Submitted by the IWG on EVE

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Status report of Part A of the November 2014 mandate for the Electric Vehicles and the Environment Informal Working Group (EVE IWG)

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List of Acronyms

AC.3 – Administrative Committee for the International Convention on the Harmonization of Frontier Controls of Goods, 1982

AER – All Electric Range

ANL – Argonne National Laboratory

BEV – Battery Electric Vehicle

CAN – Canada

CN – China

EU – Europe Union

EV – Electric Vehicle

EVE – Electric Vehicles and the Environment

FCV – Fuel Cell Vehicles

GHG – Green House Gas

GRPE – Working Party on Pollution and Energy (Groupe de travail de la pollution et de l'énergie)

GTR – Global Technical Regulation

HEV – Hybrid Electric Vehicle

ICE – Internal Combustion Engine

ISO – International Organization for Standardization

IWG – Informal Working Group

JARI – Japan Automobile Research Institute

JP – Japan

KATRI – Korea Automobile Testing & Research Institute

KOR – Republic of Korea

L category vehicle– Motor vehicle with less than four wheels

M category vehicle - Power-driven vehicle with at least four wheels and used for the carriage of passengers

M1 – passenger car

N category vehicles – Power-driven vehicles with at least four wheels and used for the carriage of goods

N1 – pickup truck

NG – Natural Gas

NOVC-HEV – Not Off-Vehicle Charge HEV

NRMM – nonroad mobile machinery

NWIP – New Work Item Proposal

OEM – Original Equipment Manufacturer

OICA – Organisation Internationale des Constructeurs d'Automobiles

OVC HEV – Off-Vehicle Charge HEV

PEV – Pure Electric Vehicle

PHEV – Plug-in Hybrid Electric Vehicle

pmr – Power to Mass Ratio

P-t-M – Power to Mass

REESS – Rechargeable Electric Energy Storage System

REX – Range Extended EV

RP – Recommended Practice

SAE – Society of Automotive Engineers

SOC – State of Charge

SP – System Power

SR – special resolution

TF – Task Force

UNECE – United Nations Economic Commission for Europe

UN-R85 – United Nations Regulation No. 85

WLTP –Worldwide harmonized Light vehicles Test Procedures

WP.29 – World Forum for Harmonization of Vehicle Regulations

1 Introduction

Section to be expanded based on comments from EVE IWG

The Executive Committee (AC.3) of the 1998 Agreement authorized the second mandate of the Electric Vehicles and the Environment Working Group at their November 2014 session. The full document is ECE/TRANS/WP.29/AC.3/40[1], and selected text from Part A of the EVE mandate is shown below, and follows up on work in the Electric Vehicle Regulatory Reference Guide (ECE/TRANS/WP.29/2014/81)[2], often referred to elsewhere in this document as simply "the Guide."

"Therefore, a new mandate for the IWG on EVE (separate from the IWG on EVS) is desired to conduct additional research to address the recommendations outlined in Chapter 5 of the Guide and EV power determination:

Issues to be addressed in Parts A and B:

a) Battery performance and durability (recommendation 5.3, ECE/TRANS/WP.29/2014/81);
b) Determining the powertrain performance (maximum power and torque) of EVs).

Issues to be addressed only in Part A (information-sharing only):

a) Method of stating energy consumption (recommendation 5.2, ECE/TRANS/WP.29/2014/81);
b) Battery recycling/recyclability (recommendation 5.4, ECE/TRANS/WP.29/2014/81).

(iii) June 2016:

a) IWG on EVE presents a first draft on the status of Part A and proposed gtr request(s) for Part B to GRPE;
b) *IWG on EVE presents informal documents on the status of Part A and proposed gtr request(s) for Part B for review by AC.3."*

Based on the mandate given to the group by AC.3, work was undertaken on the four topics mentioned. The results of the group's work and their subsequent recommendations are shown in the sections below.

2 Battery performance and durability

2.1 Background

This section summarizes the progress of the EVE IWG on Battery Performance and Durability, a topic of Part A of the second EVE mandate. It is intended to serve the following goals:

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[1] Can be accessed here: http://www.unece.org/trans/main/wp29/wp29wgs/wp29gen/wp29glob_proposal.html
[2] Can be accessed here: http://www.unece.org/trans/main/wp29/wp29wgs/wp29gen/electric_vehicle_ref_guide.html

a) Review the topic of battery performance and durability of electrified vehicles, as it relates to the EVE mandate
b) Summarize the issues that the IWG identified and discussed in developing its recommendation to the GRPE
c) Outline the options that the IWG considered for moving forward on this topic
d) Recommend a path forward to the GRPE

Electrified vehicles are herein defined to include battery electric vehicles (BEVs), plug-in hybrid electric vehicles (PHEVs) with all-electric range (AER) and/or blended mode operation, and hybrid electric vehicles (HEVs) which do not have significant all-electric range. Electrified vehicles of all types are herein referred to as xEVs.

2.2 Battery performance and durability and the EVE Mandate

2.2.1 Background

An outcome of the first mandate (2012-2014) of the IWG on EVE was the identification of "a need to understand and document the degradation in attainable range and vehicle energy efficiency (and hence CO2 emissions) over the operating lifecycle of [electrified vehicles]." (Electric Vehicle Regulatory Reference Guide, ECE/TRANS/WP.29/2014/81). This degradation in vehicle-level performance (range and energy efficiency) was understood to be primarily the result of deterioration in battery performance over time. Accordingly, it was recommended that future test protocols developed for existing GTRs or new GTRs should attempt to capture this deterioration at key points during the battery life cycle. It was further recommended that "the outcome from any such deterioration testing be used to influence the reporting of vehicle range and energy efficiency."

Part A of the second mandate of the EVE (ECE/TRANS/WP.29/AC.3/40) therefore included "battery performance and durability" as one of the topics authorized for study and potential GTR development. Specifically, Part A authorized activity "to further develop the recommendations for future work outlined in the Electric Vehicle Regulatory Reference Guide by: (i) conducting additional research to support the recommendations; (ii) identifying which recommendations are suitable for the development of (a) global technical regulation(s) (gtr(s)) by the World Forum for Harmonization of Vehicle Regulations (WP.29); and (iii) developing a work plan [for development of potential GTRs identified through this process]."

2.2.2 Motivation

The primary motivation for the EVE mandate on battery performance and durability stems from the recognition that the environmental performance of electrified vehicles may be affected by degradation of the battery system over time. As stated in the Electric Vehicle Regulatory Reference Guide, loss of electric range and loss of vehicle energy efficiency are primary concerns. Both can affect not only the utility of the vehicle to the consumer, but also the environmental performance of the vehicle. Loss of environmental performance is important in particular because governmental regulatory compliance programs often credit electrified vehicles with a certain level of expected environmental benefit, which might fail to be realized over the life of the vehicle if sufficient battery degradation occurs. In addition to changes in range and energy consumption, for hybrid electric vehicles that are often equipped with both a conventional and electric powertrain, the criteria pollutants emissions from the conventional powertrain could be impacted by the degradation of the battery.

Because battery degradation is not currently subject to uniform standards, there is a desire to understand the potential for battery degradation to affect environmental performance of electrified vehicles, and to consider the need for regulations to ensure that battery durability of an electrified vehicle is sufficiently controlled to maintain the expected environmental performance for the life of the vehicle.

The IWG has therefore been charged with the task of gathering information related to this topic, and to make recommendations concerning the possibility of establishing a GTR for this purpose.

2.2.3 Assumptions

Much of the discussion and technical review leading to the current recommendations of the IWG was premised on several assumptions regarding the goals of the effort. The recommendations are therefore reflective of these assumptions.

Part A of the second EVE mandate describes the topic at hand as "battery performance and durability," suggesting that the topic includes those two components. As suggested by Finding 5.3 of the Electric Vehicle Regulatory Reference Guide, the "performance" component is concerned with "measurement of energy consumption and range of electrified vehicles" (p. 37), and further recommends that "currently available international standards be used as references in this work, in particular ISO 12405-1 and 12405-2." In contrast, no such references were suggested for guidance on the "durability" component of the topic (or "degradation in attainable range and vehicle energy efficiency").

Discussions among the members of the EVE IWG have accordingly focused primarily on durability, and in particular, the effect of battery durability on the environmental performance of electrified vehicles. Therefore, usage scenarios outside the normal expected duty cycle of an xEV application (such as durability under mechanical stress, vibration, or abuse conditions), or issues of battery durability that do not relate to environmental performance of the vehicle, were not considered to be within scope of the discussion.

In considering the potential for a GTR to be developed, it was also assumed that any such GTR would be oriented toward establishing a type approval procedure applicable to testing at the vehicle level, rather than the component (battery) level. Therefore, in developing its recommendations regarding potential development of a GTR on durability, the IWG primarily considered the feasibility of developing a representative and robust test procedure that would reliably establish the environmental durability of an electrified vehicle by means of a vehicle test procedure without regard to specifics of battery design (such as, for example, battery chemistry).

The EVE IWG had also initially understood that, if development of a GTR were to be recommended, the EVE would then be concerned with establishing specific durability performance requirements for electrified vehicles, and then developing one or more test protocols suitable for use by manufacturers to demonstrate that these performance requirements are met. At EVE-17 in January 2016, this expectation was modified by further discussion with the WLTP. There, a working agreement was informally established wherein vehicle performance requirements with respect to battery durability would be supplied by WLTP, and EVE would then pursue development of vehicle test procedures designed to demonstrate attainment of those requirements. The performance requirements had not yet been defined at the time of the making of the recommendation.

2.2.4 Information and Sources

The IWG recognized that information gathering would be key to understanding the potential for a GTR to be developed on battery durability.

The contracting parties contributed significant expertise to this effort by assigning participants with extensive knowledge in electrified vehicle and battery design. Additionally, the IWG commissioned a comprehensive literature review on factors affecting battery durability, performed by FEV Inc. The results of the study were presented in the form of a written report and a presentation by FEV at EVE-16 in November 2015. IWG members also regularly monitored developments in the industry, and represented these findings in the discussion as necessary.

2.3 Findings

The information gathering process provided the IWG with a good understanding of the primary factors and issues related to battery and electrified vehicle durability. It also helped the IWG understand that battery durability is a very complex topic that presents significant room for debate and discussion on the potential for development of effective test procedures.

2.3.1 Points of Agreement

Members of the IWG appear to be in general agreement about the following concepts related to electrified vehicle durability:

- It is possible for the long term environmental performance of electrified vehicles to be negatively impacted by degradation of the battery system over time.
- The primary forms of battery degradation that relate to environmental performance are capacity degradation and power degradation. The effect of capacity degradation and power degradation on environmental performance is likely to differ significantly among the various xEV architectures (BEV, PHEV, and HEV).
- Electrified vehicle manufacturers are aware of the issues posed by battery durability, and currently manage battery durability by agreements and warranties between the manufacturer and the user/consumer. Based on confidential business information shared by manufacturers and the EPA, each manufacturer has a unique and proprietary method for establishing the durability of its electrified vehicles.
- The presence of electrified vehicles in the market suggests that manufacturers have found it possible to establish the durability of specific battery implementations sufficiently to bring the products to market with some degree of confidence that customary provisions for customer satisfaction and warranty terms are being met.

- However, the presence of existing products with warranty terms does not automatically mean that manufacturers have successfully predicted battery durability for these products. Manufacturers continue to rely on long-term, ongoing experimental lab research and tracking of vehicles in use to verify that the methods used to establish durability were effective and to modify durability metrics as this experience dictates. As a result, it cannot be said that the metrics to determine durability for arbitrary battery implementations are fully developed even for a single manufacturer. It is possible that some manufacturers will overperform and some will underperform with respect to both customer expectations and environmental performance.
- Not every manufacturer is establishing durability in the same way. Manufacturers employ a wide variety of testing regimens often tailored to specific product configurations, applications, customer groups, and geographic considerations. There is a lack of standard methods that are generally accepted to be effective at reliably predicting battery durability for arbitrary usage scenarios across all battery chemistries and configurations.
- There are at least five major vehicle operating conditions that affect battery durability, each differing in importance depending on whether the application is BEV, PHEV, or HEV:
    - (a) Discharge rates, as determined by vehicle duty cycle, or activity and inactivity
    - (b) Charge rates, as determined by type and frequency of charging
    - (c) State of charge (SOC) window used in system operation of the battery
    - (d) Battery temperature during operation (operation includes all temperature exposures from vehicle purchase through retirement, both while being operated and during periods of inactivity)
    - (e) Time (calendar life)

Each of these factors must therefore be considered in developing a test procedure that reliably predicts battery durability in a specific vehicle application.

2.3.2 Discussion Items

With respect to the potential for developing a GTR on battery durability, the following additional considerations have been identified and discussed within the IWG.

2.3.2.1 Differences Among xEV Architectures

Members noted that the issue of battery degradation can have significantly different implications for the environmental performance of different xEV architectures (HEV, PHEV, and BEV).

For example, the primary motivation for regulating battery durability for a BEV might be to promote the preservation of electric driving range during the life of the vehicle, on the grounds that loss of electric range might result in less displacement of conventionally fueled mileage during the life of the vehicle than was originally anticipated. The motivation for regulating durability in PHEVs may be slightly different. Loss of all-electric range in a PHEV leads directly to loss of utility factor (i.e. an increase in conventionally fueled mileage) that causes the vehicle to generate more CO2 due to more frequent use of the conventional powertrain. Unlike with BEVs, this can cause the PHEV to exceed the level of CO2 emissions to which it was certified. Finally, HEVs are different from both BEVs and PHEVs in that they do not have an all-electric range, meaning that a GTR would be concerned with other issues such as energy efficiency or overall CO2 emissions and not range. It is also conceivable that potential HEV powertrains could be designed that rely on battery assistance in such a way that criteria pollutant emissions could be affected by loss of battery capacity or power (although it is not clear that any such designs are currently in production).

The effect of battery degradation itself may also be experienced in different ways by users of different architectures. In the case of HEVs, consumers are most likely to experience the effect of battery degradation as a loss of fuel economy, while in a BEV or PHEV it is likely to be experienced primarily as a loss of electric range. At this time, shortfalls in fuel economy are more likely than shortfalls in power or driving range to trigger regulatory penalties or recalls. Either is likely to result in loss of customer satisfaction.

The impact of possible test conditions on the battery system may also vary significantly among architectures. HEVs differ from PHEVs and BEVs in that the battery is smaller and so has a smaller thermal mass. This means that only a short soak is necessary for an HEV battery to reach ambient temperature conditions, while a larger PHEV or BEV battery may take many hours. This leads to different implications for the impact of test procedure length (or trip length in real life) on environmental performance and battery durability. For example, frequent short trips in cold weather with an HEV may involve on average a colder battery operation temperature than for BEVs and PHEVs which may retain their internal temperature for a longer time between trips. Also, since BEVs and PHEVs are charged from an external source, they offer the possibility of charge station warming to further prevent battery cooling while soaking in cold weather.

As stated previously, the impact of the two major types of degradation (capacity degradation and power degradation) can also differ among architectures. In the case of BEVs and PHEVs, capacity degradation is perhaps most important to environmental performance because it directly affects the capability for the vehicle to deliver all-electric mileage and thus affects utility factor or the displacement of conventionally fueled range even though the vehicle may still operate at the same overall efficiency. Power degradation is typically less important because the large capacity of the battery often brings along with it a greater power capability than needed for vehicle acceleration, with the power rating of the electric propulsion motor acting as the limiting factor. In the case of HEVs, capacity degradation is also important but for different reasons; in particular, it may affect the ability of the system to effectively manage power flows of the internal combustion engine, and so may affect fuel economy and/or vehicle power output. Power degradation is much more important for these smaller batteries than for those of BEVs and PHEVs because they operate closer to their design power limits and power degradation may thus have a noticeable effect on system performance. It may also have an effect on the ability of the battery to effectively manage power flows from the internal combustion engine, causing more propulsion energy to be derived from the engine and increasing loads on the engine.

Further, it was noted that requirements for durability may depend on specific vehicle applications within each xEV type. Different vehicle classes may have different battery durability needs.

The purpose and feasibility of establishing a GTR governing vehicle and battery durability may therefore differ depending on the xEV architecture. Therefore it was suggested that the effort should first identify the goals of a GTR with respect to each specific xEV architecture, including for example, specific performance requirements for each architecture. At that point, the issue of considering the possibility of a standard test to prove out these performance requirements would become easier to address.

2.3.2.2 Current Manufacturer and Regulatory Practices to Manage Durability

The IWG noted that a review of current manufacturer and regulatory practices could inform the potential for a GTR on durability.

To reduce the effect of capacity degradation on range, manufacturers may choose to slightly oversize a BEV or PHEV battery to allow for a widening of the state-of-charge (SOC) window as capacity degrades. Others may choose to design for a beginning-of-life range, and account for degradation by warranting the battery to a specified degree of capacity retention over a specified period of time. In the latter case, the consumer is expected to understand that a potential reduction in electric range may be experienced during the life of the vehicle.

Despite the potential for loss of electric range over time, regulatory practice does not uniformly account for it. For example, US EPA range labeling rules for BEVs and PHEVs effectively treat driving range as a beginning-of-life criterion, by measuring range at beginning of-life and omitting any adjustment for future capacity degradation. For PHEVs, however, manufacturers are indirectly compelled to account for degradation in range, in that it directly affects the calculated in-use emissions later in life. PHEV GHG emissions are calculated using the SAE J1711 procedure, which accounts for utility factor[3], a function of all-electric range. If range degrades during useful life, the utility factor correction would change and thus, the calculated GHG emissions would increase. Because vehicles are considered noncompliant if their emissions exceed the certified emission level by more than 10 percent during the useful life, manufacturers that do not factor capacity degradation into their PHEV designs risk exceeding the GHG standards in-use. Accordingly, for PHEVs, manufacturers typically use a combination of battery oversizing and an energy management strategy that provides for a consistent range throughout the useful life.

The IWG also discussed accelerated aging as a familiar technique used by many manufacturers as a component of their battery durability testing methods. This technique assumes that a regimen of rapid aging cycles can be translated to a projected useful life in service. However, it is uncertain whether the translation from accelerated aging to an in-use life projection is equally applicable to all forms of lithium-ion chemistries either currently in use or in the future. One of the major mechanisms by which capacity and power degradation occurs in these chemistries is the swelling and contraction of anode and cathode materials during cycling. Specific chemistries differ significantly in this respect, suggesting that the relation between rapid cycling and long term cycling may also differ significantly (for example, silicon content in the anode is a newly emerging method for increasing battery capacity, and is also recognized as having a particularly large potential for swelling upon charging). An accelerated test that accurately

[3] The US EPA has determined the appropriate utility factor using data from the US Household Transportation Survey. Each contracting party could establish a unique utility factor based on its in-region activity.

projects useful life for one chemistry may therefore predict poor life for another chemistry, even though both chemistries may achieve an equal life in actual use. Therefore it is uncertain at this time whether a test procedure that relies on accelerated cycling would treat all current or future chemistries on an equal footing, perhaps favoring certain chemistries over others that may be equally effective.

It is clear that manufacturers are using different methods to predict battery durability, but not as clear at this time that they have been equally successful in doing so. Due to the relatively young age of the xEV fleet, it is difficult to be certain that some manufacturers have not judged more conservatively than necessary, while others may have over-predicted durability. This may place into question the ability to prescribe a regulatory test that would be more effective than current manufacturer practices.

2.3.2.3 Timeliness of Regulation and Potential Impact on Innovation

Members of the IWG noted that the relative infancy of the xEV battery industry suggests that it may be premature to establish detailed regulations for battery durability.

One member noted that the industry is still seeking improved battery chemistries, and that no currently available xEV batteries have yet achieved the levels of specific energy, energy density, or cost targeted by the United States Advanced Battery Consortium (USABC). It was suggested that to establish guidelines for durability before battery technology has stabilized could potentially discourage the emergence of certain technology options. For example, establishing a requirement that the original battery last the life of the vehicle might discourage research into potentially more cost-effective battery chemistries that might require scheduled replacement. This also might preclude some approaches to metal-air chemistries, such as aluminum-air and zinc-air, which have proposed regular replacement of electrode material or electrolyte as an alternative to station charging. Since it is acceptable for other vehicle components that affect environmental performance to last less than the full life of the vehicle (for example, tires or starter battery), it was suggested that a battery durability regulation should not necessarily presume that the battery must last the full life of the vehicle either.

In addition, electrified vehicle use patterns, especially with respect to vehicle charging, have a direct impact on overall vehicle durability. These use patterns are still changing, and as a result the ability to establish a representative vehicle durability test procedure could be difficult at this time. At the very least, there is very little available data that could be used to produce a test profile that is representative of current activity.

Members also discussed whether there is sufficient urgency or pressing motivation to proceed with a GTR at this time. It was noted that there seem to be relatively few examples of battery degradation having a marked effect on environmental performance outside of the bounds established by current warranty practice and regulatory frameworks. That is, the lack of explicit regulation of battery durability does not at this time appear to be resulting in widespread underperformance of environmental expectations. In the few cases that have occurred, the effects have been corrected by existing mechanisms such as recalls, consumer rebates, etc. Particularly for many BEV and PHEV models that have not been in the market long enough to have reached their useful life, the lack of examples may be due to the relatively young age of the fleet, and more time will be required to determine the prevalence of environmental underperformance during the life of these vehicles. In addition, the market share of electrified vehicles is small at this time. Increasing stringency of greenhouse gas emission standards could drive increased penetration of electrified vehicles in the future so the issue of vehicle durability will become more pressing in the future.

Some members expressed the opinion that management of battery durability is best left as a warranty issue between manufacturers and consumers, on the grounds that degradation in environmental performance would likely be accompanied by sufficient loss of utility (in terms of fuel economy, power, or driving range) that manufacturers are already motivated to manage battery durability in order to offer competitive warranty terms and maintain customer satisfaction.

The case for proceeding with a GTR recommendation would be strengthened if it was clear that production electrified vehicles were commonly underachieving their expected environmental performance. At this time, it is unclear whether this is a problem in part simply because the xEV fleet, particularly BEVs and PHEVs, may not be old enough for such problems to have yet become evident, or their cause determined if found.

It was noted that in this early stage of xEV development, manufacturers often supplement their test-based judgements of battery durability by monitoring the performance of production vehicles in the field; that is, having vehicles in production and in actual use is currently an important component of the overall determination of battery durability. A requirement for type approval of xEVs for battery durability may make it more difficult to get vehicles into the field to provide in-use data at a time when the industry is relying on this mechanism for validation.

2.3.2.4 Complexity of Establishing Battery Durability

At EVE 16, FEV presented the results of a literature review of the factors affecting battery durability. From this presentation it was clear that the problem of establishing battery durability for representative usage scenarios, chemistries, and configurations is extremely complex.

Specifically, IWG members noted the following considerations:

- The factors which affect battery durability vary among different chemistries and usage conditions, and have differing importance to environmental performance.
- Battery aging is very path dependent, making it difficult to reliably model the actual life of an in-use battery by means of a single simplified test protocol.
- Influences on durability that occur during vehicle operation are not necessarily the same as those that occur while parked. For example, a vehicle parked in a hot environment for long periods of time may experience degradation due to elevated battery temperature, while a vehicle being actively operated in the same environment may avoid degradation because the battery is being actively cooled.
- Ambient temperatures have mixed relevance to battery durability. Manufacturers have the option to actively manage the temperature of the battery itself so that actual battery cell operating temperatures are rarely the same as ambient air temperatures.

- Some members noted that any steps to predefine battery aging conditions may lead manufacturers to optimize performance for test conditions rather than for the range of actual usage likely to be experienced by customers. That is, if a test procedure is more demanding than necessary to demonstrate full useful life in the field, it might compel manufacturers to over-specify battery performance and unnecessarily increase cost; or if the test procedure is not demanding enough it may have little value in ensuring that environmental goals are met during the life of the vehicle.

The IWG also identified and discussed some quantitative approaches to predicting battery degradation that have recently been described in the literature. The IWG acknowledged research conducted by researcher Jeff Dahn at Dalhousie University, in which a technique known as high-precision coulomb counting is used to predict future degradation rates by measuring loss of charge in early cycling of battery cells.[4] The IWG also acknowledged a research initiative at Pennsylvania State University in which a formula was developed for battery degradation using inputs describing state of charge, how often the battery charges or discharges completely, operating temperature, and current. It was concluded that both methods appear to be best suited to cell-level analysis in a research environment, and so do not appear to be readily adaptable to vehicle-level testing. Also, because both methods primarily attempt to quantify the future rate of formation of solid-electrolyte interphase (SEI) on a carbon-based Li-ion anode, they presumably would not reflect other mechanisms of degradation, nor mechanisms that would apply to non-carbon anodes or non-Li-ion chemistries. Since these methods are still in research stage and still undergoing verification and development, the IWG feels that they are of limited value for application as a regulatory norm for battery durability determination.

Members of the IWG have also discussed the possibility of defining durability in terms of the total amount of energy that a battery must deliver during its useful life in order to achieve the environmental performance expected in a given application. Evidence of this capability might then be established by testing the ability of a battery to deliver this energy through a series of appropriately specified charge and discharge cycles. The potential capability of such a test to deliver reliable estimates of durability for arbitrary usage cycles, chemistries and configurations has not been examined. Considerable further research would be required to evaluate the applicability of this method. For example, it is not immediately clear what the appropriate test conditions would be, or how to validate the test results for vehicles of varying degree of electric propulsion as well as different usage conditions.

2.3.2.5 Definition of Battery Useful Life

Depending on its structure, a GTR relating to battery durability may require specification of a criterion for battery lifetime. Members of the IWG noted that either capacity degradation or power degradation may be the factor that causes a battery to be judged as having reached the end of its useful life. Further, whether it is capacity or power degradation that is life-limiting depends on the application and vehicle type. Hence, an end-of-life criterion specified in any eventual regulation must consider the application and vehicle type.

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[4] More information can be found here: http://www.dal.ca/diff/dahn/research/adv_diagnostics/hpc_additive_studies.html

The industry has not yet established uniform standards for end-of-life. For BEV applications, some manufacturers have loosely defined acceptable capacity retention to be approximately 70% to 80% of original capacity. These criteria currently largely depend on manufacturer assumptions regarding minimum acceptable performance and customer satisfaction, and are thus somewhat arbitrary and may differ among manufacturers. Establishing an appropriate end-of-life criterion on the basis of capacity degradation also depends on the vehicle type, system design factors, and how the battery is used. For example, if a manufacturer of a BEV feels that consumers will be dissatisfied with loss in driving range after a battery degrades to 80 percent capacity, it might define this point as end-of-life for warranty purposes, although the vehicle may still be capable of operating with a reduced range. For a potential GTR to proceed, a durability definition, which is reflective of both the vehicle architecture and its required environmental performance, must be defined.

2.4 Options for Proceeding

2.4.1 Options

At EVE-16, the IWG began formally identifying options for proceeding on the topic of battery performance and durability. Three options were identified to exist within the framework of EVE. The options below are not listed in any order of preference by the IWG.

Option A: Recommend that a GTR is appropriate for electrified vehicle durability, and note that it will take time to obtain the information required. For example, information relating to the effect of vehicle duty cycle, vehicle charging, operating temperature, and calendar time will need to be collected to inform this action. Proceeding in this direction may require initiating a new mandate for the EVE IWG and/or forming another IWG.

Option B: Extend the mandate of the EVE IWG to continue active research into electrified vehicle durability. This would involve gathering data to inform a potential future GTR.

Option C: Recommend to the GRPE that it is premature at this time to develop a GTR for electrified vehicle durability, but the question should be revisited in the future, likely in two years, when work developing a GTR on determining powertrain performance is expected to be completed. Stakeholders should be encouraged to independently gather data to inform a future GTR, particularly with respect to charging profiles and temperature exposures.

2.4.2 Positions of the Major EVE Contributors

Japan

Japan expressed a preference for Option C, with an option to continue to discuss several outstanding issues as well as to continue investigating relevant technological developments and testing procedures. In particular, Japan cited a need to further discuss: (1) clarification of how battery durability affects the environment, followed by addressing those specific items for which the government considers it necessary to establish regulations or evaluation procedures as information for consumers; (2) clarification of the purpose of the current discussion regarding battery durability for electrified vehicles (for example, should we discuss the effect of electrified vehicle battery durability on running range as information for consumers, or on the charge depleting cycle range in the Charge Depleting mode of plug-in hybrid vehicles, or on the exhaust emissions?), and (3) clarifying that any durability evaluation to be developed or discussed should be based on the vehicle rather than the battery itself.

Japan further supported its preference for option C by stating that "it is questionable whether we would be able to establish general durability evaluation procedures that can be adopted as a regulation while battery development is still progressing," and pointing out that "test procedures for type approval are required to have, in particular, robustness, repeatability, and fairness. Thus, we must avoid introducing test procedures that evaluate only a part of the functions of batteries under development. It is premature at this time to discuss the introduction of procedures for testing the durability of the battery itself as a type approval test."

Japan has also indicated a clear demand for a durability procedure for air pollutants.

United States & Canada

In general, the United States & Canada feels that Option A is not feasible at this time, and prefers either Option B, with

a) further clarification of the issues raised by Japan
b) definition of xEV performance requirements by WLTP, and
c) an explicit provision for continued information gathering.

Option B is considered most preferable because it does not suspend the work of the EVE and therefore provides a mechanism for work to continue. However, other members expressed a preference for Option C on the basis that Option B would require continued meetings of the EVE at a time when the uncertainties identified above make it difficult to establish a firm work plan under that option.

Canada and the United States note that because the system power determination subgroup is expected to meet and work to develop a GTR over the upcoming years, work on EV durability could continue without requiring additional EVE IWG meetings or travel.

OICA

OICA prefers Option C. OICA feels that durability is an issue best handled between OEMs and customers, and that a regulation is not needed because the manufacturer has to deliver on it anyway. Also, OICA feels that the lack of compelling examples of failure to achieve environmental performance in production vehicles suggests that it has not yet been proven that a GTR is needed.

EU

EU has not formally expressed a preference, but participated in discussions at EVE-19 and has verbally expressed a preference for Option A, indicating that Option B would likely also be acceptable.

China

China has not formally expressed a preference, but participated in discussions at EVE-18.

Korea

Korea has not formally expressed a preference, but participated in discussions at EVE-18.

All stakeholders not reflected above are encouraged to provide feedback regarding their views and positions.

2.4.3 Discussion of Options

Discussion among the participants at EVE-18 appeared to most broadly support recommendation of Option C, with a stipulation that a specific date or event be specified at which the question would be revisited.

Canada and the United States feel that Option B remains a viable and potentially preferable alternative, and should be discussed further. Option B retains a formal structure for continued study that would help most effectively determine when the industry has evolved enough, or the need for regulation becomes clear enough, that the question should be revisited again. It also facilitates continued cooperation with WLTP for the purpose of establishing performance requirements for which test procedures might be developed.

Option C would effectively recommend that, at this time, the IWG feels that developing a GTR on battery durability would be premature. It is also important to note that Option C does not specify that the topic should be abandoned, but only postponed, and explicitly requires that the issue be revisited in the future.

The judgement that a GTR would be premature at this time is derived from several general findings of the discussions of the IWG.

For one, it reflects the complexity of establishing battery durability in a fair, robust, and repeatable way by means of a standard vehicle-level test procedure, at a time when manufacturers do not yet appear to have discovered their own test procedures that have been proven to be reliable and robust for all chemistries that might be effective in-use.

It also reflects the desire for clarification of several uncertainties, as expressed by Japan. Clarification of these uncertainties would improve the ability for the IWG to judge the feasibility of establishing GTRs relating to battery durability.

Also, the IWG notes that the question of the feasibility of developing test procedures for battery durability would be easier to address after the WLTP establishes specific performance requirements for xEVs and provides those requirements to the EVE. Therefore, at minimum, cooperation with WLTP should be continued for this purpose.

Finally, although members of the IWG agree that battery durability can have an impact on environmental performance, it is unclear to many members of the IWG that a regulation is needed at this time, and it is felt that more evidence should be collected to support this need before proceeding. The IWG is also sensitive to the possibility that enacting a regulation at this time is faced with significant uncertainty as to whether it would have unintended consequences on the direction of innovation.

2.5 Recommendations

1) It is recommended that the EVE and GRPE take up the issue of deciding further on the merits of all options.
2) EVE requests that WLTP continue its plans to define xEV performance requirements (as related to battery durability) and provide them to the EVE for use in planning future work, regardless of the option chosen.
3) It is important that EVE provide for continued recognition of developments that could influence future work. Therefore in the case that Option C is finalized, it is recommended that a specific date or event be identified at which the need for regulation and the feasibility of developing a GTR would be revisited, and also identify the persons or organizations responsible for monitoring developments and initiating activity in the meantime.
4) With regard to continued monitoring of developments, it is recommended if Option B or C is selected, that this also include data acquisition topics that would inform any future development that might be indicated, such as: (a) identification of an appropriate electrical drive cycle, (b) identification of charging activity characteristic of in-use activity (e.g. frequency, level, duration); (c) defining appropriate temperature exposure during operation (operation to include vehicle discharge, charge, and inactivity), and so on.

3 Determining the powertrain performance

3.1 Background

This section summarizes the views of the EVE IWG on determining the powertrain performance of EVs (focused on HEV system power determination), a topic of Part A of the EVE mandate. This section serves three primary goals:

a) Outlines the overall topic of HEV system power determination as it relates to the EVE mandate
b) Summarizes initial findings of the working group, as represented by comments and discussion that took place at EVE-17 and prior meetings
c) Considers the available options for moving forward on the topic of HEV system power determination

3.2 Determining the powertrain performance and the EVE Mandate

The Electric Vehicles and the Environment (EVE) Informal Working Group is mandated by the WP.29 and has been formed to examine environmental issues related to all types of road vehicles (motorcycles, passenger cars, light, medium and heavy-duty vehicles) with electrical propulsion, including pure electric vehicles (PEVs), hybrid electric vehicles (HEVs) and plug-in hybrids (PHEVs). Over the course if its first mandate, the group developed the “EV Regulatory Reference Guide” for environmentally-related EV requirements, which was officially published on 28 August 2014. In addition to the identified regulatory gaps listed in Chapter 5 of the Guide, the group was tasked with conducting additional research and analysis related to a regulatory requirement to determine the system power of electrified vehicles. The

WLTP IWG recently also found that this topic warranted further investigation, however, could not be tackled by that group due to the limitations of their mandate and resources.

3.2.1 Current Situation

For purposes of rating the motive power of light vehicles, the UNECE currently provides a regulation under the 1958 Agreement that can be used for approval of internal combustion engines (ICE) and electric drivetrains for M and N category vehicles. It focuses on the determination of engine power values, however, the technical description part of the regulation merely provides for the individual determination of the power of either an ICE or an electric motor.

3.2.2 Problem

The role of the propulsion battery is not considered by the regulation. A determination or recommendation for a calculation of the 'motive power' of the vehicle expressed as combined power or system power is missing. Furthermore, in many cases (likely the majority) it is the propulsion battery system, also referred to as rechargeable electric energy storage system (REESS) and not the electric motor that limits and therefore determines the power of an electric powertrain. Consequently in many state-of-the-art powertrain concept and production hybrid electric vehicles, the simple addition of individual power results from engine and electric motor is insufficient and leads to incorrect estimations of the power performance of the vehicle. Distinct information about the combined power of the system, however, is eligible or needed, as the following paragraph will show. The situation may become even worse, in the future because more and more sophisticated hybrid vehicle concepts with distributed power sources are likely to gain market maturity (e.g. electrified vehicles with rim motor concepts).

3.2.3 Motivation

Currently a clear demand for an improved power determination procedure comes from the members of the WLTP IWG. The subgroup "Electrified Vehicles" is in need of a system power specification for the following both purposes:

a) Classification of electrified vehicles into distinct Power-to-Mass ratio classes
b) Application of the so-called "downscaling method" that enables adaption of the test reference cycle for low powered vehicles

Furthermore system power specifications may be used in different ways. Among others, it may serve as customer technical information, may be used by regulators (as basis for taxation programs) or by insurance providers (as a classifier for determining premiums).

3.2.4 Goal

Given the above described situation and according to its mandate under the UNECE, the EVE IWG established a subgroup "Determining power of EVs." The goal was to clarify how an improved technical procedure for the determination of the system power of sophisticated powertrains, like with pure electric vehicles with more than one electric motor and hybrid electric vehicles could be realized in an efficient and simple way.

The scope of the work covered light duty vehicles (passenger cars -M1 and light duty vehicles -N1) and aimed to develop a recommendation or regulation for determination of the performance criteria “system power.” In this regard the EVE IWG took advantage of the fact that activities with similar focus are currently also being pursued by international standardization organizations.

3.3 Findings

EVE IWG performed a questionnaire-based inquiry in 2015 among relevant stakeholders including contracting parties (’58-Agreement and ’98-Agreement) regarding their attitude, possible applications and needs to develop an overview of initial opinions. The following gives a brief appraisal of the feedback received.

CAN and the U.S. are party of the ’98-Agreement and thus the UN-R85 has not been adopted or applied by them. Both contracting parties abstained from voting on phase 1 of WLTP since analysis of the GTR No. 15 (WLTP) is still ongoing and because stringent light duty vehicle regulations are already in place domestically. Canada and the United States have the same procedures for compliance testing of PEVs. Recommended Practice (RP) refers to SAE J1634 for determination of energy consumption and range. There is no compliance procedure for vehicle power.

EU regards the subject HEV system power determination as important and relevant since it is needed in the WLTP and would form the basis for proper vehicle classification. EU could even envisage expanding the scope beyond passenger cars and light duty vehicles and strive for a harmonized procedure including also L category vehicles and NRMM.

JP understands that the demand is only for the WLTP for Power-to-Mass (P-t-M) classification and downscaling method. The regulation shall be limited to the determination of the system power of hybrid electric vehicles (HEVs) and multi-motor PEVs. There is only need to define the system power of HEVs and no need to re-define the power of single-motor pure electric vehicles (PEVs) and fuel cell vehicles (FCVs), since the electric drive train has already been defined in UN-R85.

KOR is of the opinion that net power ratings from current UN-R85 are being regarded as sufficient but the power limit ascribed to the traction battery should be properly considered and determined. Determination of power (and torque, if needed) should be done with a completed vehicle applying a chassis dyno or powertrain dyno measurement.

OICA supports the development of a harmonized procedure for every category of electrified vehicles to determine comparable system power (and system torque -if required-) based on needs, priorities and requests from relevant groups (e.g. WLTP IWG). The preferred methodology would be the measurement of the individual components (e.g. power of ICE, battery output) followed by a calculation method that finally results in the system power rating. In general and independent from the applicable procedure which will be finally decided on, the value should be derived by a standardized procedure and by harmonized load collectives for the sake of good reproducibility and competitive comparison. OICA proposes integrating the topic “electrified vehicles system power determination” into a regulation either WLTP GTR No.15 or another global technical regulation.

Discussions among the members of the IWG have taken place for some time. Members appear to be in general agreement on some points, while others continue to be discussed.

3.3.1 Points of Agreement

At EVE-18, the EVE IWG appeared to generally agree on the following points.

3.3.1.1 Requirements:

The procedure shall cover all types of HEV (ordinary –NOVC-HEVs and plug-in –OVC HEVs[5]) and including the following configurations:

- Series HEV
- Parallel HEV
- Power split HEV

Moreover, the procedure shall also cover pure electric vehicles (PEVs or rather battery electric vehicles – BEV) with one or more than one electric motor for propulsion (e.g. rim motor concepts). EVE IWG members agreed that the regulation shall be integrated into GTR No. 15 (WLTP).

The HEV system power rating shall be equivalent to the rated power of an ICE. This means that the procedure to determine the system power by stating the delivered power at the wheels will not be further pursued.

3.3.1.2 Methodologies:

The EVE IWG considered several possible paths forward … *[information to be added describing what options we considered]*

The EVE members agreed on starting with the ISO method (SAE/ KATRI "Method 1") as a basis for possible future development under EVE IWG. It shows good verifiability and is closest to ICE rated power, which makes it easy to compare ICE ratings from conventional vehicles with maximum HEV system power ratings.

The following gives a short overview of relevant worldwide projects dealing with the development of a standard for system power determination, in the U.S. (SAE-standard, ANL), Japan (ISO-standard, JARI) and Korea (KATRI).

SAE J2908 Task Force led by Argonne National Laboratory (ANL) started the project in November 2014. The project was initially scheduled to be finalized towards end of 2015. Draft documentation related to the test procedure is currently available. Three primary methods of determining HEV system power emerged from the research. From these three approaches, the so called "Method 1" found the broadest acceptance during discussions among EVE members, since it showed to be quite similar to or the same as KATRI and ISO methodologies (see below).

[5] NOVC- / OVC-HEV: Not Off-Vehicle / Off-Vehicle Charge Hybrid Electric Vehicle

The nominal rating method ("Method 1") is based on determination of the individual power on component-level (internal combustion engine, battery power) and can therefore be considered as similar to current engine power ratings. ANL has investigated different test types (e.g. running a test vehicle at several fixed speeds vs. running a test vehicle with a speed sweep or ramp) in order to determine the maximum system power a vehicle can deliver.

The definition of the hybrid system power follows a simple addition of the rated engine power and the electric power of the battery (Hybrid system power = Engine power + Electric power).

Hybrid system power is a rated powertrain power comparable to current engine ratings. The engine power is the rated power by SAE J1349. Electric power is a measured electric assist on dyno.

On the contrary, the system power test ("Method 3") is based upon hub dyno or chassis dyno measurements and provides accurate determination of axle or wheel power. It is a sophisticated test, leading to highly verifiable results, e.g. for engineers to communicate power levels.

The SAE J2908 TF also gives information on system power as well as the power of electric assist and regeneration.

KATRI (Korea Automobile Testing & Research Institute) started its research project in July 2013 with the aim of developing a national standard for the determination of a representative power for (N)OVC-HEVs and EVs with in-wheel motors. It is intended for use in the national vehicle classification. It was finalized in June 2015 and the result will be harmonized with the research result on determining power of EVs in EVE IWG. Nominal rating and system power tests were studied using a powertrain dyno or a chassis dyno with added instrumentation.

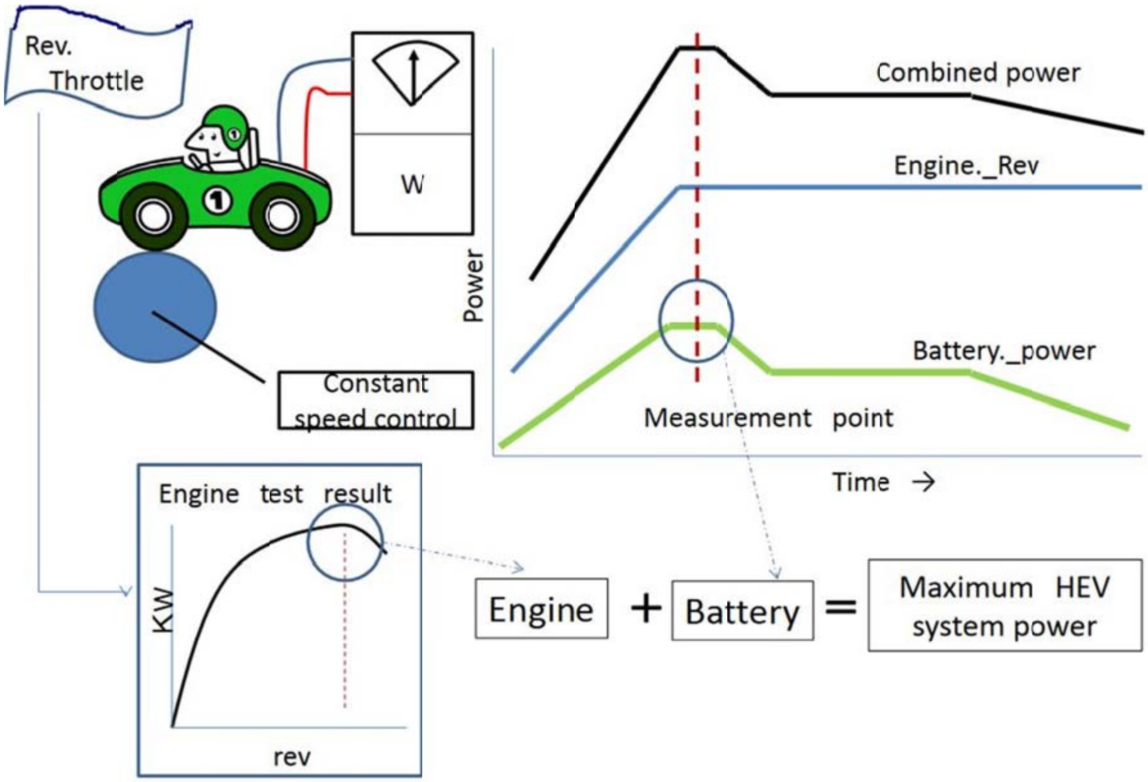
The definition of the hybrid system power follows the same approach as the SAE procedure, namely that it involves a simple addition of the rated engine power and the electric power of the battery (Hybrid system power = Engine power + Electric power).

The engine power is the rated power according UN-R85. The electric power is the measured power of the electric on board power source of the vehicle determined during a chassis dyno testing.

Aside from this procedure and similar to the SAE methodology, a somewhat more sophisticated system power test provides not only accurate measurement of wheel or axle power but also useful information of system torque.

ISO New Work Item Proposal (NWIP) N3477 proposed by the Japan Automobile Research Institute (JARI) was approved in June 2015. It started as a formal project of ISO/ TC22/SC37/WG02. This ISO methodology also includes the definition of the hybrid system power as the arithmetic sum of engine power and battery power, as shown in previous cases (Hybrid system power = Engine power + Battery power).

It is necessary to measure the battery output under the HEV system control. The engine power is the rated power determined by ISO 1585. The battery output should be measured when the hybrid system as a whole delivers maximum power on a chassis dyno. The exact point of maximum system power is determined by carrying out a series of test runs while driving the vehicle at different but constant speeds to find the maximum brake power of the chassis dyno that the vehicle is able to run against. The evaluation results in a power-versus-speed curve that shows a point of maximum power at a certain speed.



3.3.1.3 HEV System Layout and Control Strategy:

All HEV configurations (series-, parallel-, power split-) should be reasonably assessed. As has been shown by an ANL study, SAE "Method 1" can result in an over estimation of system power in certain series hybrid systems. EVE members agreed that further research work would be necessary and seems appropriate to fully assess and incorporate appropriate aspects of the ISO method.

3.3.1.4 Input / Output Data

EVE IWG members agreed that all necessary input data needed for a robust power determination procedure must be specified. The same holds true for the list of output data resulting for use of the procedure. Examples of each category are given below. The list is currently not finalized and would form one task of a later technical work program.

- Examples of input data: road load values (parameters of the road load polynomial F1, F2, F3), vehicle weight, engine power map, etc.
- Examples of output data: system power, vehicle speed, engine / motor speed, REESS-data (voltage, current, power), etc.

3.3.1.5 Operating Points

- **Definition of appropriate power rating(s):**

  Peak Power, Rated Maximum System Power: Technical discussions with experts from the WLTP IWG Subgroup EV regarding the vehicle classification concept and downscaling method led to following results:

  - Vehicle classification of the WLTP development process: The WLTP vehicle classification is one of the important issues of GTR No. 15 and is based on the ratio between **rated power** and **curb mass** (pmr). Based on an analysis of the dynamics of in-use data the following classification was agreed during an early period of WLTP development:

    Class 1: pmr ≤ 22 kW/t
    Class 2: 22 kW/t < pmr ≤ 34 kW/t
    Class 3: pmr > 34 kW/t

    For **(N)OVC-HEV** a system power value is needed, which would be equivalent to the rated power for an ICE (=> rated maximum system power).
    For **PEV** it was already decided to use the peak power of the electric machine for the pmr determination (=> e.g. according UN-R85). Nevertheless, this decision was made as a preliminary one "worst case solution," and discussion concerning PEV system power will be included in the work of the EVE System Power task force, who will evaluate if there is a more appropriate solution.

  - Downscaling method: In drivability studies some vehicles near the border line of the above shown classification were unable to follow the prescribed speed trace. For the particular cycle sections where the drivability problems occur, a so called downscaling procedure takes effect. The speed trace is lowered by a factor that is based on the **ratio between the maximum required power of the cycle** phases where the downscaling has to be applied and **the rated power of the vehicle**.

    Remarks:

  1. Also in this case for (N)OVC-HEV a system power value is needed, which would correlate equally well with the maximum cycle power as the rated power for an ICE.
  2. This equivalent system power is, however, not necessarily the same for vehicle classification, because the acceleration behaviour at low speeds is more important for vehicle classification.

- **Definition of appropriate SOC of the REESS:**

  After technical discussions with experts from the WLTP –IWG Subgroup EV regarding the State of Charge of the REESS the Members of the EVE IWG agreed on the concept to determine the maximum HEV system power with REESS fully charged.

3.3.2 Discussion Items

The following topics continue to be discussed within the IWG.

3.3.2.1 Load Collectives and Maximum Power

Definition of an appropriate load pattern (fixed speed, speed ramp, etc.) to find the point at which the vehicle delivers maximum system power.

SAE J2908 TF uses a full power sweep or a segment sweep to find the vehicle speed at which the maximum system power is delivered. For the unambiguous determination of maximum system power, a 1s to 5s window filter is considered to overcome transient spikes or signal noise.

ISO provides series of fixed vehicle speeds to test and identify maximum system power. However, a detailed method of dividing and specifying vehicle speed intervals has not been set. In some cases the manufacturer's recommendation seems to be needed. For the unambiguous determination of maximum system power, a maximum power curve is needed that is based on a filtered raw data curve applying a 1s moving average filter.

3.3.2.2 Reference Method => Chassis Dyno Testing with completed vehicle

The EVE IWG assumes the next phase of work will involve close cooperation between the expert groups from the respective standardization organizations SAE, ISO and the KATRI, as they are the leading experts concerning the determination of the system power by means of chassis or hub dyno methods. These organizations will likely provide the necessary test capabilities. Test burden collectives must be defined in detail in order to get meaningful maximum system power ratings. Additionally, since this item is closely related to demands coming from the WLTP (GTR No.15), it is indispensable and expected that experts from WLTP SG-EV will support the work.

3.3.2.3 Candidate Method => Component Testing and calculation to determine SP

In an effort to reduce the financial burden of testing and to improve process flexibility during type approval, manufacturers have expressed an interest in a certified procedure that is based on a combination of component testing (partly after UN-R85, partly pursuant battery specification practice) and calculation. That is why such a pathway should be investigated as well. The latter methodology, however, must be carefully validated against the SAE / ISO /KATRI standard before it could be endorsed as an alternative method.

3.3.2.4 Customer Information and other information with added value

Possibility for a fair comparison between battery-like HEVs and PEVs

Examples: REX (Range extended EV) and series HEV with a high all electric range (AER).

In some cases a PEV and a REX have the same electric powertrain, but each vehicle (PEV and REX) would be tested by a different test method in order to get maximum power. This may lead to confusion and misunderstandings for customers for purchasing vehicles. For instance the PEV identifies maximum power by UN-R85 and the REX considered as series HEV should be tested by system power method applying the power of REESS.

3.4 Options for Proceeding

Option A: Develop a reference method for HEV and multi-motor PEV system power determination and a candidate method that must be validated against the reference. All methods which can be validated via testing will be incorporated as an addendum to the existing WLTP regulation (GTR No. 15).

The following draft work plan is proposed, however should be duly reconsidered and finalised by the expert working group that will be in charge of the development at a later stage:

Work Plan (draft)

I. Consideration of the concepts:
   - Reference Method – Chassis Dyno
   - Candidate Method – Component Testing and calculation

II. Consideration of the Open Points under paragraph
   - Load Collectives and Maximum Power
   - Reference Method => Chassis Dyno Testing with completed vehicle
   - Candidate Method => Component Testing and calculation to determine SP
   - Customer Information and other information with added value

III. Determination of work plan with task list and including allocation of work load

IV. Proof of concepts: Studies with different types of HEVs including. series HEV, REX and PEVs (with one or more electric motors)

V. Test, refine / improve and validation of the method(s)

VI. Drafting of the regulation

VII. Proposal for a draft amendment to GTR No. 15

VIII. Approval at GRPE, voting at WP.29 AC.3

Option B: Instruct the EVE IWG to continue gathering information and research on the methodologies being developed by other organizations for determining powertrain performance of electric vehicles, but abstain from developing a procedure which could be incorporated into GTR No. 15.

3.5 Recommendations

Given the clear desire for a procedure for determining powertrain performance from contracting parties, manufacturers and other informal working groups such as the WLTP, it is recommended that the GRPE endorse the work plan outlined in option A.

4 Method of stating energy consumption

4.1 Background

Accounting for upstream emissions related to electrified vehicles being operated in all electric modes was identified in the Guide as an important environmental performance metric for electrified vehicles. This topic of upstream emissions, while an important environmental consideration, has been controversial within the GRPE mandate. The GRPE mandate is to focus on vehicle level performance and upstream emissions are beyond the scope of the GRPE. This topic has been maintained under Part A of the new EVE mandate for information sharing in recognition of its importance to regulators and the potential impact these emissions could have on efforts to reduce greenhouse gas emissions.

The model was built without extensive consultation with experts in the electricity generation sector, and values used for construction, decommissioning, emissions intensity of various fuels, etc. were obtained from a variety of publications, and are only intended as representative values.

This section summarizes the work completed by the EVE IWG and views developed by the group for the work topic developing a method of stating energy consumption of electric vehicles. This work was led by China, and is topic of Part A of the EVE mandate. This section serves three primary goals:

a) Introduces a method of stating energy consumption and greenhouse gas emissions of electric vehicles
b) Summarizes initial findings of the working subgroup and the subsequent comments and recommendations
c) Considers the available options to continue the research on the method of stating energy consumption and greenhouse gas emissions developed by the EVE IWG

4.2 Method of stating energy consumption and the EVE Mandate

The EVE mandate on the method of stating energy consumption stems from the recognition that a common metric which can be used to state and compare the energy used by vehicles (i.e. MPG, L/100km, or kWh/100km, etc.) is an important environmental issue. Advanced EVs represent a promising opportunity to reduce overall energy consumption and, by using electricity, EVs are potentially able to displace petroleum-based fuels. EVs sales are expected to see rapid growth in the future, in part because of increasingly stringent regional CO2 regulations. Research on the topic of energy consumption is a priority in many jurisdictions and has been conducted for quite some time. The development of such an assessment method is important as the expected increase in use of electric vehicles will displace emissions from vehicles to electricity grids, and the impact of electric vehicles on a region's emissions profile may be underestimated if these upstream impacts are not properly considered.

Differences between manufacturers in EV architecture, battery technology, battery capacity, charge management systems, testing conditions and other factors increase the difficulty of developing criteria which can be uniformly applied to meet labelling requirements. Differences in the composition of the electricity grid between and often within countries means there is also variation of the upstream emissions impacts of a given electric vehicle depending on its geographic location. It is important in particular to develop a method of stating energy consumption which is acceptable to most countries, manufacturers and consumers.

In addition to reducing energy consumption, electric vehicles offer the potential of reducing GHG emissions associated with transportation, in an effort to combat global climate warming. For these reasons, a standardized method for calculating and stating energy consumption and the associated GHG emissions for electrified vehicles is desired and has been developed for consideration.

The EVE mandate primarily considers plug-in hybrid electric vehicles (PHEV) and pure electric vehicles (PEVs) [sometimes also called battery electric vehicles (BEVs)]. Both PHEVs and PEVs will be referred to as EVs in this section. The method of stating energy consumption and GHG emissions developed by the EVE IWG could likely provide theoretical and methodological reference for the corresponding policies and regulations in the contracting parties. Note that the purpose of the work is to develop a method of stating energy consumption rather than evaluate the energy consumption and GHG emissions in different regions.

4.3 Findings

The method of stating energy consumption uses Excel tools to get life-cycle analysis results[6], and has gone through multiple iterations incorporating comments from EVE group members. Some of the highlights are below.

4.3.1 Method of Stating energy consumption

The life-cycle analysis of the energy consumption and associated GHG emissions was conducted with the functional unit of 1 kilometer driven by an EV under real-world driving conditions. A model using Excel tools used to perform the life-cycle analysis. The time that the vehicle is operating on electric power and the time the vehicle uses conventional power (in the case of a PHEV) were both considered in the calculation. Upstream emission impacts included both the impact of electricity generation and distribution and the impact of conventional fuel production and distribution. The specific metrics included are listed below, and each can be individually modified to match regional conditions:

- vehicle energy source
- upstream consumption and emissions
- power transmission loss
- electricity loss in charging process

The energy consumption and GHG emissions intensity for a given power generation mix was assumed to be the production weighted average consumption and emissions per unit of electrical energy (MJ or kWh) from all electrical generation sources in a given region. The regional generation mixes differ significantly.

The tool states the fuel economy of EVs in two forms, including power consumption (kWh /100 km) and the equivalent gasoline consumption (Liter /100 km). The life-cycle energy consumption of EVs was assessed by primary energy consumption (MJ /km) and the associated GHG emissions were estimated by equivalent CO_2 intensity (g CO_2, e/km).

[6] Life-cycle analysis refers to emissions from the life-cycle of the upstream fuel source (i.e. extraction, refining, transportation of fuels and/or in some cases, facility construction)

4.3.2 Discussed Items

4.3.2.1 Boundary of the Method

Members of the EVE group noted that electricity generation is the dominant consumption and emission stage of EVs and thus should be examined in more detail. The composition of regional electrical grids can be classified into two main categories of power generation:

- Traditional fossil fuel power
- Alternative energy sources which do not rely on fossil-fuels

Traditional fossil fuel power includes coal-fired power, natural gas(NG)-based power and heavy oil-fired power. Alternative energy power is also an important part of electricity mix, and includes hydro power, nuclear power, solar power, wind power, biomass, geothermal, tidal and others. These alternative power sources have gained more attention and have seen their share of the global electricity market increase in recent years.

In the model, two types of fuels (fossil fuel and non-fossil fuel) mentioned above are used as feedstock in power generation. Energy consumption and the associated GHG emissions should be analyzed over the life cycle of the fuel, which may include mining, refining, transportation, facility construction, decommissioning, and the fuel utilization. The energy consumption and emissions from the preliminary stages should be allocated and amortized over the total lifetime power supplied by the power generating station. Emissions and energy consumption from vehicle manufacturing is excluded for all powertrain architectures.

Members also emphasized that the model should include the impact of power plant construction and decommissioning when considering the life-cycle impact of various fuels and energy sources. Data for life cycle energy consumption and GHG emissions of power generation is most reliable from relevant energy or environment departments. However, it should be noted that in the case of fossil fuel power stations (coal, oil, and natural gas), the energy consumption and GHG emissions from the facility construction and decommissioning always account for tiny percentage of total life cycle emissions, and can sometimes difficult to collect. For this reason construction and decommissioning effects are sometime ignored in the data statistics in some countries. Some members recommend that energy consumption and GHG emissions from the construction and decommissioning stages should be set as an essential variable in the model, even if the impact is small. In cases where these impacts cannot be calculated or are otherwise unknown, the variable could be assigned a value of zero.

4.3.2.2 Distinction between BEVs and PHEVs

Members of EVE group noted that the calculation methodologies are significantly different between BEVs and PHEVs due to differences in their propulsion systems. Therefore, it was suggested that any method developed by the EVE IWG should calculate energy consumption and GHG emissions separately with respect to BEVs and PHEVs.

There are significant differences in the structure and function of BEVs and conventional vehicles powered by internal combustion engines. The most obvious difference is that the internal combustion engine and fuel tank are replaced by an electric motor and battery pack. Propulsion power is provided by electricity from the battery. Thus in order to analyze the life-cycle energy consumption and GHG emissions of a BEV, a formula was developed using several variables, including life cycle energy consumption (MJ /km) and GHG emissions (g CO2, e/km) for different sources of electricity. The model consider the type of power generation facility, the composition of regional electrical grids, electricity transmission loss, charging efficiency and the energy efficiency (kWh /100km) for BEVs. The results are expressed in the form of how much primary energy is consumed (MJ /km) and the associated GHG emissions (g CO2, e/km) per km driver.

In the case of PHEVs, the drive system contains both an electrical motor and an internal combustion engine, and PHEVs normally have the ability to operate solely using electrical power, solely using the internal combustion engine, or via a combination of the two. Thus PHEV energy consumption and GHG emissions are more complex than that of BEVs. In the model, the running stage of PHEV operation was divided into two distinct modes; all-electric mode and an all-gasoline mode. A formula was developed to conduct the life-cycle analysis on PHEVs. Other variables in addition to those used in the BEV formula needed to be considered for PHEVs. These included fuel economy when driven by electricity (kWh /100 km), fuel economy when driven by gasoline (liter/100 km), and the % of total kms travelled using all-electric capabilities.

Members noted that for PHEVs, the range shared by electricity varies from region to region and could not be set as a fixed value.

4.3.2.3 Charging for BEVs and PHEVs

Members of the EVE group noted that the charging efficiency of an EV can be difficult to assess and quantify. Some members recommend that charging effect could be measured as a charge ratio. As devices of energy conversion and storage, the battery is the power source of EVs. Many consumers have expressed concerns about the capacity of the battery in electric vehicles and range anxiety has been acknowledged by many consumers and manufacturers. As batteries age (through use and simply by the passage of time), it is normal for maximum energy storage capacity to decline. As an example, a new EV with a battery capacity of 40 kWh may only be capable of storing 36 kWh later in the vehicle’s useful life.

Charging efficiency is an important factor when assessing the energy consumption and GHG emissions of an EV. Charging efficiency should be taken into consideration because losses associated with imperfect energy conversion from the grid to the vehicle’s battery account for a non-negligible percentage of total energy consumption. Depending on factors such as battery chemistry, charging voltage, charging current, etc., this energy can of be approximately 10%-20% of the total energy drawn from the grid. In the model developed by the EVE IWG, the charging efficiency is assumed to be 90%, which is a simplified, convenient value often used by vehicle manufacturers and consumers. Some members of the EVE IWG suggested that charging efficiency could be assessed using the ratio between stored capacity in battery and the output capacity from the grid.

4.3.3 Calculation with the Model Based on the Sample Data

Members of the EVE group expressed the opinion that the method should clearly emphasize that the numbers presented in the model are sample numbers, and that sample values should not be used for any specific case. The calculation results produced by the model are only a demonstration of the method of stating energy consumption and GHG emissions rather than evaluating the energy consumption for specific vehicles in specific regions.

Some working group members were interested in how emissions levels for various sources of electricity (nuclear, coal, etc.) were quantified, as well as assessing the composition of the grid in different regions. And some of them recommend a few examples of how the model calculated emissions for different types of vehicles. In order to help make the model more broadly applicable, a database was established containing electricity mix data and upstream emissions factors for different power sources in some countries and regions (China, USA, EU, Japan and Canada). The data was collected from a variety of sources including literature review, statistical publications, formal reports and responses from member countries. The GHG emissions intensity of a power generation mix is calculated based on the database and the model. The value is the production weighted average GHG emissions per unit of electrical energy generated by all of the electricity sources in a given region. However, direct energy consumption (fuel economy) of BEVs and PHEVs are only assumed values in the model for the purpose of generating sample calculations, and comparing the performance of a given electric vehicle in China, USA, EU, Japan and Canada. Actual energy consumption values should be developed in accordance with test results using the WLTP cycle.

Members emphasized the importance of the source of database information and pointed out that the data must be accurate and publicly published, and that additional effort should be done to ensure all data sources are properly referenced.

4.3.4 Other comments and discussions

In the EVE meetings, members of the IWG noted that some manufacturers may have some influence on the power source for EVs through proprietary power purchase contracts with utility companies in certain regions. Given that this is an emerging and evolving business, the model allows the user to individually adjust the power mix, rather than restricting the power mix to certain default values for various regions.

As a contrary point, OICA emphasized that many upstream factors were beyond the control of manufacturers, and that any method of stating energy consumption of EVs consider this reality. Manufacturers can primarily control vehicle specific factors, but not the source of the electricity.

The EVE IWG also considered the concept of the energy consumption of electric vehicles as an incremental load. In this case, the source of incremental generation may be more relevant to upstream emissions than the average power supply mix for the grid as a whole.

Some EVE members noted that governments around the world are generally making efforts to reduce the carbon intensity of their electrical grids, and that data on historical energy supply mix may not be an accurate prediction of future energy supply for EV. In the model, the default energy mix is based on historical recordings. A user would need to make their own assumptions and modify energy mix data accordingly if they wish to model future scenarios.

Some members also noted that the assumed user of the model is not defined, and variable definitions are somewhat related to actual user. Additional refinement is needed to specifically target the model for vehicle manufacturers and/or make it more easily understood by consumers.

China was supportive of Option B, noting that further refinement of the model, including consultation with a broader coalition of experts from places such as the electrical utility sector and a comparison with other EV models developed around the world would make it more robust and useful for contracting parties.

4.4 Options for Proceeding

In summary, the EVE group noted that unified method of stating energy consumption of electric vehicles is an important tool for both highlighting the distinctions between EVs and conventionally powered vehicles, and allowing the comparison of EVs produced by different manufacturers. The goal of this work was the development of a method of stating energy consumption rather than the evaluation of the energy consumption in separate regions.

Members in EVE IWG reached a basic agreement on the method put forward, though additional model refinement is needed if it is to be used more broadly. The EVE IWG also notes that region specific input data are not directly available for some regions; it is recommended that unique modifications be applied by the user when the model is used in specific regions. The ability to customize the model allows it to be applied across a wider number of regions, or by various manufacturers. However, these minor modifications have little to do with concept or framework of the proposed method. They are only related to alternative ways of gathering and applying data.

Two options exist for the subgroup to continue the topic of the method of energy consumption:

<u>Option A:</u> Recommend that the report and accompanying model are enough for the purposes of information sharing as outlined in Part A of the EVE mandate. The concept and framework of suggested method are accepted by members of EVE. Research results can be referred to as guidance documents.

<u>Option B:</u> Instruct the EVE IWG to continue development and refinement of the model as specific work item under an extend mandate of EVE IWG (Part B). This work could inform the potential development of SR or GTR at some point in the future.

4.5 Recommendations

The EVE IWG recommends that GRPE/WP.29 endorse option A or B, or a hybrid of the two.

5 Battery recycling/recyclability

5.1 Background

This section summarizes the views of the EVE IWG on battery recycling/recyclability, a topic of Part A of the EVE mandate. This section serves three primary goals:

a) Outlines the overall topic of battery recycling/recyclability as it relates to the EVE mandate
b) Summarizes the findings of the working group during Part A of the mandate
c) Considers the available options for moving forward on the topic of electrified vehicle battery recycling/recyclability

5.2 Battery recycling/recyclability and the EVE Mandate

Sections 3.8 and 3.9 of the Electric Vehicle Regulatory Reference Guide dealt with the subjects of battery recyclability and battery re-use (post-mobility). The Guide highlighted that some countries in North America, Europe and Asia have battery recycling requirements through either general battery recycling requirements or general vehicle recycling requirements. The Guide did not highlight any regulations or requirements specifically targeted at hybrid or PEV batteries.

The Guide's recommendations concerning battery recyclability are shown below:

> *Global battery recycling requirements are presently either lacking completely or where they exist, differ substantially in practice and/or depth of coverage. The EU has adopted Directives 2000/53/EC on the end-of-life vehicles and 2005/64/EC on the recyclability, reusability and recovery of automotive vehicles and parts. These two directives provide some basic requirements with respect to vehicle batteries. However, they do not have specific requirements or provisions for battery packs of pure electric and hybrid electric vehicles. This represents a gap, but one that is likely to be challenging to close on a global basis due to the complex nature of both practices, and attitudes towards recycling worldwide. Given that battery recycling is not within the mandate of WP.29, no formal recommendations are provided here. However, WP.29 recently adopted a new UN Regulation on uniform provisions concerning the recyclability of motor vehicles; as this Regulation is based on the existing two EU directives, it exhibits the same limitations present with Directives 2000/53/EC and 2005/64/EC. It is recommended to consider the following concerns in developing a GTR to address battery recyclability. Having well thought and standardized requirements in this area is likely to make actual recycling requirements easier to specify and more effective in the long term. In developing such requirements, it will be necessary to look closely at current battery manufacturing practices, while accounting for differences in materials and chemical composition from manufacturer to manufacturer. Any cascading impact such recyclability requirements may have on the performance or durability of batteries will also need to be evaluated with care. Such requirements may also reveal the necessary consideration of change in the upstream engineering of battery products to ensure recyclability. This may require parallel consideration of any cost consequences that result from such re-engineering for*

recyclability. Incremental battery pack cost in exchange for an added degree of recyclability is unlikely to be acceptable at the present price point per kWh, so this is likely to be a strong factor that limits the extent of recyclability requirements and should be carefully considered.

5.3 Findings

Every meeting of the EVE IWG since the authorization of Part A of the new mandate included an agenda item specifically focused on battery recyclability. However, there was little new information brought forward or discussed by group members. The Guide's point that "*Incremental battery pack cost in exchange for an added degree of recyclability is unlikely to be acceptable at the present price point per kWh, so this is likely to be a strong factor that limits the extent of recyclability requirements and should be carefully considered*" is still considered to be valid.

Electric vehicles are still a rapidly evolving technology. In many markets, they make up less than 1% of the current fleet of vehicles on the road. Additionally, most electric vehicle models have been on the market less than 10 years; as examples, the first Tesla Roadster was delivered in early 2008 and the first Toyota Prius Plug-in Hybrid was delivered in 2012. Factors like the relatively small market share and relatively recent introduction of electric vehicles means that only a small number of EVs have reached the end of their useful life and have limited the number of EV batteries in need of recycling. Many early EVs were only (or primarily) leased to customers, and subsequently disassembled and studied by manufacturers to inform future EV development. This has further suppressed the number of EV batteries which needed to be recycled.

In general, contracting parties and other members of the EVE IWG (such as manufacturers), brought forward little new research or findings related to battery recyclability during Part A of the mandate. Members noted that battery recycling programs and requirements continue to evolve at the national, subnational and supranational levels around the world. There are also many manufacturer specific programs in place to repurpose EV batteries at the end of a vehicle's life for use in commercial and residential stationary power storage applications. Some country specific initiatives are shown below.

<u>Canada</u>

While Canada does not have notational laws or regulations governing electric vehicle battery recycling, there are a variety of programs in place to address battery recycling. Lead-acid batteries are primarily recycled through the Canadian Battery Association and their *Call2Recycle* program. Many provinces have mandatory recycling programs for all batteries (including EV batteries), and in many provinces, it is illegal to landfill automotive batteries.

<u>China</u>

China has a series national standards related to battery recycling. China has developed two standards for discharging and methods of testing residual energy level. There are four standards under development which will address topics such as delivering, packing and material recycling. Development of these standards is expected to be completed by the end of 2017. China has a positive attitude to deal with the battery recycling issues.

European Union

Electric vehicle battery recycling is regulated by two different aspects within the European Union Legislation: *The End-of-Life (ELV) Directive 2000/53/EC* and *The Battery Directive 2006/66/EC*. The ELV Directive is product specific and only applies to road vehicles. According to this legislation OEMs are required to achieve reuse/recovery and reuse/recycling quotas for vehicles that are placed on the market. As of 2015, these quotas are specified as 95% for reuse/recovery and 85 % reuse/recycling, respectively, based on an average weight per vehicle and year. The ELV Directive is a Type Approval requirement for new vehicle types, regulated by 2005/64/EC and amended by 2009/01/EC.

In addition, OEMs must also fulfil *The Battery Directive*. This is a non-product specific requirement that applies to all batteries placed on the EU market. In addition to regulating maximum allowable content limits for certain heavy metals, it also includes mandatory collection and recycling targets for batteries. The collection targets primarily address consumer and portable batteries, since the collection of industrial batteries, including batteries used in vehicles, is very effective within member states. An analysis made by IHS[7] showed that 99% of lead-acid starter batteries are collected and recovered, which is considered a closed loop operation. Due to the efficient recovery streams of currently used automotive batteries, it is reasonable to assume that spent traction batteries from electrical vehicle batteries will form a similar closed loop operation once electric vehicles gain more significant market penetration. The material recycling targets apply to all batteries, regardless of application, and minimum thresholds are currently defined as 65% for lead-acid batteries, 75% for nickel-cadmium batteries and 50% for other battery technologies, based on the annual sales of batteries in preceding years. The recovery and recycling targets are intended to be progressive as recovery and recycling processes develop and become more efficient and effective.

Japan

Japan understands that battery recycling should be taken seriously as a general issue to protect the environment. However, urgent demands to regulate battery recycling are hardly seen in current situations because issues of battery recycling are not placed within Japanese vehicle regulations.

United States

The United States does not generally regulate battery recycling on a national level either for consumer-product batteries or automotive batteries. The degree to which recyclable items such as automotive batteries are recycled ordinarily depends on economic forces (primarily the recovery value of the constituent compounds) and local regulations that govern recycling and landfilling. For lead-acid starter batteries, collection and recovery rates are very high, commonly described as in excess of 99 percent. Collection is often encouraged by local regulations that require retailers to collect a refundable core charge when purchasing a new starter battery, which is refunded upon return of the old battery.

[7] IHS, EUROBAT, ILA, ACEA, JAMA and KAMA (2014), The Availability of Automotive Lead-Based Batteries for Recycling in the EU - A joint industry analysis of EU collection and recycling rates 2010-2012, prepared by information company IHS, Pg. 20, available under:
http://www.eurobat.org/sites/default/files/ihs_eurobat_report_lead_lores_final.pdf

Recycling is encouraged by the market value of lead, prohibitions on disposal of hazardous items in landfills, and a highly mature recycling infrastructure. Nickel-metal hydride batteries contain significant amounts of rare-earth metals that are likely to encourage their recycling based on recovery value alone. Lithium-ion chemistries vary in recovery value. While most batteries contain aluminum and copper, it is anticipated that some chemistries that do not contain relatively valuable metals (such as cobalt and nickel) will present a marginal case at best for recycling of their constituent materials. Battery and vehicle manufacturers are anticipating a future influx of used batteries, and are actively researching second-use applications as an alternative to recycling.

5.4 Options for Proceeding

Option A: Authorize the EVE IWG to begin a program to actively research battery recycling/recyclability and develop a path forward for potential GTR development.

Option B: Continue to passively monitor new research and developments related to battery recycling/recyclability, and considering bringing forward recommendations for additional research or GTR development in the future.

Option C: Remove battery recycling/recyclability from any subsequent mandate of the EVE IWG. In general, EV battery recycling/recyclability is currently being managed by the various regional and manufacturer sponsored programs which currently exist or are under development around the world. Additionally, only a small number of EV batteries have reached the end of their useful life, and at this time it is not clear whether regulators will need to develop programs to address EV recycling/recyclability issues.

Additionally, the GRPE is primarily focused on vehicle performance topics. The EVE IWG does not feel that battery recycling/recyclability is a vehicle performance focused topic at this time, though it may be appropriate for another group within the broader UNECE framework.

5.5 Recommendations

The EVE IWG recommends that GRPE/WP.29 endorse option C.

6 Conclusion

Over the past two years, the EVE IWG has conducted work focused on the four issues outlined in Part A of the new EVE mandate, and developed recommendations, as required by the mandate. As a result of this work, the EVE IWG has the following recommendations.

6.1 Battery performance and durability

The EVE IWG recommends that …. EITHER OPTION B or C WILL NEED TO BE FORMALLY RECOMMENDED

Option B: Extend the mandate of the EVE to continue active research into electrified vehicle durability. This would involve gathering data to inform a potential future GTR.

Option C: Recommend to the GRPE that it is premature at this time to develop a GTR for electrified vehicle durability, but the question should be revisited in the future, likely in two years, when work developing a GTR on determining powertrain performance is expected to be completed.

6.2 Determining the powertrain performance

The EVE IWG recommends that the GRPE endorse the draft workplan outlined in section 3.4 of this report. The EVE IWG also recommends that the GRPE emphasize that a reference method based on chassis dyno testing should be the highest priority goal during GTR development, and that a candidate method only be included in the GTR if testing can demonstrate sufficient degree of confidence that the candidate method and reference method provide equivalent results.

The EVE IWG expects that significant testing and validation will be required to develop both the reference and candidate methods outlined in the draft workplan. For this reason, the EVE IWG further recommends that the GRPE endorse the timelines in section 10.(b) of the new EVE mandate as target timelines, and state that the EVE IWG may take up to 1 additional year if testing and validation demonstrates this is necessary. The target timelines from ECE/TRANS/WP.29/AC.3/40 are as follows:

- i) November 2016: Approval of the authorization to develop a gtr (see Part B) by AC.3; New work begins;
- ii) June 2018: Draft gtr available, guidance on any open issues by GRPE;
- iii) June 2018-January 2019: Final drafting work on gtr text;
- iv) January 2019:
  - (a) Endorsement of the draft gtr based on an informal document by GRPE;
  - (b) Transmission of the draft gtr as an official document twelve weeks before the June 2019 session of GRPE.
- v) June 2019: Recommendation of the draft gtr by GRPE;
- vi) November 2019: establishment of the gtr by AC.3 in the Global Registry.

6.3 Method of stating energy consumption

The EVE IWG recommends that the GRPE endorse the report and accompanying model as suitable for the purposes of information sharing, as outlined in Part A of the EVE mandate. Should the issue of stating the energy consumption of electric vehicles be considered further in the future, the EVE IWG believes that the research results and model would be able to provide valuable guidance.

6.4 Battery recycling/recyclability

The EVE IWG recommends that the GRPE remove battery recycling/recyclability from any subsequent mandate of the EVE IWG.

Although only a small number of EV batteries have reached the end of their useful life, EV battery recycling/recyclability is currently being managed by various regional and manufacturer sponsored programs in most regions of the world. A number of these programs have been highlighted in this report. Given the many options available and being developed for EV battery use after it has been removed from the vehicle, the EVE IWG also believes that EV battery recycling/recyclability is outside the normal scope GRPE work, which is primarily focused on vehicle performance topics.