Japan Comments for Battery Durability GTR

24.March.2020

Contents

Status of In-Vehicle Battery Durability

- The EVE IWG has identified a potential solution for a durability GTR and has a proposal and timeline available as document (EVE-33-03-Rev#)
- Building on a proposal from Japan to adopt a battery State of Health monitor and by EU to add in service conformity checks, the future durability GTR may include:

1. Adoption of State of Health monitor (SOH)
2. Minimum performance requirement (PR)
3. In service conformity checks (ISC)
4. Adoption of vehicle normal usage indices (NUI)

Status of In-Vehicle Battery Durability

- The proposal includes a multi-phase approach where:
- Phase 1 *(By November 2021)*
  - Introduce a first version of a GTR with:
    - Minimum performance requirements established through consensus with vehicle manufacturers and all stakeholders
    - Adopt requirement for battery state of health (SOH) and normal usage indices (NUI) to be recorded by vehicle (e.g. on OBD)
    - Provisional in-service conformity (ISC) test which will include a way to consider usage of vehicle and a statistical method
    - SOH and NUI to be readable for ISC, and provides source of data for improving GTR in the future

Battery Durability Proposed mandate timeline

- (i) March 2020: Approval of mandate from AC.3
- (ii) January 2020 – June 2020: EVE IWG formulates new drafting group, and begins drafting GTR with elements agreed upon by EVE IWG
- (iii) June 2020: EVE IWG provides update to GRPE outlining details of draft outline of GTR
- (iv) June 2020 – December 2020: EVE begins validation testing of relevant aspects of the proposed procedure, assesses results and makes changes to GTR
- (v) January 2021: EVE IWG submits first draft proposal for the GTR as an informal document to January 2021 session of GRPE for further discussion and recommendation.
- (vi) January 2021- March 2021
  - a. EVE revises draft proposal based on recommendations from GRPE
  - b. Transmission of the draft GTR as an informal document twelve weeks before the June 2021 session of GRPE;
  - c. Endorsement of the draft GTR based on an informal document by GRPE.
- (vii) June 2021: EVE presents the final GTR to GRPE
- (viii) November 2021: establishment of the GTR by AC.3 in the Global Registry.
- (ix) January 2021-January 2024: EVE IWG continues information gathering on possible modifications to the GTR and develops amendments to the GTR for consideration by WP.29 and AC.3, as deemed appropriate.

Next Steps For Electrified Vehicle Durability

- Form a new drafting group and begin drafting a new GTR with elements agreed upon in the EVE's new mandate
- Start new validation testing during the summer of 2020 to facilitate the timeline of the new GTR

Contents

2-1.Required elements of the SOH test [OVER VIEW]

1.Vehicle equipment and OEM preparation

1) Preparation of SOH display or readout tool according to the following methods
   - (1) EV distance measurement
   - (2) Capacity measurement

2) Preparation of NUI data collection

2. Certification test

1) Check the SOH display or readout from OBD port
2) Confirm SOH in ECU are equivalent to measured SOH

3.Data collection

1) Read and Record the SOH and NUI values by the dealer, etc.
   (Purpose: Market Data Distribution Survey)
2) Implementation of WLTP by third party
   (Purpose: To check and confirm the accuracy of the display or readout)
3) Data aggregation from 1) and 2)

[PROPOSAL] State of Health monitor (SOH)

1） **Definition of SOH :**

The **capacity estimation value in the ECU** should be used in phase 1 of GTR

2） **Methods of verification**

These TWO methods should be prepared.

<EV range method >

SOH = Current EV Range/EV Range in CoC @ WLTP

<Capacity method* >

SOH = Current EAC / EAC in Certification Test report of WLTP

where, the denominator (EAC)is the value of the test report at the time of authentication.

i) For third-party evaluations or verification , make test report values available for them.

or ii) Add EAC to CoC, if necessary

***Need for Capacity Method**

It is desirable to prepare a verification method in consideration of the **development of HDV** with larger difference of Electric consumption depending on the vehicle type and **Re-use of the In-vehicle battery** to other purposes.

If the degradation of the electric consumption is considered to be negligible small, EV Range method and capacity method can be considered to produce the same results. [evidence in P.11]

[for information] Basic formula of SOH in ECU

SOH in ECU = Current Estimated Usable Capacity/Cert. Vehicle Usable Capacity(fixed value)

EV Range(in ECU)= Usable capacity in ECU / Electric consumption (fixed value).

The effect of Electric consumption degradation is negligible small

Japan has developed the guideline from an industrial perspective

Guideline of in-vehicle battery performance by Japan

(Partially excerpted and quoted)

The Guideline are designed to facilitate automakers to provide the basic methods which enable users to know state of health of LIB, so that users can get rid of excessive anxiety over battery degradation and re-sale values of EVs (Electric vehicle) and PHVs (Plug-in Hybrid Electric vehicle) can be evaluated properly . The basic methods shall (1) present initial performance of electrified vehicles and (2) help users understand objectively how much performance the vehicles maintain compared to their initial performance

Certified specification or specification in the catalogue such as **all-electric driving range** or **battery capacity shall be used to indicate how much performance the vehicles still preserve**

Two methods to verify the SOH are proposed , EV range and charge measurement.
The difference between the validation results based on EV range and battery capacity was examined.

1. **Validation in the EV range** includes not only a decrease in the EV range due to **battery capacity degradation**, but also a decrease due to a **degradation in electric consumption**.
2. In the **validation by capacity**, **only the capacity degradation of the battery** can be evaluated.

IF significant difference between the two validation methods exists, it would be a problem. So that we verified its possibility.

[EVIDENCE] Factors Affecting Electric consumption (Wh/km)

1.Way of thinking

1) Vehicle side factor (Tire and each part friction) is not considered:
it is the same as conventional vehicles.

2) Only the electric system components are considered.

(1) Increase in the internal resistance of the battery

(2) Motor and inverter electric system efficiency

(3) Friction of the rotating part of the motor

2.Estimation **(based on actual data by Toyota)**

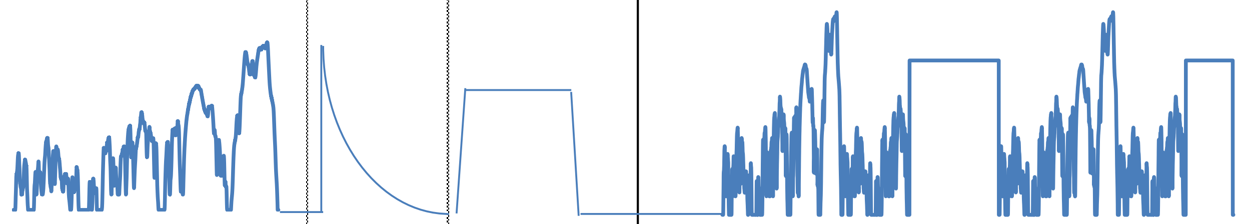
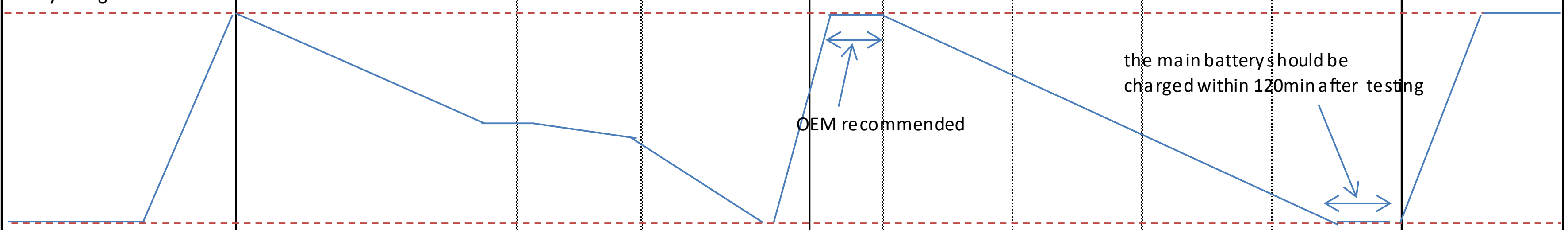
(1) Degradation of Internal resistance of the battery

(2) There is almost no deterioration in efficiency or friction of the electric system based upon our market data .

Even if the internal resistance degradation of the battery is estimated by the worst, **the influence on the electric consumption** of the aged Prius PHV **is 1.2%.**

Since these values will be far below the variation of EV range measurement, We concluded that degradation of electric consumption is Negligible small.

WLTP

		Day 0	Day 1			Day 2					Day 3	
TEST		vehicle preparation (charging battery)	vehicle warming up & coastdown matching preconditioning			Type 1: Electric Energy Consumption & Pure Electric Range testing Shortened Type1 procedure					test result calculation	
vehicle speed												n=2 if needed
Procedure		charging the main battery	vehicle warming up WLTC * 1 cycle	coastdown matching * fixed run method	pre-con & soaking, charging *discharging driving : constant speed @100km/h	EC & PER testing CSS speed : 100km/h Break off criterion : when the vehicle exeeds the speed tolerance for 4 consecutive seconds. (*)speed tolerance : 100 - 2 = 98km/h					soak & charging	Calculate the EC and PER
CDY mode			certification mode			certification mode						
SOC												n=2 if needed
measuring item	Cycle	–	WLTC	–	discharging cycle	–	DS1	CSSM	DS2	CSSE	–	–
	distance (km)	–	–	–	–	–	d_j	–	d_j	–	–	–
	electric energy change (Wh)	–	–	–	–	–	$\Delta E_{REESS,DS1}$	$\Delta E_{REESS,CSSM}$	$\Delta E_{REESS,DS2}$	$\Delta E_{REESS,CSSE}$	–	–
	electric energy (Wh)	–	–	–	–	–	–	–	–	–	E_{AC}	–

Range method : Ranges written in the Test Report

Sample : Prius PHV

2.5.3.7. Ranges:

2.5.3.7.1. All Electric Range AER

AER (km)	Test	City
AER values	1	
	2	
	3	
Final values AER		

2.5.3.7.2. Equivalent All Electric Range EAER

EAER (km)	City
EAER values	

2.5.3.7.3. Actual Charge Depleting Range R_{CDA}

R_{CDA} (km)	
R_{CDA} values	

2.5.3.7.4. Charge Depleting Cycle Range R_{CDC}

R_{CDC} (km)	Test
R_{CDC} values	1
	2
	3
Final values R_{CDC}	

2.5.3.7. Ranges :

2.5.3.7.1. All Electric Range AER :

AER (km)	Test	City	Combined
AER values	1	51.7	39.9
	2	-	-
	3	-	-
	Avg	51.7	39.9
Final values AER		51.7	39.9

2.5.3.7.2. Equivalent All Electric Range EAER :

EAER (km)	City	Combined
EAER values	51.9	40.4

2.5.3.7.3. Actual Charge Depleting Range R_{CDA} :

R_{CDA} (km)	Combined
R_{CDA} values	40.4

2.5.3.7.4. Charge Depleting Cycle Range R_{CDC} :

R_{CDC} (km)	Test	Combined
R_{CDC} values	1	46.5
	2	-
	3	-
	Avg	46.5
Final values R_{CDC}		46.5

Capacity method : E_{AC} written in the Test Report

ECE/TRANS/WP.29/GRPE/2020/4

Appendix 1 WLTP Test Report

2. Test results

2.1.1.5.2. Electric energy consumption of PEVs (if applicable)

Test 1

E_{AC}(Wh)	

EC (Wh/km)	City	Combined
Calculated values EC		
Declared value	-	

Test 2 (if applicable)

Record test results in accordance with the table of Test 1

Test 3 (if applicable)

Record test results in accordance with the table of Test 1

EC (Wh/km)	Low	Medium	High	Extra High	City	Combined
Averaging EC						
Final values EC						

Information for COP

	Combined
Electric Energy Consumption (Wh/km) $EC_{DC,COP}$	
AF_{EC}	

The UNR WLTP, which was approved by the GRPE in January of this year, requires the inclusion of EAC in test report.

This value will be used as the initial value of the capacity method.

JARI validation studies

JARI measured both the EV range and the amount of charge of Prius PHV and LEAF based upon the METI guideline made by Japan.

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Guideline of in-vehicle battery performance by Japan

(Partially excerpted and quoted)

The Guideline are designed to facilitate automakers to provide the basic methods which enable users to know state of health of LIB, so that users can get rid of excessive anxiety over battery degradation and re-sale values of EVs (Electric vehicle) and PHVs (Plug-in Hybrid Electric vehicle) can be evaluated properly . The basic methods shall (1) present initial performance of electrified vehicles and (2) help users understand objectively how much performance the vehicles maintain compared to their initial performance

Certified specification or specification in the catalogue such as **all-electric driving range** or **battery capacity shall be used to indicate how much performance the vehicles still preserve**

III. Examples

Quoted from Guideline Ver. 1.0

Case 1. Indication of state of health based on **all-electric driving range**

① This method provides **how much proportion of all-electric driving range** an EV and PHV **maintain against the range referred to in catalogue**. *1 *2

② The State of health is **measured by using Electronic Control Unit in vehicles**.

③ **The State of health** through Vehicle diagnostic tools shall be indicated on this tool, the **instrumental panels**, **or** the **portable information terminals** such as smartphones upon request of users.

④ The State of health is indicated in 10% increments.

III. Examples

Case 2. Indication of the state of health based on **the battery capacity** (in vehicle*3)

① This method provides **how much proportion of the battery capacity preserved** in an EV and PHV against the capacity referred to in the catalogue. *4 *5

② The State of health is **measured by using Electronic Control Unit in vehicles**.

③ The State of health through Vehicle diagnostic tools shall be indicated on this tool, the instrumental panels, or the portable information terminals such as smartphones upon request of users.

④ The State of health is indicated in 10% increments.

JARI Validation Test results（Prius PHV & Leaf）

1.Verification of consistency between SOH indication value and battery capacity degradation by the range and capacity method
2.analysis of variation

表 1 プラグインハイブリッド車のばらつき解析結果

Prius PHV		JC08 N=1	JC08 N=2	1回目と2回目の difference	1回目と2回目 割合	1回目 Difference of Drive Index の差(RMSSE)	2回 の差(IWR)
EV range	Vehicle A	65.8km*	68.5km	2.7km	4.1%	0.03km/h	0.08%
	Vehicle A With compensation	67.8km	68.5km	0.7km	1.0%	0.03km/h	0.08%
	Vehicle B	68.8km	67.4km	1.4km	2.1%	0.02km/h	0.01%
AC Charge Amount	Vehicle A	6.14kWh	6.07kWh	0.07kWh	1.2%	–	–
	Vehicle B	6.09kWh	6.09kWh	0.00kWh	0.0%	–	–

*The vehicle was stopped for 40 minutes due to the emission analyzer trouble.

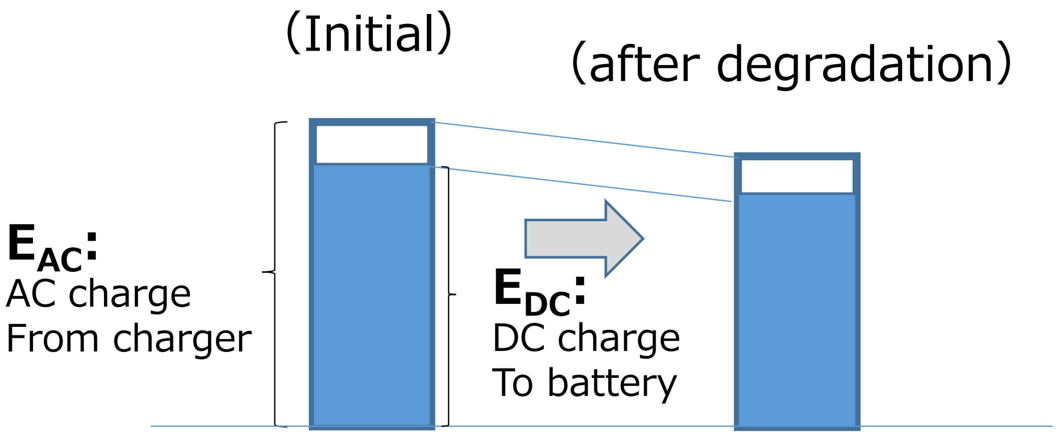
表 2 電気自動車のばらつき解析結果

Leaf	WLTC N=1	WLTC N=2	WLTC N=3	最大と最少 Max. difference	最大と最少 合
EV range 離 (4phase)	262km	255 km	255km	7km	2.7%
AC Charge Amount	44.68kWh	44.67kWh	44.67kWh	0.01kWh	0.0%

Although the variation of the distance method is sufficiently low
The variation of the capacity method is even smaller.

Variation factor for Range method
1.driver's operation
2.acceptable operation within the WLTP

Capacity evaluation: Ascertain the amount of battery charge in the vehicle



Capacity evaluation :
Compare the AC charged amount to the initial values at the time of authentication.
・Can be evaluated with relatively good reproducibility.

Issue:
Amount discharged from the charger includes the loss (white portion of the figure above)
If there is a difference in the rate of change of this part after the deterioration, an error might occur in some level.

E_{DC} (Wh) = Battery Voltage x Batt. Current x Time
E_{AC} (Wh) = Charger Voltage x Current x Time

E_{DC} (Wh) = E_{AC} (Wh) x AC_DC efficiency (Charger, 12V_load)

SOH has to be
$SOH_{DC} = E_{DC}now / E_{DC}int$

Easy to measure
$SOH_{AC} = E_{AC}now / E_{AC}int$

表 4　設計 typ. 値および認証値からの低下割合

		Vehicle A	Vehicle B
Capacity	Typical designed value	25.00Ah	25.00Ah
	Measured value by Toyota ﾉた値）	22.01Ah	22.44Ah
	低下割合	88.0%	89.8%
EV Range	Certi. value	68.2km	68.2km
	JARI result (Ave.)	67.2km	68.1km
	低下割合	98.5%	99.9%

Design median :capacity without ECU control

Measured data :capacity without ECU control as defined and measured by Toyota

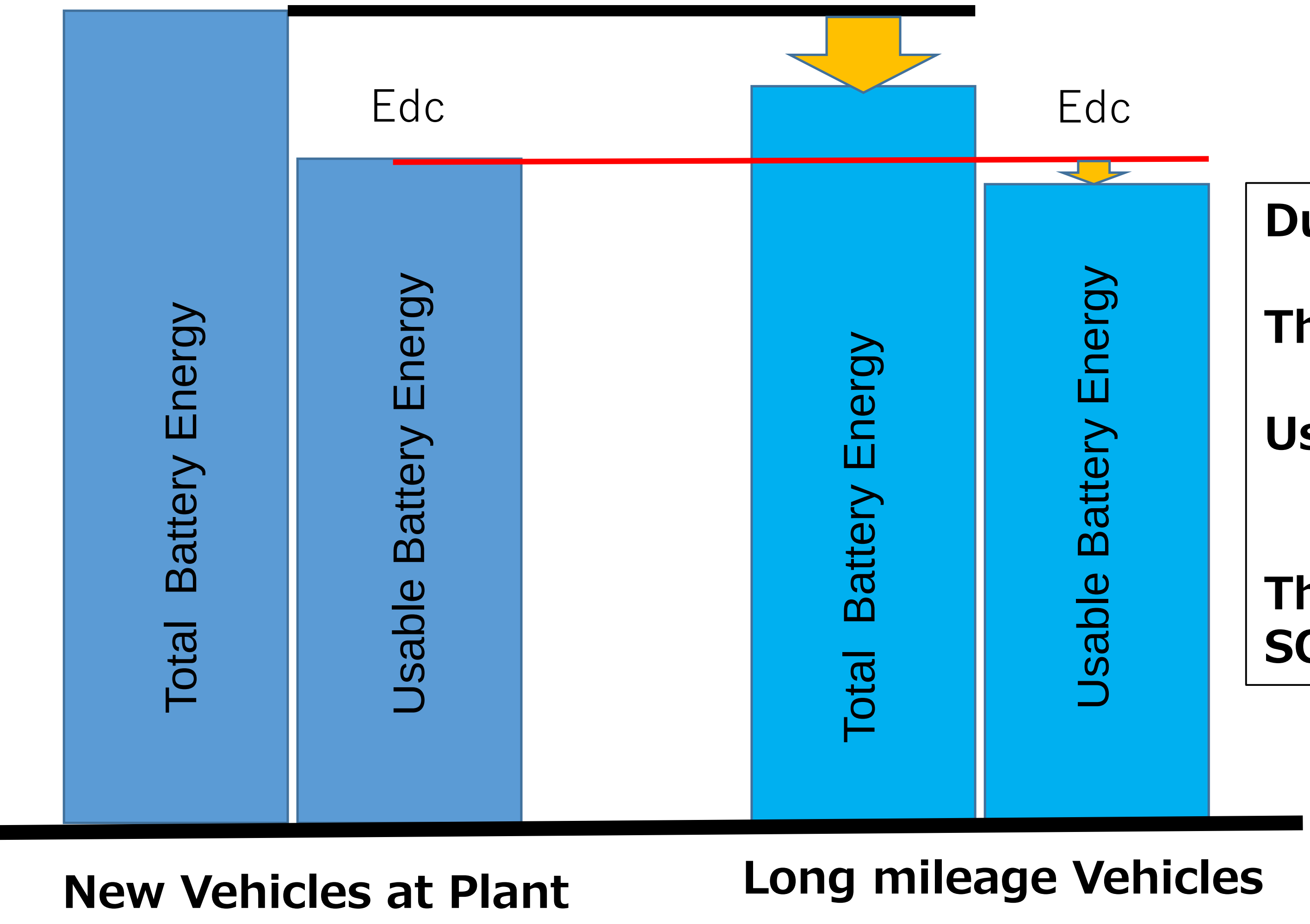
	Vehicle A	Vehicle B	
mileage	45,316	41,944	(Km)
Cert.Value	68.2	68.2	(Km)
Validation	67.2	68.1	(Km)
SOH	98.5	99.9	(%)
SOH@ECU	97	94	(%)

As the battery capacity decreases, the SOC range that can be actually used is widened, so that the control of the initial degradation characteristic specific to the battery and the relaxation of the decrease in the EV range can be made possible.

1.SOH is determined by the control-constrained capacity (EDC).
= > utilize the calculated EDC value in the ECU
Estimated EV range is calculated as EDC/Electricity consumption (fixed value for each mode)
2.The initial value of EDC in the denominator of SOH is less than 25 Ah inclusive of the initial degradation.
3.The current EDC value of in the numerator of SOH compensates the capacity degradation by expanding the SOC range

4.Calculated SOH in ECU, vehicle A: 97%, vehicle B: 94%
(Reference: Certified vehicle battery capacity is positioned 50% lower than the center of the designed Typ distribution.)

Battery Energy Management



Due to aging of battery capacity

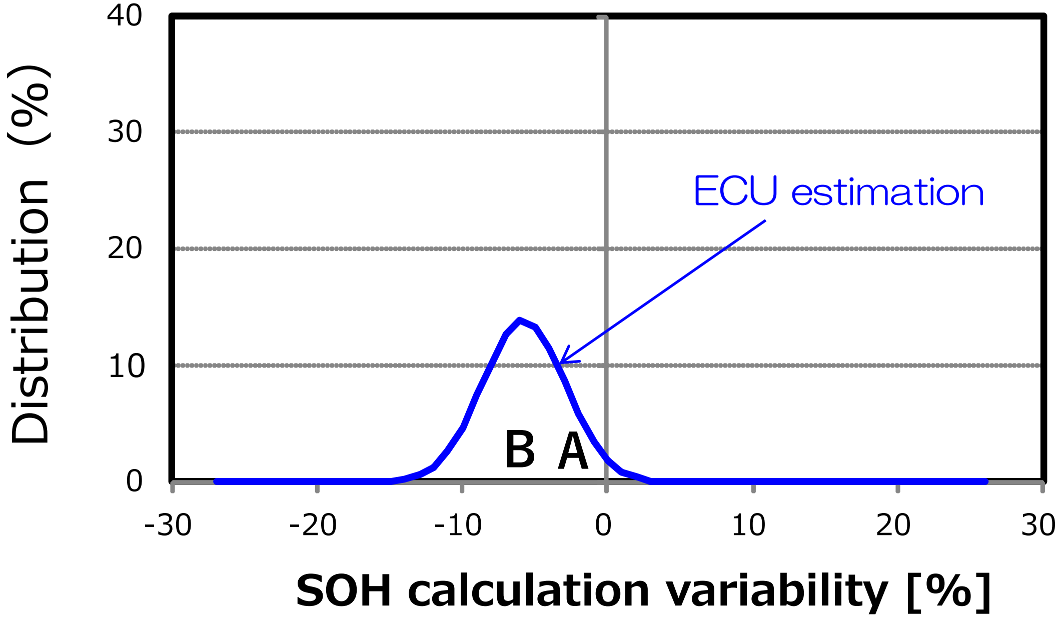
There is the tendency to degrade more early

Usable Battery Energy (UBE) can be increased by control

Therefore,
SOH should be determined by UBE

ECU estimation accuracy of SOH

2012MY Prius PHV (previous Model)



Current model has not recovered yet

[%]	-99 Percentile	Average	+99 Percentile
Calculation error in in-vehicle ECU	-12.0	-5.3	1.4

Variation factor of capacity in ECU

1. Current and voltage sensors
2. Characteristic deviation of SOC-voltage relationship
3. Other, such as conservative estimation…

In the previous model, SOH in the in-vehicle ECU is lower than the measured true value by 5% on average and varies in a range of about 15%. Accumulating design tolerance further increases the variation.
Note; Vehicle A and B are within this variation.

2-2．Minimum performance requirement (PR) [PROPOSAL]

Minimum Performance Requirement

1) It will be desirable that The criteria of substandard battery will discussed and the consensus will be reached within EVE.
2) The warranties of each company do not show performance based on common measure, because each OEMs determine the warranty levels as a competitive area.
3) SOH information on past vehicles linked to usage information is only held by each company and cannot be shared.
4) Information on user expectations might be useful, which is one of the criteria for judging low or unexpected battery quality.
   (Example: Are short distance EV and long distance EV the same user expectations?

<Proposal>

A harmonized value (or harmonized determination method of Minimum PR) should be discussed in EVE with consensus from expected value of each CP, (from the costumers), and the proposed value based on the past data of each OEM.

2-3. In service conformity checks (ISC) [PROPOSAL]

1.way of thinking

1) Understand the traditional ISC (Europe and the United States) procedures for exhaust emissions
2) For the purpose of Phase 1, only the minimum necessary procedures are extracted.
3) A new NUI collection procedure needs to be added for Phase 1 purposes.

2.Phase 1 ISC Objectives

1) Collect Data
2) Elimination of substandard batteries or products

Data should be collected as much data as possible with less burden (time and cost)

3.Proposal

1)Collect ECU information of SOH and NUI from OBD port at dealer or net work communication (market data distribution survey)
= > Register to the authorities' platform
2)Conduct ISC (Check the accuracy of the SOH indication) by a 3rd party organization for a EV/PHV family selected arbitrarily from the above SOH information groups.
= > Compare and validate against collecting SOH in ECU.
3)Inform to the public the above SOH results. But collected NUI does not open to the public.

Reference of battery degradation ISC - Overview of exhaust gas ISC -

■Sampling rules for exhaust gas ISC

■ISC vehicle numbers (exhaust gas)

Sales volume	1～ 5,000	5,001～ 15,000	15,001～ 50,000	50,001～ 250,000	250,001 Or more
LOW mileage (10Kmile or more	voluntary	0	2	3	4
High mileage (50kmile or more)	voluntary	2	4	5	6

■ISC vehicle numbers (exhaust gas)

Following numbers for each family
1 test with less than 5000 ~ 100000 units registered (At least 3 x 1)
2 tests with 100,000 to less than 200,000 units registered
(Minimum of 3 x 2)
3 tests with more than 200,000 units registered (At least 3 x 3)
1 Test is at least 3. The statistical method will increase up to 10.

<u>Comments</u>

Considering the number of units specified by the exhaust gas ISC,
Assuming that 100,000 electric vehicles were sold,
The numbers of the battery degradation ISC will be 8 in US and 6 in EU.

The main objective of Phase 1 is to collect a lot of market data on battery degradation, but the ISC of exhaust gas sampling protocol requires a small number of samples.

Compared with exhaust gas ISC, battery degradation ISC (WLTP Test) requires AER test/charging capacity measurement which needs considerable time, cost and equipment.

2-4. Adoption of vehicle normal usage indices (NUI) [PROPOSAL]

1. NUI information

To understand how traction batteries are used in the market,
we suggest that the following items be collected from the OBD port
or net work communication .

NUI information

Item
ID information linking SOH to NUI
Battery temperature
Battery voltage
Battery current
SOC
Number of charges
Number of fast charges
Mileage
Number of V2X

2. Data Processing [DISCUSSION POINT]

Following discussions and comparison are necessary.

1) In China, vehicle information is not processed on an individual vehicle ECU but is always transmitted to a communication center. the information is processed in the communication center and it becomes big data.

2) To perform information processing simultaneously with data accumulation by an individual vehicle ECU. In order to index the information, the analysis format corresponding to NUI information should be considered beforehand (Distribution, etc.). ECU information is collected at ISC and summarized at the center.

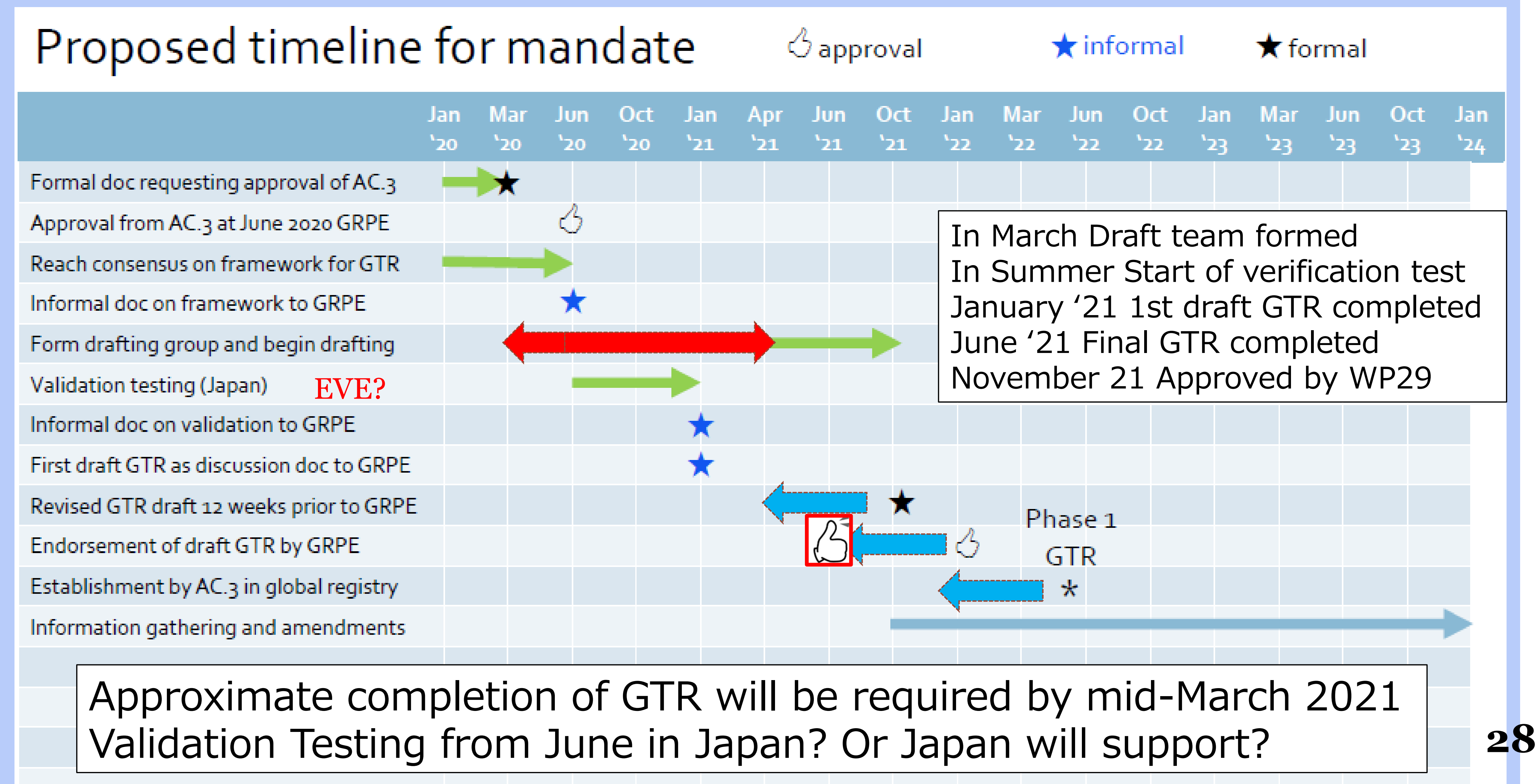
Comparison between 1) centralized control system(China NEV) and 2) vehicle ECU processing system

	Pros	Cons
1) centralized control system	1. Small ROM/RAM capacity in vehicle ECU 2. Just to decide on the information 3. Can change analysis method later 4. Can Collect all vehicle information	1. Communication equipment required for vehicles 2. the communication center(*) is required. 3. Data analysis capability is required at the communication center. 4. Confidentiality 5. Burden of communication expenses
2) vehicle ECU processing system	1. Communication equipment and communication center is not required. 2. Findings can be incorporated for analysis 3. highly confidential	1. Small ROM/RAM capacity in vehicle ECU 2. Need a unified data processing format 3. Authorities need information centers, OEM needs a management server 4. workload at the dealer

(*)For each CP or each OEM

Contents

3 – 1 GTR Time Line



In March Draft team formed
In Summer Start of verification test
January '21 1st draft GTR completed
June '21 Final GTR completed
November 21 Approved by WP29

Approximate completion of GTR will be required by mid-March 2021
Validation Testing from June in Japan? Or Japan will support?

3 -2 Validation [DISCUSSION POINT]
Basic evaluation is based on the WLTP procedure.
(Assumed to be implemented in Europe/US/Canada)

<WHAT HAVE DONE in JAPAN>

Items implemented by JARI (with OEM)

1.Verification of consistency between SOH indication* and battery degradation level

   1 -1 Compare with EV Range and SOH indication value

   1 -2 Compare with Charge capacity and SOH indication value

2.Analysis of variation

3.Verification of the test method itself. (Identifying defects and improvements)

*SOH indication or software is already installed in Prius PHV and LEAF

<u><Future validation in summer 2020></u>

What should be done by “validation testing”?

(needs to be discussed in EVE)

Concern:

Expect implementation at the JRC/EPA/ECCC.

Europe/US OEM Support will be strongly Required