UNECE EVE-IWG

In-Vehicle Battery Durability

OICA comments on EVE-41-03

EVE #42 meeting

08. January 2021

Overview of topics with OICA concerns

- Inputs for MPR discussion:
  - TEMA model
  - Assumption of capacity reserve
  - Geotab database
- Averaged MPR concept vs Backstop concept
- MPR levels for PHEV / BEV and M1 / N1 vehicles
- Timeline of In-Vehicle-Battery GTR development

Concerns on input for MPR discussion → TEMA model

Concerns on TEMA model:

- The purpose of the TEMA model was not clear from the beginning
- The validation of the results was questioned many times from OICA
- It was offered to the industry to check the model and compare it with in-house simulations

  → When this was requested by Volvo Cars it was not possible
- Since the TEMA model was presented as main source for the MPR level, OICA continuously asked for access

  → This was not possible, finally JRC stated the reason is that TEMA has no user interface
- Limited representation of vehicles designs in TEMA, e.g. vehicles designed for heavier and van use cases not covered

OICA has consolidated an open question list, please refer to the Backup:

Besides questionnaire, OICA proposed a workshop in order to clarify the open points

→ Up to now no reply to the questions, the workshop proposal was rejected.

Concerns on input for MPR discussion → Assumption of capacity reserve

The TEMA model has the clear asumption of a capacity reserve for BEV (15%) and PHEV (25%)

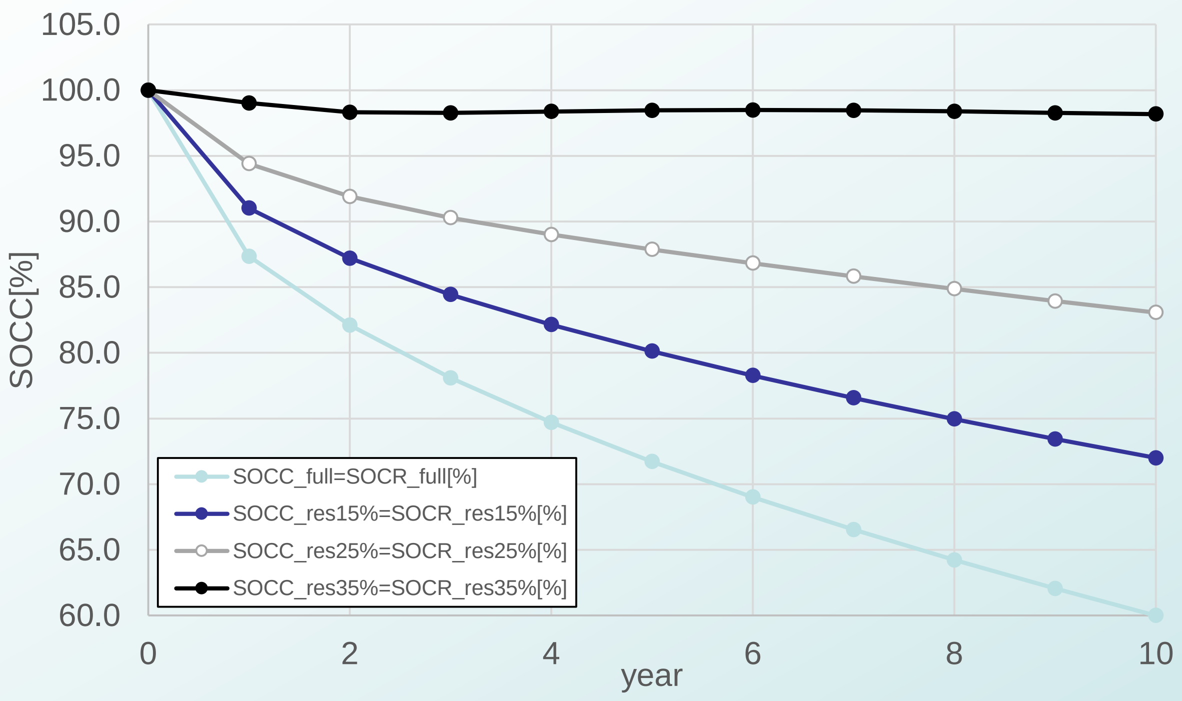
- This values were taken following an oral information of OEMs some years ago but should not be used as basis for setting up the MPR level → These figures can be possible but are not mandatory installed in all vehicles
- Current MPR proposal (based on TEMA) is taking this capacity reserve which means that a capacity reserve for aging effect compensation will become a mandatory requirement

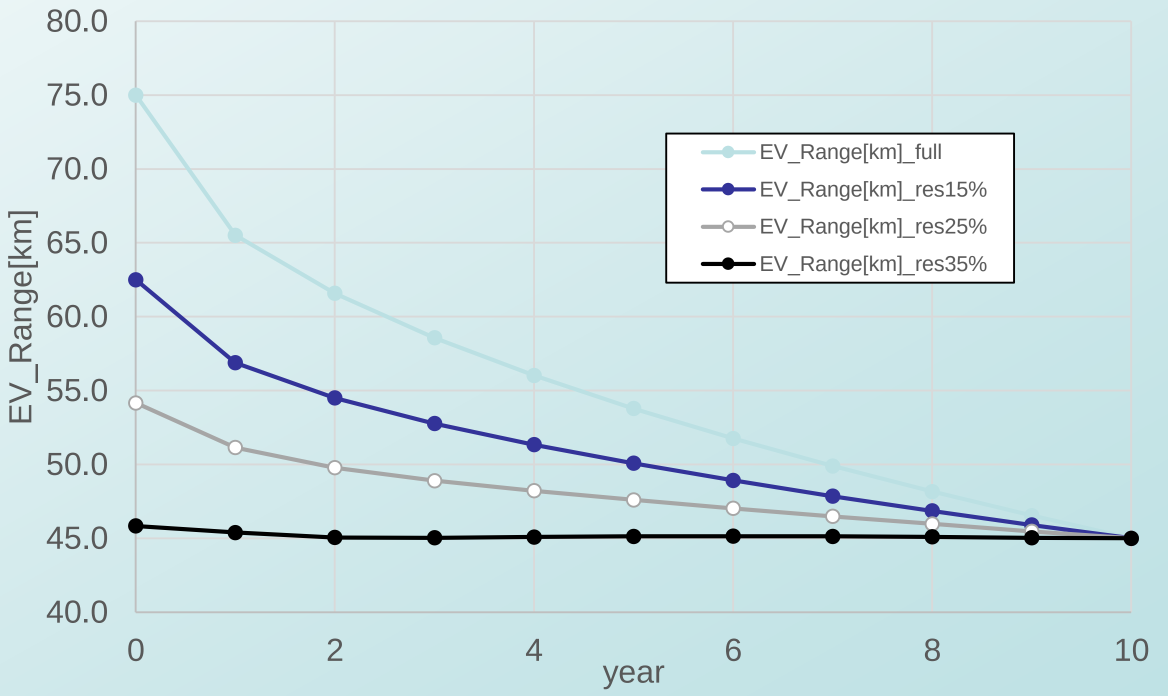
➔ Minimum reserve is technically required for purposes like battery protection but not for aging compensation

➔ All OEM aiming to keep reserve as small as possible to avoid unnecessary cost, weight and higher consumption

Concerns on input for MPR discussion → Assumption of capacity reserve

Example for showing the effect of a capacity reserve*





***source: Toyota estimation**

Concerns on input for MPR discussion → Impacts of capacity reserve

Battery reserve has a significant negative impact on driving electric consumption and vehicle price/running costs:

- Additional weight with reserve → constantly higher energy consumption during operation
- Additional costs with reserve → for less range degradation over lifetime, more battery is required

Negative consequences on important customer and environmental aspects:

- Higher consumption footprint (environment); higher running costs (customer)
- Less affordable vehicles as consequence (customer, environment)
- More battery replacements means “more batteries” (environment impact just shifted to another area → big picture?)

Too challenging requirements and therefore required battery reserve not appropriate as:

- Customer may not want constant performance over lifetime if that is coming along with a higher vehicle price and a higher running electric energy consumption, customer wants transparency → provided by UBE indicator
- Negative environmental impacts due to higher running vehicle electric energy consumption and more replacements

➔ **Excessive MPRs based on larger reserve are slowing down the spread of electrification of mobility and will reduce the positive environmental impact of these vehicles**

Concerns on input for MPR discussion → Geotab database

Limitations & Open Questions

- The prediction for the fleet may not be accurate due to limited vehicle models used in this analysis (probably the data from less than 1/3 vehicle models around the world have been available in GEOTAB database).

- How does GeoTab access vehicle data? Is it through an aftermarket OBDII port device?
  - If so, how does that device communicate to read out values of interest?

- What confidence do we have in the capacity data?
  - The battery capacity data from GeoTab may be hacked from the automaker onboard calculations for SOH
  - If GeoTab is attempting to calculate their own SOH using data on remaining capacity and state of charge, there will likely be problems as those values, developed and used within the vehicle CAN system, may not be as simplistic as GeoTab assumes.
  - GeoTab data likely doesn't account for the SOH accuracy issues that automakers are struggling with as they compare SOH calculation results with actual battery capacity values

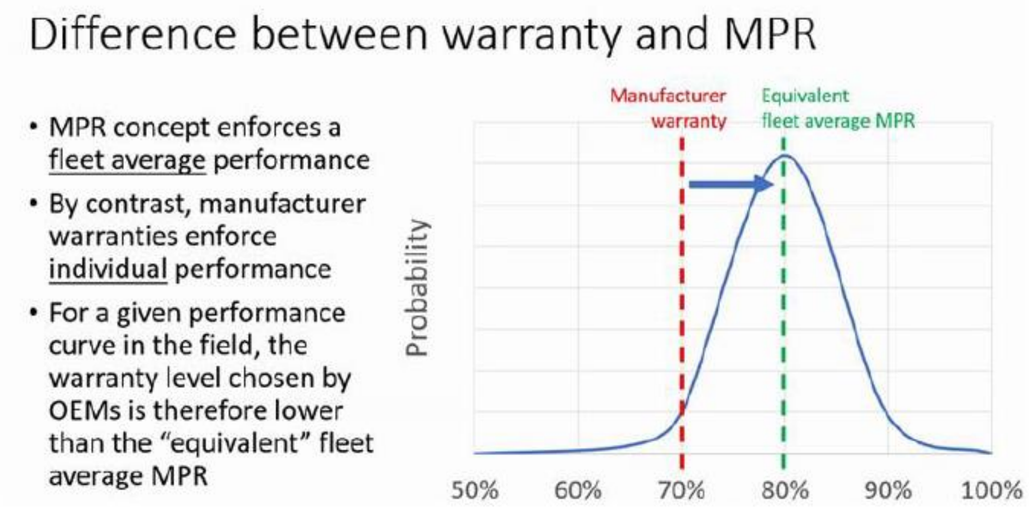
- It is highly unlikely that GeoTab has any actual measured data on battery capacity to go with the data they took from the OBDII CAN bus
  - CAN bus numbers can look really clean, with no indication of just how much of an approximation they are.

- Potential prospects of a deeper data analysis with GEOTAB
  - Opportunity for performing higher fidelity studies.
  - Individual vehicle data, as opposed to family data.
  - Determine differences between vehicles with (alleged) battery energy reserve vs. those without.
  - Other factors, such as thermal management, fast charge, etc.

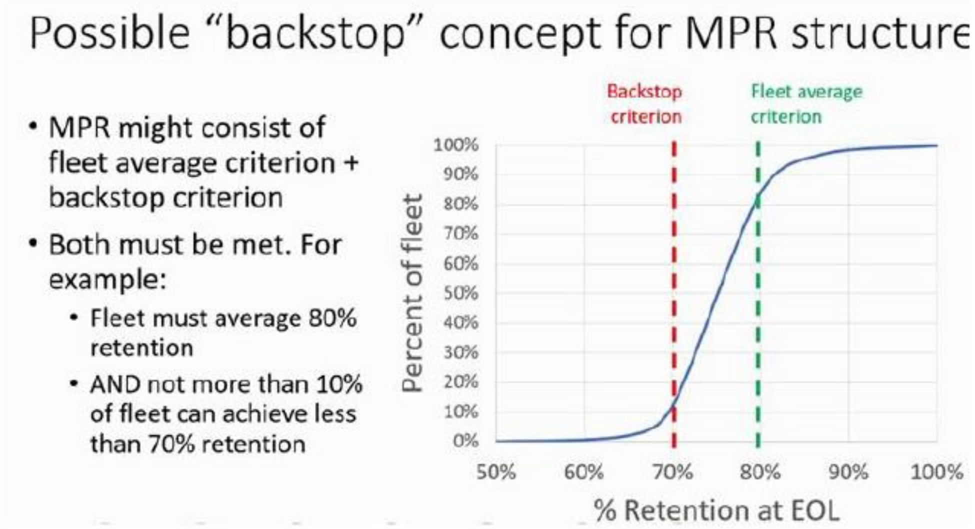
Reflections on Backstop concept and fleet average concept

Explanation of the backstop concept with the following figures from EVE-40-02-Rev1e

NOTE: the concepts presented here are for discussion only, and values presented are only for illustration of the concepts.



NOTE: the concepts presented here are for discussion only, and values presented are only for illustration of the concepts.



Key concerns from OICA:

- The shape of the curve is critical as at this stage, OEMs don't know the shape of the curve:
  Different regions, driving profiles, battery chemistry all play into the shape, etc.
- TEMA model cannot be used for creating the shape of that curve as TEMA still needs further evaluation

➔ Phase 1 with implemented SOCC and SOCR should be used to identify the distribution in the field and the shape of the curve

Reflections on Backstop concept and fleet average concept

- The MPR level verification was understood from the beginning as an average value („big picture“)

  → The environment is not interested in the single vehicle, the environment is interested in the big picture

  → Individual customers below the MPR could still be handled by provided manufacturer warranty

- Fleet average concept not requiring concept to exclude vehicles with abnormal usage and from extreme regions

  → Benefit: No vehicles selection process required (abnormal usage and extreme region vehicles compensated)

- Backstop concept is requiring a concept to exclude vehicles with abnormal usage and from extreme regions

  → Concern: No vehicle selection process is currently in place (means vehicles with extreme usage included)

  → Vehicle selection process still need to be developed and conditions for read out need to be defined

Reflections on MPR level proposal

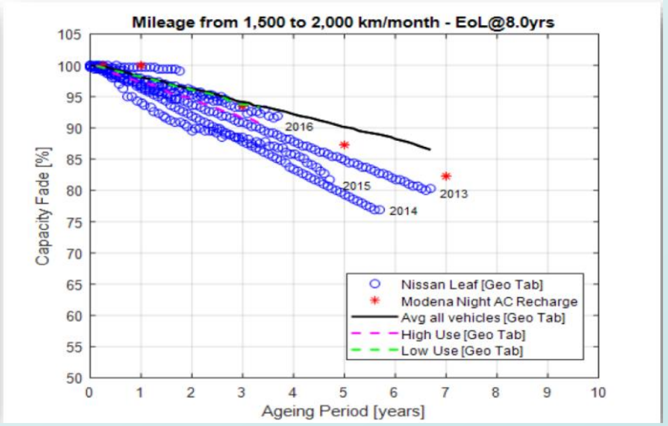
Different view between OICA and legislators on the definition on „What is a substandard product?“:

- Legislators view:

  Warranty conditions are defining an appropriate separation level for standard from substandard products

- Industry view:
  - Considered warranty conditions are taken show mainly from upper level vehicles from quality manufacturers
  - Warranty conditions are competitive and have also marketing related components

*Source: Geotabe data from EVE-41-03e



According to the shown GEO tab data in EVE-41, there are cases where the Nissan LEAF does not meet the 5 year 80%.

Does this indicate that proposed MPR judged LEAF as a substandard product to be excluded from the market?

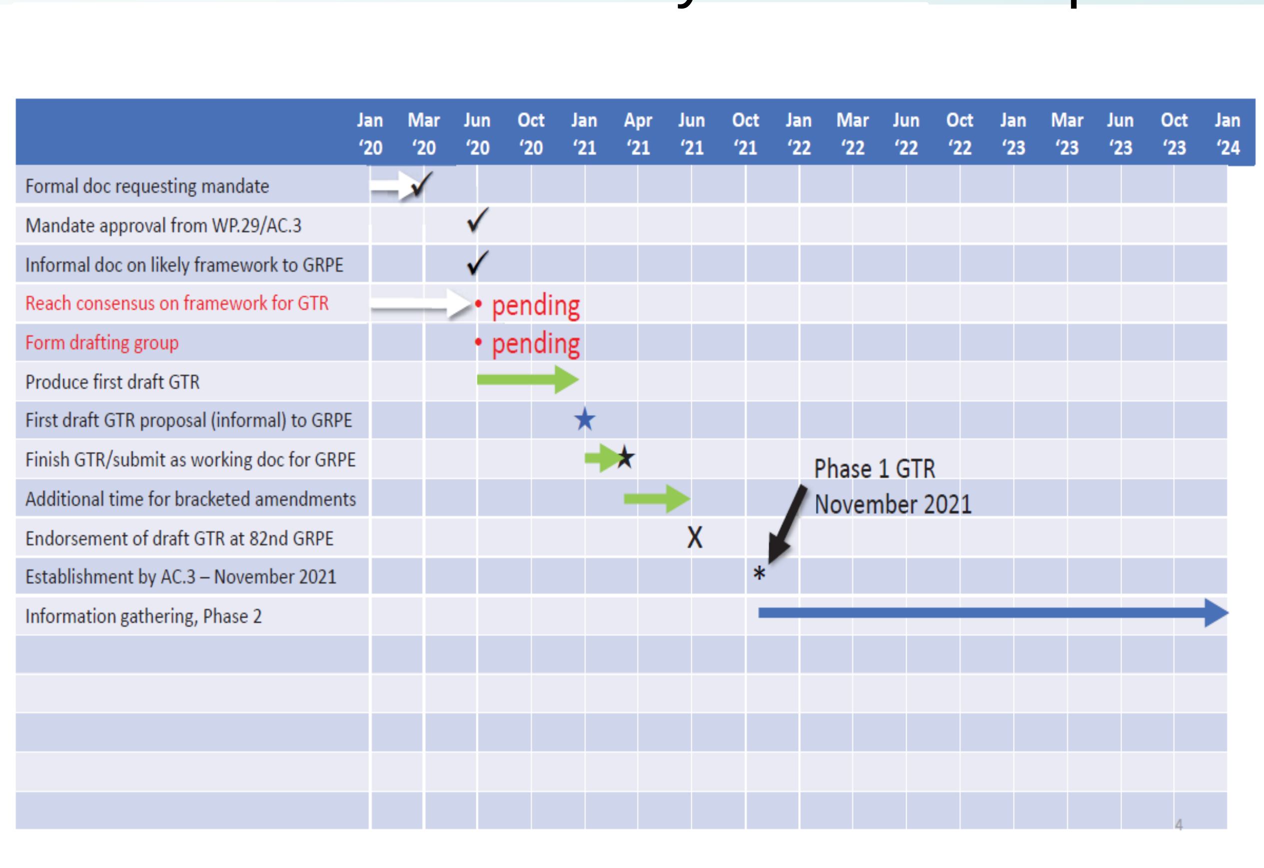
Concerns on timeline of In-Vehicle-Battery GTR development

Currently planned timeline from IWG EVE

→ Informal Document January 2021

→ Working Document June 2021

(submission March 2021)



OICA concern:

- Currently planned timeline is very ambitious
- OICA is supporting the GTR development actively following the very tight meeting schedule
- Many topics are still in intensive discussion and require further evaluation (see slides before)
- Details of the procedure and the process need to be well defined to avoid any unexpected impacts which would need to be corrected later on anyway

OICA recommendation → In case of missing agreements the additional time in the mandate should be used

Backup

Questions on the TEMA model

Input from ACEA, JAMA and AI member companies compiled by Annika Ahlberg Tidblad 2020-12-05.

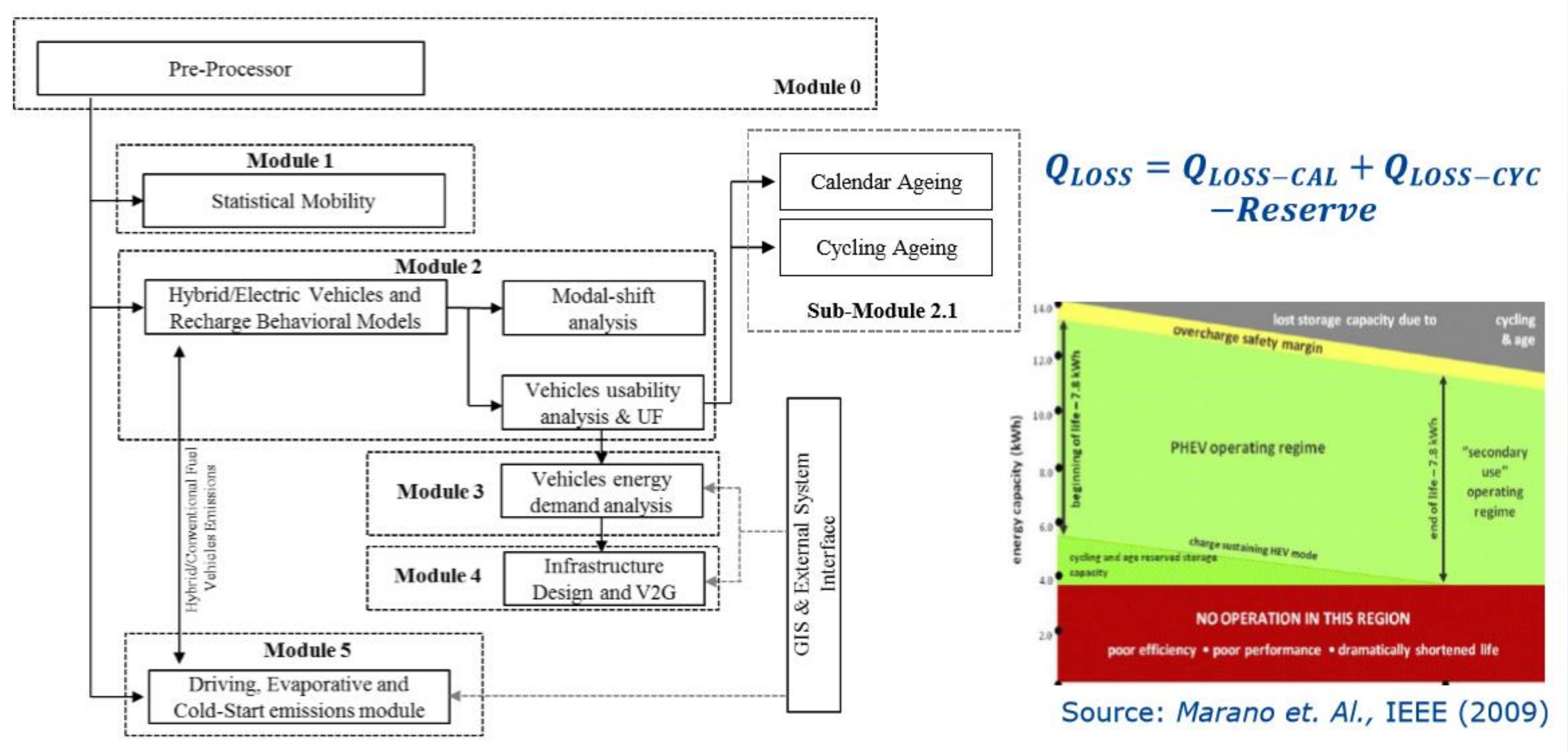
Documents reviewed:

EVE-22-07; EVE-23-08; EVE-24-10; EVE-28-13; EVE-30-12; EVE-32-13; EVE-33-07; EVE-34-16; EVE 36-09; EVE-38-02

General questions and comments:

1. The transitions between data analysis and simulations is unclear in the presented material, especially regarding Big Data. Is the Big Data only used for data analysis and to calibrate the model, develop customer profiles or is it used also as input into the model?
2. What is the age span and distribution of the vehicles in Big Data? Differences in the Big Data sets with respect to BEV and PHEV, i.e. age distribution, population size, types/categories of vehicles, etc?
3. What are the sources of the Big Data? Car pools, professional drivers, household vehicles,..? Relative distribution of sources?
4. Benchmarking against other lifetime prediction models is essential. How do you propose this can be done?

Model construction (EVE-23-08):



OICA

Questionnaire on TEMA model

1. What are the input and output parameters in the different modules (1-5)? (To be able to track how parameters are used in the model)
2. What assumptions are made in the different modules) (To analyze error multiplication effects and accumulated errors)
3. Life prediction estimates (year and milage) are outputs from Module 2. How does Module 4 feed back to module 2 for life estimations including e.g. V2G ageing?
4. Please explain the diagram on the right. What does it mean and what is the relevance for the model?
5. GIS and External System interface – is this where the geographic and climatic impact factors are introduced? If yes, then why is this only feeding into Module 3, 4 and 5?
6. Module 5 appears to be associated with ICE operation in PHEV. Is this correct?
7. Usage conditions (e.g., 25% reserve for PHEV and 15% reserve for BEV) and results/sample size (e.g., EVE-30-12e.pdf & EVE-34-16e.pdf data comparison for Nissan Leaf and Tesla) are limited and not representative of how all OEMs may choose to use the battery and how batteries will degrade in the field. Many PHEVs and BEVs use smaller reserve (many of today's BEVs can use <10% reserve).
    a. *How are the energy reserves positioned relative to battery SOC?* Positioning of this reserve band will have a significant impact on the degradation characteristics of the battery. This effect is highly nonlinear and specific to a given battery design. Neither Sarasketa-Zabala et Al. nor Cordoba-Arenas et Al. conducted testing with fine enough granularity to determine the aging characteristics accurately with respect to SOC. For example, Sarasketa-Zabala et Al. used only 3 SOC points, while Cordoba-Arenas et Al. did not consider the effect of different upper SOC values.
    b. It is unclear how the model takes the "reserve" capacity into account? Is it assumed that the "reserve" is an isolated part of the battery, which is not used? This is unrealistic, and it is much more likely that the "reserve" is used and ages together with the rest of the battery. Needs to be elaborated.
        i. How were the "reserve" values (25% for PHEV and 15% for BEV) determined?
        ii. How does is the "reserve" treated in the capacity retention (UBE) algorithm?
        iii. What is the sensitivity for "reserve"?
        iv. Is it the intension of TEMA, and the GTR, to force battery designs with huge "reserves"?
        v. How does the model consider trade-off between capacity retention and battery life prediction against negative environmental impacts from oversized batteries (added weight, added energy consumption, added material and energy resources in production,..) and reduces total energy throughput (per Ah of battery) during the lifetime of the battery?

Questionnaire on TEMA model

Assumptions:

EVE-24-10

1. The strong dependency on architecture is surprising and is most likely an indirect consequence of parameters hidden in the assumption, mainly related to the temperature profile inside the battery pack.
   a. What assumptions are made about the vehicle electric architectures?
   b. What cooling strategies are included and considered? How are there accounted for in the model?
   c. Thermal management and cooling strategies is an area where significant technical advances have been and are continued to be made compared to when TEMA was developed. How can the model take this into consideration in order to reduce errors introduced by this assumption?
   d. Connections (parallel/series)? Why focus on type of connections? The load vs capacity rating is main factor, whether the load is managed by a single cell (with high capacity) or several cells in parallel (each with a lower capacity) is not relevant. Reasoning is unclear.
2. "*The model assumes average quantities in the reference period per each vehicle for DOD, C-rate, Ah-throughput and temperature*"
   a. How are the averages of the different parameters derived?
   b. What temperature is inferred here, battery or ambient temperature?
   c. What is the impact of substituting static values for dynamic parameters on the model results??
3. The model assumes the BMS regulates the battery temperature between 22-27 °C in the cycling capacity fade model. This is a very rough assumption that is unlikely to apply in most vehicles. OEMs must balance vehicle operating efficiency with battery life in the choice of thermal management temperature, and most batteries are robust enough to allow operation to at least 35 – 40 deg C or higher. Battery resistance rise with cycling usage and calendar time should be included in the degradation estimates. This will cause the battery to generate more heat as it degrades and therefore it will operate at higher temperature, with the possibility of accelerating the observed degradation.The internal battery temperature is one of the most important parameters used to calibrate ageing in life prediction models and this assumption disables or ignores the predictive strategies widely employed in the industry. Furthermore, operating temperature is a function of cell chemistry. Due to the high importance of the battery temperature on ageing, this assumption needs to be assessed for sensitivity.
   a. How were the temperature limits determined?
   b. What justifies this assumption?
   c. How does the model take account expected changes is operating temperature as a result of internal resistance increase later in the battery life?

Questionnaire on TEMA model

Assumptions:

EVE-24-10

1. The model assumes that the battery has ambient temperature when parked (calendar capacity fade model). This is a very rough assumption and the error introduced depends on how frequently the vehicle is used, if the battery is being charged while it is parked, etc. This is a very important parameter and it is standard for automotive battery ageing models to use actual internal battery temperatures. It is common for battery packs to take hours (>12h for huge BEV packs) to acclimatize with the ambient, and this has a huge impact on temperature conditions inside the battery during calendar ageing. Due to the high importance of the battery temperature on ageing, this assumption needs to be assessed for sensitivity.
    a. How does the model take the thermal inertia of the battery pack into consideration?
2. It is unclear what internal battery temperature is assumed during charging, the assumed BMS regulated range 22-27 °C or ambient temperature. Since the charging is associated with electrochemical activity and heat generation, the latter would not make sense. Since heat generated during charging strongly depends on the type of charge, assuming a constant temperature range for all charging protocols introduces significant error to the estimate. Due to the high importance of the battery temperature on ageing, this assumption needs to be assessed for sensitivity.
    a. How is battery internal temperature during charging treated in the model?
    b. How does the model account for different charging protocols with regards to heat generation and battery temperature?
3. The model assumes and average ambient temperature based on only two values, the maximum and the minimum temperature of the month. This is a very rough assumption and the error induced depends strongly on the climatic zone the vehicle is used in. This is a very important parameter in battery life prediction models and is typically modelled with much higher granularity. How is the average derived? Is it a simple arithmetic average or does it take into account daytime/nighttime hours and other meteorological variations? Due to the high importance of the battery temperature on ageing, this assumption needs to be assessed for sensitivity.
4. Five different charging strategies are assumed.
    a. Please describe the distribution between the charging strategies used in the model for estimating battery durability?
    b. Battery usage in BEV and PHEV are different by design. How does the model differentiate between expected charging strategies for BEV and PHEV considering the development of the future charging infrastructure?
5. The consumption values for BEVs presented by TEMA seem quite low compared with industry durability estimates. For example, the highest consumption value from EVE-36-09, slide 6, for a "HP Large Sized BEV", is 262 Wh/km = 419 Wh/mi = < 1.1 Ah/mi assuming 3.6 V per cell. This is probably only representative of very mild use customers (less than 50^{th} percentile) and will produce optimistic estimates of battery degradation for the higher end of the customer distribution. Some vehicle designs require more than double the energy/distance (Wh/km) of smaller, more energy-efficient vehicle designs. Future PHEV and BEV designs may also use the high-voltage battery for on-board, non-propulsion power generation (e.g., work site 110-V power) and for electrical grid support – these will also increase the effective Wh/km required of the battery over 160K km

Questionnaire on TEMA model

Cell models:

EVE-24-10 lists 4 different cell model options:

#1 ($LiFePO_4$): Sarasketa-Zabala et Al. (2013/14) model for calendar plus Wang et Al. (2011) model for cycle

#2 ($LiFePO_4$): Sarasketa-Zabala et Al. (2013/14) model for calendar plus Sarasketa-Zabala et Al. (2015) model for cycle

#3 (NCM + Spinel Mn): Wang et Al. (2014) for calendar plus Wang et Al. (2014) for cycle

#4 (NCM-LMO): Wang et Al. (2014) for calendar plus Cordoba-Arenas et Al. (2015) for cycle

1. #1 and #2 both address LFP cells.
    a. How does the model use the two options for the calendar and cycle life estimations?
    b. Are two different life estimates made and combined? If yes, how are the two models weighted in the final life estimate? If no, why does the model include 2 options for the same chemistry?
2. #3 and #4 both address NMC-LMO cells (spinel Mn is the same as LMO). How does the model use the two options for the calendar and cycle life estimations? ? If yes, how are the two models weighted in the final life estimate? If no, why does the model include 2 options for the same chemistry?
3. How are other cell chemistries taken into account in the cell models: NCA, NMC, etc?
4. Which are the tuning and the fixed parameters in the cell models?
5. The model seems to assume all mixes belonging to a certain chemical family age in the same way. Experience shows this is not accurate, e.g. the main ageing mechanisms in NMC 111 are different from those in NMC 811. Recalibration of modelling parameters is always required when making changes in manufacturer, chemical composition, physical material properties, etc.
    a. How are different mixes of a specific cell chemistry taken into account by the cell models?
    b. How is the approach validated?
6. Natural variations in cell capacity needs to be accounted for when considering connection schemes and the influence on load conditions. How is this treated in the cell model?
7. The cell model references are from 2013-2015. Significant advances in battery ageing modelling has occurred in the last 5 years, e.g. transition from 1D to 3D models, new chemistries. Different tuning parameters are used in the more recent models. Although the basic parameters may be used to model different types of cells, recalibration is needed in order to be representative of new cells on the market (e.g. particle distributions, electrode thickness, electrolyte additives…), or a statistical recalibration made for a specific cell.
    a. How can TEMA be updated to reflect the expanding knowledge base in the research and manufacturing communities?
    b. What specific efforts have been made to update TEMA with additional cell chemistries?
8. In EVE-24-10, slide 9, are the curves based on one or two data sets?
9. Can JRC provide copies of the paper references for the cell models: Wang et al. (2011), Wang et al. (2014); Sarasketa-Zabala et al. (2013), Sarasketa-Zabala et al. (2014), Sarasketa-Zabala et al. (2015), Cordoba-Arenas et al. (2014) and Cordoba-Arenas (2015)?
10. Power to energy ratios of the cells considered are much higher than the present state of the art for BEV cells, and corresponding energy densities are much lower. For example: Sarasketa-Zabala et Al. (2013/2014 & 2015): P/E of 25 and Cordoba-Arenas et Al. (2015): P/E of 15. Different power to energy ratios will result in different sensitivity to aging factors and affect the conclusions of the study. Chemistry will of course also play a role, and neither of the chemistries utilized in the references are common in future BEV applications.

Questionnaire on TEMA model

Data:

1. The presentations name the type of data required as input, but there is no information about the data format required by the model. In order to enable benchmarking, this must be elaborated in detail.
2. The table with input data (e.g. EVE-38-02, slide 31, suggests that all input data are single values.
    a. Is this a correct understanding?
    b. Does this mean that each customer is assumed to have a single drive cycle or can a dynamic driving profile be used?
    c. How are the drive cycles for BEV and PHEV, respectively, defined in the model
    d. How does the model derive representative single values for each parameter?
3. Can JRC disclose the following (i.e. parameters and specific data distribution):
    a. The customer drive cycle used for the simulations, i.e. 24h x 1 week for weekday commuting and weekend activities
    b. How climate in different regions are modelled
    c. Any weighting considerations done e.g. based on regional sales statistics
4. It is inappropriate to develop regulatory guidelines for battery degradation based on averaged regression fitting of a few fleet data. Further validation and incorporation of wider scenarios required.

Other questions:

1. EVE-23-08, slide 13: Axis parameters are missing. What does this graph show?
2. EVE-24-10, slide 16; What is the intention of the question: "*Is there an in-vehicle battery durability potential issue (i.e. customer-expectation / comparison of technologies)?"* Is the issue related to customer expectation or technical ageing?
3. EVE-36-09 slides 9-11: "Benchmarking" of model output with field data shows that the simulated ageing has a wider spread than the field data. How is this possible?
4. EVE-38-02 (slide 17-18): MPR recommendations for "advanced vehicles"
    a. How is "advanced vehicles" defined?
    b. This implies that different MPR will be developed for other categories of vehicles. Which categories are considered and how are they defined?
    c. What is the market distribution in the data sets used to determine MPR recommendations?