

Evaluation of the Draft UNECE EVE Power Determination Test Procedure

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Acronyms

DFI	Direct fuel injection	P_{intake}	Engine intake pressure
Diff	Differential	REESS	Rechargeable Electrical Energy storage System
DOHC	Dual overhead cam	SOC_{bat}	Battery state-of-charge
EV	Electric vehicle	τ	Torque
GVWR	Gross vehicle weight rating	T_{batt}	Battery temperature
HEV	Hybrid electric vehicle	$T_{\text{eng coolant}}$	Engine coolant temperature
I4	Inline 4 cylinders	$T_{\text{gear/tx}}$	Transmission temperature
I_{bat}	Battery current	T_{motor}	Motor temperature
ICE	Internal combustion engine	TC	Transfer Case
INV	Inverter	TX	Transmission
MDI	Mobile Diagnostics Interface	U_{bat}	Battery voltage
MG	Motor-generator	VVT	Variable valve timing
OBD	On-board diagnostics	ω	Rotational speed
OEM	Original equipment manufacturer		

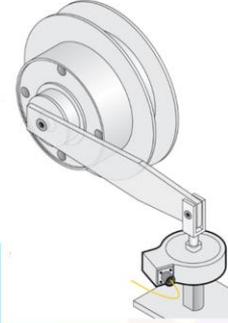
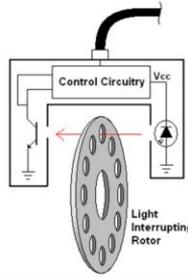
Test Specimens

Metric	2018 BMW 530e	2016 Chevrolet Volt	2018 Prius Prime	2009 Saturn Vue
Engine	2.0 TwinPower Turbo I-4	1.5L DOHC I-4 DFI	1.8L AI DOHC 16VVT-i i4	L4 DOHC 16VVT 2.4L i-4
Combined Motor-Engine Power (kW)	185	110	90	127
Type	Lithium-ion	Prismatic NMC-LMO Pouch	Lithium-ion	NiMH
Capacity (kWh)	9.2	18.4	8.79	
Voltage (V)	351	360	351.5	36
Drivetrain Structure	Parallel	Series/Parallel	Series/Parallel	BAS
All-Electric Range (km)	24	85	40	0
Fuel Consumption (L/100km)	8.11	5.74	4.4	8.4
GVWR (lb)	5470	4438	3946	4900
Curb Weight (lb)	4385	3560	3365	3789

HIOKI



Dynamometer



Wheel torque sensors



Instrumentation

OBD Scantool



Instrumentation

Metric	Units	Accuracy	Instrument
Engine Speed	min ⁻¹	±0.5%	OBD Scantool
Intake Mainfold Pressure	Pa	±50Pa	OBD Scantool
Atmospheric Pressure	Pa	±0.3kPa	Vaisala
Humidity	%	± 1.0 %	Vaisala
Fuel Flow Rate	g/s	± 3%	OBD Scantool
Electrical Voltage	V	± 0.3%	HIOKI
Electrical Current	A	± 0.3%	HIOKI
Electrical Energy	Wh	± 1%	HIOKI
Room Temperature	K	± 0.2 °C	Vaisala RTD
Chassis Dyno roller Speed	Km·h ⁻¹	± 0.2kph	Optical Speed Sensor on dyno shaft
Time	s	± 10ms	Dyno computer
Axle/Wheel rotational speed	s ⁻¹	± 0.05 s ⁻¹ or 1% (greater)	Wheel Torque Sensors
Axle/Wheel torque	Nm	± 6Nm or 0.5% of max total toque, (greater)	Wheel Torque Sensors

Progress to date

1. Instrumented all 4 vehicles with OBD loggers, wheel torque sensors, HIOKI power analysers and dynamometer metrics
 2. Tested all vehicles between August and September 2019.
 3. Used same dynamometer system described in Phase 1 presentation
 4. Processed the Prius Prime fully, part way through the Saturn Vue data
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Anecdotaly, wheel slip was visually and audibly decreased. There was also less smell of burnt rubber. Ideally, wheel sensors vs dyno optical speed is preferable to these anecdotal observations, but rolling radius of the tires is a calculated parameter, and speed calculation is highly sensitive to this estimation; thus this comparison was not made.

Progress to date Cont'd

Metric	2018 BMW 530e	2016 Chevrolet Volt	2018 Prius Prime	2009 Saturn Vue
Wheel Torque Sensors	Front Passenger & Rear Driver side	Front Axle	Front Axle	Front Axle
OBD	Diagra D (partial)	GM MDI (partial)	Techstream (full)	GM MDI (partial)
Dynamometer	All pertinent metrics	All pertinent metrics	All pertinent metrics	All pertinent metrics
HIOKI	U and I at battery	U and I at battery	U and I at battery	U and I at battery

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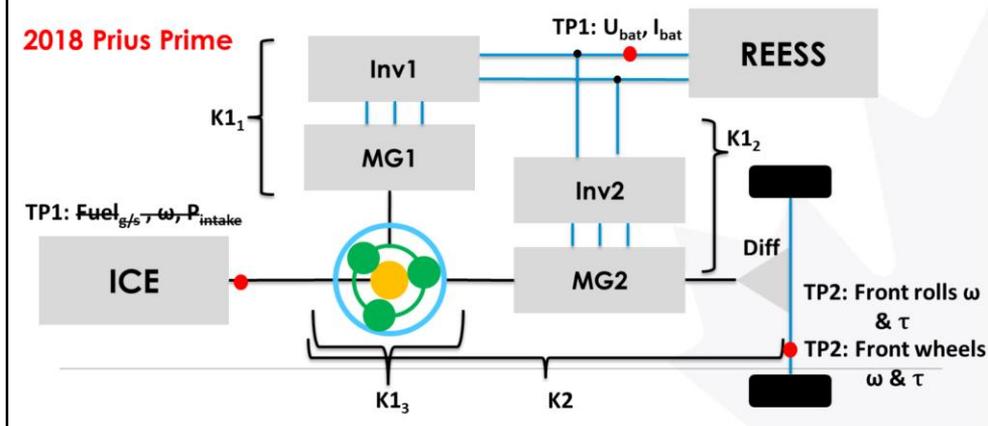
Experiences with the GTR – Section 6.2

1. Reducing Tire Slippage
 - a. 160kg of salt bags and steel weights were added in front passenger seat for front wheel drive vehicles
 - b. 160kg of salt bags and steel weights were distributed between the front passenger, rear passenger, and rear driver-side seats for the BMW 530e
 2. The front and rear tires will be inflated to lower limit of range, specified by OEM...
 - This lower limit was not found
 - Used door plate tire pressure recommendations
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Experiences with the GTR – Section 6.5

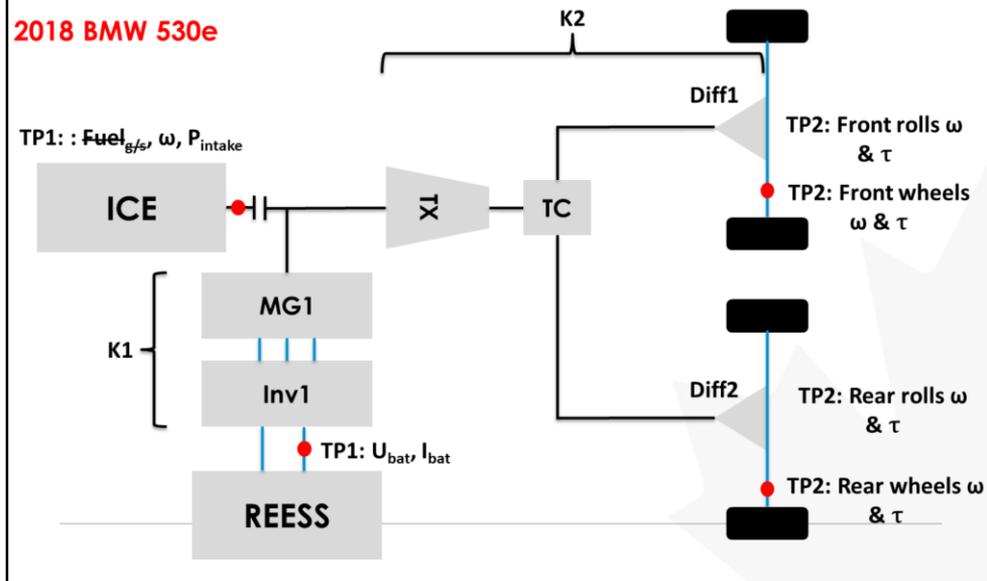
- Section 6.5 - Instrument the vehicle in the appropriate locations to measure TP1 AND TP2 (for purposes of this validation testing)



1. To calculate power using TP1, the fuel rate, engine rpm and intake pressure would be required, along with current and voltage measurements at the motor input from the inverters. As it is, TP1 was unsuccessful because of a glitch in the Toyota OEM scantool that prohibits us from exporting data from the scantool. Also, measuring voltage and current at the motor inputs would have been ideal, but this was not done on the Prius Prime or any other test vehicles for several reasons. One: a 3-phase motor requires 3 amp probes, with the shielding pulled back to reduce EMF noise at low amperages and then re-connected in a large loop to allow an amp probe to be clamped around the unshielded portion. With the Prius Prime and Chevy Volt, this means 6 amp probes. Aside from being time and resource intensive, this is usually space prohibitive because of how tightly HEVs and PHEVs are packaged, and because we want to avoid placing these 6 amp probes in close proximity to hot engine components.

Experiences with the GTR – Section 6.5

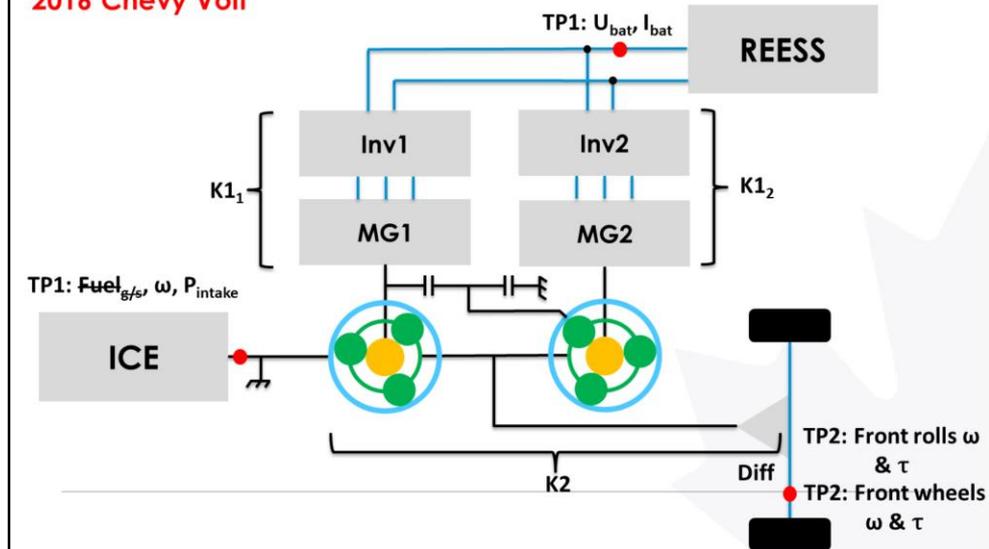
2018 BMW 530e



The BMW drivetrain looks something like this. Similar to the Prime, the K1 factor, given where we take the amperage and voltage measurements, needs to account for the efficiencies of the inverter and motor. K2 however, needs to account the losses in the transmission, transfer case and differentials. Wheel torque sensors were used on the BMW on all four wheels, but due to issues with the sensors only two reported coherent data; thankfully, one of these sensors was on the front axle and the other was on the rear, allowing us to calculate TP2 with the wheel torque sensors. We are also able to calculate TP2 using the dynamometer torque and speed. Finally, we used a Diagra D OBD scanning software/hardware kit to measure engine rpm and intake pressure. The fuel flow rate was not captured, unfortunately. This was a limitation of the scantool, which is non-OEM specific.

Experiences with the GTR – Section 6.5

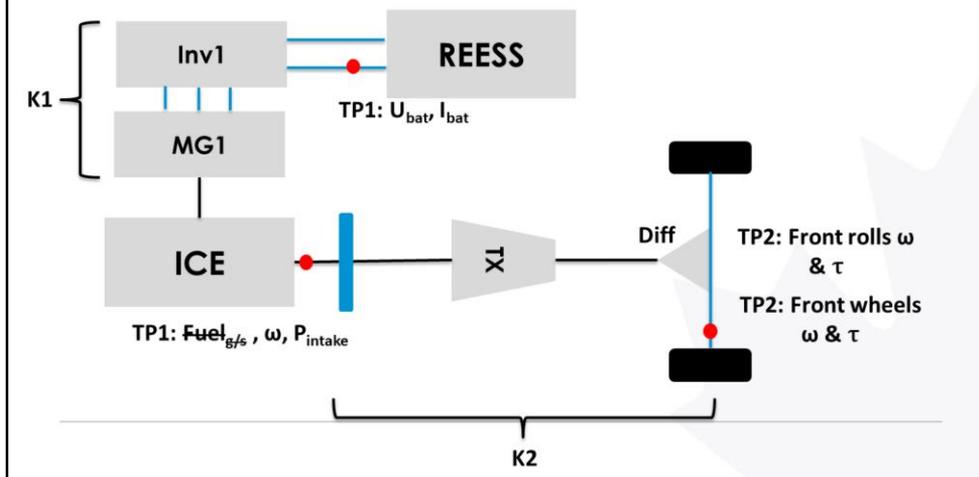
2016 Chevy Volt



The Chevy Volt drivetrain includes 2 planetary gears. The K1 factor is actually split into two separate factors because it has 2 motors. With the use of OEM scantool GM MDI, we were able to measure all the parameters relevant to calculating TP1. We also measured the front drive wheel torque and speeds for calculating TP2, and as always, we have the dyno metrics for calculating TP2. When we are at the stage of data processing we'll be able to compare TP2 and TP1.

Experiences with the GTR – Section 6.5

2009 Saturn Vue



Similar to the Volt, the GM MDI was used to measure metrics pertinent to calculating TP1. The simpler drivetrain of the Vue makes the comparison between TP2 and TP1 less onerous and prone to errors. Being a Belt Alternator System, the motor/generator output is directly connected to the engine shaft output. Unfortunately, because the Vue is such an old vehicle, the battery metrics available from the scantool are limited, so battery temperature was not measured and battery voltage, amperage and power were not recorded with the MDI.

Experiences with the GTR – Section 6.9.1

GTR Required Metrics	BMW 530e	Prius Prime	Chevy Volt	Saturn Vue
$T_{\text{eng coolant}}$	Diagra D (also oil)	TechStream 2	MDI	MDI
T_{batt}	X	TechStream 2	MDI	
$T_{\text{gear / Tx}}$	X	TechStream 2		
T_{motor}	X	TechStream 2		
$\text{SOC}_{\text{batt}} \%$	Diagra D	TechStream 2	MDI	

Experiences with the GTR – Section 6.9.3

- REESS Adjustment
- Performed immediately following warmup to a preset desired value to ensure repeatable and comparable power tests

Vehicle	Battery SOC _{start} %	Mode	Sub Mode
BMW 530e	90%	Sport	Auto E-Drive
Prius Prime		Power	HV
Saturn Vue	Not Measurable	N/A	N/A
Chevy Volt	91	Sport	EV

General Experiences with the GTR

1. Section 6.5
 - 12V accessories
 - Engine power curves – carbon balance acceptable?
 - Wheel torque sensors were not easy to work with
2. Section 6.6
 - setting SOC of REESS so that maximum power is achieved
3. Section 6.9.2
 - 60 kph for 20min is insufficient
 - 89kph for 30min

We were unable to measure non-12V auxiliaries from the BMW due to complexity of HV wiring and lack of time. From initial inspection it appears we would have needed a 3-phase measurement for the AC compressor alone.

TP1 can only be calculated by employing engine power curves, which we currently do not have for any of our four test vehicles. We may be able to find these for a few of our vehicles in the near future.

Thirdly, the wheel torque sensors were not easy to work with. At times there was signal interruption, they were not transmitting or not functioning. Also, there was a zero drift over the duration of the test and afterwards. Finally, at least for the Prius Prime, the power calculated from the wheels was less than that from the dyno, so we have an unidentified issue as of now.

From Section 6.6 comes the provision to set the REESS SOC so that maximum power is achieved. This was not done because we lacked time with 4 vehicles to find this SOC, and also we lacked any support from OEMs.

In Section 6.9.2 the warmup requirements are stated. 60km/h is specified as the warmup speed with a minimum of 20min. This was insufficient, and longer warmup times were onerous so we opted to use a common steady state speed in electric vehicle testing, 55mph or 89km/h. Out of

the 4 vehicles, only 1 necessitated more than 20min of driving time at this speed to warm up the engine coolant and transmission fluid.

Experiences with the GTR – General

4. Section 6.9.3

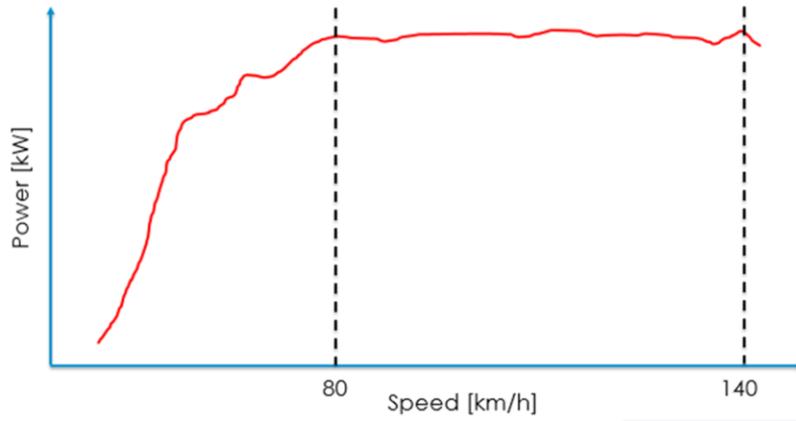
- Specifies REESS SOC adjustment after conditioning and in between repetitions of observations
 - All 4 vehicles: speed dropped to 60 km/h to accomplish this
 - Regenrative braking power at high dyno speeds was very low
 - The brake pedal was not needed to regenerate the traction batteries at an acceptable speed
 - the temperatures also dropped to their baseline values
 - The battery SOC increased to its specified baseline value faster
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Experiences with the GTR – General

5. Section 6.9.4

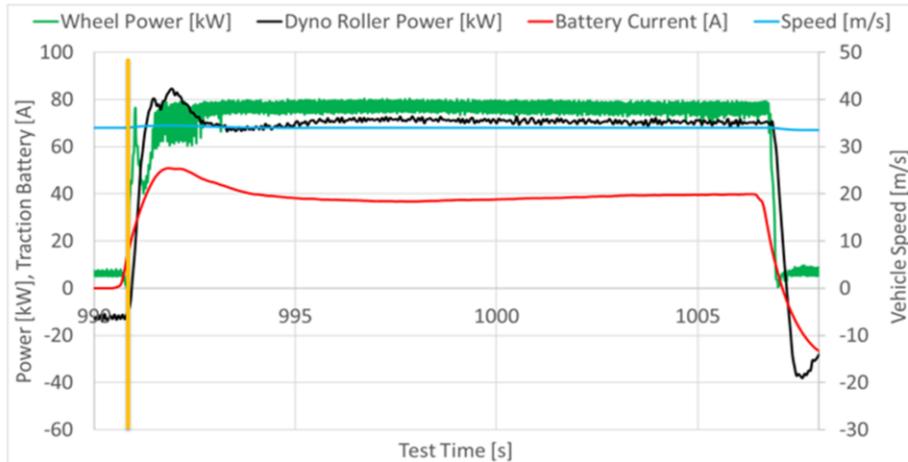
- Finding the vehicle speed at which maximum power is achieved was not accomplished using the method provided.
 - Instead, 3 quick power tests were conducted with the dyno in road load setting
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Experiences with the GTR - General



Experiences with the GTR – General

5. Section 6.9.4 Cont'd



Section 6.10.1 states that the averaging function shall begin when the accelerator pedal command reaches 100%. In this example, that would be approximately here **[press button]**.

For hub-dynos this initial stabilization period would either be not present or much less pronounced. So, we were thinking, what provisions, if any are in the GTR that specify (1) the maximum stabilization period (2) the defining metrics for stabilization and (3) the magnitude allowed during this test. Does this provision already exist?

Summary

- Tire slip is successfully mitigated with extra weights on the drive axle(s)
 - Measuring Fuel rate is difficult. Can we use carbon balance (1hz)?
 - Amp probes at motor inputs is difficult because of number and space
 - Wheel torque sensors are problematic...others?
 - REESS setting and Temp moderation → drop to 60kph, no brake pedal
 - 60kph warmup insufficient. Use 89kph
 - Non-12V accessories can be difficult to measure
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Next Steps

- Currently processing data for the Saturn Vue
 - Still need to start processing data for the Volt and BMW
 - Questions that will be investigated during analysis
 - How does TP2 – dyno compare to TP2 – wheel torque sensors?
 - How does TP1 compare to TP2 – dyno and TP2 – wheel torque sensors (requires power curve maps)
 - How well do the K factors fit the 4 vehicles
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