congested (S3) + Expressway (S4) + Artery (S5)
 - Driven twice per day, back-to-back
 - 43km loop around Ottawa
- RDE Route
 - City (M1) + Rural (M2) + Motorway (M3)
 - Driven once per day
 - Approximately 78km



Environment and
Climate Change Canada

Environnement et
Changement climatique Canada



Transport
Canada

Transports
Canada



Natural Resources
Canada

Ressources naturelles
Canada

Office of Energy Research and Development
Bureau de recherche et de développement énergétiques

Canada

Testing Matrix

- Although only 3 repeats of each double loop COMBO are required, more will be done when time allows
- RDE testing is being done to allow comparison with ICEVs tested at the lab for enhanced compliance purposes and potentially to add to an IEA project under the advanced motor fuels annex

Route	Season	
	Winter	Summer
Combo	3	3
RDE	bonus	bonus



Environment and
Climate Change Canada

Environnement et
Changement climatique Canada



Transport
Canada

Transports
Canada



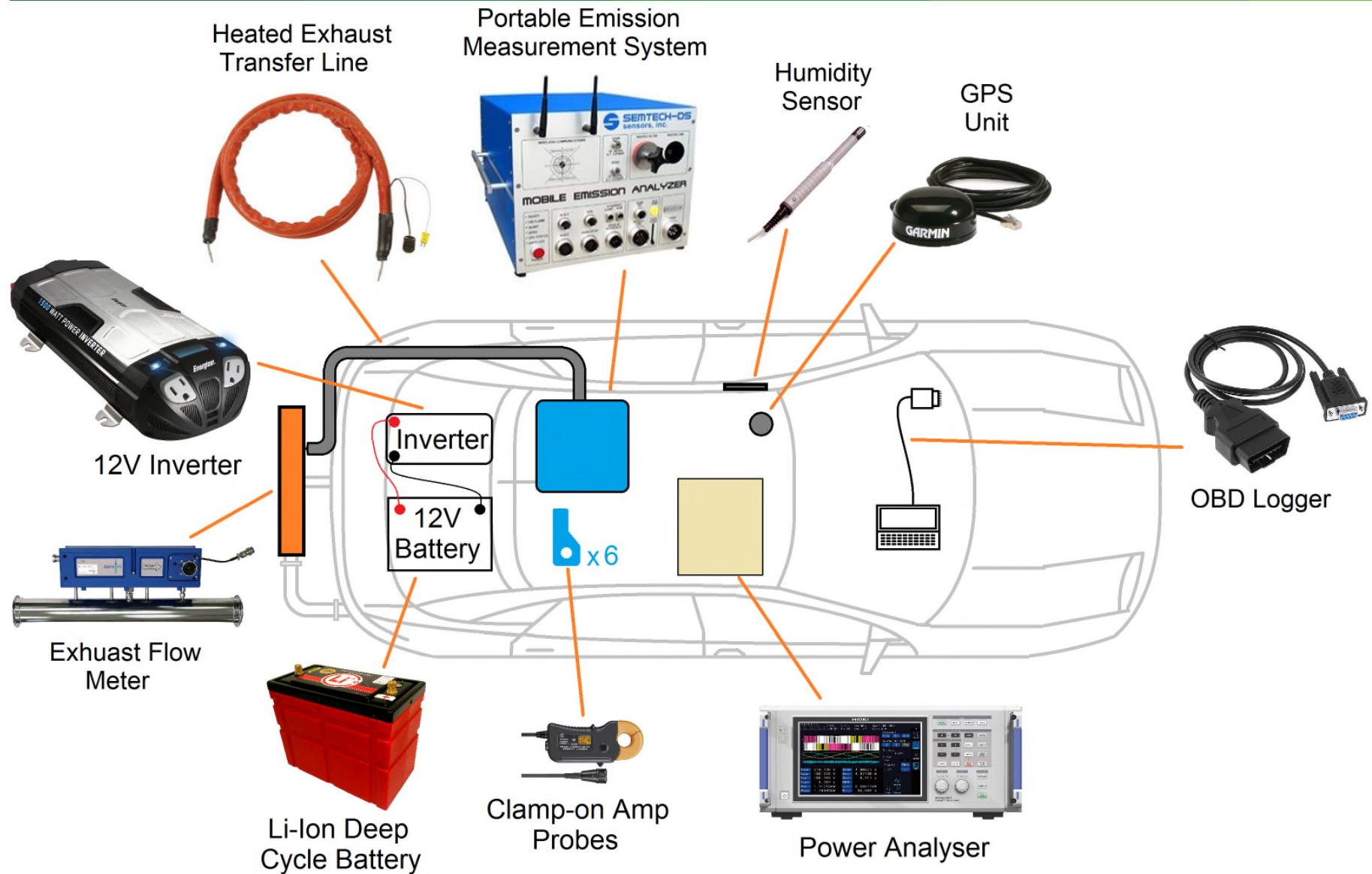
Natural Resources
Canada

Ressources naturelles
Canada

Office of Energy Research and Development
Bureau de recherche et de développement énergétiques

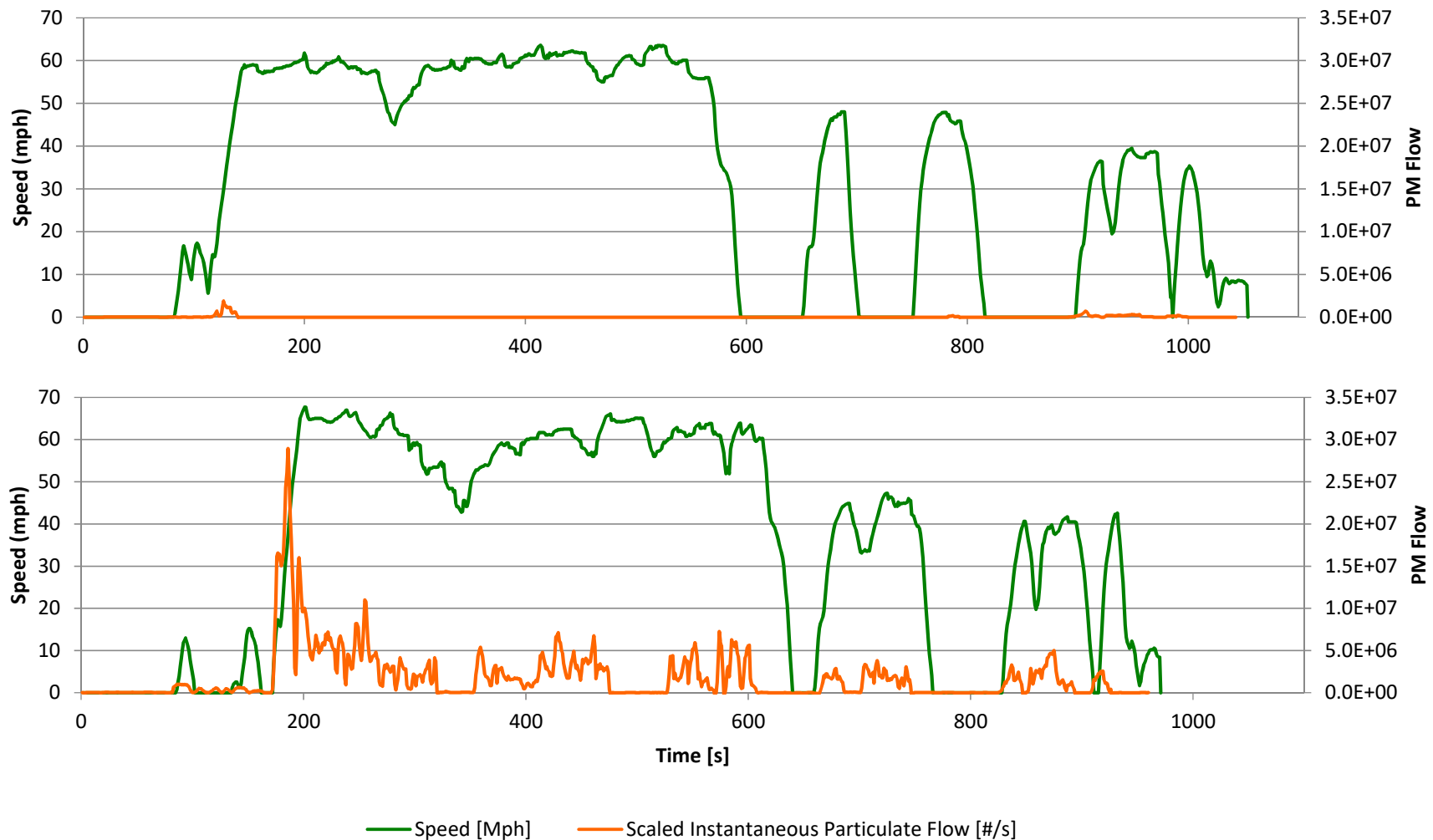
Canada

Instrumentation



Hot Start Outlander PHEV – Loop 2 Section 4

Cold-start vs Hot-start



Progress & Next Steps

- Summer and winter testing is complete on the Pacifica, Outlander, and Prime
- Ioniq is accumulated and ready for winter 2020 testing
- The Particle Number Module failed during summer tests on the Prime and Outlander, so no PN results for those summer tests
- Results have not been fully analysed



Environment and
Climate Change Canada

Environnement et
Changement climatique Canada



Transport
Canada

Transports
Canada



Natural Resources
Canada

Ressources naturelles
Canada

Office of Energy Research and Development
Bureau de recherche et de développement énergétiques

Canada



Environment and
Climate Change Canada

Environnement et
Changement climatique Canada



Transport
Canada

Transports
Canada

CENTRE
D'INNOVATION
CENTRE



Natural Resources
Canada

Ressources naturelles
Canada

Canada

Office of Energy Research and Development
Bureau de recherche et de développement énergétiques

ANNEX – RDE Route & Statistics



Environment and
Climate Change Canada

Environnement et
Changement climatique Canada



Transport
Canada

Transports
Canada



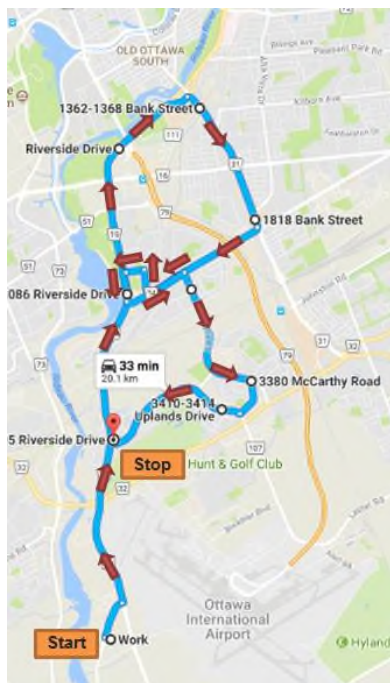
Natural Resources
Canada

Ressources naturelles
Canada

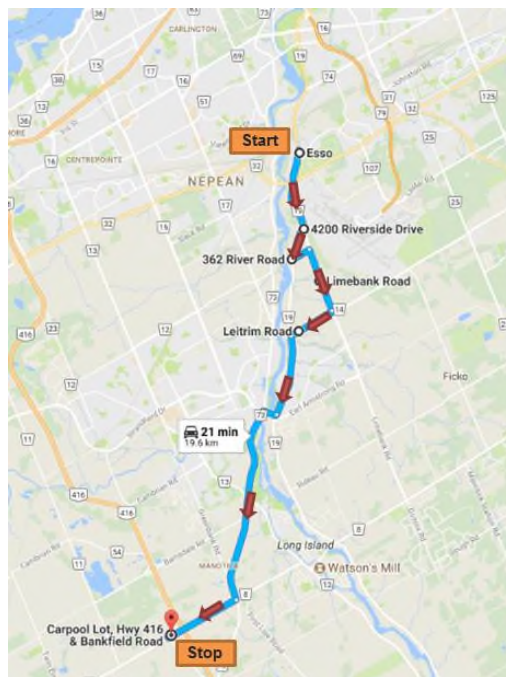
Office of Energy Research and Development
Bureau de recherche et de développement énergétiques

Canada

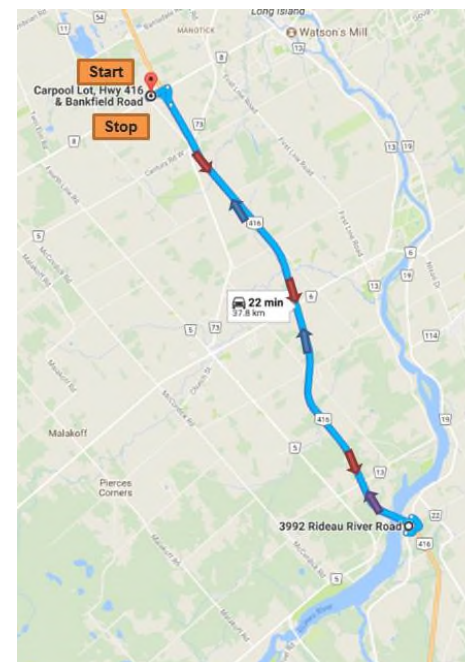
On-Road Testing RDE Route



RDE_M1:
URBAN



RDE_M2:
RURAL



RDE_M3: HIGHWAY
RDE_M4: Return to
base



Environment and
Climate Change Canada

Environnement et
Changement climatique Canada



Transport
Canada

Transports
Canada



Natural Resources
Canada

Ressources naturelles
Canada

Office of Energy Research and Development
Bureau de recherche et de développement énergétiques

Canada

Average RDE Route Statistics

IN-LAB											
Cycle	Fuel	Loading	Distance	Kinetic Intensity	Avg Speed	Avg Driving Spd	Max Speed	Avg Accel	Avg Decel	Time idle	Time total
		lb	km	1/km	km/h	km/h	km/h	m/s^2	m/s^2	s	s
F550_RDE_M1	DIESEL	29700	20.2	0.766	35.7	41.1	62.8	0.350	-0.364	266	2036
F550_RDE_M2	DIESEL	29700	18.7	0.395	46.2	55.4	82.3	0.343	-0.382	243	1454
F550_RDE_M3	DIESEL	29700	31.2	0.083	74.6	82.1	103.1	0.168	-0.170	137	1507
ON-ROAD											
Cycle	Fuel	Loading	Distance	Kinetic Intensity	Avg Speed	Avg Driving Spd	Max Speed	Avg Accel	Avg Decel	Time idle	Time total
		lb	km	1/km	km/h	km/h	km/h	m/s^2	m/s^2	s	s
RDE_M1	BIODIESEL B20	27075	20.3	0.832	35.8	42.1	78.2	0.434	-0.487	307	2040
RDE_M2	BIODIESEL B20	27075	19.4	0.408	47.5	55.4	84.8	0.358	-0.438	214	1474
RDE_M3	BIODIESEL B20	27075	37.7	0.067	84.8	86.7	101.1	0.151	-0.161	34	1599
RDE_M1	DIESEL	15075	20.1	0.917	34.6	41.2	78.8	0.484	-0.497	334	2094
RDE_M2	DIESEL	15075	19.3	0.375	52.7	58.1	83.8	0.360	-0.378	128	1322
RDE_M3	DIESEL	15075	37.5	0.068	85.9	87.2	101.4	0.163	-0.161	24	1571
RDE_M1	DIESEL	27075	20.4	0.785	35.2	41.5	78.2	0.405	-0.455	321	2088
RDE_M2	DIESEL	27075	18.8	0.365	46.3	54.9	84.1	0.333	-0.375	246	1479
RDE_M3	DIESEL	27075	35.5	0.068	85.0	86.3	102.5	0.152	-0.166	22	1500



Environment and
Climate Change Canada

Environnement et
Changement climatique Canada



Transport
Canada

Transports
Canada



Natural Resources
Canada

Ressources naturelles
Canada

Office of Energy Research and Development
Bureau de recherche et de développement énergétiques

Canada