Study on Normalization method for HEV

< preliminary report >

EV-SG, WLTP-IWG

25 April 2016

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1. Background

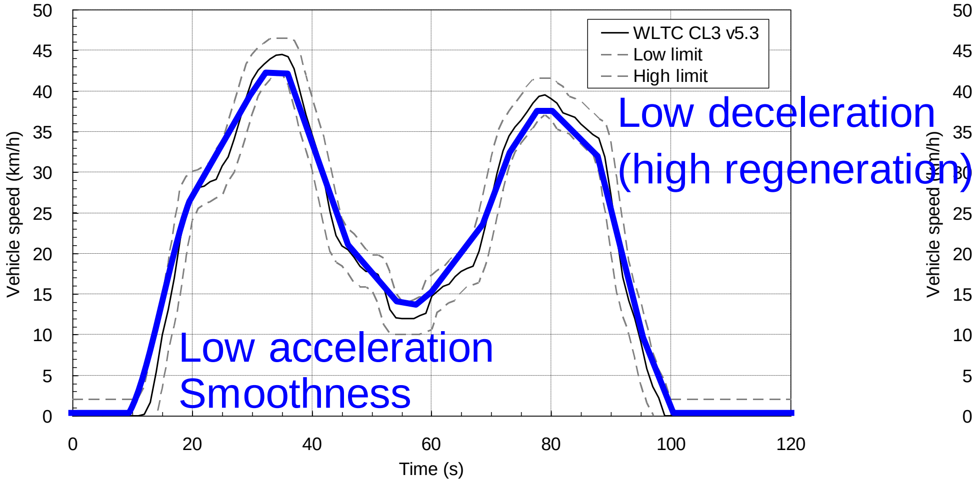
- In order to run the efficient test, some tolerance and flexibilities are allowed in all test procedure, such as speed, road load, temperature and so on.
- Some of these tolerance and flexibilities have an impact on emissions and fuel consumption.
- Technical University of Graz (TUG) have developed the “Normalization method” for ICE vehicles to compensate the deviations against the target values (see reference R1).
- The effects of Normalization method have reported in the 8th WLTP-IWG as “WLTP-08-37e”
- No further study is done for HEV(Hybrid Electric Vehicles)

2.1 Test condition and Test Procedure

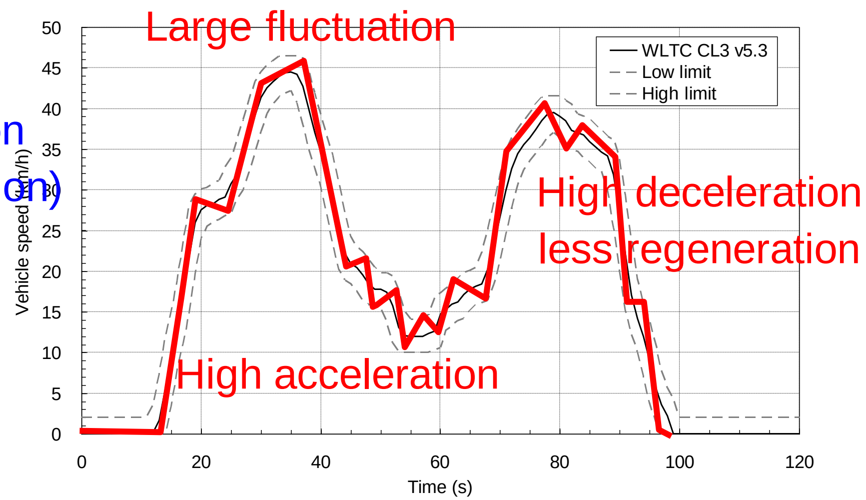
- Test vehicle：
  - OVC-HEV (Toyota PRIUS-PHV)
- Driving style & # of Test：

Normal	Smooth-Smooth	Rough-Rough	Smooth-Rough	Rough-Smooth
n = 2	n = 1	n = 1	n = 1	n = 1

◆Smooth-Smooth driving

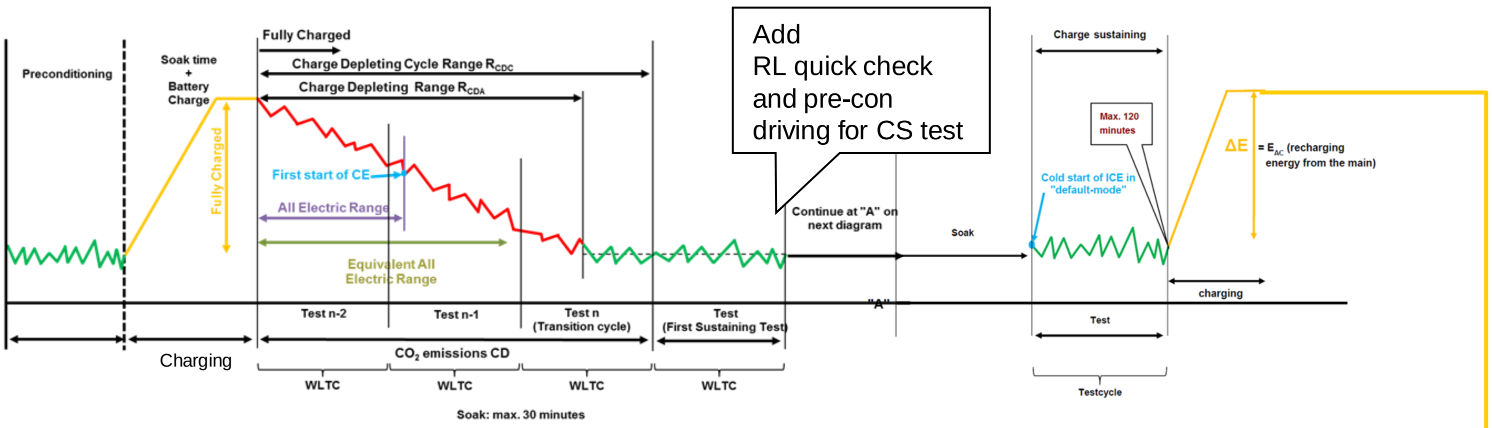


◆Rough-Rough driving

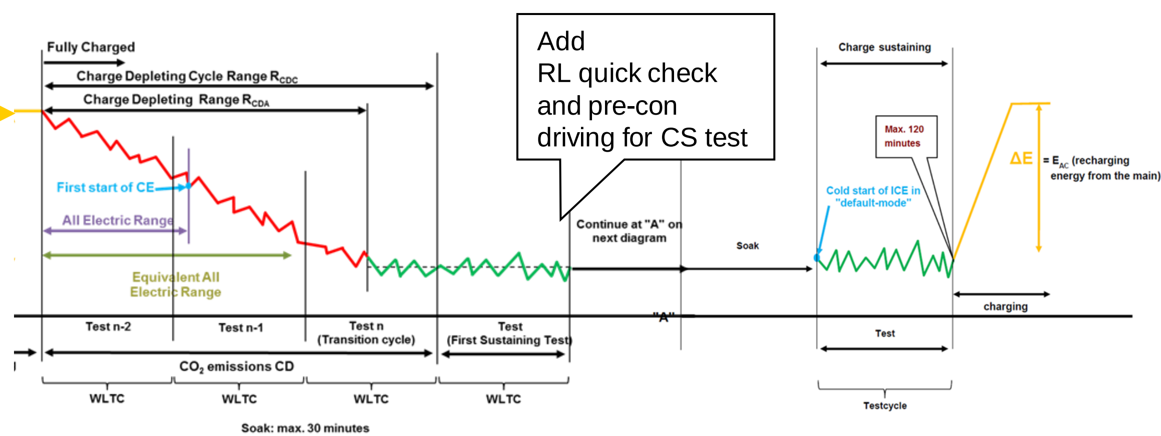


2.1 Test condition and Test Procedure

day 1		day 2 (Normal driving)			
Pre-con	Charge	CD test (3 cycles)	Soak > 6 hr	CS test	Charge

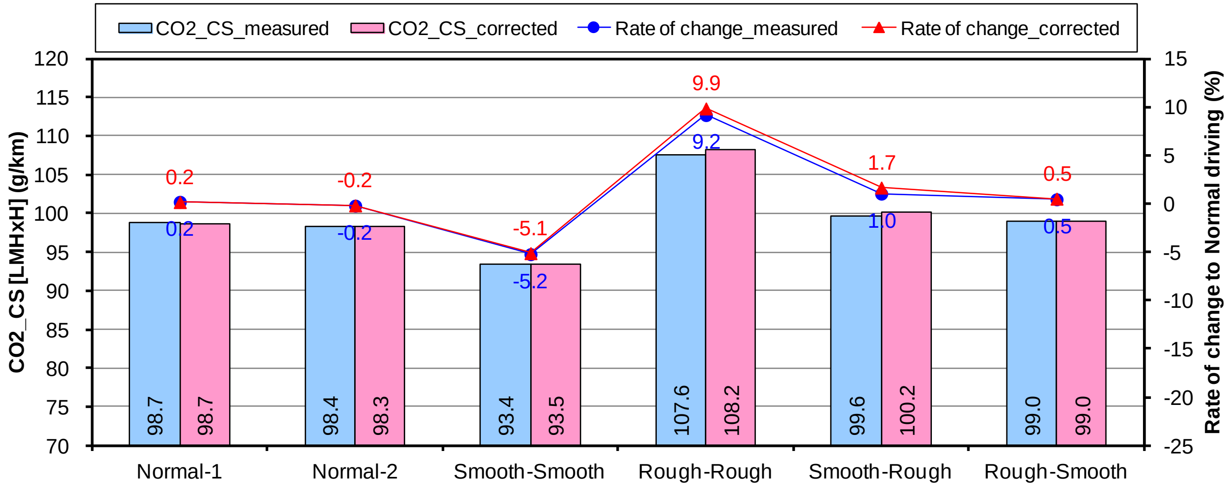


day 3 ~ (Normal/Smooth/Rough driving)			
CD test (3 cycles)	Soak > 6 hr	CS test	Charge

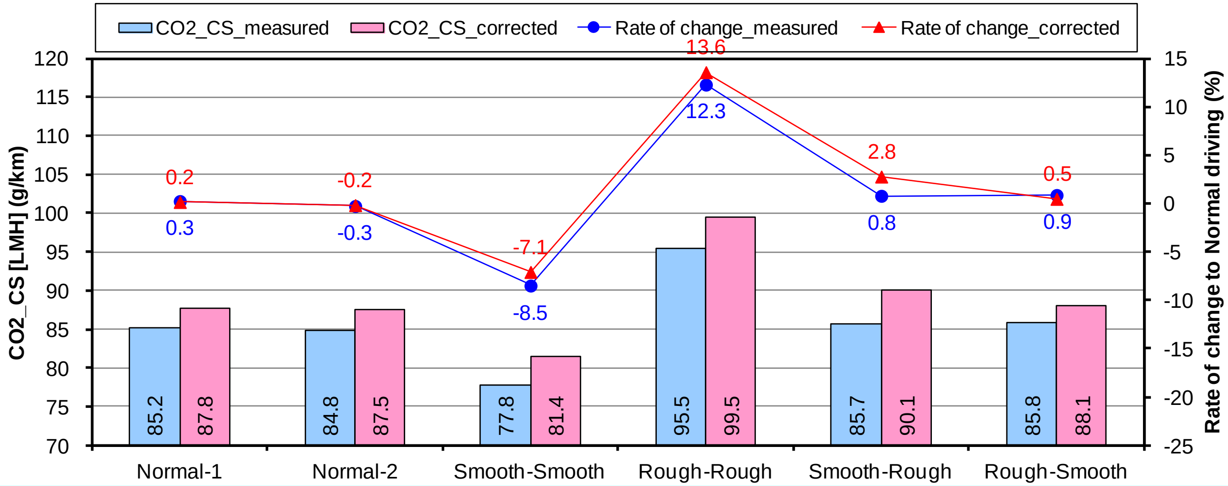


2.2. Test Results (CS condition)

◆ 4 phase [LMHxH]



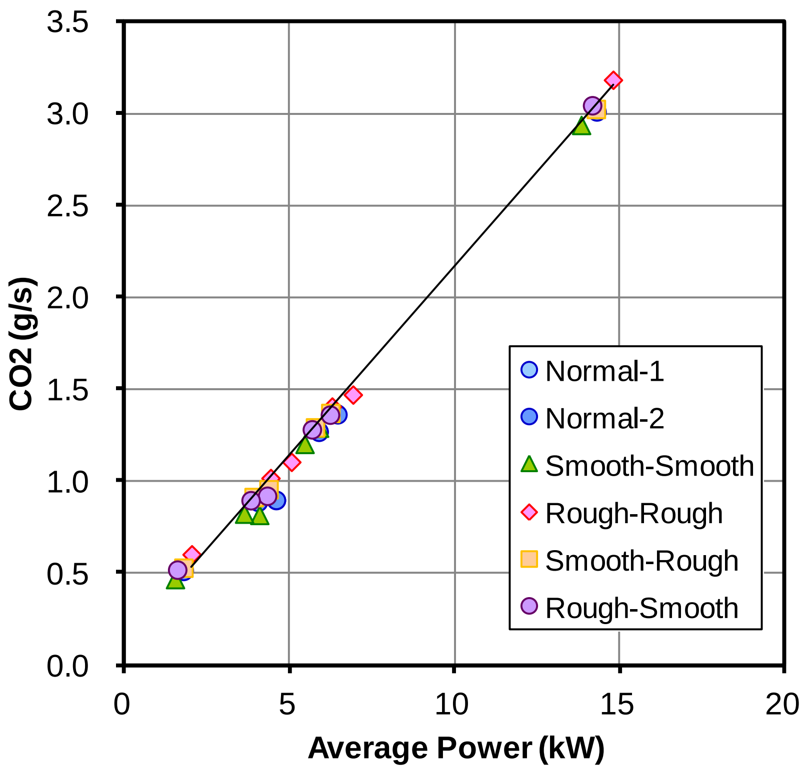
◆ 3 phase [LMH]



◆ CO_2 values are varied in the range of -10% to +15%

2.2. Test Results (CS condition)

Comparison of the veline coefficient

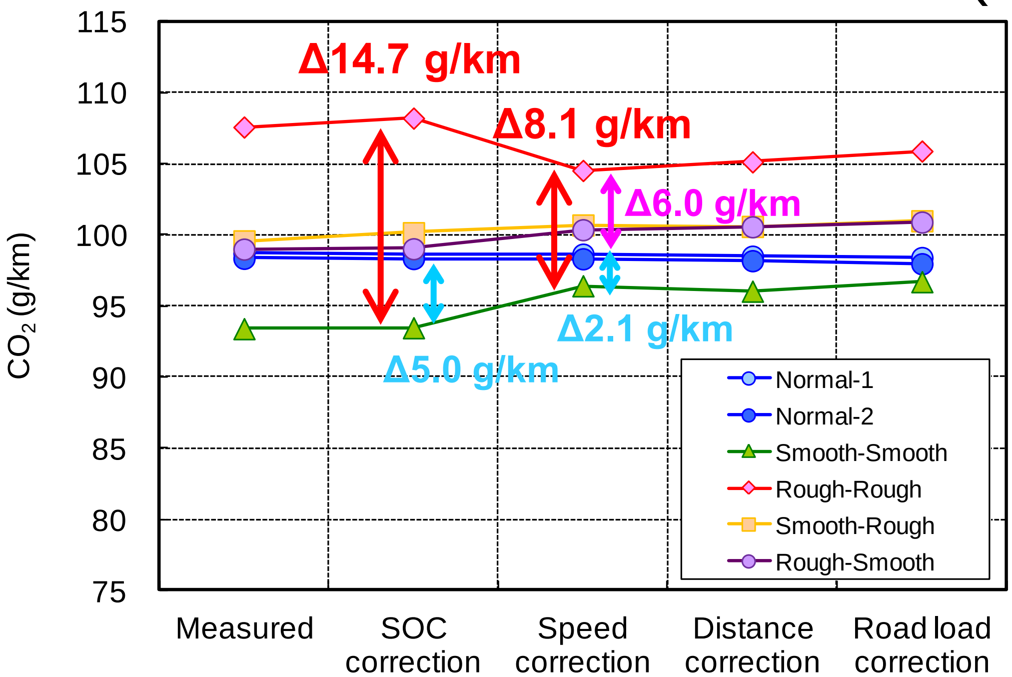


Driving style	Veline coefficient
Normal-1	0.206
Normal-2	0.204
Smooth-Smooth	0.205
Rough-Rough	0.205
Smooth-Rough	0.202
Rough-Smooth	0.205

◆The veline coefficient is identical with regardless of driving style

2.2. Test Results (CS condition)

Effects of Normalization method (4 phase)



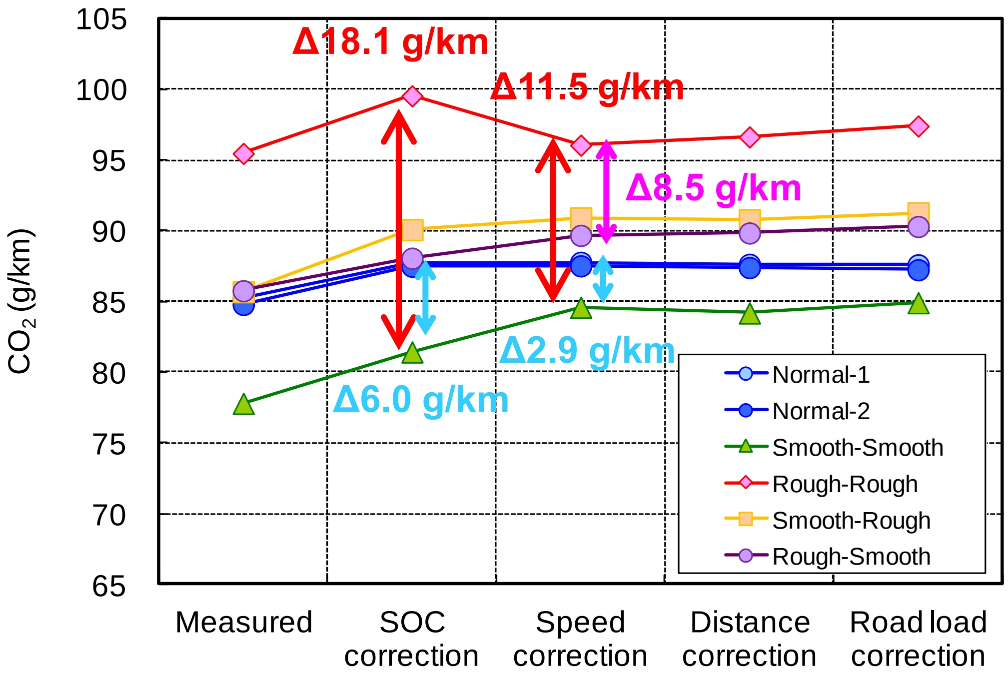
- Maximum deviation was reduced from 14.7 to 8.1 g/km.
- The deviation between normal driving and smooth-smooth driving was reduced from 5.0 to 2.1 g/km.
- The deviation of two normal driving data was 0.3 g/km.

※used RL value after CD test

Phase	Test condition	Measured data	SOC correction		Speed correction		Distance correction		RL correction ※	
		CO_2 (g/km)	ΔCO_2 (g/km)	CO_2 (g/km)	ΔCO_2 (g/km)	CO_2 (g/km)	ΔCO_2 (g/km)	CO_2 (g/km)	ΔCO_2 (g/km)	CO_2 (g/km)
LMHxH	Normal-1	98.74	-0.07	98.68	-0.03	98.65	-0.14	98.50	-0.09	98.41
	Normal-2	98.36	-0.02	98.34	-0.02	98.32	-0.13	98.19	-0.21	97.97
	Smooth-Smooth	93.41	0.07	93.47	2.95	96.42	-0.38	96.05	0.67	96.71
	Rough-Rough	107.59	0.63	108.21	-3.68	104.53	0.61	105.14	0.76	105.90
	Smooth-Rough	99.58	0.58	100.15	0.54	100.70	-0.10	100.60	0.40	100.99
	Rough-Smooth	99.00	0.03	99.03	1.34	100.37	0.21	100.57	0.33	100.90
Standard Deviation (g/km)		4.6	-	4.8	-	2.8	-	3.1	-	3.3
Differenc between MAX and MIN (g/km)		14.2	-	14.7	-	8.1	-	9.1	-	9.2

2.2. Test Results (CS condition)

Effects of Normalization method (3 phase)



- Maximum deviation was reduced from 18.1 to 11.5 g/km.
- The deviation between normal driving and smooth-smooth driving was reduced from 6.0 to 2.9 g/km.
- The deviation of two normal driving data was 0.3 g/km.

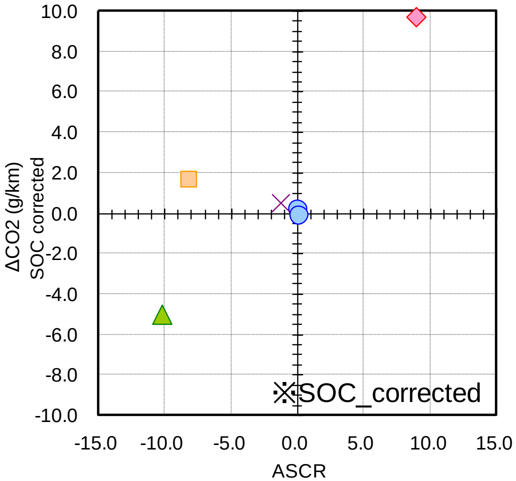
※used RL value after CD test

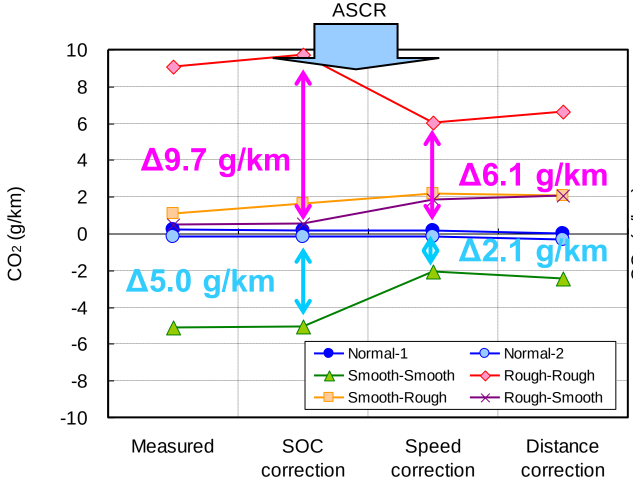
Phase	Test condition	Measured data	SOC correction		Speed correction		Distance correction		RL correction ※	
		CO_2 (g/km)	ΔCO_2 (g/km)	CO_2 (g/km)	ΔCO_2 (g/km)	CO_2 (g/km)	ΔCO_2 (g/km)	CO_2 (g/km)	ΔCO_2 (g/km)	CO_2 (g/km)
LMH	Normal-1	85.23	2.55	87.78	-0.01	87.77	-0.14	87.63	-0.04	87.60
	Normal-2	84.79	2.70	87.49	0.03	87.52	-0.13	87.40	-0.15	87.25
	Smooth-Smooth	77.80	3.63	81.43	3.16	84.59	-0.40	84.19	0.72	84.92
	Rough-Rough	95.47	4.07	99.54	-3.49	96.05	0.58	96.63	0.77	97.41
	Smooth-Rough	85.69	4.39	90.08	0.83	90.91	-0.14	90.78	0.49	91.27
	Rough-Smooth	85.76	2.30	88.06	1.61	89.68	0.17	89.85	0.46	90.30
Standard Deviation (g/km)		5.6	-	5.9	-	3.9	-	4.2	-	4.4
Differenc between MAX and MIN (g/km)		17.7	-	18.1	-	11.5	-	12.4	-	12.5

2.2. Test Results (CS condition)

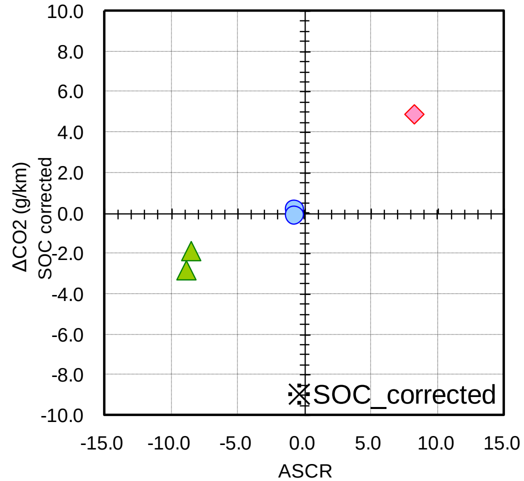
Comparison with ICE (used only +/- 10% ASCR data)

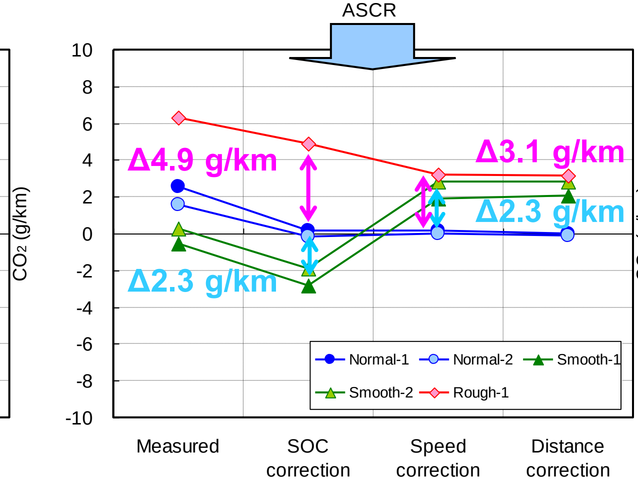
◆OVC-HEV



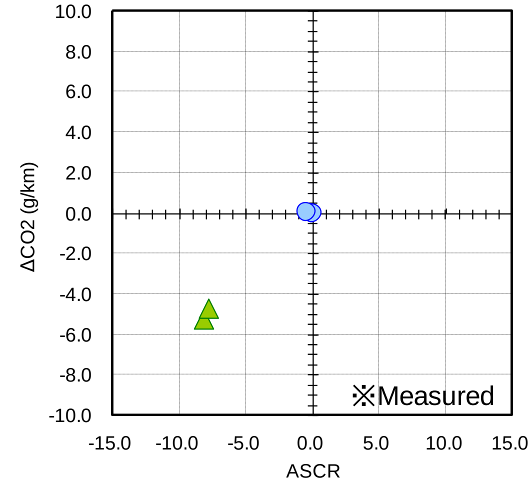


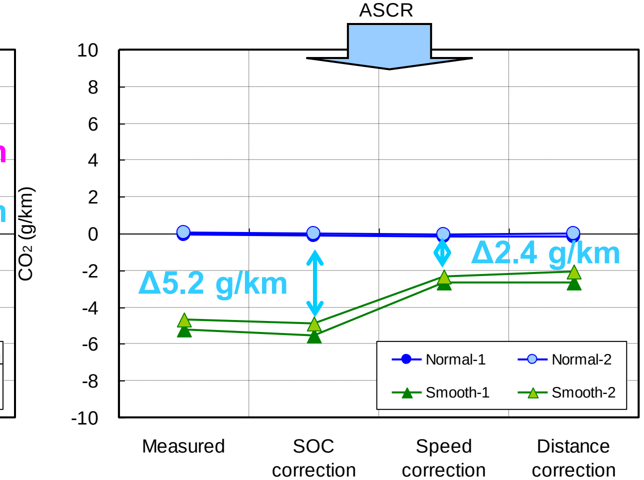
◆NOVC-HEV





◆ICE





◆Normalization method for CS condition works same level as ICE (approximately 3g/km / 10% ASCR).

2.3 Summary (CS condition)

① Impact of driving style

- CO_2 range : -5% to 10%.

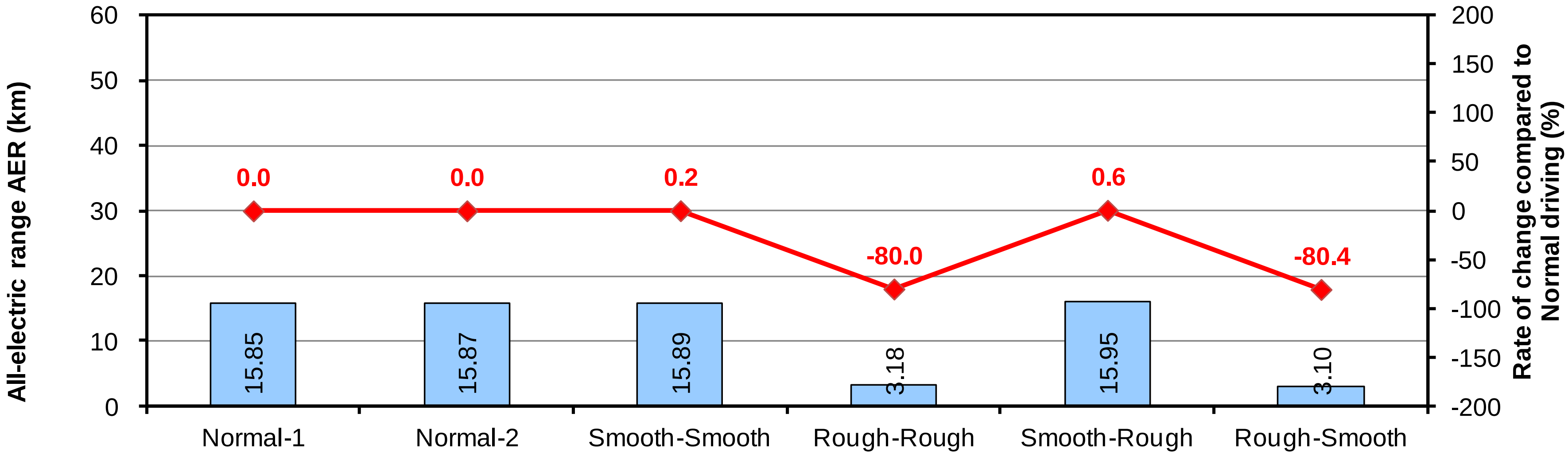
② Applicability of Normalization method

- It was observed that “normalization method” has an effectiveness to reduce the deviation of the CS test, although the deviation is still remain (approx.10 g/km)
- It seems that the effectiveness is same level as the ICE vehicles.
- Further study is necessary on the other HEV systems for final decision of “normalization method” applicability.
- The vehicle specific veline coefficient in each driving style is identical.

(additional data can be found in reference R2)

2.4. Test Results (CD condition)

All Electric Range (AER)



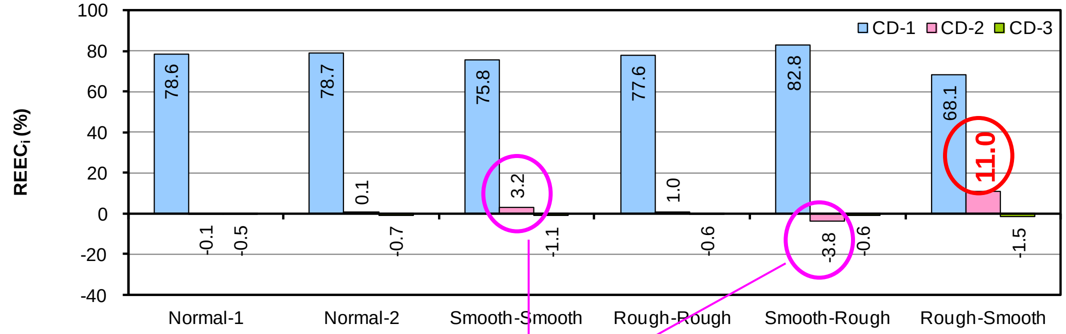
◆AERs are dramatically varied according to the driving style.
(reduced by 80% when rough driving)

2.4. Test Results (CD condition)

Charge Depleting Cycle Range (R_{CDC})

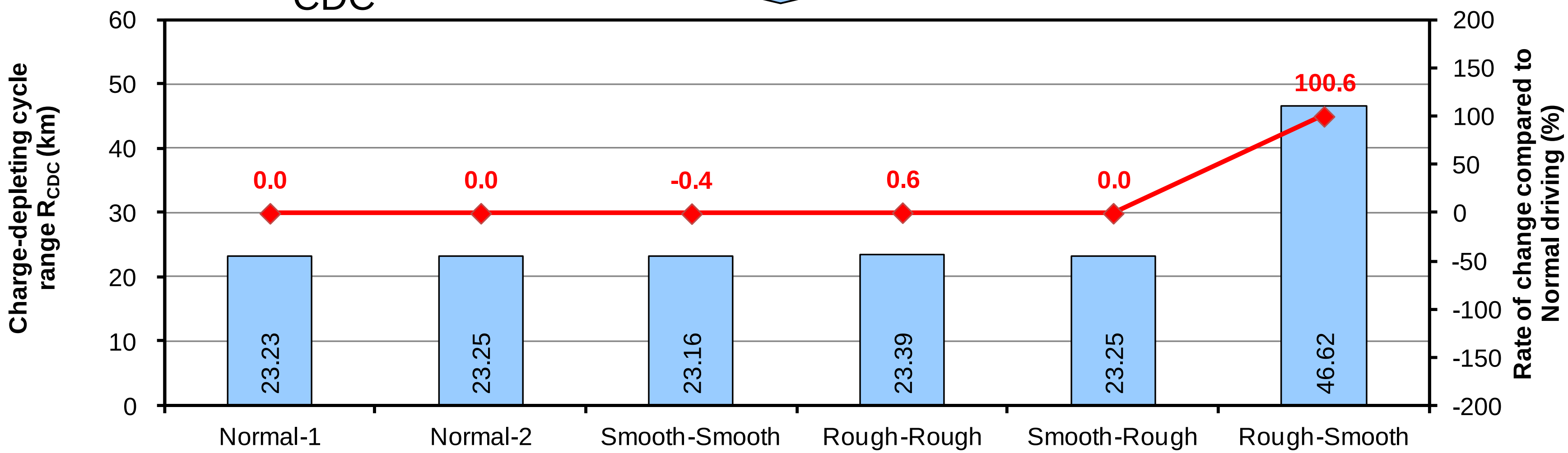
◆Break-off criterion

$$REECi(\%) = \frac{\left|\Delta E_{REESS,i}\right|}{E_{cycle} \times \frac{1}{3600}} \times 100 < 4\%$$



Very near the criterion. There is possibility to exceed the criterion if drive drove more extremely

◆R_{CDC}



◆ The R_{CDC} has a high possibility to be different due to SOC level and break-off criteria.

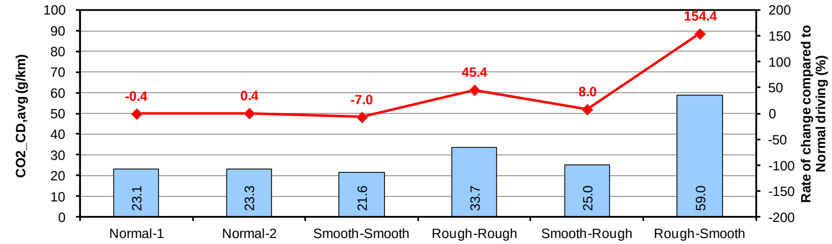
2.4. Test Results (CD condition)

Equivalent all-electric range (EAER)

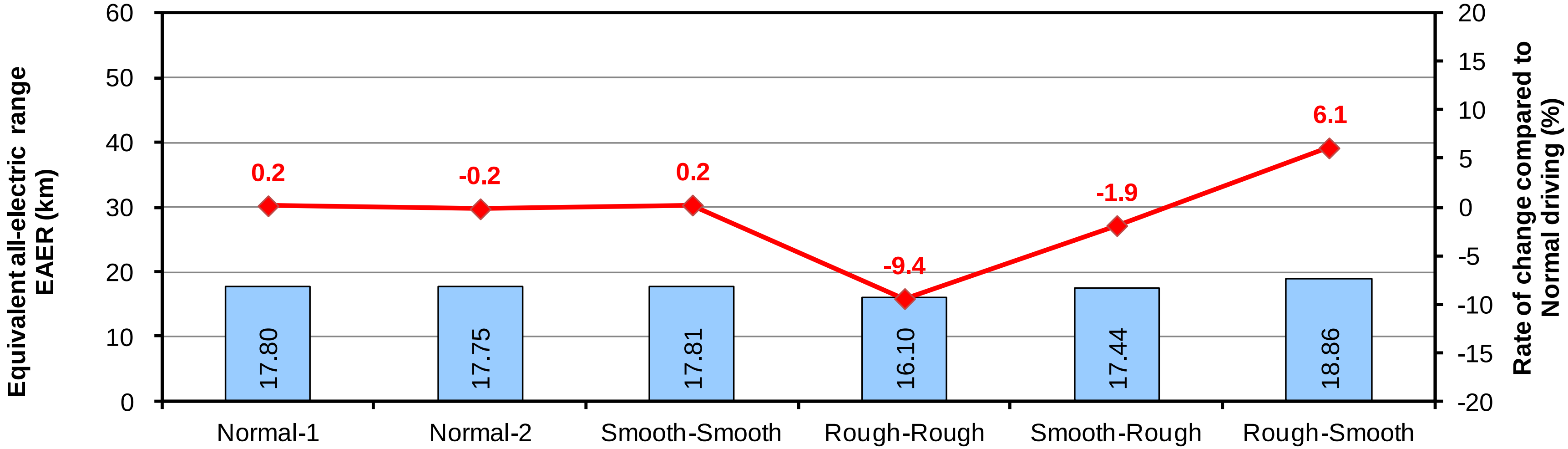
◆equation

$$EAER = \left(\frac{CO_{2,CS} - CO_{2,CD,avg}}{CO_{2,CS}} \right) \times R_{CDC}$$

◆$CO_{2,CD,avg}$



◆EAER



◆ The EAERs are varied by -10% to +6% even though different Rcdc.

2.4. Test Results (CD condition)

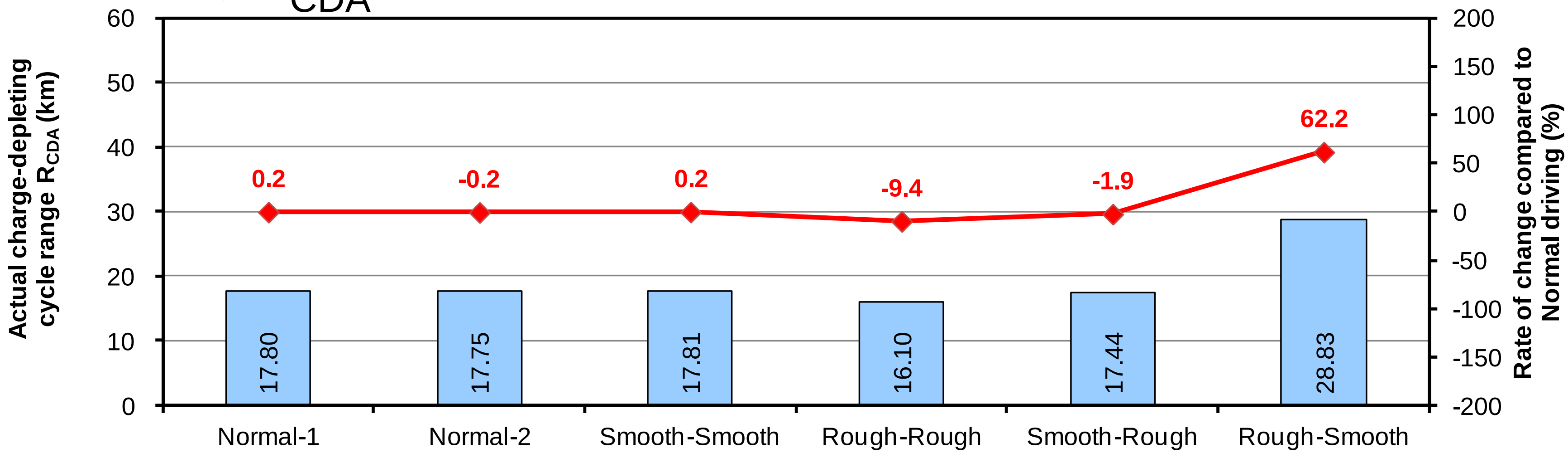
Actual charge-depleting range (R_{CDA})

$$R_{CDA} = \sum_{c=1}^{n-1} d_c + \left(\frac{M_{CO2,CS} - M_{CO2,n,cycle}}{M_{CO2,CS} - M_{CO2,CD,avg,n-1}} \right) \times d_n$$

n is the number of applicable WLTP test cycles driven including the transition cycle

※When the Transition cycle was 1st cycle, then $M_{CO2,CD,avg,n-1}$ was considered 0.

◆R_{CDA}

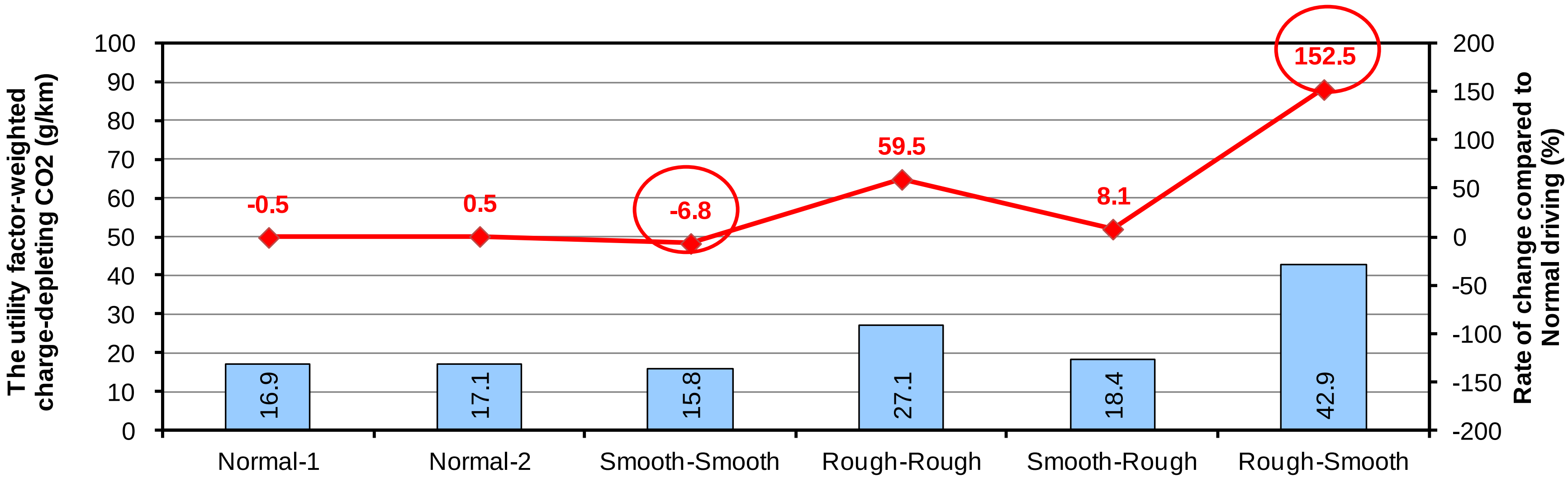


◆R_{CDA} is dramatically changed when the # of CD cycle is different.

2.4. Test Results (CD condition)

Utility factor-weighted charge-depleting CO2 ($M_{CO2,CD}$)

◆Utility factor-weighted charge-depleting CO_2 mass emission $M_{CO2,CD}$

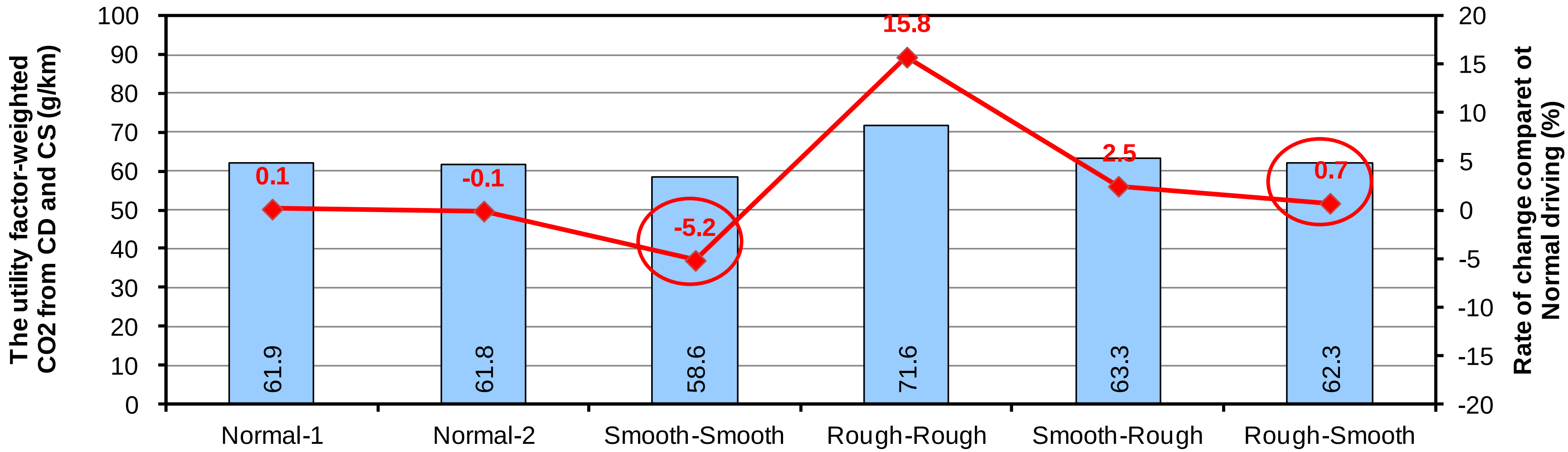


- ◆ $M_{CO2,CD}$ of the smooth-Smooth driving is 7% lower than that of the Normal driving.
- ◆ If the transition cycle is varied, $M_{CO2,CD}$ was dramatically changed.
- ◆ Impact of driving style to the $M_{CO2,CD}$ was the range from -7% to 153%

2.4. Test Results (CD condition)

Utility factor-weighted CO2 mass emissions ($M_{CO2,weighted}$)

◆Utility factor-weighted CO2 mass emissions $M_{CO2,weighted}$

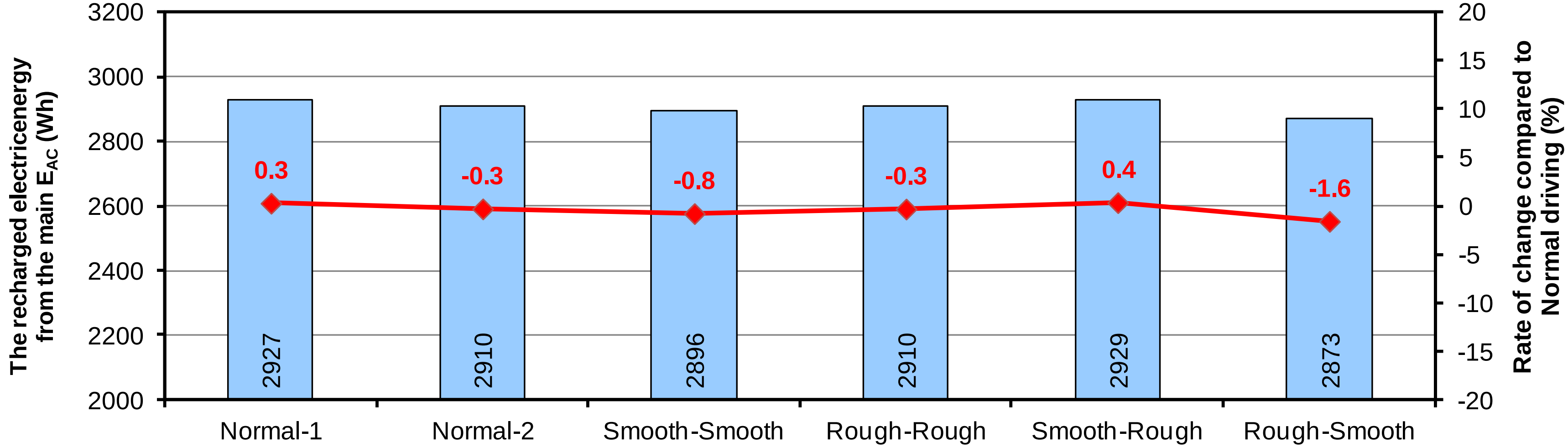


- ◆ $M_{CO2,weighted}$ of the smooth-Smooth driving is 5% lower than that of the Normal driving.
- ◆ Rough-Smooth CO2 is well correlated to other driving style even though huge CO2 deviation under CD condition.

2.4. Test Results (CD condition)

Recharged electric energy (E_{AC})

◆E_{AC}

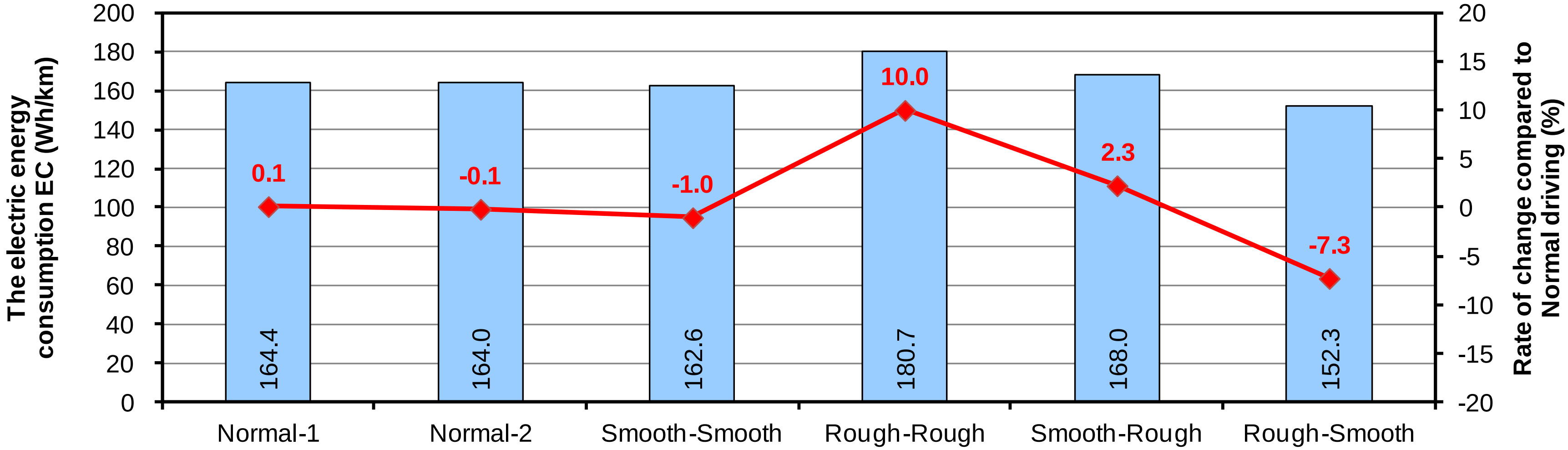


◆ Recharged electric energy (E_{AC}) in each test is identical (within 2%)

2.4. Test Results (CD condition)

Electric energy consumption (EC)

◆EC $$EC = \frac{E_{AC}}{EAER}$$



◆ The ECs are varied from -7% to +10% depends on driving style

2.5. Summary（CD condition)

① Impact of driving style

- CO_2/Range/EC : -80% to 150%.

② Applicability of Normalization method

- Due to its unique test procedure(CD condition), it was observed that “normalization method” doesn’t work on most of parameters (AER, Rcdc, Rcda., CO_2, EC,,)

③ New methodologies or Driving Index ?

- New methodologies are absolutely necessary.
- On the other hands, the practical lab. operation needs to be kept.
- One of solutions is to apply “drive trace index”

(additional data can be found in reference R3)

3. Next Actions

① Asking other parties to conduct CS testing on different type of HEV system.

② Seek whether an appropriate correction method for CD testing exist or not.

③ Options to Proceed

- ✓ Option1 : No correction algorithm but apply drive trace index with criteria for all type of vehicles
- ✓ Option2 : Apply correction algorithm on only parameters which are well justified.
- ✓ Option3 : Develop the methodologies to take care of all parameters.

Reference

R1. Previous study by TUG

R2. Detailed data (CS testing)

R3. Detailed data (CD testing)

R1. Correction algorithm of Normalization by TUG

1. Correction for imbalance of battery SOC

- ✓ correct in each phase
- ✓ Two option for the correction
  - A) simple option: $W_{bat}=\Sigma U_{(t)} \times I_{(t)} \times 0.001 \cdot dt$ [kWs]
  - B) detailed option: $W_{bat} = W_{bat\_discharge} - (W_{bat\_charge} \times \eta_{bat})$ [kWs]
  - ➢ ΔCO_{2SOC} [g] = $W_{bat} / \eta_{Alt} \times k_e$
  - ➢ η_{bat}: Pb 87%, Ni-Mh 90%, Li-Ion 97%, η_{Alt}: 67%, k_e: Willans係数

for OVC-HEV vehicle, apply normal RCB correction (Not use Willans factor)

2. Set up a Vehicle specific Veline function

- ✓ Set up the vehicle specific veline function from the SOC corrected test data and average power
- ✓ Calculate average Power (if $P_{(j)} < P_{overrun}$, $P_{(j)}=P_{overrun}$)
- ✓ CO_2 [g/s] = $k_v \times P_{wheel} + D$
- ✓ $P_{overrun}$ = Maximum power × 0.02 (*) for OVC-HEV: Maximum rated power of Engine

3. Correction for the deviation of the vehicle speed

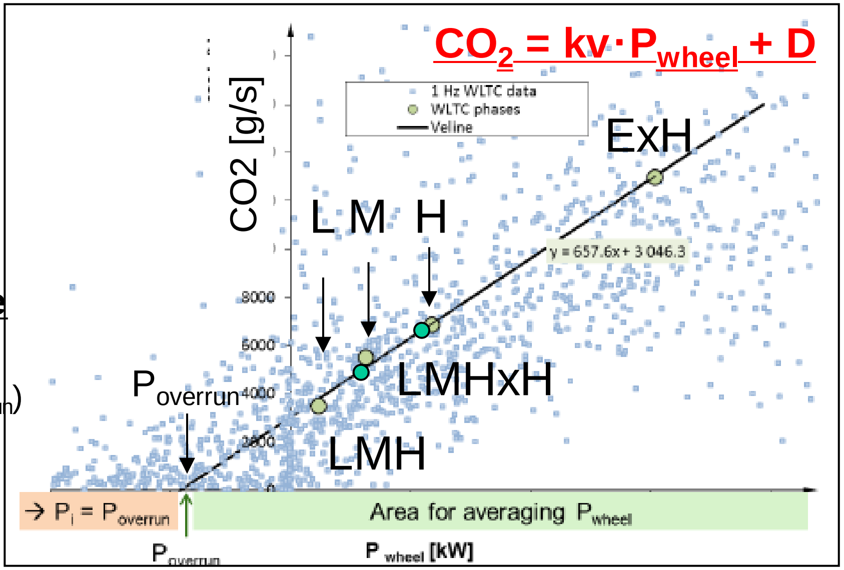
- ✓ Correct the deviation against target speed
- ✓ ΔCO_{2v} [g] = $\Delta W_{wheel} \times kv$
- ✓ $\Delta W_{wheel} = (W_{w\_pos} - W_{pos}) \times 0.001$ [kWs]
- ✓ $W_{pos} = \Sigma P(t) \cdot dt$ （ if $P_{(j)} < P_{overrun}$, $P_{(j)}=P_{overrun}$ ）
- ✓ $P = (R0 + R1 \times V + R2 \times V2 + ma) \times V$

4. Correction for the deviation of the travelled distance

- ✓ Correct the deviation against target distance
- ✓ Consider that CO2 is not emit during deceleration (< $P_{overrun}$)
- ✓ CO2 [g/km] = $(CO_{2measured} + \Delta CO_{2SOC} + \Delta CO_{2v})$ / 23.27

5. Correction for the deviation of road load

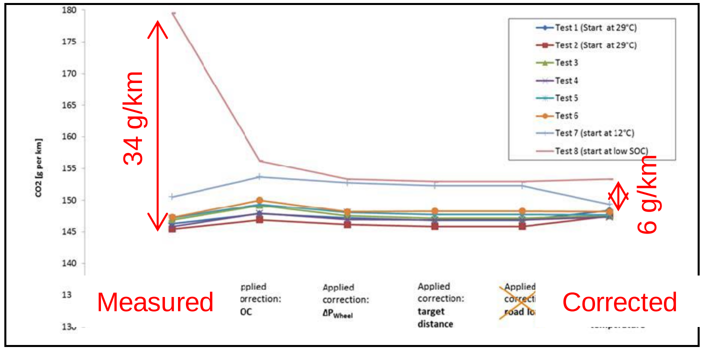
- ✓ Correct the deviation against target road load
- ✓ $\Delta CO2$ [g] = $\Delta W_{wheel} \times kv$
- ✓ $\Delta W_{wheel} = \Sigma(P_{p(t)} - P_{(t)}) \cdot dt$
- ✓ $P_{p(t)} - P_{(t)} = R_{0w} - R_0 + (R_{1w} - R_1) \times v_{(t)} + (R_{2w} - R_2) \times v_{(t)}^2$



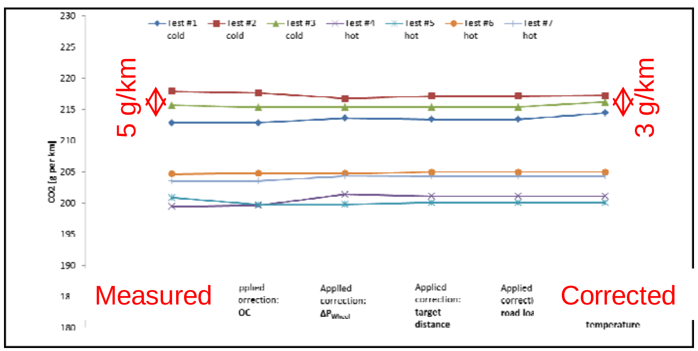
Develop the regression line based on the relationship between average power and CO2 in each phase

R1. Normalization method for ICE vehicle

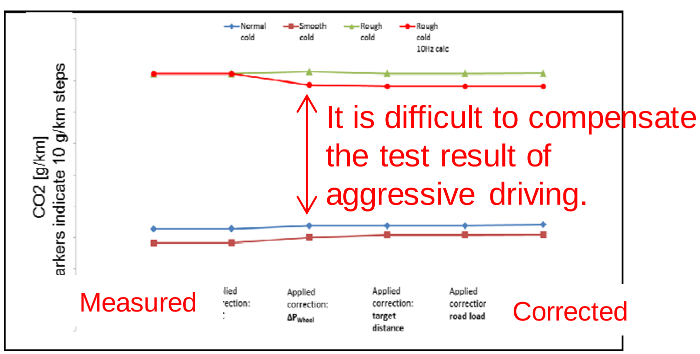
◆Test-A



◆Test-B



◆Test-C

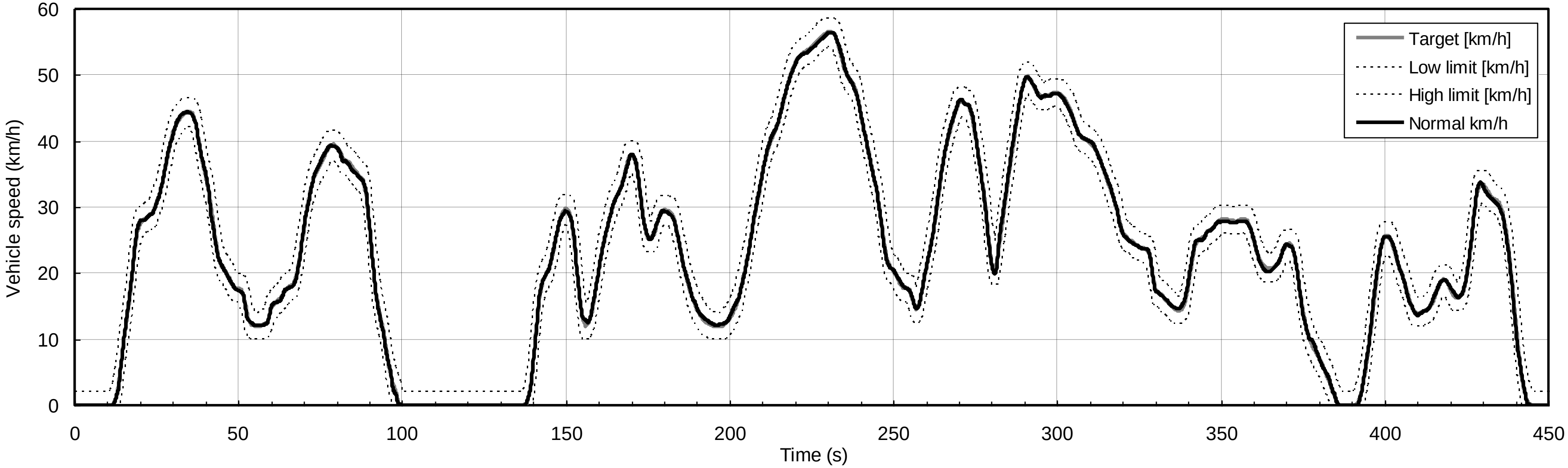


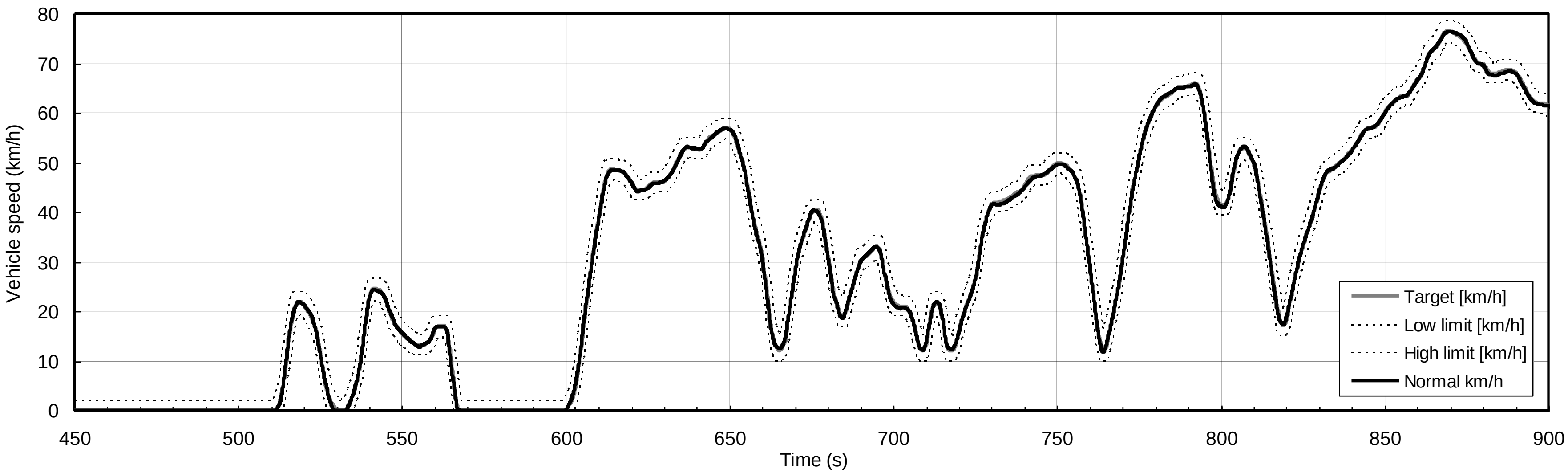
- It was observed that the normalization method tend to reduce the deviation between the tests.
  - ✓ SOC correction
  - ✓ Speed & distance correction
  - ✓ Road load correction
  - ✓ Soak temperature correction
- The CO2 value for the aggressive driving style is reduced only if 10Hz speed signals are used for the correction of speed deviations
- It was hardly to correct the aggressive driving for the vehicle with automatic transmission.
- Driving index as defined in SAE J2951 seems to be helpful to eliminate improper driver behavior.

Source: WLTP-08-37e – WLTP correction algorithms report

R2. Normal driving (Low ~ Medium)

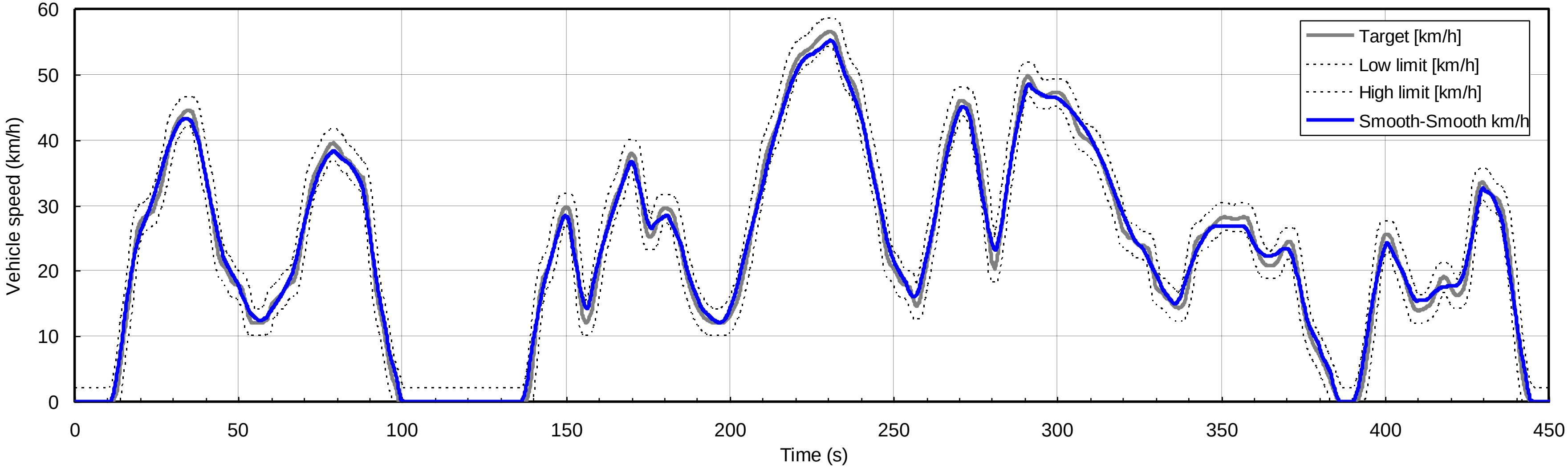
Trace the target speed as match as possible

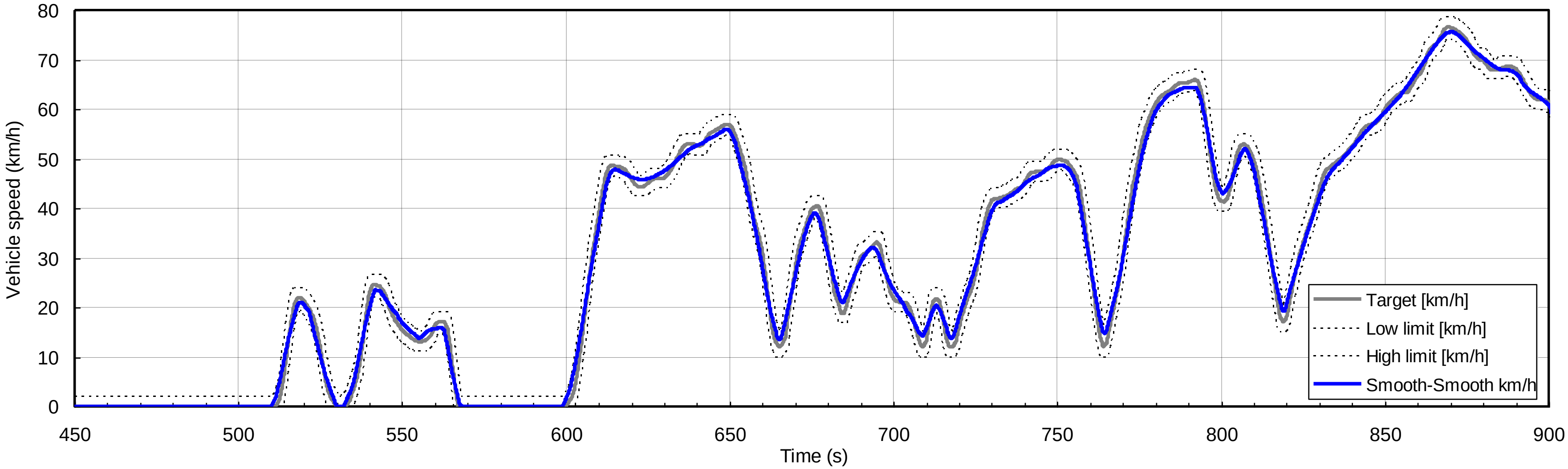




R2. Smooth-Smooth driving (Low ~ Medium)

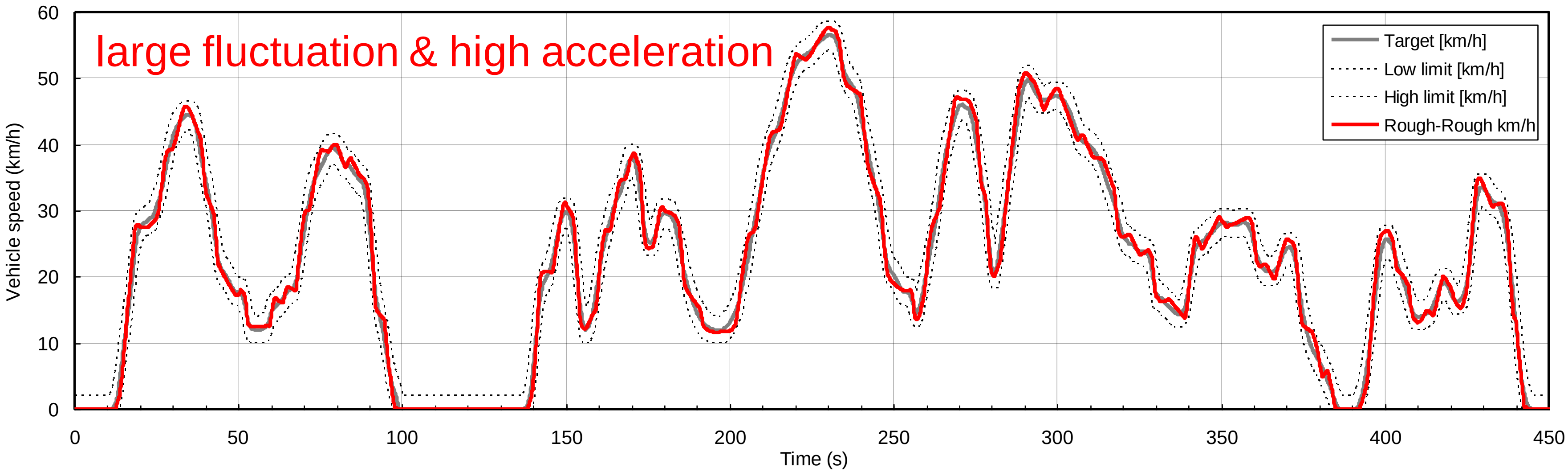
Smooth acceleration and Smooth deceleration

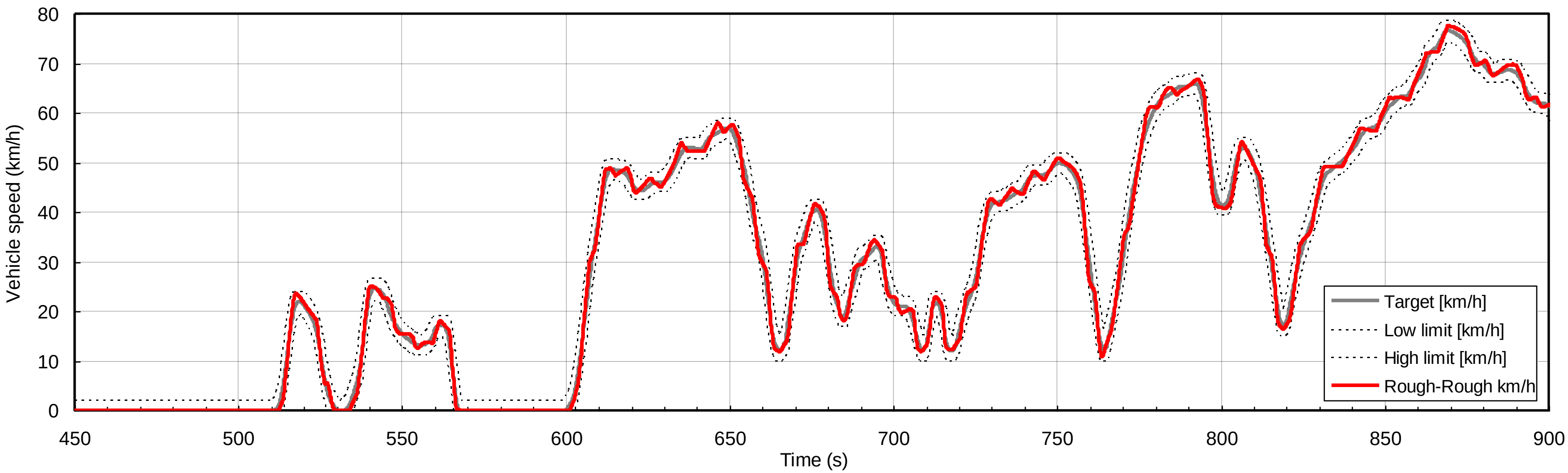




R2. Rough-Rough driving (Low ~ Medium)

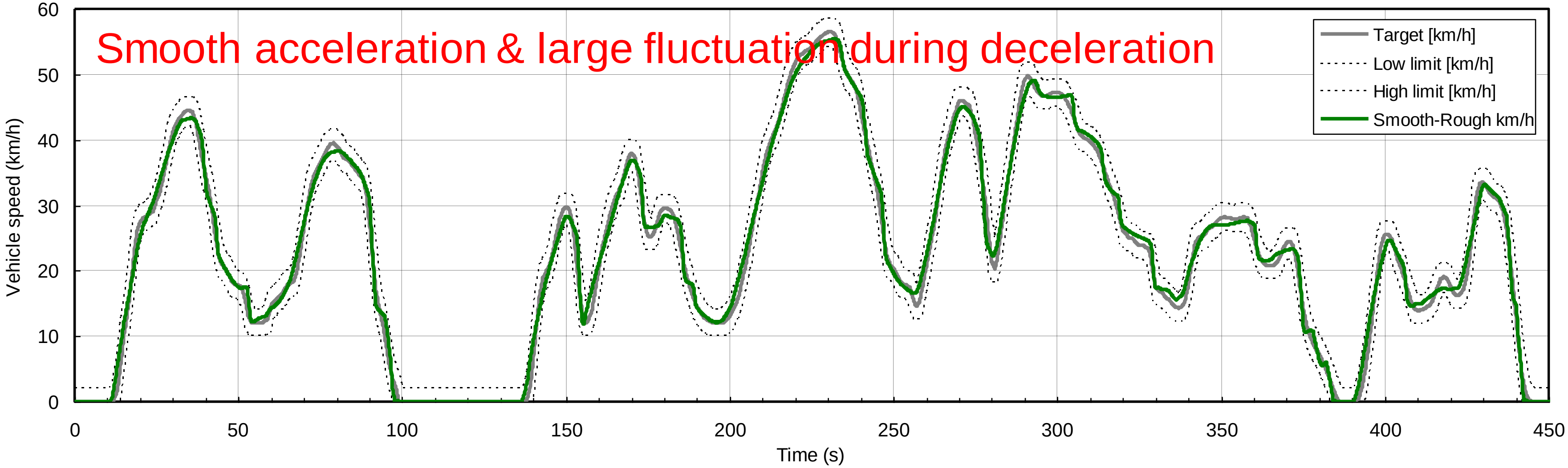
Rough acceleration and Rough deceleration

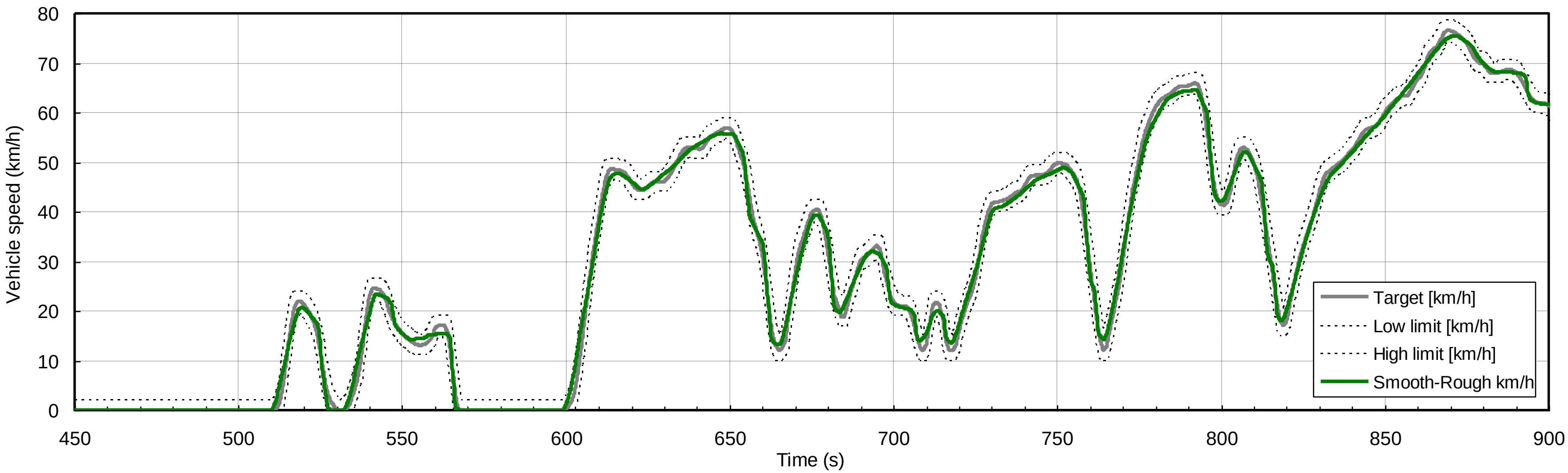




R2. Smooth-Rough driving (Low ~ Medium)

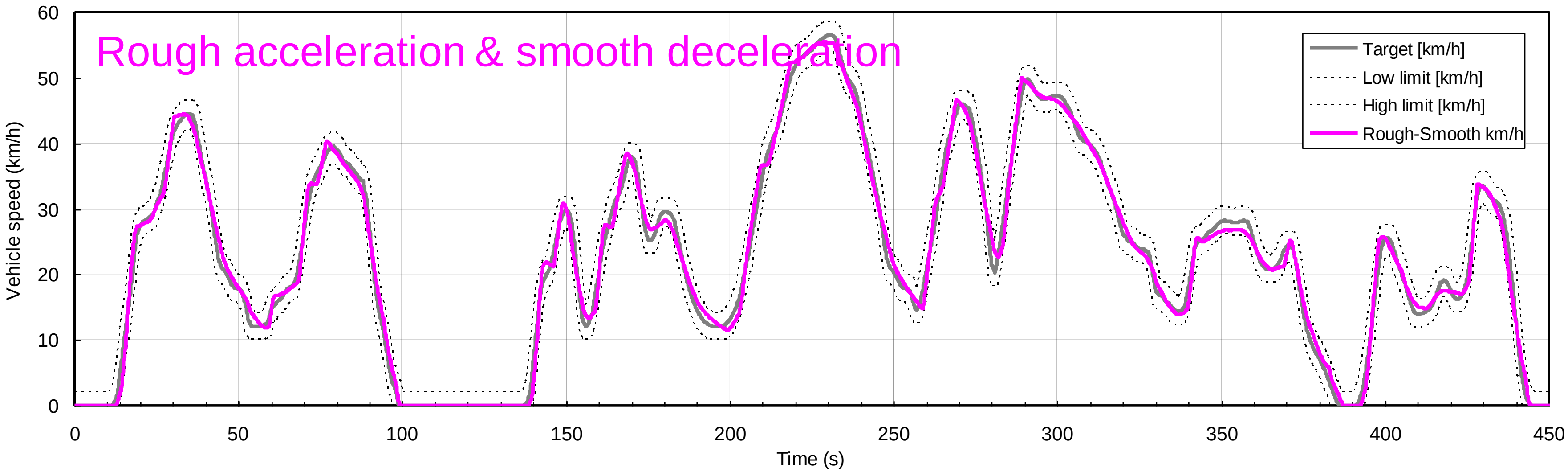
Smooth acceleration and Rough deceleration

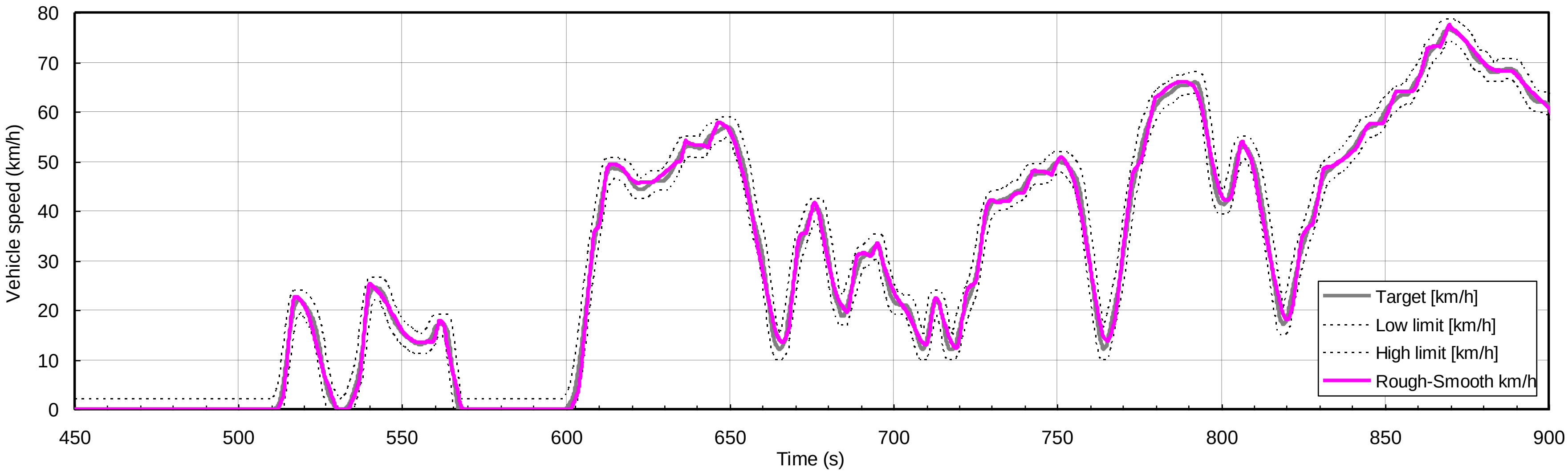




R2. Rough-Smooth driving (Low ~ Medium)

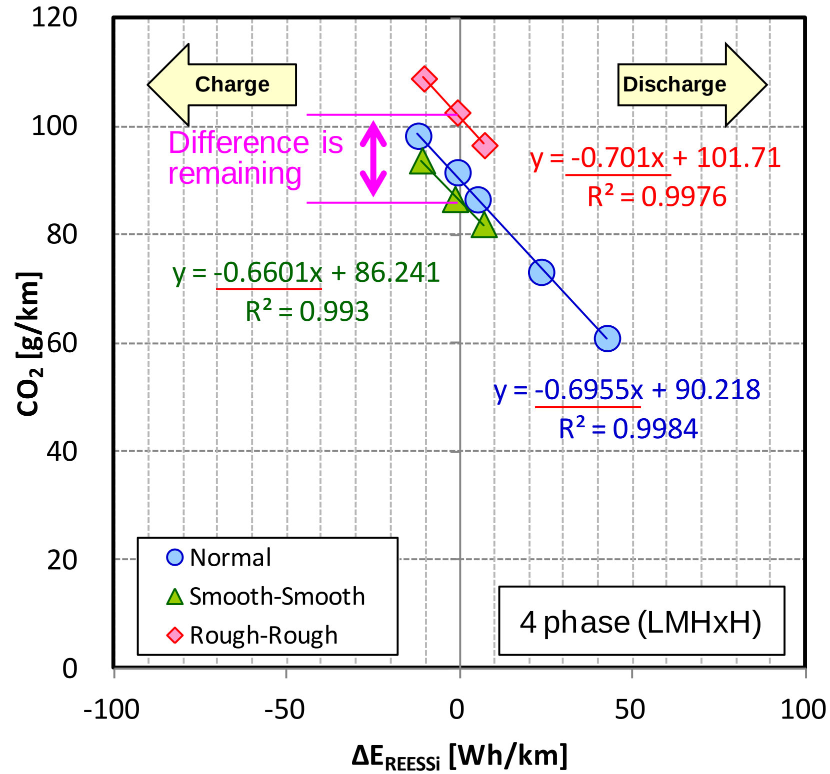
Rough acceleration and Smooth deceleration



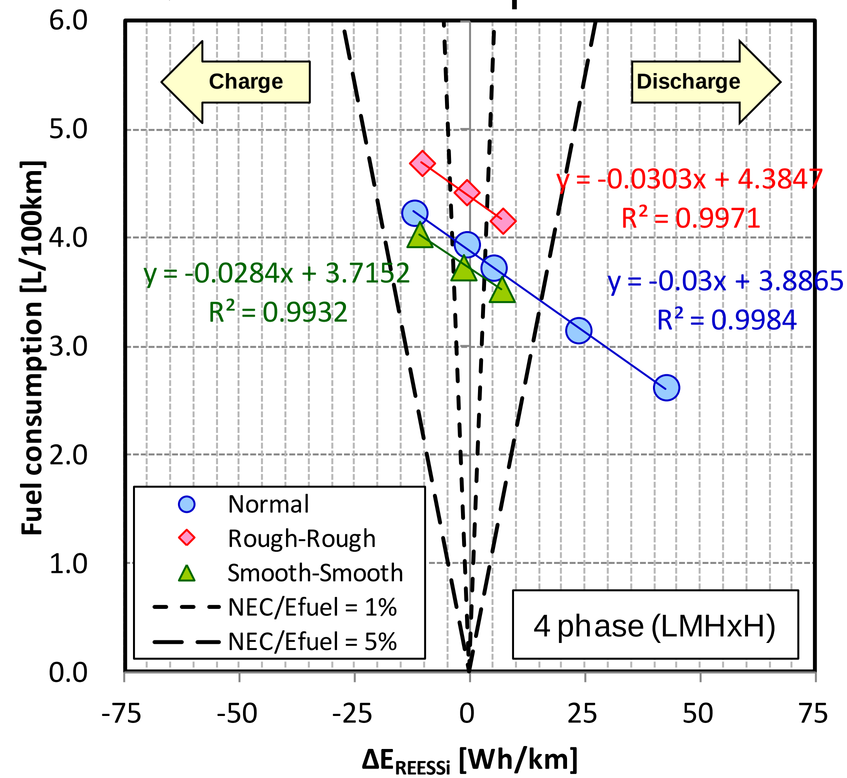


R2. RCB correction coefficients

◆ CO2



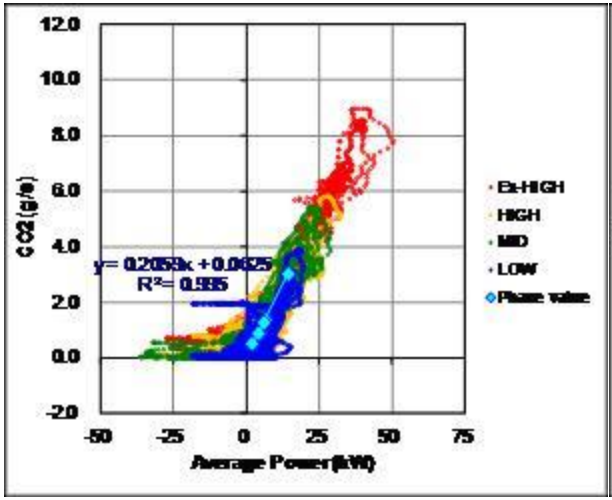
◆ Fuel consumption



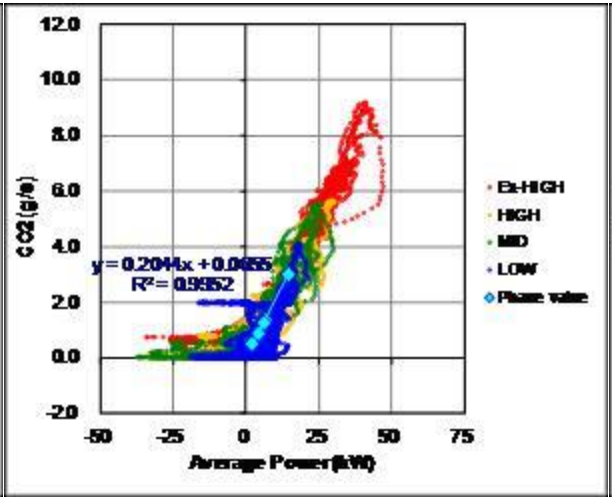
- ◆ K_{CO2} and K_{fuel} in each driving style is identical
- ◆ Same coefficient can be used for RCB correction with regardless the driving style.

R2. Relationship between Power and CO2

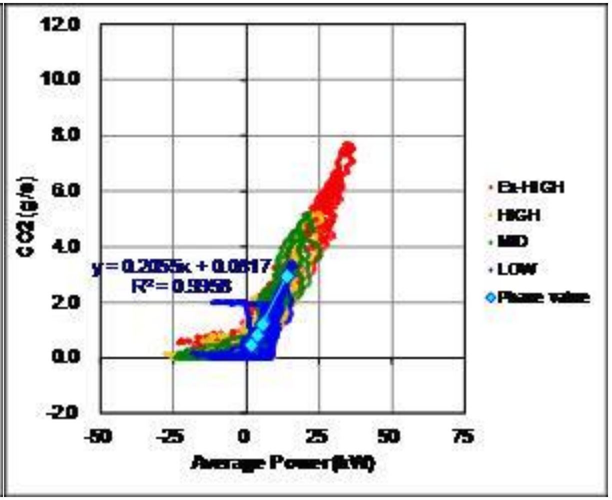
◆ Normal-1



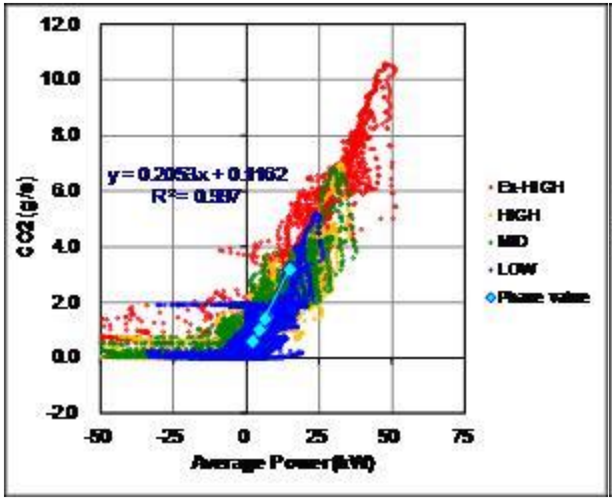
◆ Normal-2



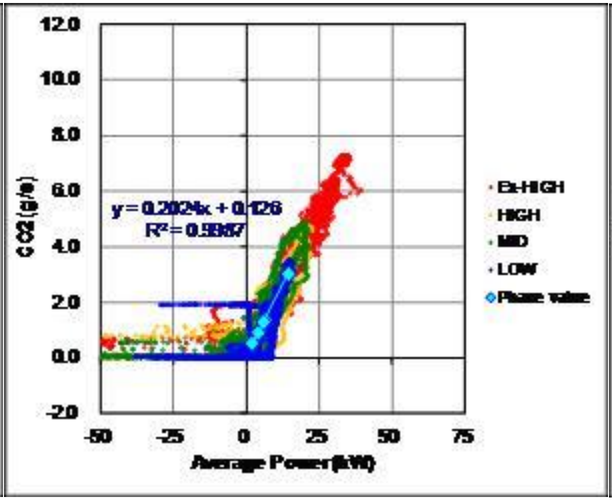
◆ Smooth-Smooth



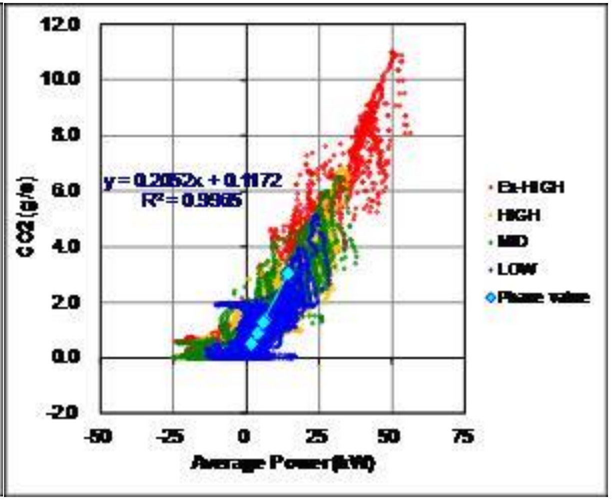
◆ Rough-Rough



◆ Smooth-Rough

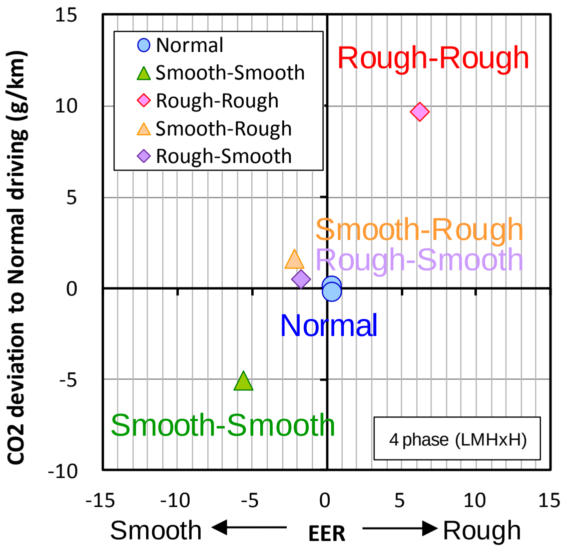


◆ Rough-Smooth

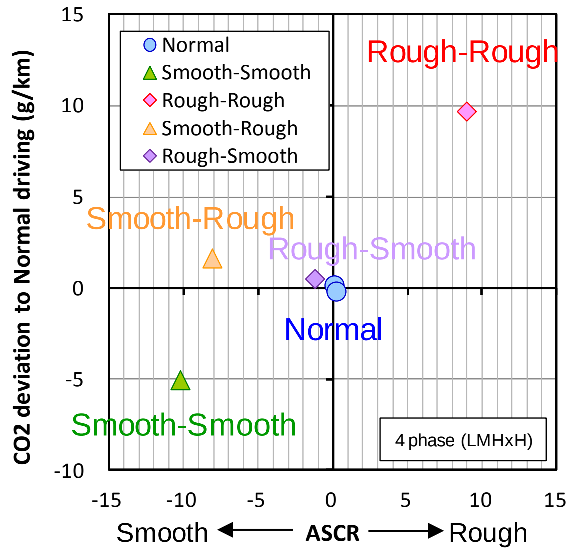


R2. Drive trace index

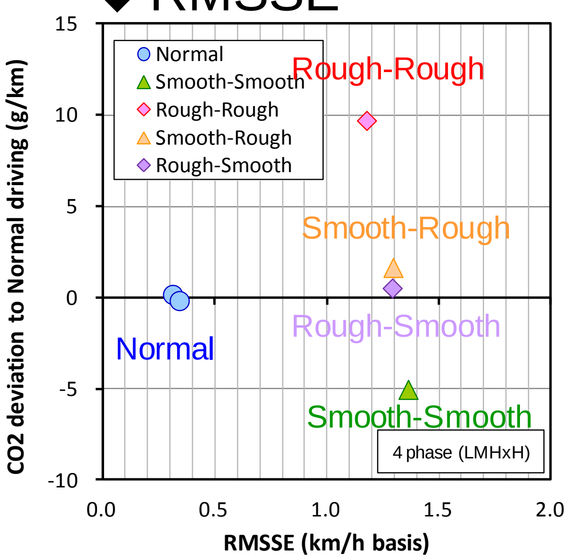
◆ EER



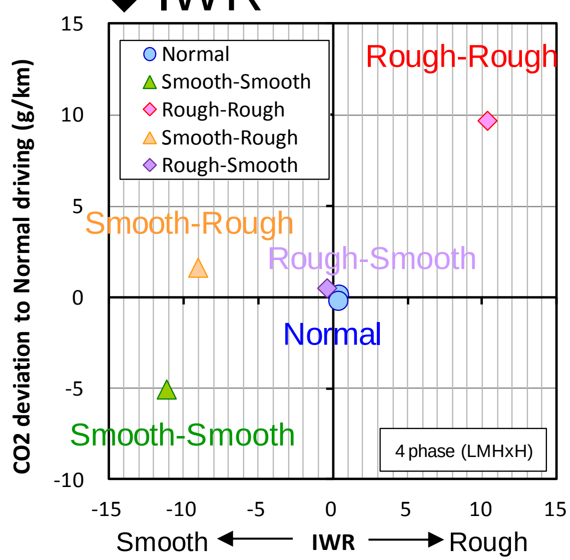
◆ ASCR



◆ RMSSE

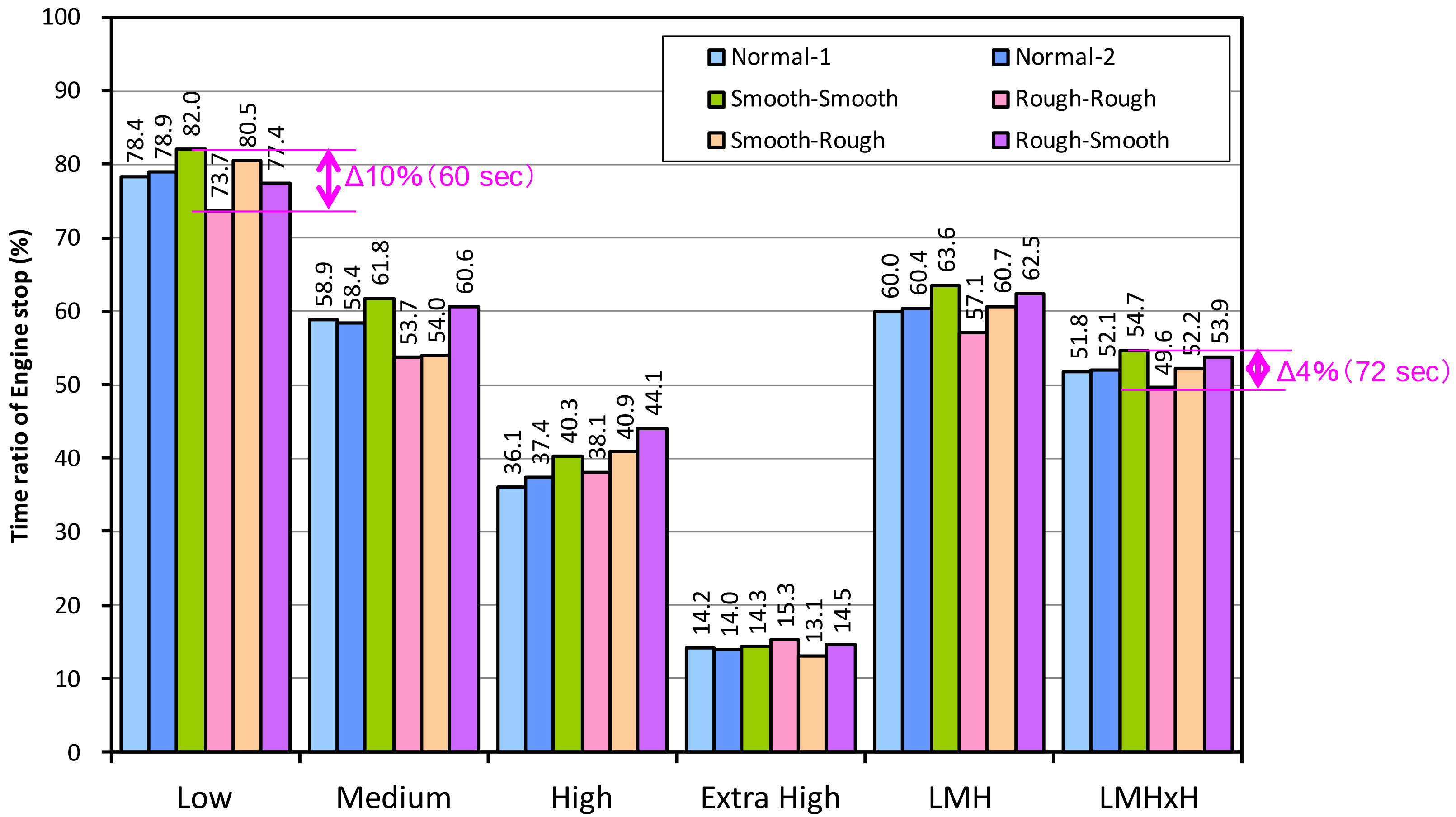


◆ IWR



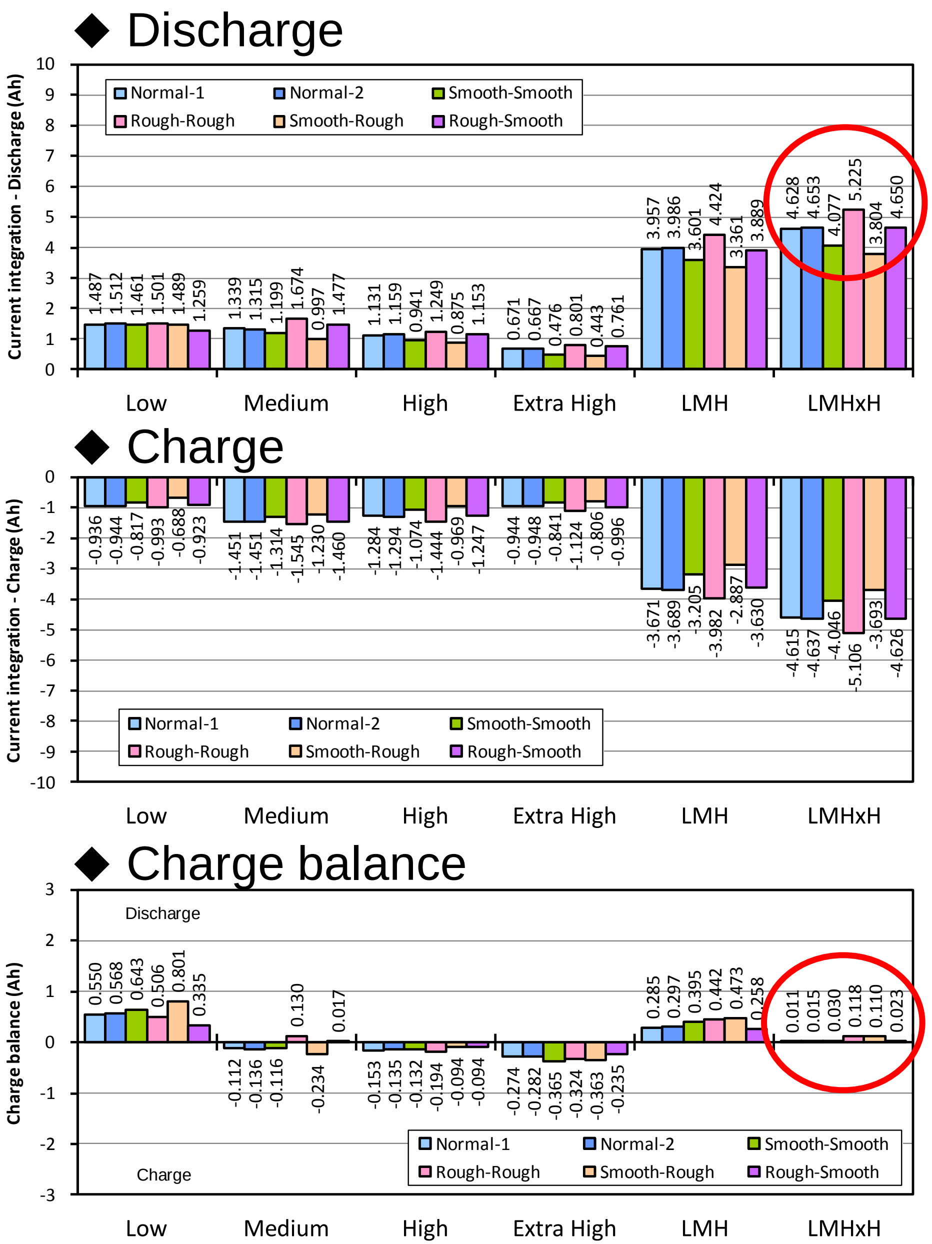
- ◆All Smooth-Smooth driving data and Rough-Rough driving data were varied and detected by all indexes
- ◆Smooth-Rough driving data were detected by ASCR, RMSSE and IWR
- ◆Rough-Smooth driving data were detected by only RMSSE
- ◆Good repeatability was obtained when the Normal driving was performed

R2. Time ratio of Engine stop



◆Engine stop duration of Smooth-Smooth driving is longer than that of other driving styles.

R2. Charge balance

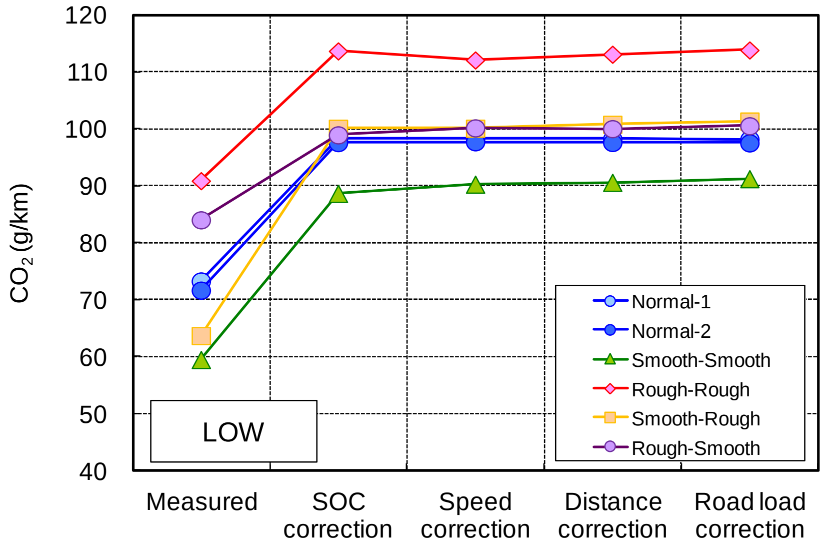


- The discharge electricity of Smooth-Smooth driving is lower than that of other driving styles.
- The discharge electricity of Rough-Rough driving is higher than that of other driving styles.
- The charge balance of whole cycle in each driving style is close to zero.

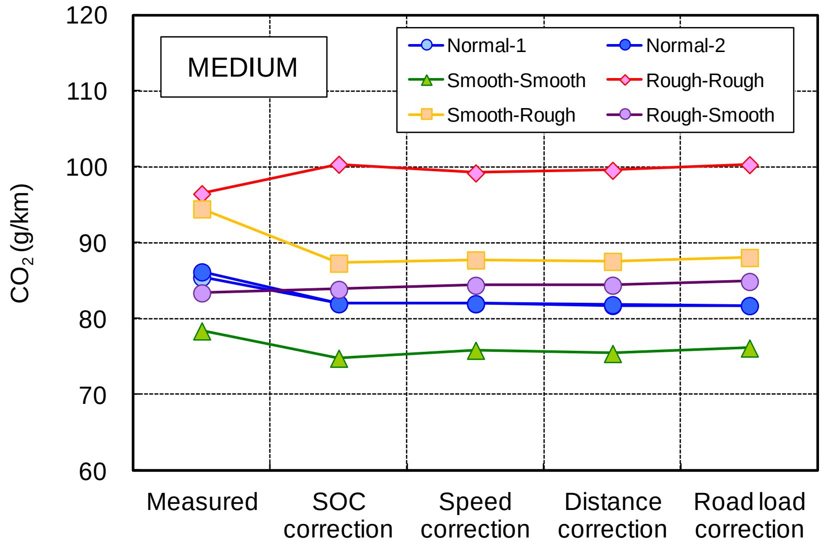
R2. Test Results (CS condition)

Effects of Normalization method (each phase)

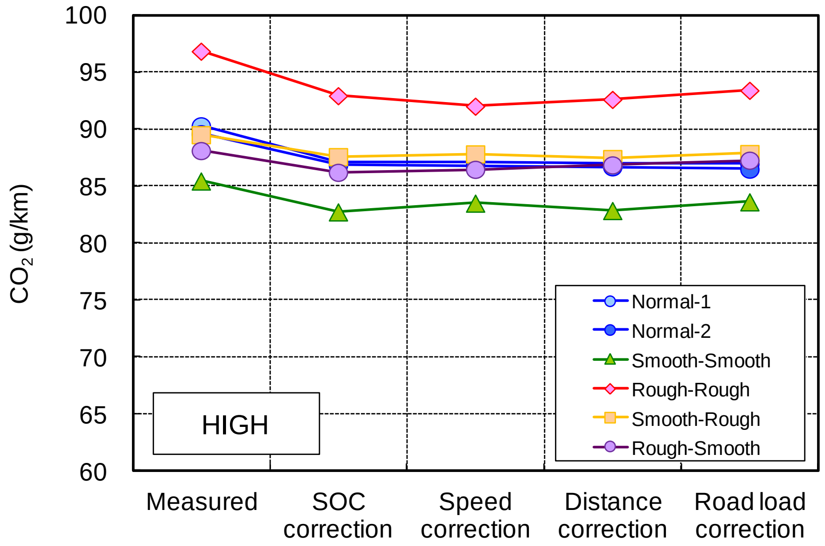
◆LOW



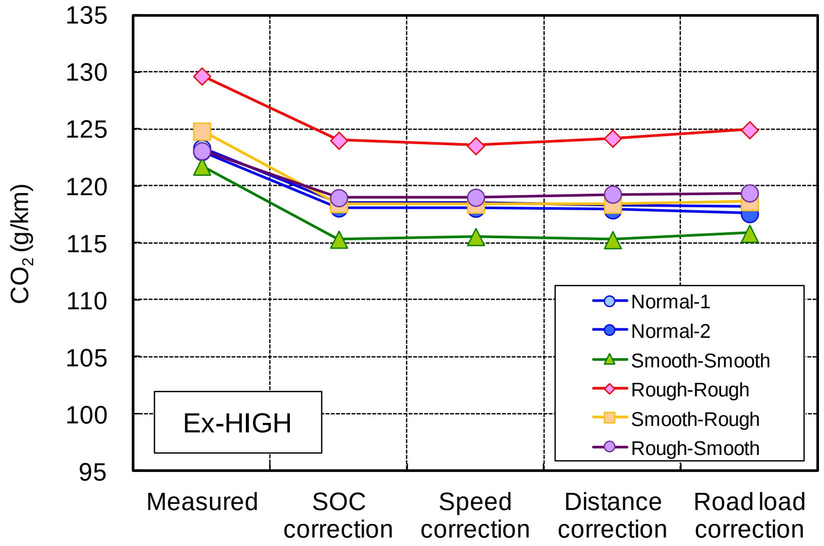
◆MEDIUM



◆HIGH

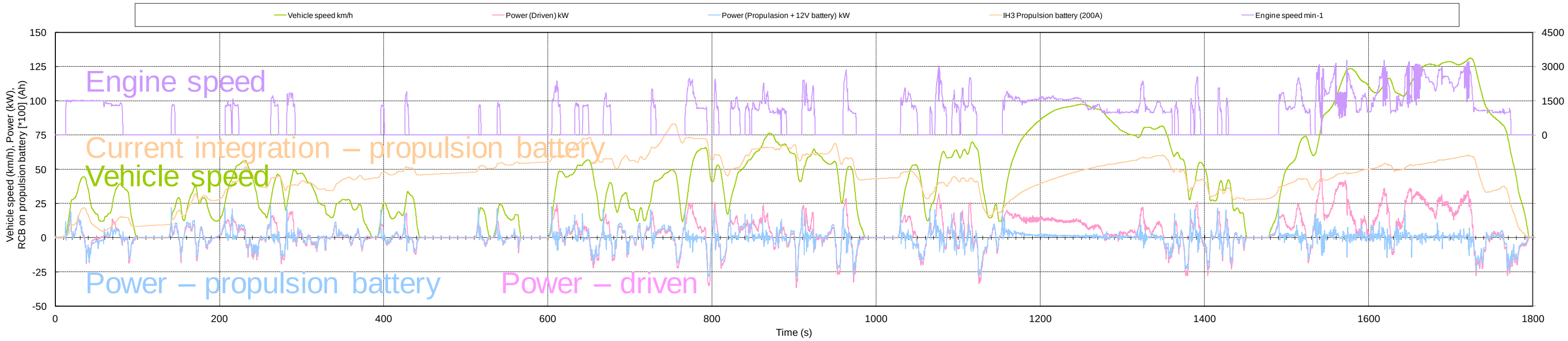


◆Ex-HIGH

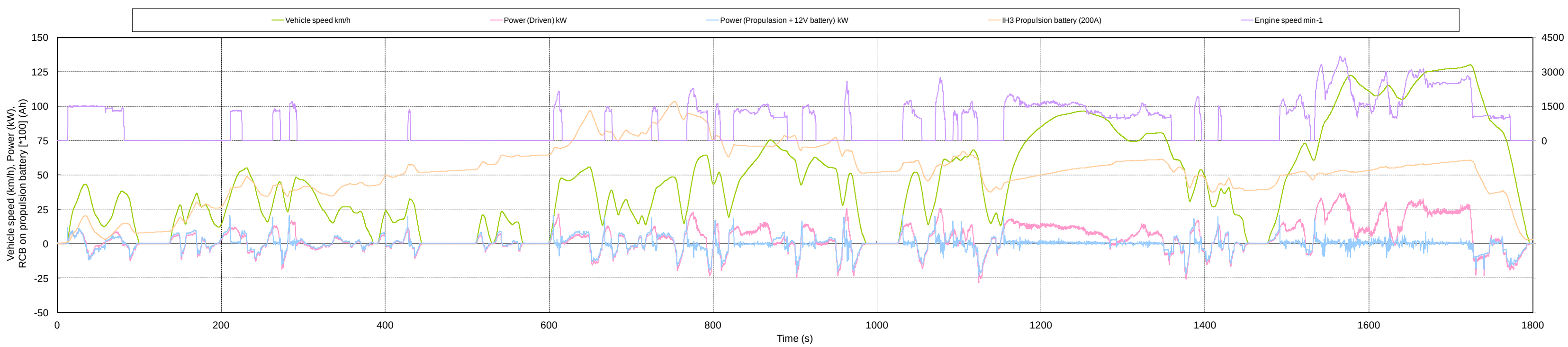


R2. Continuous data

◆ Normal-1



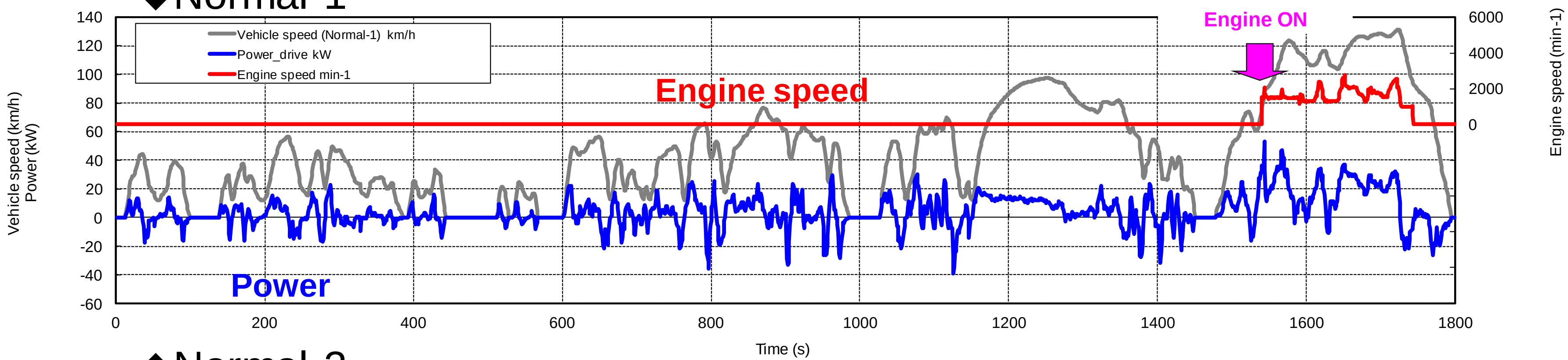
◆ Smooth-Smooth



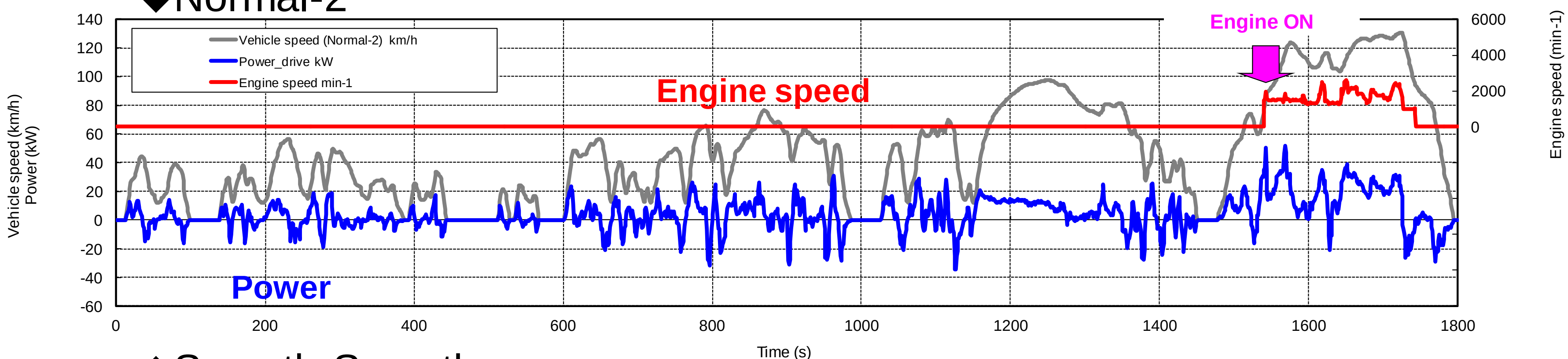
◆ Rough-Rough

R3. The timing of first engine operation

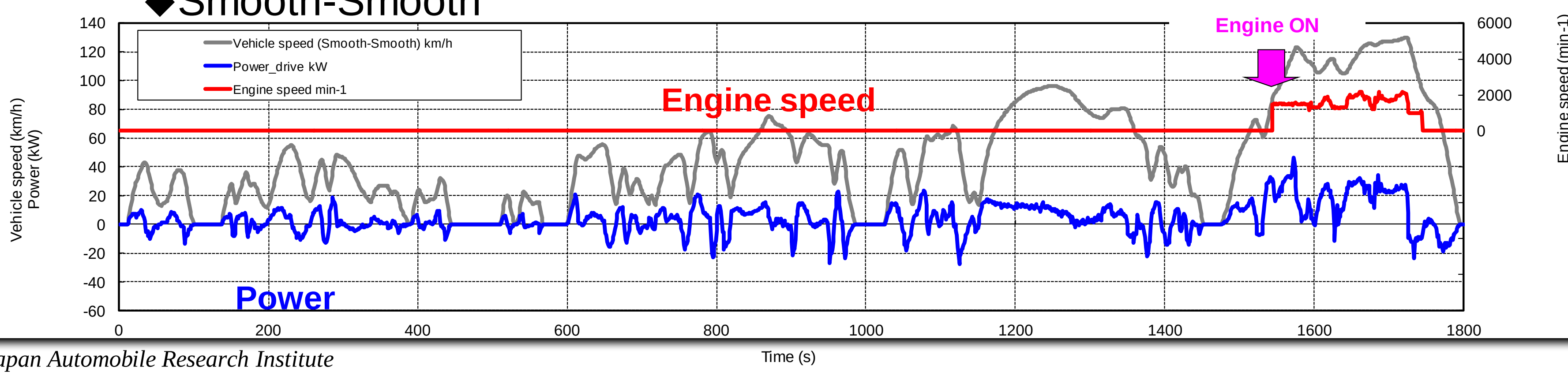
◆Normal-1



◆Normal-2

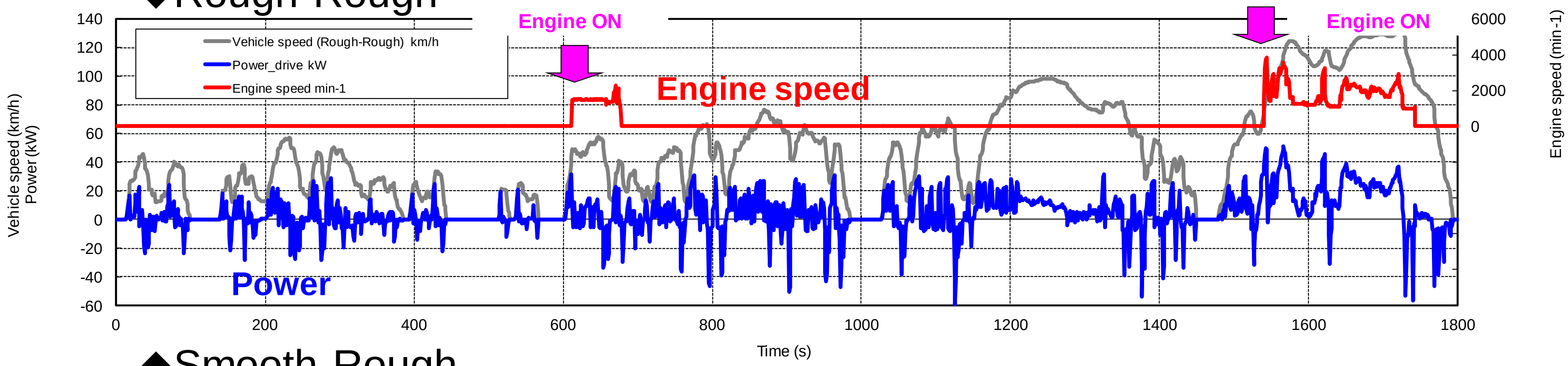


◆Smooth-Smooth

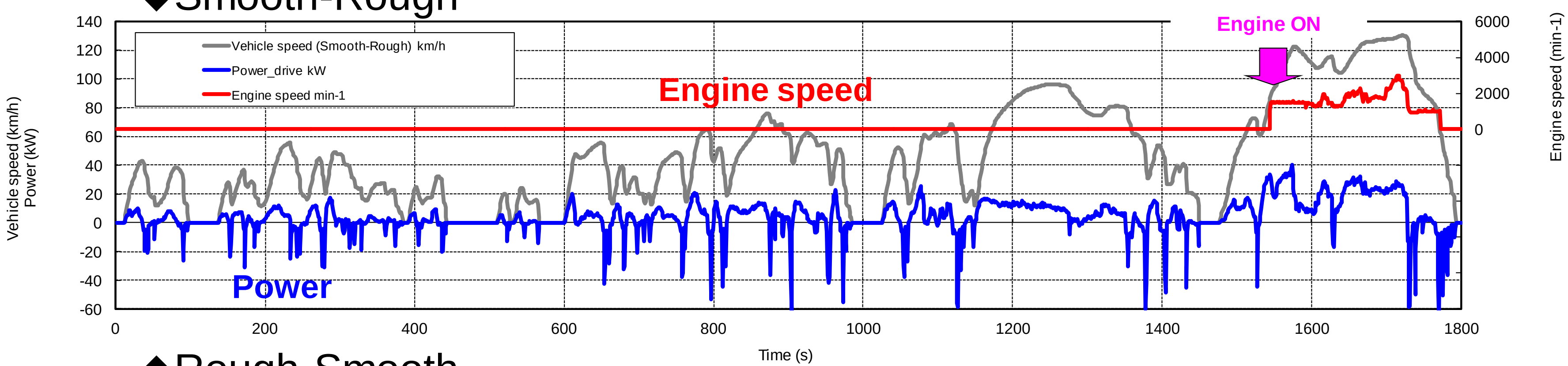


R3. The timing of first engine operation

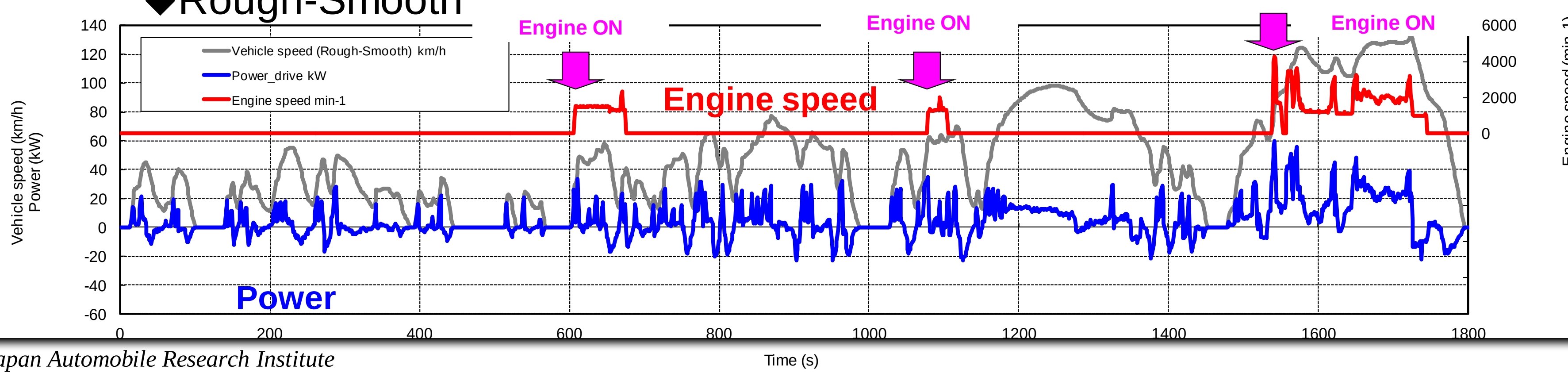
◆Rough-Rough



◆Smooth-Rough



◆Rough-Smooth



R3. The utility factor-weighted CO2

◆ Example of calculation

Rough-Smooth

Cycle	Phase	CO2	UF	CO2_CD	CO2 weighted
CD-1	Low	0	0.09	42.9	62.3
	Medium	23	0.11		
	High	6	0.13		
	Extra High	78	0.12		
CD-2	Low	0	0.04		
	Medium	57	0.05		
	High	91	0.06		
	Extra High	124	0.06		
CS	LMHxX	99	-	-	

Normal

Cycle	Phase	CO2	UF	CO2_CD	CO2 weighted
CD-1	Low	0	0.09	16.9	61.9
	Medium	0	0.11		
	High	0	0.13		
	Extra High	65	0.12		
CS	LMHxX	99	-	-	

◆ The utility factor-weighted charge-depleting CO_2 mass emission $M_{CO2,CD}$

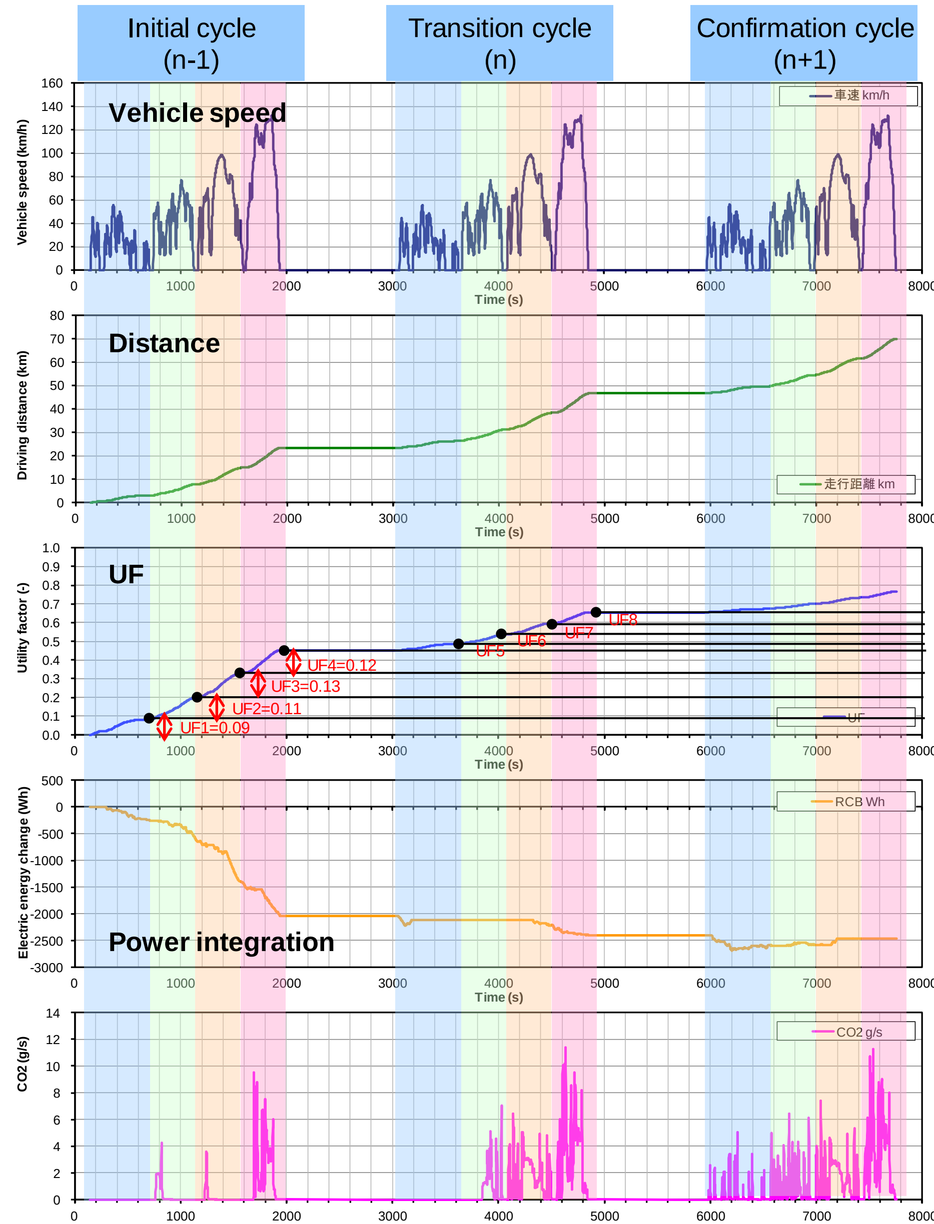
$$M_{CO2,CD} = \frac{\sum_{j=1}^{k} \left(UF_j \times M_{CO2,CD,j} \right)}{\sum_{j=1}^{k} UF_j}$$

k is the number of phases driven up to the end of the transition cycle

◆ Utility factor-weighted CO_2 mass emissions $M_{CO2,weighted}$

$$M_{CO2,weighted} = \sum_{j=1}^{k} \left(UF_j \times M_{CO2,CD,j} \right) + \left(1 - \sum_{j=1}^{k} UF_j \right) \times M_{CO2,CS}$$

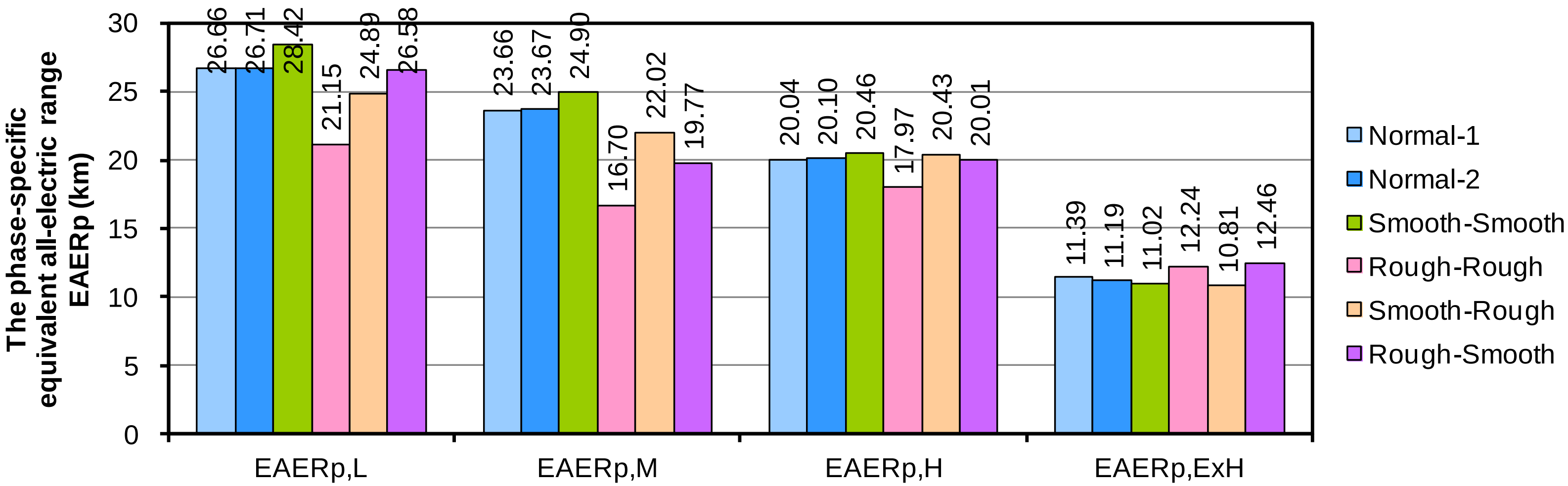
◆ Rough-Smooth driving



R3. Phase specific $EAER_p$

$$EAER_p = \left(\frac{M_{CO2,CS,p} - M_{CO2,CD,avg,p}}{M_{CO2,CS,p}} \right) \times \frac{\sum_{j=1}^{k} \Delta E_{REESS,j}}{EC_{DC,CD,p}}$$

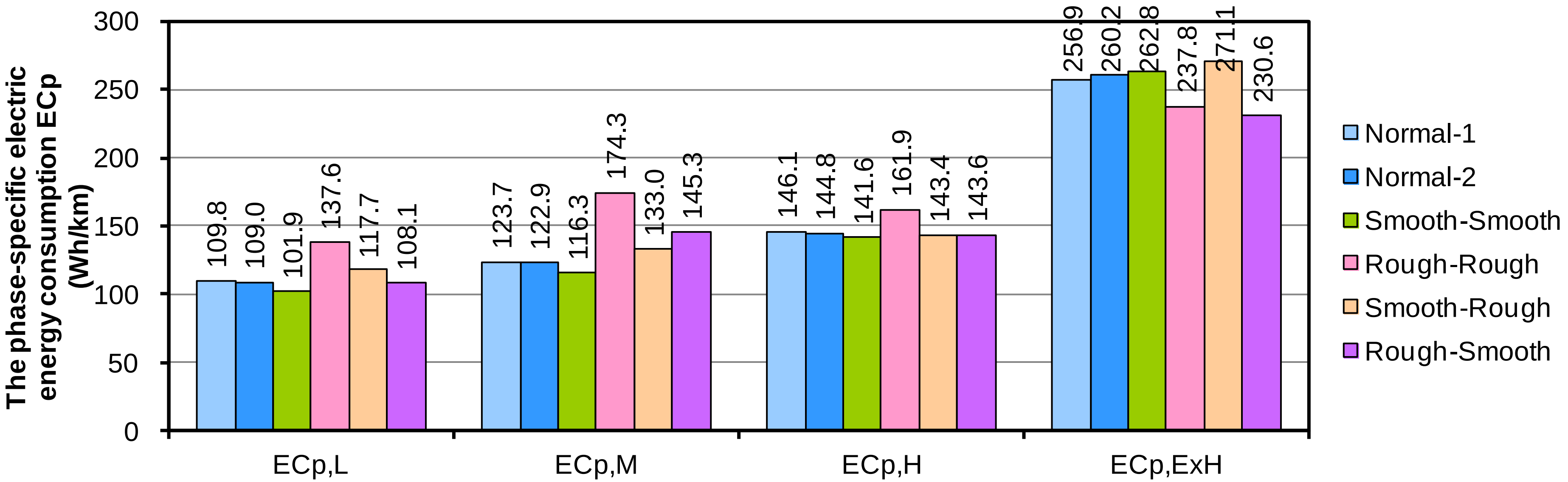
◆$EAER_p$



- ◆ The $EAER_{p,L}$ are varied from -20% to +7% depends on driving style
- ◆ The $EAER_{p,M}$ are varied from -30% to +5% depends on driving style
- ◆ The $EAER_{p,H}$ are varied from -10% to +2% depends on driving style
- ◆ The $EAER_{p,ExH}$ are varied from -4% to +10% depends on driving style

R3. Phase specific Electric energy consumption (EC_p)

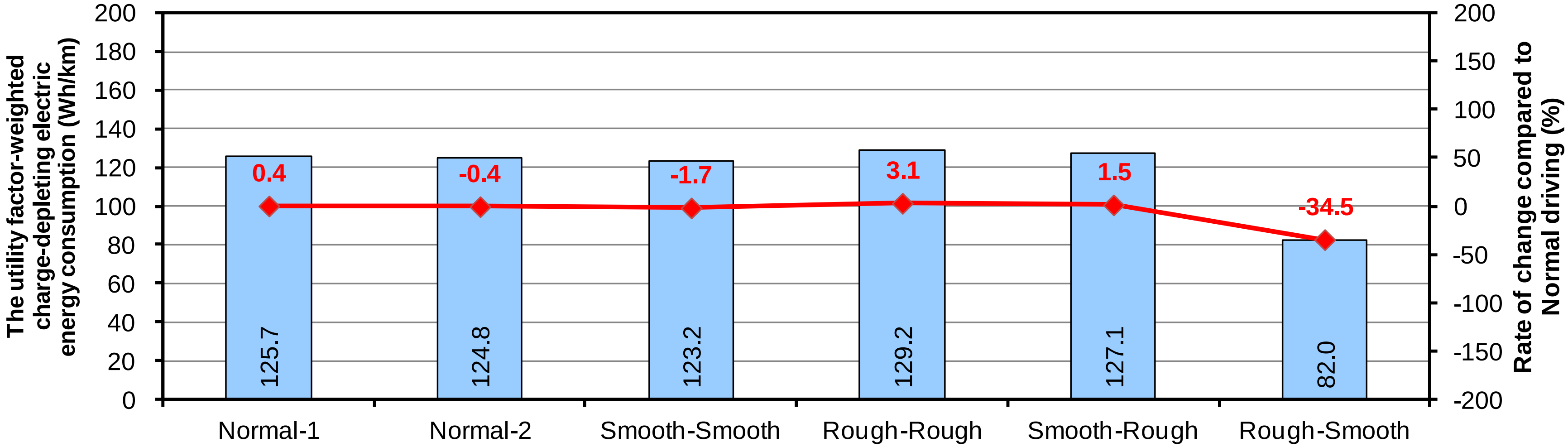
◆EC_p $$EC = \frac{E_{AC}}{EAER_p}$$



- ◆ The $EC_{p,L}$ was varied from -7% to +26% depends on driving style
- ◆ The $EC_{p,M}$ was varied from -6% to +41% depends on driving style
- ◆ The $EC_{p,H}$ was varied from -3% to +11% depends on driving style
- ◆ The $EC_{p,ExH}$ was varied from -11% to +5% depends on driving style

R3. Utility factor-weighted CD $EC_{AC,CD}$

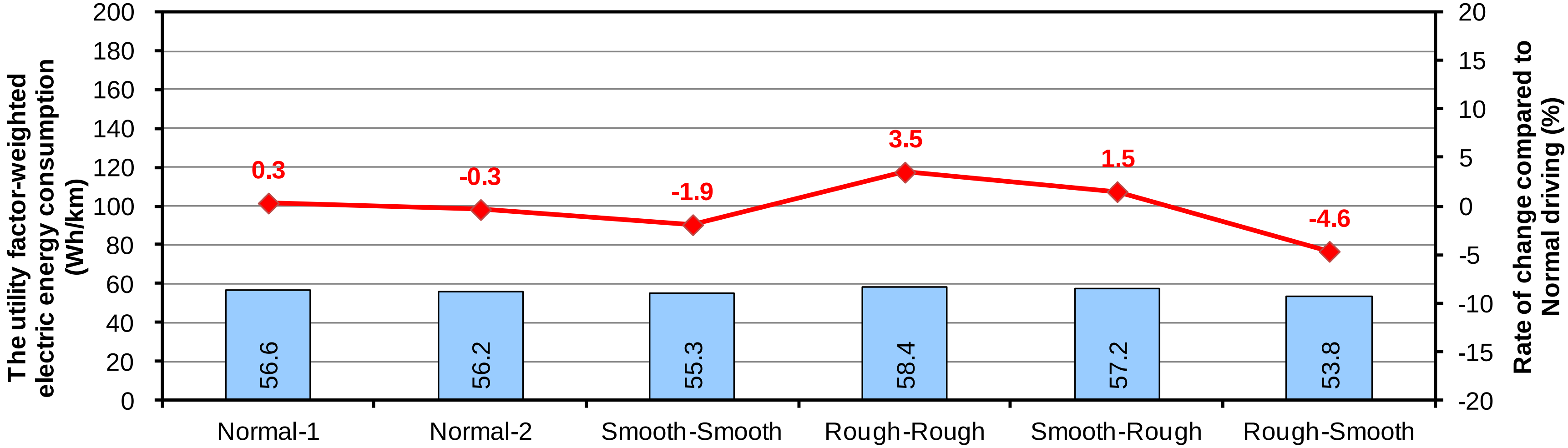
◆$EC_{AC,CD}$ $$EC_{AC,CD} = \frac{\sum_{j=1}^{k}\left(UF_j \times EC_{AC,CD,j}\right)}{\sum_{j=1}^{k} UF_j}$$



◆ The EC was varied from -35% to +3% depends on driving style

R3. Utility factor-weighted $EC_{AC,weighted}$

◆$EC_{AC,weighted}$ $$EC_{AC,CD} = \sum_{j=1}^{k} \left(UF_j \times EC_{AC,CD,j} \right)$$



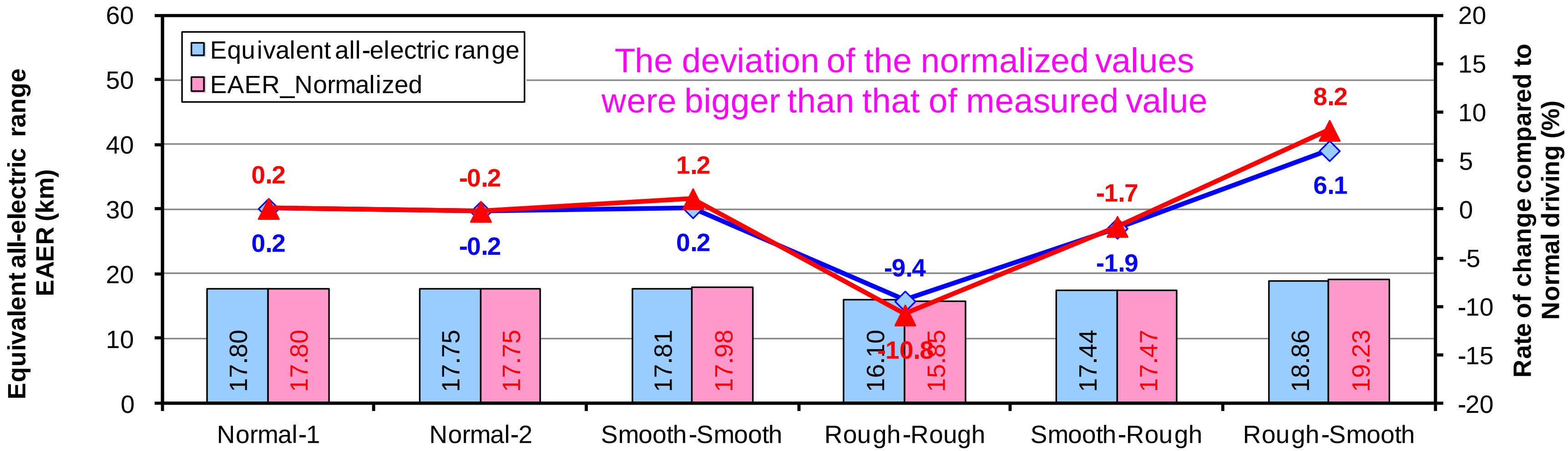
◆ The EC was varied from -5% to +4% depends on driving style

R3. Study of the normalization method for CD test

◆The equivalent all-electric range EAER

$$EAER = \left(\frac{CO_{2,CS} - CO_{2,CDavg}}{CO_{2,CS}} \right) \times R_{CDC}$$

input the normalized value



◆ The correction didn't work appropriately.

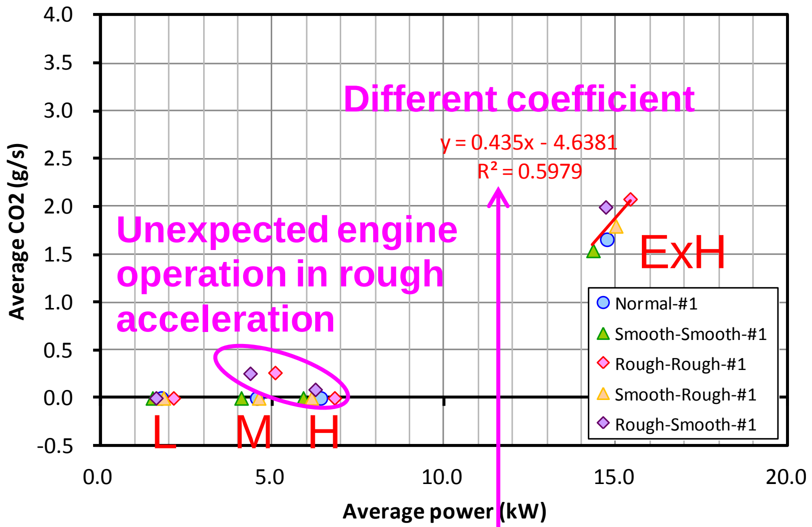
◆ CO2 on the CD test and R_{CDC} should be corrected.

R3. Impacts of driving style on the CS and CD test

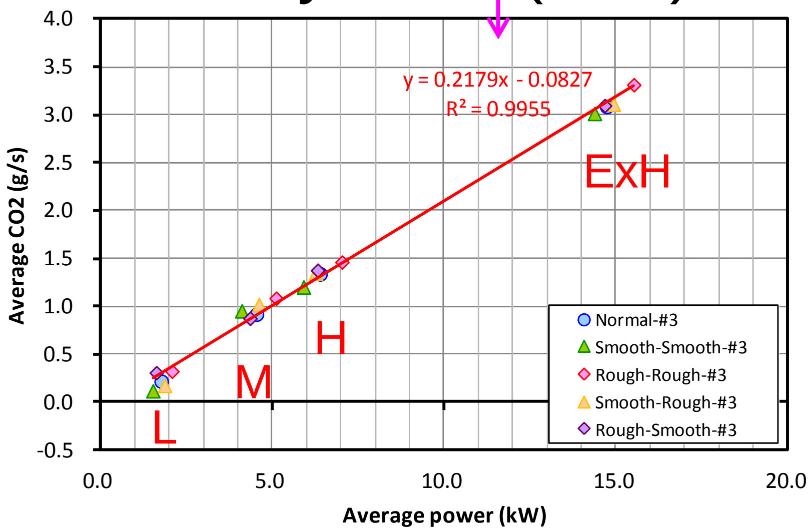
Item		Unit	Test results						Rate of change compared to the mean of Normal driving (%)					
			Normal-1	Normal-2	Smooth-Smooth	Rough-Rough	Smooth-Rough	Rough-Smooth	Normal-1	Normal-2	Smooth-Smooth	Rough-Rough	Smooth-Rough	Rough-Smooth
Range	AER	km	15.9	15.9	15.9	3.2	16.0	3.1	0.0	0.0	0.2	-80.0	0.6	-80.4
	EAER	km	17.8	17.7	17.8	16.1	17.4	18.9	0.2	-0.2	0.2	-9.4	-1.9	6.1
	EAER,L	km	26.7	26.7	28.4	21.2	24.9	26.6	-0.1	0.1	6.5	-20.7	-6.7	-0.4
	EAER,M	km	23.7	23.7	24.9	16.7	22.0	19.8	0.0	0.0	5.2	-29.4	-6.9	-16.5
	EAER,H	km	20.0	20.1	20.5	18.0	20.4	20.0	-0.2	0.2	1.9	-10.5	1.8	-0.3
	EAER,ExH	km	11.4	11.2	11.0	12.2	10.8	12.5	0.9	-0.9	-2.4	8.4	-4.3	10.3
	R_{CDA}	km	17.8	17.7	17.8	16.1	17.4	28.8	0.2	-0.2	0.2	-9.4	-1.9	62.2
	R_{CDC}	km	23.2	23.2	23.2	23.4	23.2	46.6	0.0	0.0	-0.4	0.6	0.0	100.6
CO2	$M_{CO2,CS}$	g/km	98.7	98.3	93.5	108.2	100.2	99.0	0.2	-0.2	-5.1	9.9	1.7	0.5
	$M_{CO2,CS,L}$	g/km	98.2	97.6	88.6	113.7	100.1	98.9	0.3	-0.3	-9.4	16.1	2.3	1.1
	$M_{CO2,CS,M}$	g/km	81.9	82.0	74.8	100.3	87.3	83.8	0.0	0.0	-8.8	22.4	6.5	2.3
	$M_{CO2,CS,H}$	g/km	87.1	86.8	82.7	92.9	87.6	86.2	0.2	-0.2	-4.9	6.8	0.7	-0.9
	$M_{CO2,CS,ExH}$	g/km	118.5	118.1	115.3	124.0	118.4	119.0	0.2	-0.2	-2.5	4.8	0.1	0.6
	$M_{CO2,CD}$	g/km	16.9	17.1	15.8	27.1	18.4	42.9	-0.5	0.5	-6.8	59.5	8.1	152.5
	$M_{CO2,weighted}$	g/km	61.9	61.8	58.6	71.6	63.3	62.3	0.1	-0.1	-5.2	15.8	2.5	0.7
EC	EC	Wh/km	164.4	164.0	162.6	180.7	168.0	152.3	0.1	-0.1	-1.0	10.0	2.3	-7.3
	EC,L	Wh/km	109.8	109.0	101.9	137.6	117.7	108.1	0.4	-0.4	-6.9	25.8	7.6	-1.2
	EC,M	Wh/km	123.7	122.9	116.3	174.3	133.0	145.3	0.3	-0.3	-5.7	41.3	7.8	17.8
	EC,H	Wh/km	146.1	144.8	141.6	161.9	143.4	143.6	0.5	-0.5	-2.7	11.3	-1.4	-1.3
	EC,ExH	Wh/km	256.9	260.2	262.8	237.8	271.1	230.6	-0.6	0.6	1.7	-8.0	4.8	-10.8
	$EC_{AC,CD}$	Wh/km	125.7	124.8	123.2	129.2	127.1	82.0	0.4	-0.4	-1.7	3.1	1.5	-34.5
	$EC_{AC,weighted}$	Wh/km	56.6	56.2	55.3	58.4	57.2	53.8	0.3	-0.3	-1.9	3.5	1.5	-4.6

R3. Relationship between power and CO_2 in CD test

◆CD cycle-#1



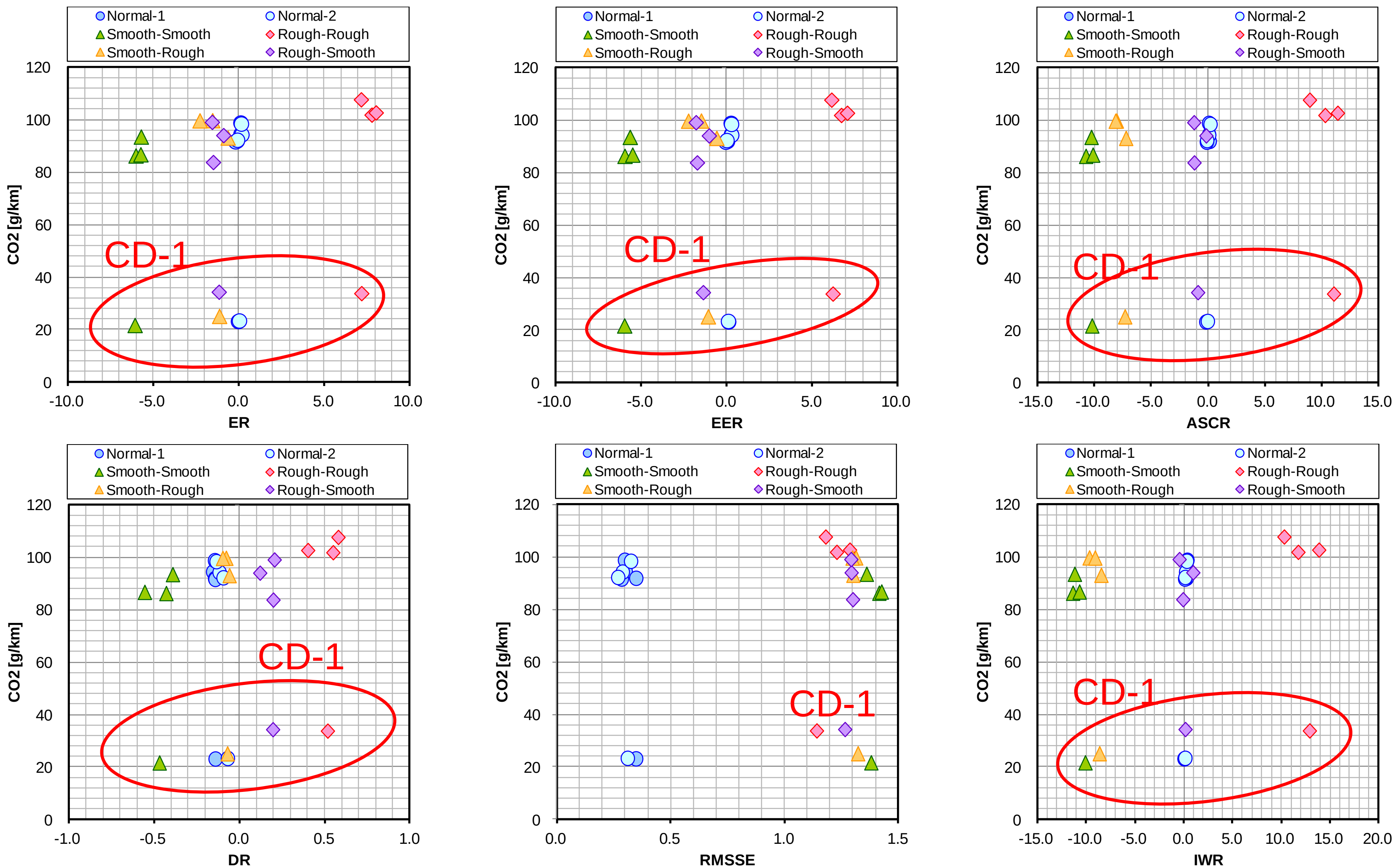
◆CD cycle-#3 (=CS)



- ◆ There was no relationship between average power and average CO_2 during L~M~H phase in 1st cycle.
- ◆ The vehicle specific veline concept can't use for CD test.
- ◆ The coefficient of regression line of Extra High phase of 1st cycle and the coefficient of regression line of 3rd cycle is different. (can't substitute)
- ◆ It seems difficult to compensate the CO_2 during CD cycle

R3. Drive trace Index of CD and CS test

CD-1, CD-2, CD-3 and CS test



R5. Energy flow of HEV