Determining the environmental impacts of conventional and alternatively fuelled vehicles through Life Cycle Assessment

Summary of the Delphi Survey Round 1 Responses

1 Introduction

On behalf of the European Commission's DG CLIMA, Ricardo Energy & Environment and their partners ifeu and E4tech are carrying out a study on "Determining the environmental impacts of conventional and alternatively fuelled vehicles through Life Cycle Assessment".

The first round of the Delphi Survey was launched on 14th December 2018 and was open for responses until 18th January 2019 (5 weeks). The Delphi Survey was sent to specifically targeted stakeholders with expertise in Life Cycle Assessments (LCAs) or in related areas of interest to the study.

This summary of the Delphi Survey is intended to provide an overall view of the responses received. Overall, 35 stakeholders responded to the survey.

Please note that the views presented can only be associated to respondents to this specific consultation and may not be representative of the views of all or specific groups of stakeholders.

2 Overview and profile of respondents

A total of 35 stakeholders responded to the survey.

The survey questionnaire was also split into different sections, each focussing on a specific area of the study (overall approach, vehicle life cycle, fuel/electricity life cycle). Whilst all respondents were requested to answer the questions on the section on the overall methodological approach, they could select which of the following topic-specific sections they would provide answers to. This was to account for the breadth of the topics covered - it was recognised that respondents will not necessarily have expertise/ knowledge across all areas. The number of responses received to each section is indicated in Table 2.1.

Table 2.1: Overview of number of responses to different sections of the survey

Area	Section	No. of responses	%
Overall methodological approach	1	34	97%
Vehicle specification, operation/use	2	25	71%
Vehicle production, maintenance and end-of-life	3	27	77%
Fuel production	4	23	66%
Electricity production	5	21	60%
Total Respondents	-	**35**	**100%**

Overall, there is a good balance of response rates between the different sections of the survey, with slightly fewer responses received on the fuel/electricity production sections.

The responses were also provided by a wide range of stakeholder groups (Table 2.2).

Table 2.2: Analysis of responses by type of stakeholder

Stakeholder category	No. of responses	%
Academics & research institutions	10	29%
Associations	9	26%
Individual Companies	10	29%
NGOs	1	3%
Other	5	14%
Total Respondents	**35**	**100%**

Overall, respondents provided an answer to the majority of the questions in the survey sections they selected as well as provided insightful comments to explain the reasoning behind their views.

The following sections in this document describe the results of this first round consultation.

3 Analysis of responses

The following analysis is broken down by question and contains a mix of quantitative and qualitative responses as well as conclusions from round 1 of the survey.

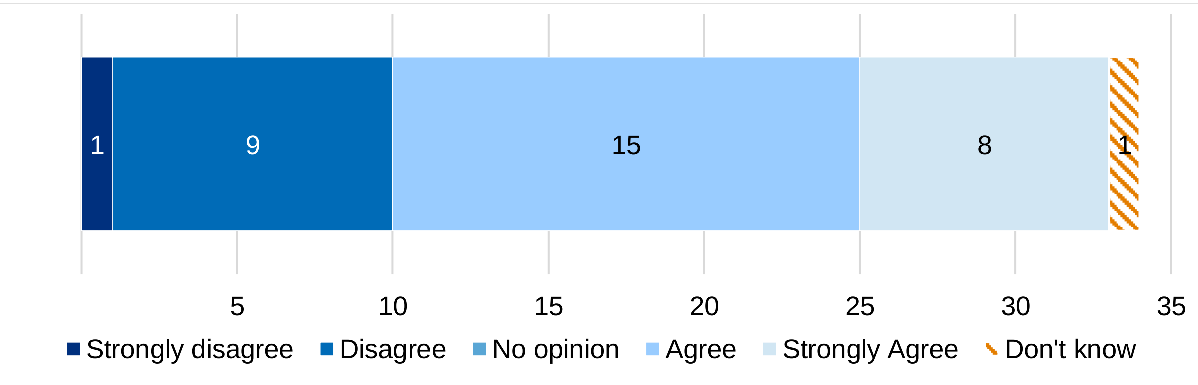
3.1 Section 1: Overall methodological approach

Stakeholders that participated in the first round of the survey largely validated the proposed overall methodological approach. Areas that generated more discussion and/or polarised views include the modelling of end-of-life stage and the proposed coverage of environmental impact categories.

"Question 5. Do you agree that the proposed overall methodological approach using in some cases/areas a hybrid approach/different options (e.g. attributional vs consequential) is appropriate in respect to the goal of the study?"

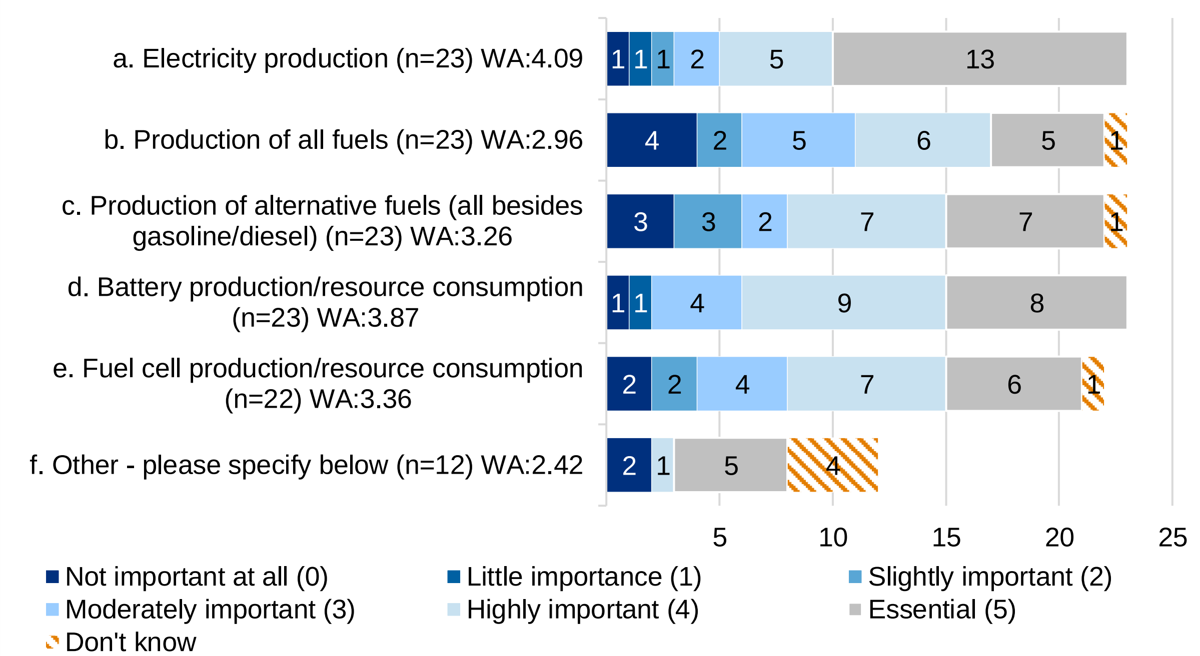
Most respondents agreed or strongly agreed with the study's proposal to use an overall consistent attributional approach as the basis for the assessment, except for selected stages of the process chains (e.g. electricity generation and fuel supply), where an additional consequential modelling is advised (Figure 3-1).

Figure 3-1: Appropriateness of the proposed hybrid approach in respect to the goal of the study (n=34)



For those that (strongly) agreed, they were subsequently asked to score from 0-5 (where 0 = Not important at all, 1 = Little importance, …, 5 =Essential) which consequential aspects should be taken into account among a range of process chains identified in Figure 3-2. Many respondents considered that electricity production (weighted average (WA): 4.09), and battery production/ resource consumption (WA: 3.87) should be modelled based on a consequential approach.

Figure 3-2: Consequential aspects to be taken into account



Those that indicated other aspects referred to: material production (three respondents), rebound impacts (one respondent), vehicle parts production (one respondent), end-of-life (one respondent), vehicle production (one respondent, explaining that the expected decarbonisation of electricity will lead to a decarbonisation of production processes which ought to be modelled using a consequential approach).

In the comments provided, these respondents explained why specific aspects should be modelled using a consequential approach. Three stakeholders advised to focus on aspects that have a significant impact on the results, and three also indicated the importance of applying a consequential approach to the modelling of the production processes where rapid technological developments are expected.

In particular, the modelling of electricity production was generally perceived as a key aspect: three stakeholders explained that expected changes in demand for electricity and decarbonisation of electricity production are key aspects warranting the use a consequential approach, whilst another pointed to the fact that electricity production affects all other life cycle data and production strategies.

Two other respondents suggested that biofuels production should also be modelled a consequential approach to more accurately assess iLUC impacts and diversion of wastes from existing uses. One respondent also noted that the fair comparison of the completely different processes of fuels and electricity requires consequential approach to ensure robustness of the model. Another referred to the impacts of lower demand for fossil fuels in Europe on the global market and their effects on other regions of the world if crude oil prices go down. For another the focus should be on fuel and energy storage.

In addition, one respondent also advised that the production processes in their infancy or at small scale (e.g. alternative fuels, fuel cells) should be covered by consequential modelling. For another respondent, it is the areas that are subject to future scarcity problems that should be the focus of consequential modelling, suggesting that resources for fuel cells and batteries are more relevant than electricity and fuel production. One respondent also considered that the effects of lightweighting and changes in material supply ought to be assessed using a consequential approach, whereas another identified the impacts of material demand for production of batteries. Conversely, one other respondent argued that it is more important to use a consequential approach to model impacts from fuels and energy mixes on vehicle use and material production than for battery and fuel cell production.

Another stakeholder suggested that the analysis of time of day variation in EV charging would be more relevant but might be out of the scope and could be included as a sensitivity analysis.

Finally, three respondents alerted to the risk of biased assumptions and high level of uncertainty on future developments. Given that a consequential approach requires subjective interpretation and decisions, it can distort the study’s results.

Those that (strongly) disagreed were also asked to provide a preference for attributional or consequential approach. Their comments revealed that stakeholders that do not agree with a hybrid approach also have mixed views on the best approach:

- Four respondents noted that the approach should be consistently attributional. For two respondents, a sensitivity analysis could be performed for specific alternative scenarios where a consequential approach might be adopted.
- For three other stakeholders, a consequential approach would be more appropriate for the study as it is more suited for policy making. One of these stakeholders suggested that a hybrid approach could highly influence the results as it involves subjective choices. Similarly, another responded noted that a consequential LCA should be adopted without any arbitrary hybridisation. The other stakeholder recommended modelling different scenarios for evaluating new/alternative fuels.

Two other stakeholders noted that consequential modelling is needed for the process chain for refining fuels and referred to the Concawe study "Estimating the marginal CO2 intensities of EU refinery products" for a suitable method. Regarding alternative fuels, one of these stakeholders also suggested using the same approach as the JEC consortium (JRC, EUCAR, Concawe) based on a marginal approach for alternative fuel pathways.

Finally, one other respondent suggested using a “prospective attributional approach with scenarios" as it addresses potential future changes and developments and is less uncertain than a consequential approach.

Q5 Response by the project team to results and comments:

It is concluded that the hybrid approach, with attributional analyses as the default option complemented by consequential analyses for specific aspects, is validated by the majority of stakeholders, despite some concerns regarding uncertainty and potential bias. A consequential approach will be pursued for the production of electricity and alternative fuels which have also been regarded as particularly important by the stakeholders (see respective sections for detailed discussion). Consequential elements (new cell chemistries, electricity split and decarbonisation of materials) will also be considered implicitly in the scenarios for modelling of battery and fuel cell production. A full consequential modelling of further aspects mentioned by some stakeholders is nevertheless ruled out as beyond the scope of the project.

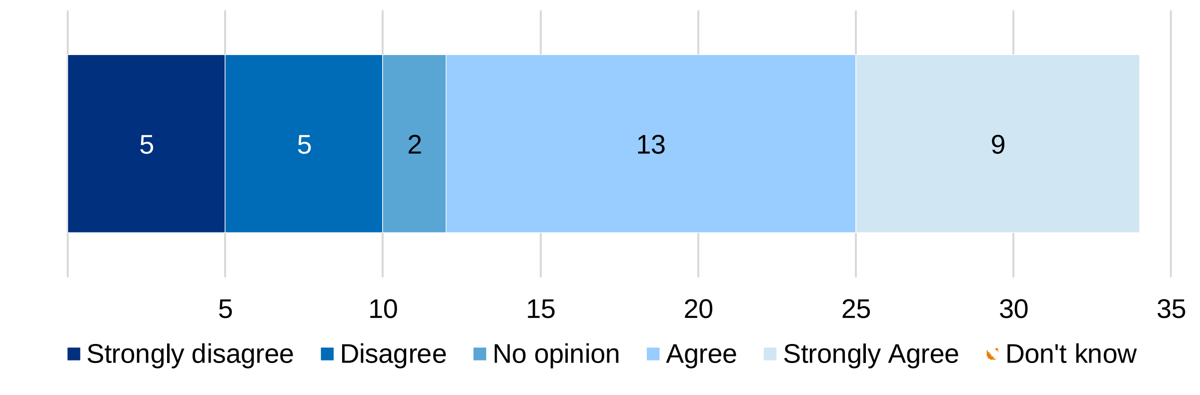
“Question 6. The specifications for this pilot study defined the scope and system boundaries as covering the whole life-cycle but mostly no infrastructure, do you agree that this is adequate for the goal and scope of the study?”

The majority of respondents (strongly) agreed with the proposed scope and system boundaries of the study (Figure 3-3).

In the comments provided by the experts that agreed with the proposal, respondents explained that most infrastructure does not need to be included due to reasons such as: impacts are expected to be negligible (six respondents), quality of data on infrastructure is considered to be flawed and create uncertainty (one respondent) and infrastructure is already in place and built for a different purpose (e.g. electricity generation) (one respondent). However, one stakeholder advised care when assessing low volume, renewable or novel materials and fuels, and another noted that infrastructure can be important for trolley busses and possibly charging points. For another stakeholder, it is critical to include renewable power generation facilities.

Two other respondents argued that if infrastructure for electricity generation, transmission and charging of EVs is included, then infrastructure for fuel production and refuelling should also be included – otherwise it produces biased results. As such, one of these respondents advised not to include any emissions due to the production of capital goods but only report these as part of the sensitivity analysis.

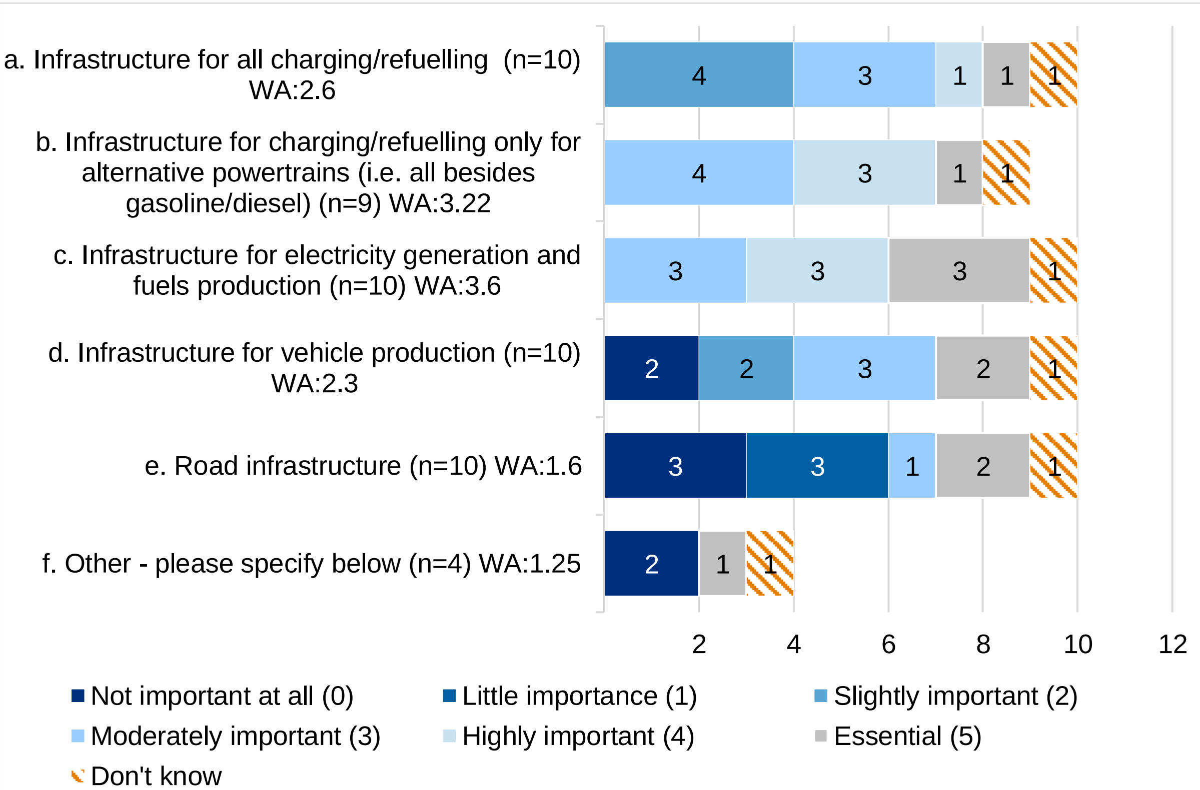
Figure 3-3: Appropriateness of proposed scope and system boundaries (n=34)



Those that disagreed were asked which important aspects were missing and should be included (Figure 3-4): infrastructure for electricity generation and fuels production was considered the most important element (WA: 3.6) followed by infrastructure for charging/refuelling only for alternative powertrains (WA is 3.22).

In the comments provided, one expert argued similarly that it is necessary to include fuel production infrastructure if also including electricity production infrastructure to ensure a fair comparison between powertrains. Four respondents indicated that the impacts of infrastructure should still be assessed in order to understand the significance of its impacts. If deemed small, then infrastructure could be excluded on the basis of evidence (as recommended by the eLCAr guidelines which were referred to by one respondent). Another respondent pointed to important sources of impacts from the different infrastructure identified above.

Figure 3-4: Potential aspects missing from scope and system boundaries of the study



Q6 Response by the project team to results and comments:

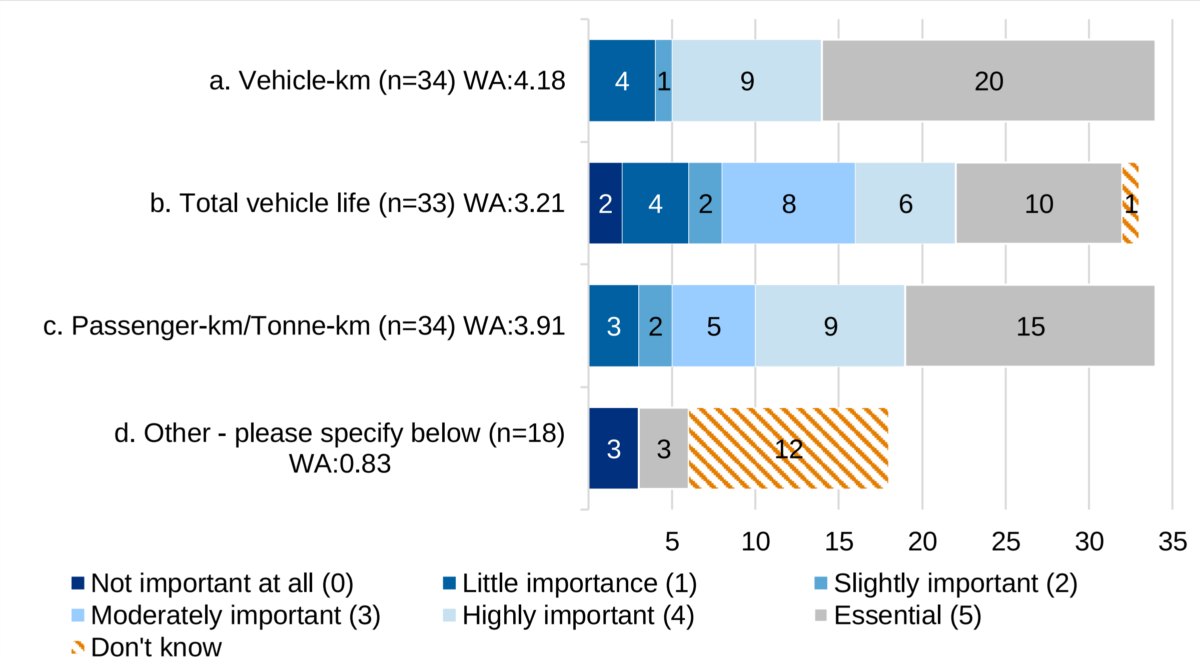
It is concluded that road as well as recharging and refuelling infrastructure can be neglected due to the expected small overall contribution and potential further uncertainties. Since infrastructure (capital goods) for the production of renewable energy is expected to be relevant at least in relative terms, this will be taken into account for the energy sector (see respective sections for further details).

"Question 7. Which functional units should be used for impacts in the study for the full life-cycle in respect to the overall goal of the study?"

Some stakeholders have been confused by the focus of the question on the unit of the "reference flow" within the broader context of the functional unit. The following answers largely reflect the views on the proposed reference flows.

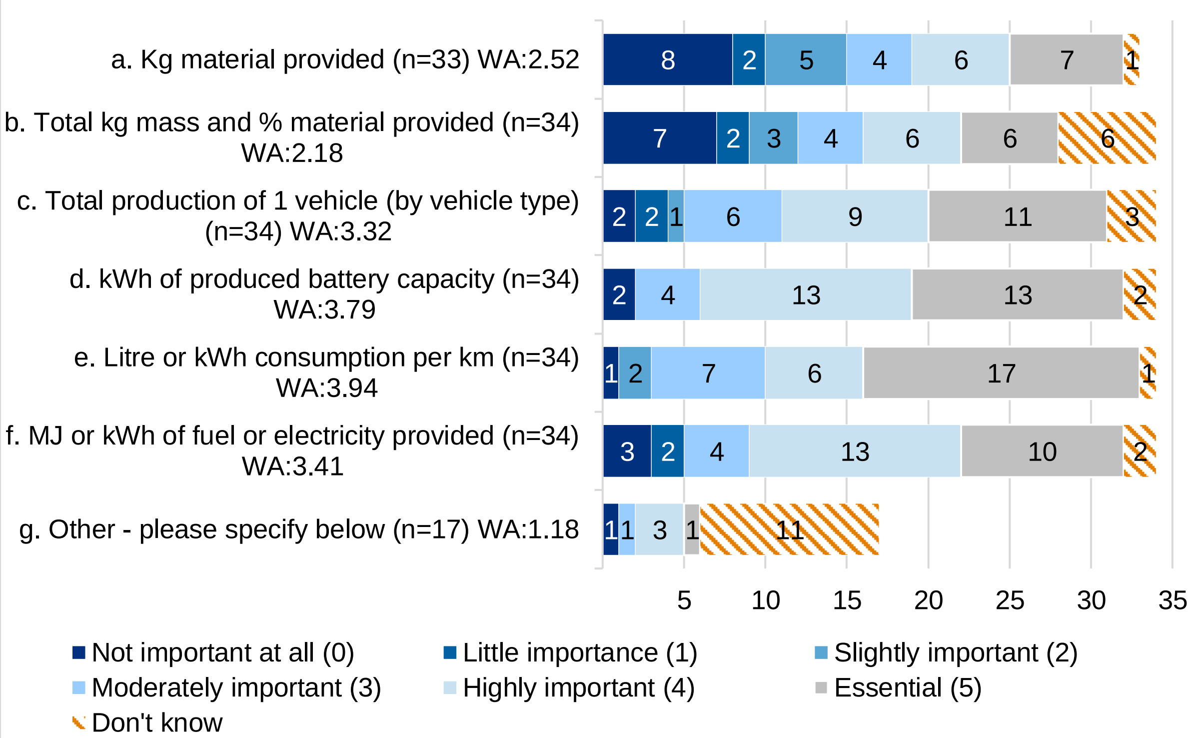
Overall, the 34 respondents largely supported the use of vehicle-km (WA: 4.18), total vehicle life (WA: 3.21) and passenger-km/tonne-km (WA: 3.91) as reference flows to define the overall impacts assessed in this study.

Figure 3-5: Choice of functional units



Considering reference flows for sub-systems of the life cycle, stakeholders also suggested that energy consumption-related units to be important (Figure 3-6): litre or kWh consumption per km (WA: 3.94), kWh of produced battery capacity (WA: 3.79), MJ or kWh of fuel or electricity provided (WA: 3.41). Other suggestions include: kg of battery mass, MJ per hectare, lifetime mileage and battery lifetime.

Figure 3-6: Choice of additional function units for sub-systems of the life cycle



Among the comments provided, one respondent argued that interim results should be reported to ensure transparency, and these will be expressed in different units. For another respondent, different vehicle segments/categories are driven differently and have different profiles that require specific metrics. Another stakeholder explained that reporting production impacts per vehicle is consistent with functional unit of lifetime travel distance, whilst battery production impact should be reported per kWh of capacity but per kg basis impact would also be useful.

Q7 Response by the project team to results and comments:

Overall it is concluded that the majority of stakeholders supports the proposed reference flows which will therefore be used in the study. It further must be stated that the functional unit is defined along the lines of vehicle size/utility. The study will therefore carry out a technical comparison of similar vehicles (size/utility). Further differences between drive concepts (e.g. driving range, maximum speed and driving dynamics) are accepted in this context, assuming that chosen vehicles are always suited to the specific usage despite differences in driving range and driving characteristics. Mobility based approaches (sharing, multimodality) will be acknowledged in a qualitative discussion

Additional reference flows as proposed will be used for subsystems and also published to ensure transparency of results.

"Question 8. Do you agree that these are the most relevant guidelines for consideration?"

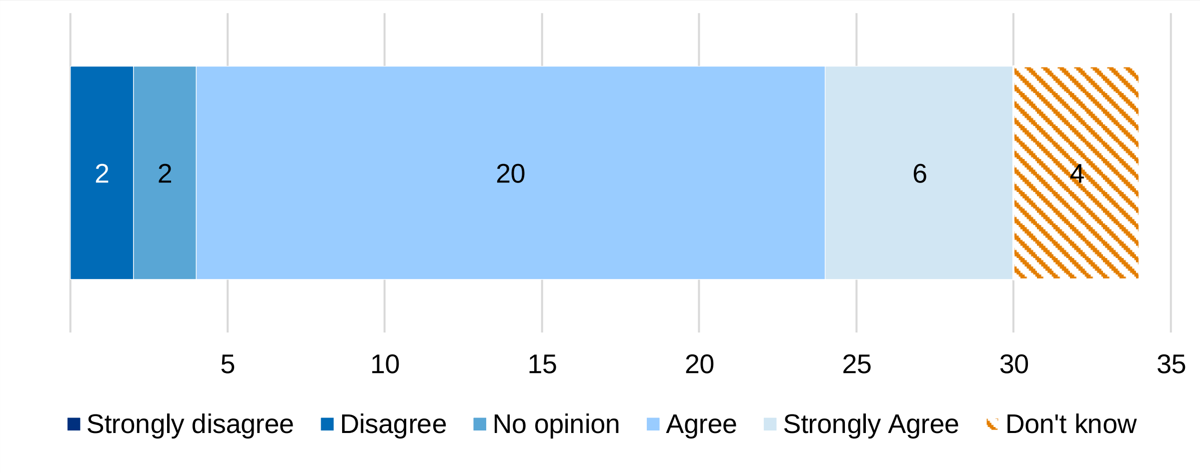
The majority of respondents considered that the most relevant guidelines have been taken into consideration in this study, as shown in The comments provided by the other stakeholders that agreed supported the view that the most relevant guidelines have been considered, with some even arguing that ISO 14040/44 should take priority but also indicating that they are not vehicle specific. One respondent also questioned how inconsistencies between guidelines will be dealt with. Some experts also suggested additional guidelines such as: ISO 14067, RED, PEF, Concawe/JEC and additional, more specific literature and case studies.

Figure 3-7.

Two of the stakeholders that disagreed explained that, whilst they recognise the existence of other standards, the ISO 14040/14044 should be the main reference guideline. One of them argued that the other standards / guidelines in their current format are not mature enough.

The comments provided by the other stakeholders that agreed supported the view that the most relevant guidelines have been considered, with some even arguing that ISO 14040/44 should take priority but also indicating that they are not vehicle specific. One respondent also questioned how inconsistencies between guidelines will be dealt with. Some experts also suggested additional guidelines such as: ISO 14067, RED, PEF, Concawe/JEC and additional, more specific literature and case studies.

Figure 3-7: Consideration of most relevant guidelines (n=34)



Q8 Response by the project team to results and comments:

It is concluded that ISO 14040/14044 are the most important guidelines considering the goal of the study. Even though methodological aspects from other mentioned guidelines (e.g. ILCD/PEF) may be incorporated where available, it is concluded that a full compliance with further guidelines is not feasible due to the large number of analysed variations (scope of the project). This is regarded to be acceptable since the focus of the study is on general policy advice rather than monitoring of specific products. Internal methodological consistency will be ensured and is regarded to be of higher importance in respect to the goal of the study.

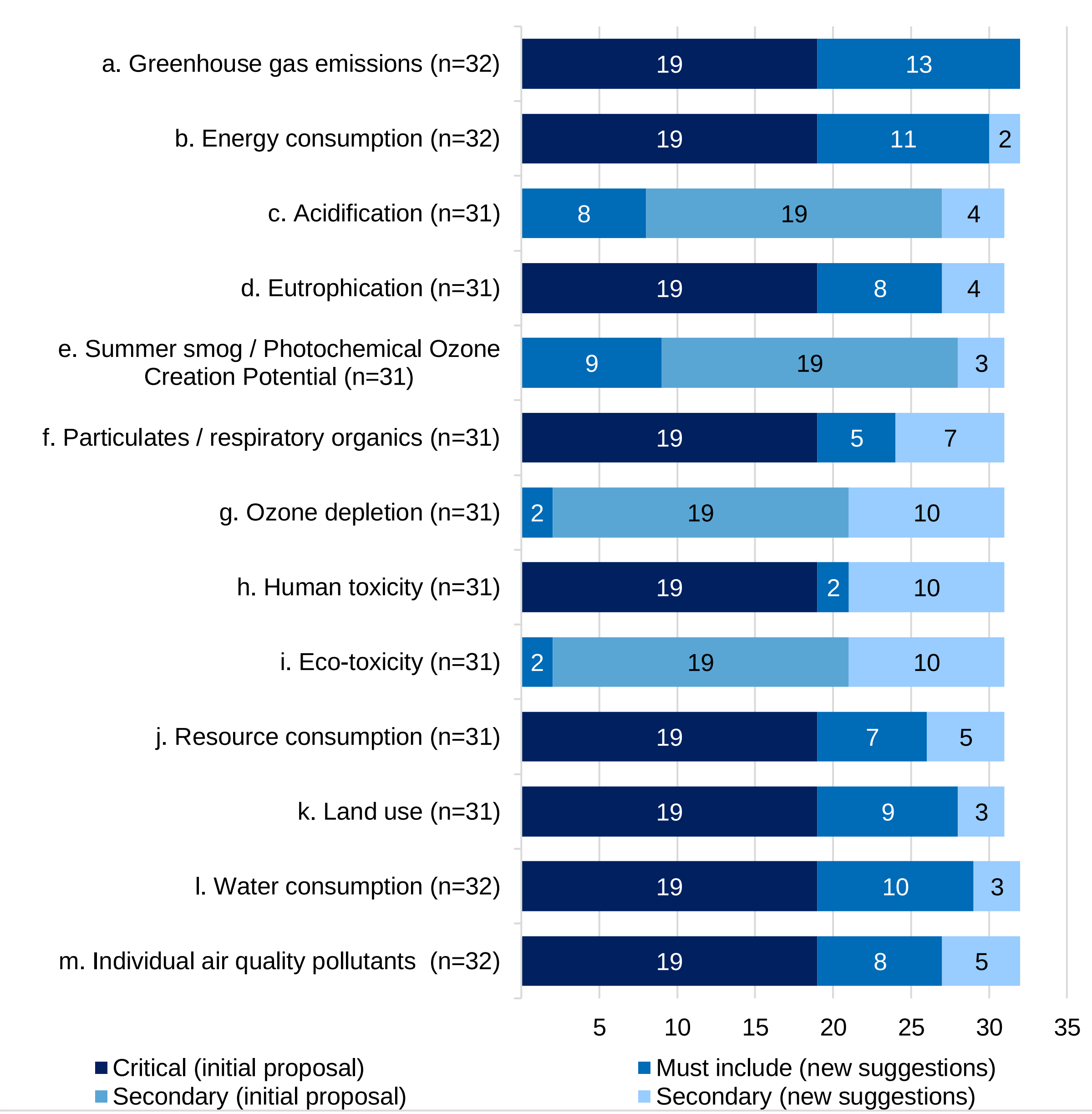
“Question 9. Do you agree that the proposed impacts cover those that are most important?”

Respondents were asked whether they agreed with the proposed coverage of impact categories, divided into two main lists, *critical impact categories*, and *secondary impact categories*. Overall, Figure 3-8 provides an overview of the stakeholders’ views on which impact categories are critical and which are secondary by summarising the combined answers of all those that responded to this question, i.e. both those that agreed and disagreed:

- If they agreed with the proposal, the critical and secondary impact categories in the proposal were considered – their responses are marked as *Critical (initial proposal)* and *Secondary (initial proposal)* in the figure;
- If they disagreed with the proposal, they were given the list of all impact categories and were asked to re-classify each category as ‘must include’ or ‘secondary importance’ – their responses are marked as *Must include (new suggestions)* and *Secondary (new suggestions).*

More respondents agreed that the proposed coverage of impacts in the study is adequate (19 of 34 (strongly) agreed compared to 14 that disagreed).

Figure 3-8: Proposed coverage of impact categories in the study



Overall, it is shown that the majority of stakeholders consider the following categories to be critical/secondary in line with our proposal:

- Critical: greenhouse gas emissions, energy consumption, water consumption, eutrophication, land use, individual air pollutants, resource consumption.
- Secondary: ozone depletion, eco-toxicity.

There are more mixed views concerning acidification, summer smog/POCP, and human toxicity. Both acidification and summer smog impacts were considered to be secondary categories in our proposal but about one-third of the respondents indicated these are essential impact categories. On the other hand, toxicity impacts were considered to be critical in our proposal but about one-third of the respondents disagreed. Toxicity impacts in particular generated a high level of discussion in the comments with many respondents indicating that their assessment is uncertain and highly variable depending on local background. In the case of POCP, two respondents argued that this is a very relevant impact in the context of vehicle emissions and in cities.

More generally, stakeholders advised to consider how mature the methodologies are for estimating these impacts. Others also highlighted differences in impacts in urban vs non-urban contexts that should be specified whenever possible.

Two other stakeholders suggested to assess a wide range of impact categories given the diversity or potential environmental impacts and to allow a critical analysis during the study. One stakeholder suggested that all categories should be given the same importance.

Experts also recommended additional categories such as fossil fuel resource depletion, emissions to land (disposal, land field), and material consumption. One other respondent noted that water consumption should be referred to as water footprint (i.e. water impact change depending on the local scarcity) – this is in line with another respondent's remark that water and energy consumption are not environmental impacts per se.

Finally, one stakeholder claimed that the reference CML 1992 seems to be outdated and instead suggested that the impact categories and the underlying methodology used should be in line with the European Commissions' Product Environmental Footprint initiative's proposed midpoint categories.

Comments provided on the same question in respect to fuels and electricity generation (Question 33 and 49) pointed out that the list of impact categories should be the same across all stages.

Q9 Response by the project team to results and comments:

It is concluded that the majority of experts has agreed with the proposed coverage of midpoint impacts. Since there are polarised views concerning toxicity impacts (less support for inclusion due to uncertainties in data and methodology), acidification and summer smog/POCP impacts (more support for inclusion), all proposed impacts will be quantified as part of the study. To address concerns regarding data transparency and controversial methodologies, a qualitative discussion about significance and uncertainties will be undertaken at the end of the study.

The scope of impacts will be applied to all life-cycle stages of the study including fuel production and electricity generation (see questions 33 and 49).

"Question 10. With which of the proposed approaches for end-of-life modelling do you agree (i.e. from avoided burden, cut-off or hybrid options?"

Respondents had different views on the most appropriate approach for end-of-life (EoL) modelling. The results in Two respondents that preferred the use of a cut-off approach only noted that the hybrid approach would be too complex and would not produce transparent results. They explained that credits for recycling processes should be granted only if re-routing of recycled material flows into production processes can be verified, and the cut-off approach is the method generally used by OEMs. Another stakeholder that suggested the use of a cut-off approach only argued that it is extremely difficult to determine the avoided burden as it depends on the ever-changing demand and supply of virgin and scrap materials. The other respondent that supported this view indicated that the applied industry approaches should be followed for a certain industry, and that many associations offer LCI datasets based on primary industry data.

One stakeholder supported the use of the avoided burden approach given that recycled content is not as important (no need to strive for a closed loop recycling if the market for secondary materials works) and the recycling rate is a better indicator for the burden of the vehicle life cycle.

Further comments have been provided in respect to question 28 which rather refer to the general EoL discussion. Here some experts stated that the importance of the EoL phase should not be overestimated and even if interesting results could come from doing a recycling study, this is not the focus of the pilot.

One respondent found that a cut-off is better than an avoided burden approach, but preferred the usage of a system expansion. One expert stated that the cut-off approach is no more robust than the other approaches, but gives no incentive for high recycling rates at the EoL. One stakeholder also commented that the EoL methods will be especially relevant for all metals, where high recycling rates are found and it may be unfair to use a cut-off approach for them. This stakeholder also stated that it rather depends on the quality of the secondary material (especially for plastics) and not just the recycling rate. One expert was concerned that the recycling in the EU is a lot more sophisticated than in other areas of the world (e.g. Asia).

One respondent also suggested a system extension approach, whilst another indicated that the most appropriate approach depends on the goal of the study.

Figure 3-9 show that stakeholders mostly agreed with the use of a hybrid approach at least for important growing material demands (and where use of secondary material differs considerably from recycling rates); a large number of stakeholders also suggested the use of a cut-off approach for minor materials (and where use of secondary material roughly equals recycling rates):

- Out of 31, 15 respondents (strongly) agreed with the use of *Cut-Off approach for minor materials (and where use of secondary material roughly equals recycling rates) and hybrid approach for important growing material demands (and where use of secondary material differs considerably from recycling rates)* against 8 that (strongly) disagreed.
- Out of 33, 11 respondents (strongly) agreed with the use of a *Hybrid approach only* against 11 that (strongly) disagreed.

On the other hand, the use of a cut-off approach or the avoided burden approach *only* is less supported by stakeholders:

- Out of 34, 7 respondents (strongly) agreed with the use of *Cut-Off approach* against 19 that (strongly) disagreed.
- Out of 33, 7 respondents (strongly) agreed with the use of an *Avoided Burden approach only* against 16 that (strongly) disagreed.

In the comments provided, three stakeholders suggested following a similar approach to the one specified by PEF that reflects the different secondary material supply/demand situations by using an allocation factor between 0:100 and 100:0 approaches for each material.

Those stakeholders that supported the use of a cut-off approach combined with the hybrid approach highlighted that this method is especially important to account for the end-of-life of batteries (and second life applications). For another, the use of a cut-off approach combined with the avoided burden approach would be more appropriate to ensure the future utility of materials with dynamic/growing demands such as EV batteries.

Two respondents that preferred the use of a cut-off approach only noted that the hybrid approach would be too complex and would not produce transparent results. They explained that credits for recycling processes should be granted only if re-routing of recycled material flows into production processes can be verified, and the cut-off approach is the method generally used by OEMs. Another stakeholder that suggested the use of a cut-off approach only argued that it is extremely difficult to determine the avoided burden as it depends on the ever-changing demand and supply of virgin and scrap materials. The other respondent that supported this view indicated that the applied industry approaches should be followed for a certain industry, and that many associations offer LCI datasets based on primary industry data.

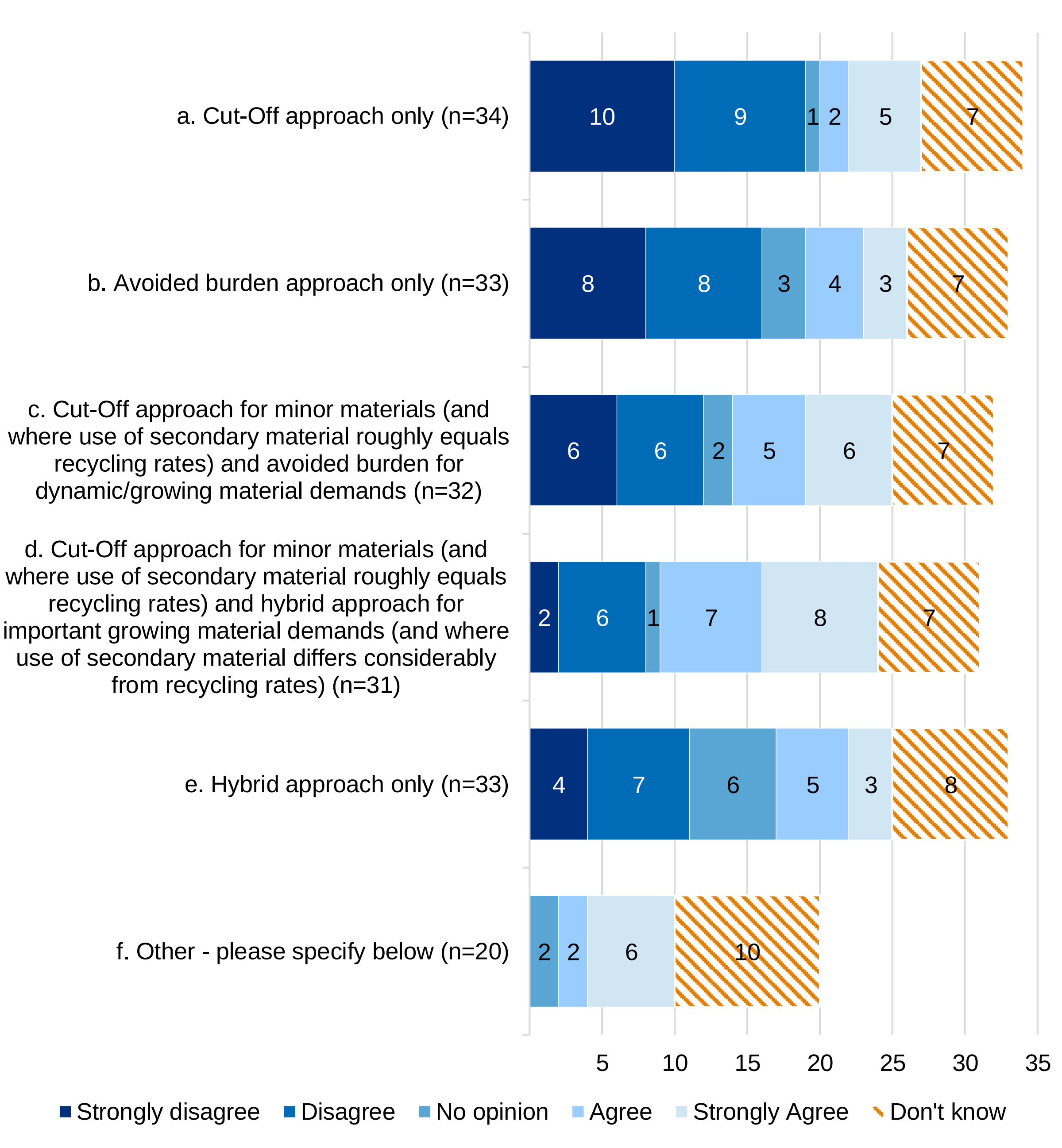
One stakeholder supported the use of the avoided burden approach given that recycled content is not as important (no need to strive for a closed loop recycling if the market for secondary materials works) and the recycling rate is a better indicator for the burden of the vehicle life cycle.

Further comments have been provided in respect to question 28 which rather refer to the general EoL discussion. Here some experts stated that the importance of the EoL phase should not be overestimated and even if interesting results could come from doing a recycling study, this is not the focus of the pilot.

One respondent found that a cut-off is better than an avoided burden approach, but preferred the usage of a system expansion. One expert stated that the cut-off approach is no more robust than the other approaches, but gives no incentive for high recycling rates at the EoL. One stakeholder also commented that the EoL methods will be especially relevant for all metals, where high recycling rates are found and it may be unfair to use a cut-off approach for them. This stakeholder also stated that it rather depends on the quality of the secondary material (especially for plastics) and not just the recycling rate. One expert was concerned that the recycling in the EU is a lot more sophisticated than in other areas of the world (e.g. Asia).

One respondent also suggested a system extension approach, whilst another indicated that the most appropriate approach depends on the goal of the study.

Figure 3-9: Proposed approaches for end-of-life modelling



Q10 Response by the project team to results and comments:

Although the survey responses show that a large part of the experts were in favour of using a hybrid approach for end-of-life modelling, the discussion at the workshop revealed mixed views. It is apparent that no single approach appears to do justice to the complex and diverse issues in question. It is also acknowledged that system expansion, which is also supported by ISO 14040/14044, would be the preferred overall solution from a scientific point of view. System expansion, however, is regarded to be not feasible due to the broad scope of the project concerning vehicle, drive train, fuel and power generation types as well as regional and temporal differentiation. From the comments provided during the consultation, it is concluded that the cut-off approach can be used as a conservative and robust default option, but should be complemented by a second approach for certain materials. It will be further investigated in round 2 of the survey which approach is most suitable to complement the cut-off approach amongst the following options:

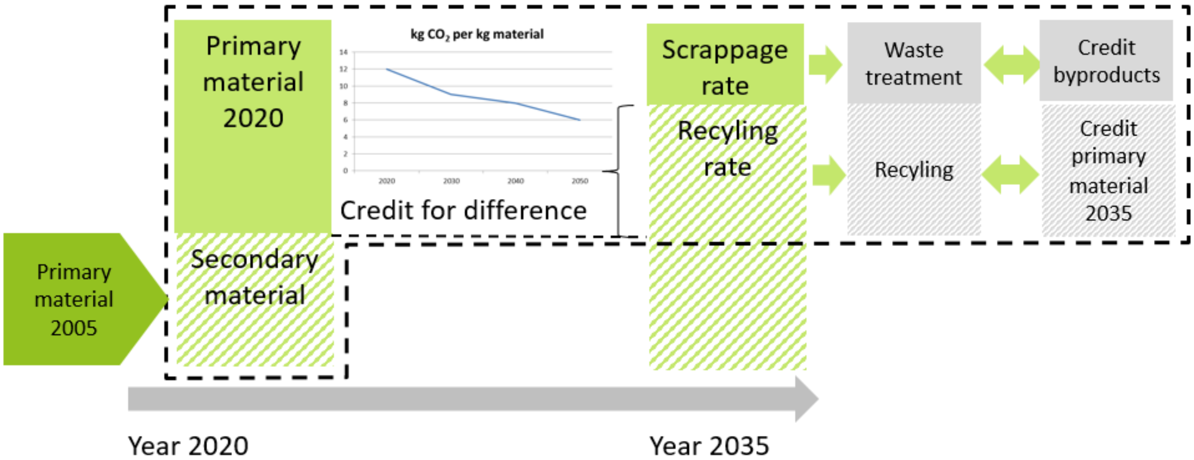
- Avoided burden approach
- Hybrid approach: this approach uses recycled content to calculate production impacts, then the difference between this and the final end-of-life recycling rate to calculate credits in the

future where recycling rates are expected to be significantly different/higher than recycled content – see Figure 3-10 for an illustration of this approach.

- EoL allocation with a factor between 0 and 100 (taking into account possible quality losses): instead of using a 0:100 or 100:0 approach at the EoL it is possible to calculate an allocation factor that takes into account possible quality losses in the secondary material (e.g. following the EoL formula in the PEF guide).

Respondents to round 2 of the survey will also be asked to indicate for which materials/situations the complementary approach should be used.

Figure 3-10: Hybrid approach



3.1.1 Section 1: Overall methodology conclusions

Q	Topic	R1 Conclusion, clarifications and refinements	R2 Status
5	Overall LCA approaches	There was good level of support for the proposed approach. *Refinements:* Consequential elements (new cell chemistries, electricity split and decarbonisation of materials) will also be considered implicitly in the scenarios for modelling of battery and fuel cell production.	Closed, comments only.
6	Scope and system boundaries	There was good level of support for the proposed scope and system boundaries. *Refinements:* None.	Closed, comments only.
7	Functional units and reference flows	There was good level of support for the use of the proposed reference flows. *Refinements:* The broad context of the functional unit is now explained in more detail.	Clarification of proposal, comments only.
8	Guidelines	There was good level of agreement that ISO 14040/14044 are the most important guidelines considering the goal of the study. *Refinements:* Additional guidelines suggested (e.g. ILCD/PEF) may be incorporated if available, but full compliance will not be feasible due to the large number of analysed variations (scope of the project).	Closed, comments only.

9	Impact categories	There was good agreement on proposed impact categories. *Refinements:* the proposed impact categories (including toxicity, acidification and summer smog/POCP impacts) will be applied to all life-cycle stages of the study. To address concerns regarding data transparency and controversial methodologies, a qualitative discussion about significance and uncertainties will be undertaken at the end of the study.	Closed, comments only.
10	End-of-Life Approach	Stakeholder views on the most appropriate EoL approach are divided. The cut-off approach remains a conservative and robust default option but for certain areas a complementary approach appears to be necessary. *Refinements:* It will be further investigated in round 2 which complementary approach is most suitable and for which materials such an additional approach should be applied.	**Open,** refining question.

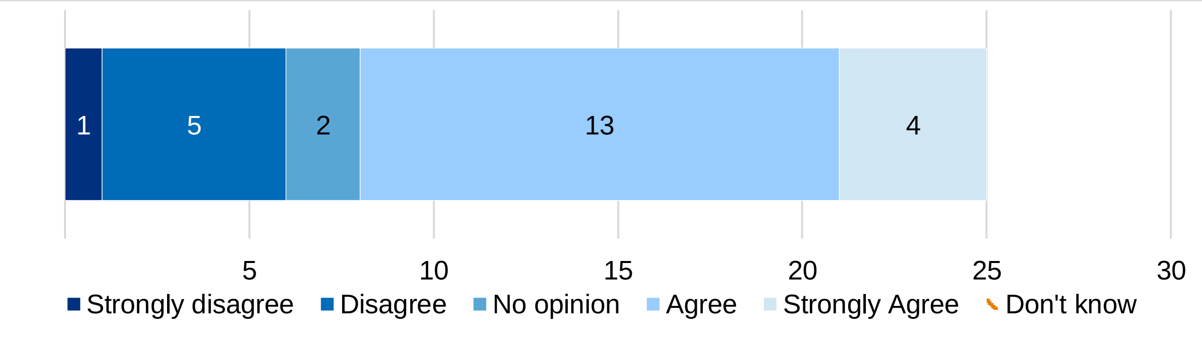
3.2 Section 2: Methodological considerations for vehicle specifications and operational emissions

Overall, respondents to the first round of the survey supported the methodological proposals for characterising vehicles and their operational emissions, although views are more divided concerning the modelling of vehicle energy consumption.

"Question 12. Do you agree with the initially proposed approach for defining general baseline vehicle specifications for conventional petrol/diesel powertrains (from market norms) and characterising alternative powertrains relative to these is the most appropriate for this study?"

The majority of stakeholders (strongly) agreed with the approach for defining equivalent baseline ICE vehicle for vehicle type/segment, based on current market norms, and characterising other powertrains relative to these (Figure 3-11).

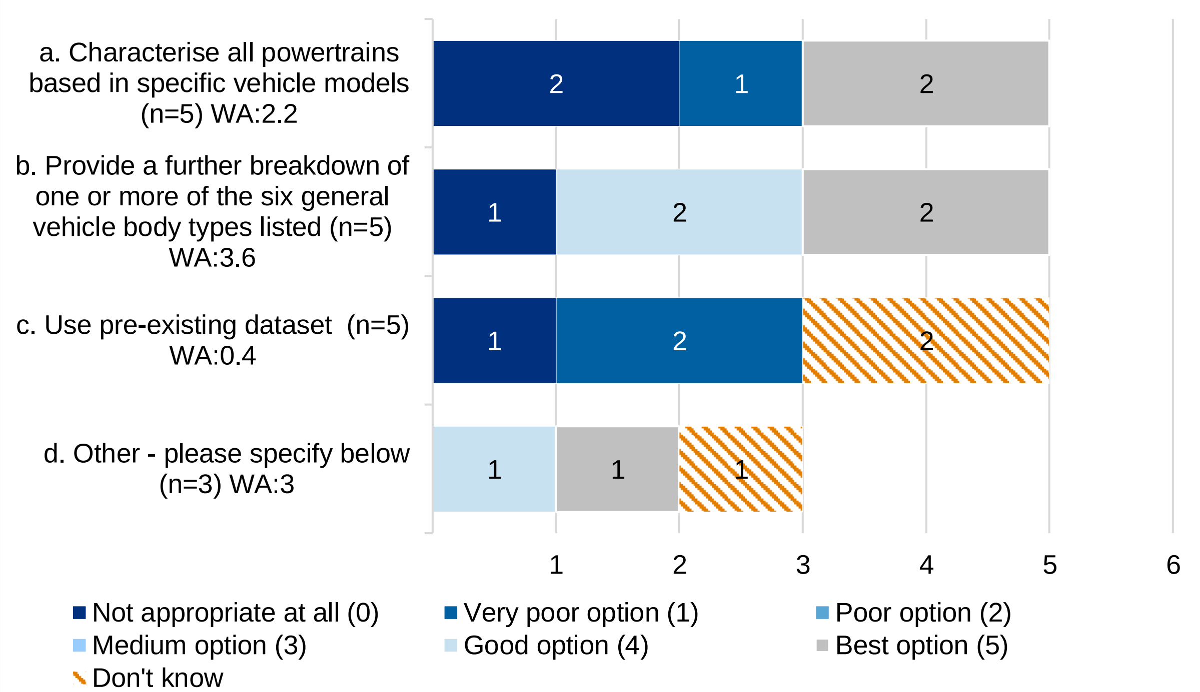
Figure 3-11: Appropriateness of the approach to general vehicle specification (n=25)



Those that disagreed mainly suggested that a further breakdown of one or more of the six general vehicle body types proposed should be provided (Figure 3-12), e.g. for small urban cars or larger cars doing higher mileage.

In the comments provided, two of the stakeholders that disagreed explained that further breakdown is advised to account for differences in characteristics and usage of vehicles; one of these stakeholders pointed to the availability of data on this. Other two respondents noted that weight and power are important variables to define equivalent vehicles. Another expert also highlighted that the use of scaling factors would distort the results given the differences in body structure between ICE vehicles and alternative powertrains.

Figure 3-12: Alternative approaches to general vehicle specification



Q12 Response by the project team to results and comments:

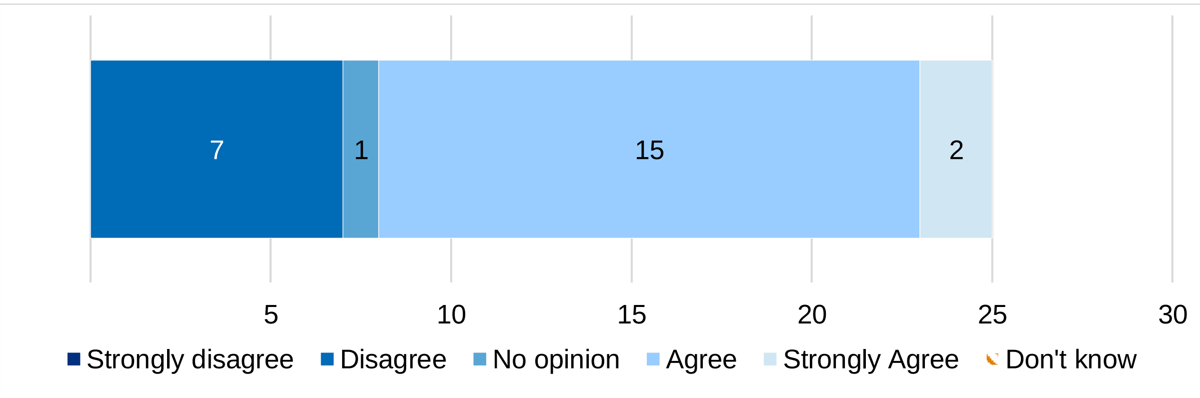
On the whole, experts supported the proposed approach. To address the comments on additional segmentation, it is proposed to break passenger cars into at least two sub-segments, potentially up to four (e.g. aligning with the segments previously analysed in reports for the Commission).

Whilst it may be expected for there to be some differences in the vehicle body/glider architecture for certain alternative powertrain vehicles (notably BEVs), the literature review and our previous experience/analysis suggests these differences are unlikely to be particularly significant to the overall result in comparison with other considerations (i.e. the powertrain-specific components, and particularly the battery specification).

"Question 13. Do you agree that the approach for vehicle composition and mass, and component-based approach to defining consistent figures for alternative powertrains provides the most appropriate level of accuracy for this study?"

Respondents also strongly supported the proposed approach for defining vehicle composition and mass (Figure 3-13).

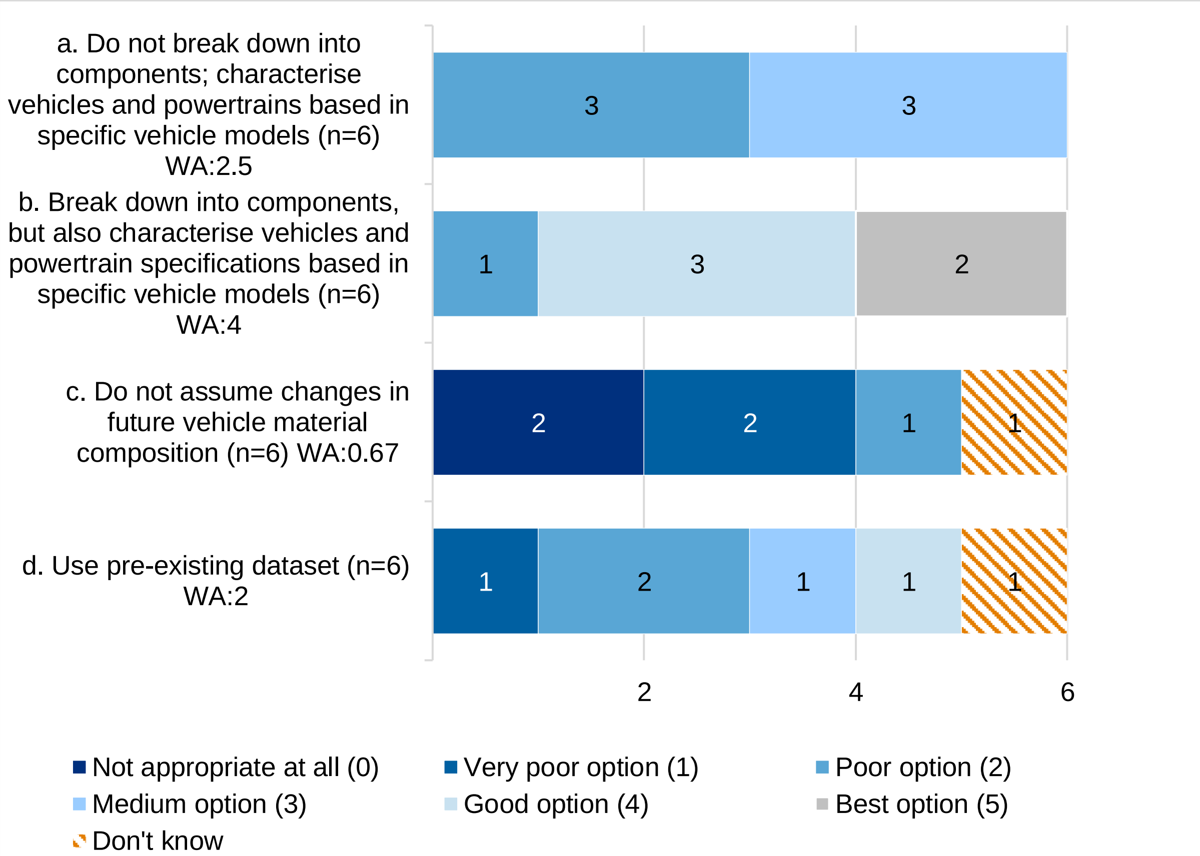
Figure 3-13: Appropriateness of the component-based approach (n=25)



Among those that disagreed, they mostly proposed to follow a component-based approach, but also characterise vehicles and powertrain specifications based on specific vehicle models (Figure 3-14).

Among the comments provided, two stakeholders that disagreed noted that body design elements are developed specifically for electric vehicles and do differ from ICEVs, thereby rendering the approach to use scaling factors inadequate (see also similar comments to Question 12). Another two respondents suggested to assess the variability within each segment and account for the impact of the use of lightweight materials.

Figure 3-14: Alternative approaches to defining vehicle composition and mass

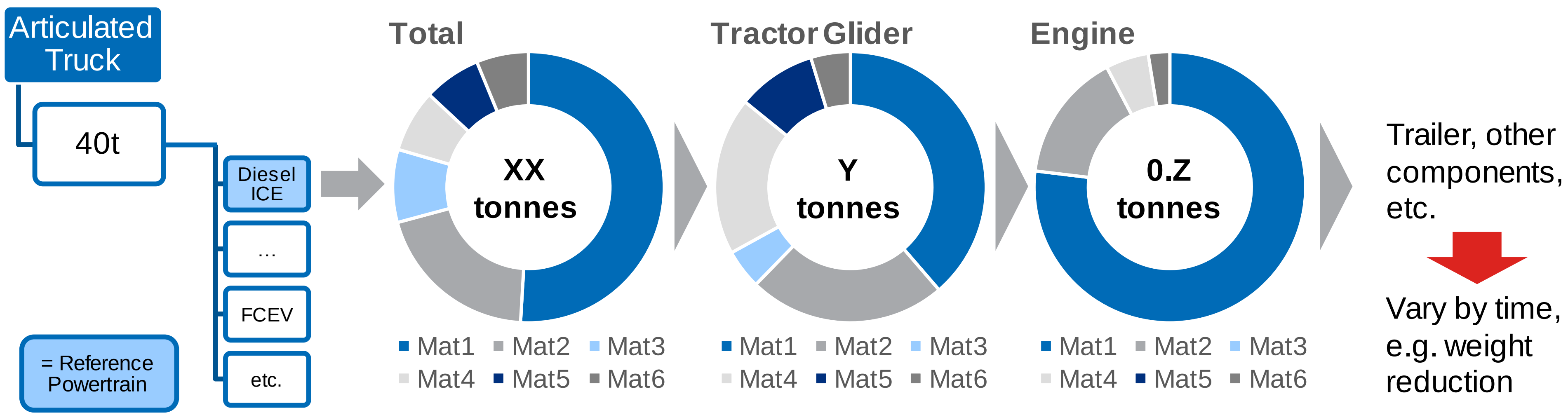


Q13 Response by the project team to results and comments:

The majority of respondents strongly supported the proposed approach for defining vehicle composition and mass. Of those who disagreed, experts mostly proposed to follow a component-based approach (illustrated in Figure 3-18); to address some support also for characterising vehicles and powertrain specifications based on specific vehicle models, we propose to benchmark/cross-check the results of the component-based approach against typical examples and adjust the analysis if necessary to compensate for significant deviations. A limited validation exercise may also be conducted on key assumptions with relevant stakeholders. As indicated in the response to Q12, we do not believe using different assumptions on body specification/characteristics (i.e. areas not related to the powertrain/fuel type) will result in significant differences compared to the powertrain-related assumptions, so do not propose to do this.

Figure 3-15: Illustration of the proposed component-based methodology for defining vehicle composition and mass for alternative powertrains

- Define reference vehicle / default powertrain by body type – e.g. Diesel Artic 40 t GVW
  - Example: convert Diesel ICEV to FCEV or BEV:
    - Replace engine with motor: ***X*** kW ICE * ***y***% (scaling factor) = ***Z*** kW electric motor
    - Mass motor (kg) = Z * motor power density (kg/kW)
    - Similarly for changing/sizing other components (with generic parameters and compositions)
- **Illustration** for composition and mass for reference vehicle:

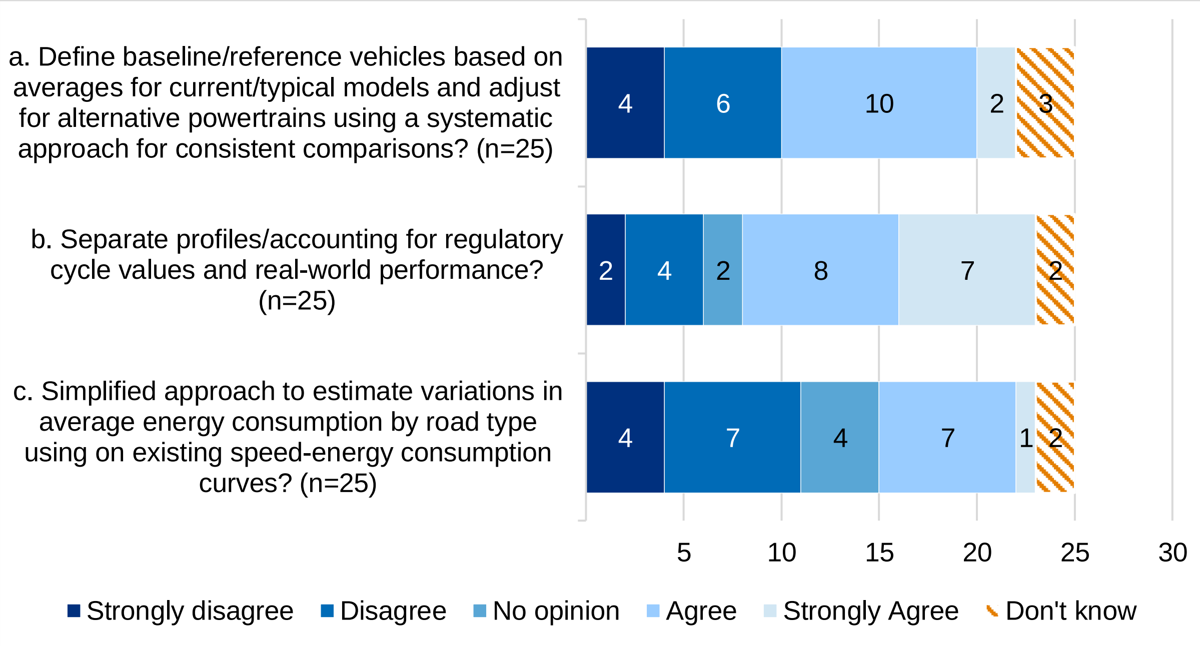


"Question 14. Do you agree with the proposed approaches for characterising vehicle energy consumption?"

Stakeholders have mixed views on how to characterise vehicle energy consumption (Figure 3-16):

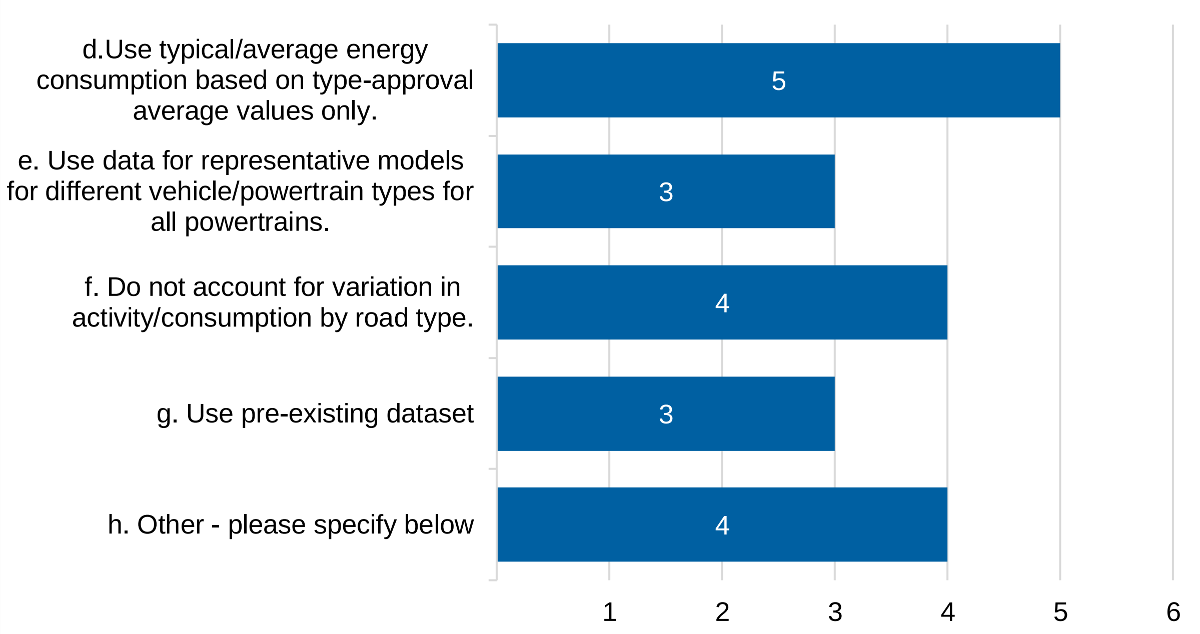
- Of the 25 respondents, 12 (strongly) agreed compared to 10 that (strongly) disagreed with the proposal *to define baseline/reference vehicles based on averages for current/typical models and adjust for alternative powertrains using a systematic approach for consistent comparisons.*
- 15 of 25 (strongly) agreed compared to 6 that (strongly) disagreed with the proposal *to separate profiles/accounting for regulatory cycle values and real-world performance.*
- 8 of 25 (strongly) agreed compared to 11 that (strongly) disagreed with the proposal *to use a simplified approach to estimate variations in average energy consumption by road type using on existing speed-energy consumption curves*.

Figure 3-16: Proposed approaches to characterising vehicle energy consumption



Those that disagreed were asked which aspects they would change from a list of options summarised in Figure 3-17. In total, five respondents suggested to use a typical/average energy consumption based on type-approval average values only, of which two explained that the type-approval values are sufficiently representative of real-world fuel economy and the gap is expected to decrease. Four also indicated that variation in activity/consumption by road type should not be accounted for, one of which explained that road differentiation is not expected to significantly change the comparison between different powertrains within the same vehicle category. Another two responses suggested developing an energy consumption model that would determine real word fuel consumption on the basis of certain vehicle characteristics.

Figure 3-17: Alternative options to characterise vehicle energy consumption



Q14 Response by the project team to results and comments:

The feedback received and further discussion at the methodology workshop with stakeholders suggested that further clarifications on the proposed methodology were needed, and that once this was provided the level of consensus improved. The following Figure 3-18 provides an illustration of the key steps/aspects of the methodology.

For Steps 1 and 2, covered by Q14a: For light duty vehicles, it is proposed to base the assumptions on analysis of detailed datasets from CO_2 monitoring (similarly to the analysis underpinning previous work on technology performance for DG CLIMA). For heavy-duty vehicles, where similarly robust data is not available, it is proposed to characterise baseline vehicles using data for representative vehicle types consistent with the baselines for VECTO / CO_2 certification analyses (i.e. for the representative duty cycles defined). For the performance of alternative powertrains where there is little existing data, it is proposed to utilise in-house simulation expertise of Ricardo to establish relative performance. Key assumptions/outputs could be cross-checked / validated with key expert stakeholders.

The development, suggested by one respondent, of an energy consumption model to estimate real-world energy consumption based on vehicle characteristics (i.e. a simulation tool) is, unfortunately, not within the scope / resources available for this work.

For Step 3, covered by Q14b: There was already a good level/clear majority of agreement on this aspect; in addition, the available evidence indicates that there will remain a significant gap between WLTP and real-world performance (though reduced vs NEDC), so it is absolutely appropriate to account for this going forwards. Additional accounting has been proposed (also at the stakeholder workshop) for differences in energy consumption in particularly hot or cold climates due to the impacts of heating/air conditioning being more significant for electric vehicles. This is particularly due to this energy demand representing a higher share of their overall operational energy consumption. A feasible/proportionate approach for this would need to be developed, if this is judged necessary.

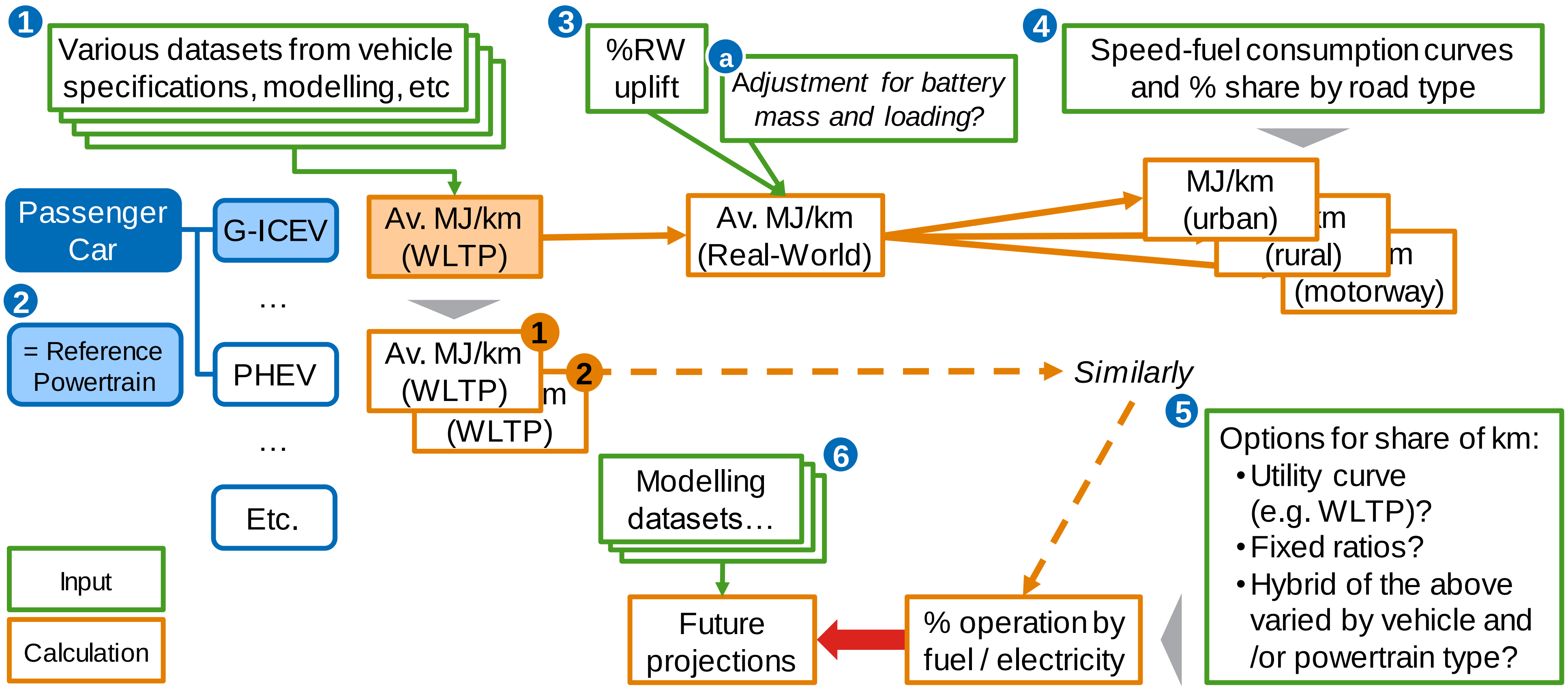
For Step 3a: This is covered by Question 15 below.

For Step 4, covered by Q14c: Not accounting for the variation in energy consumption by road type would remove the potential to assess regional variations (between different member states) in performance (as this is one of the key variables) as well as differences in performance for different operational profiles. It is clear from the available evidence (also from Ricardo's experience operating the UK's National Air Emissions Inventory) that this is the case. We believe this element should be retained therefore, and the proposed methodology is proportionate: i.e. to estimate the variability in energy demand on different road types/locations based on speed-energy consumption profiles (e.g.

using inventory methodologies, such as from COPERT) and to consider the variability in the share of operation on these road types for different EU countries.

For Step 5: This is covered by Question 16 below.

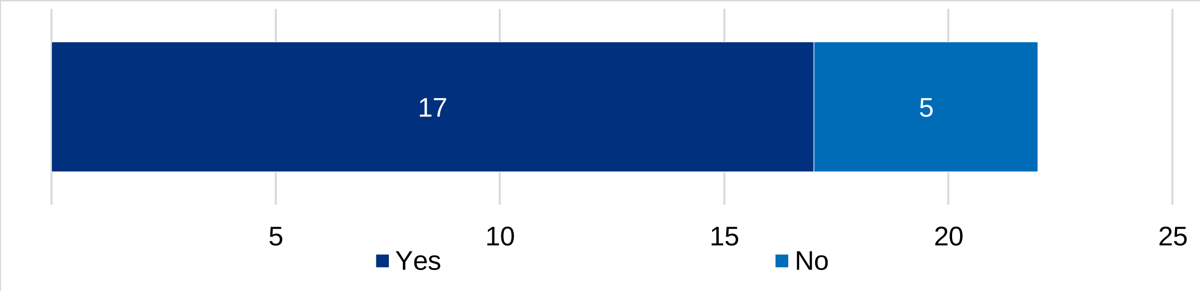
Figure 3-18: Illustration of the proposed methodological steps for defining energy consumption for different vehicle types and powertrains



"Question 15. Should the specific vehicle energy consumption (e.g. in MJ/km) be adjusted dynamically based on certain potentially adjustable settings in the life cycle analysis?"

The great majority of respondents agreed with dynamically adjusting vehicle energy consumption (Figure 3-19).

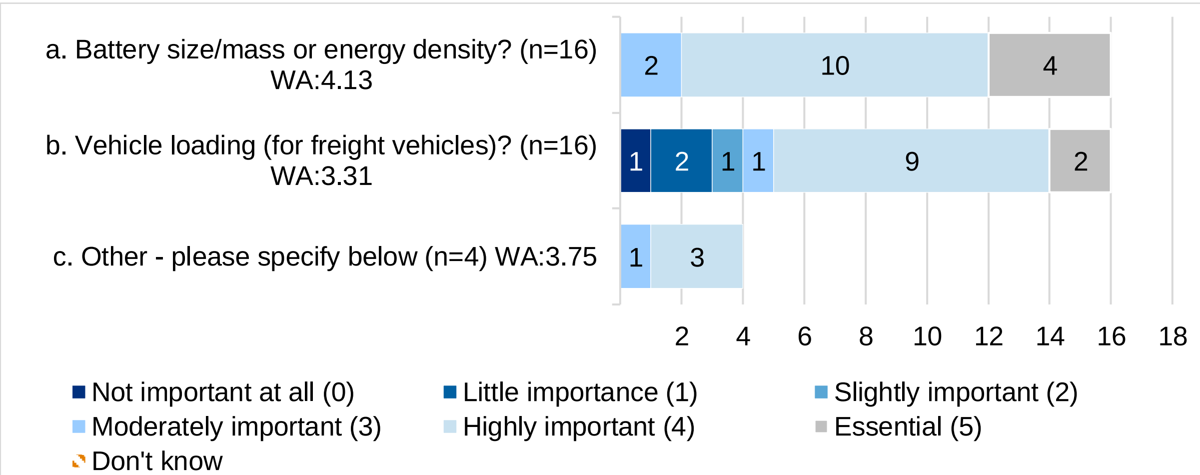
Figure 3-19: Appropriateness of dynamically adjusting energy consumption (n=16)



When asked about which settings should be the basis for the adjustment (Figure 3-20), stakeholders considered that battery size/mass or energy density were especially important (WA: 4.13) due to the expected technological advances in battery technology. To a lesser extent, stakeholders also supported the variation of vehicle energy consumption based on vehicle loading (WA:3.31) given the expected improvements in logistic operations and differences in load profiles.

In addition, two other experts suggested considering the use of air conditioning and heating, whereas another recommended taking into account developments in the frontal area/air drag coefficient, and another noted that the actual use of the vehicle (urban vs motorway) are essential.

Figure 3-20: Settings for dynamically adjusting energy consumption



On the whole, experts were in agreement with the proposal to dynamically adjust vehicle energy consumption, suggesting that battery size/mass or energy density and vehicle loading to a lesser extent are appropriate factors on the basis of which to adjust vehicle energy consumption.

Q15 Response by the project team to results and comments:

Most stakeholders indicated both of the two identified options should be taken forwards, so these will be implemented. The issue of impacts of air conditioning/heating (particularly with reference to BEVs) will be addressed under the response to Q14 above.

"Question 16. For vehicles using more than one type of fuel/energy carrier (i.e. bi- or dual-fuel vehicles, plug-in hybrids and range-extended electric vehicles), how should the share of operation on different fuels be defined?"

Respondents were asked for their views on the most appropriate approach to model energy consumption from vehicles using more than one type of fuel/energy carrier. Their responses suggest that each of the proposed alternative options have their own advantages and disadvantages, but no consensus has been reached (i.e. WA of the different options varied between 2.76 and 3.21).

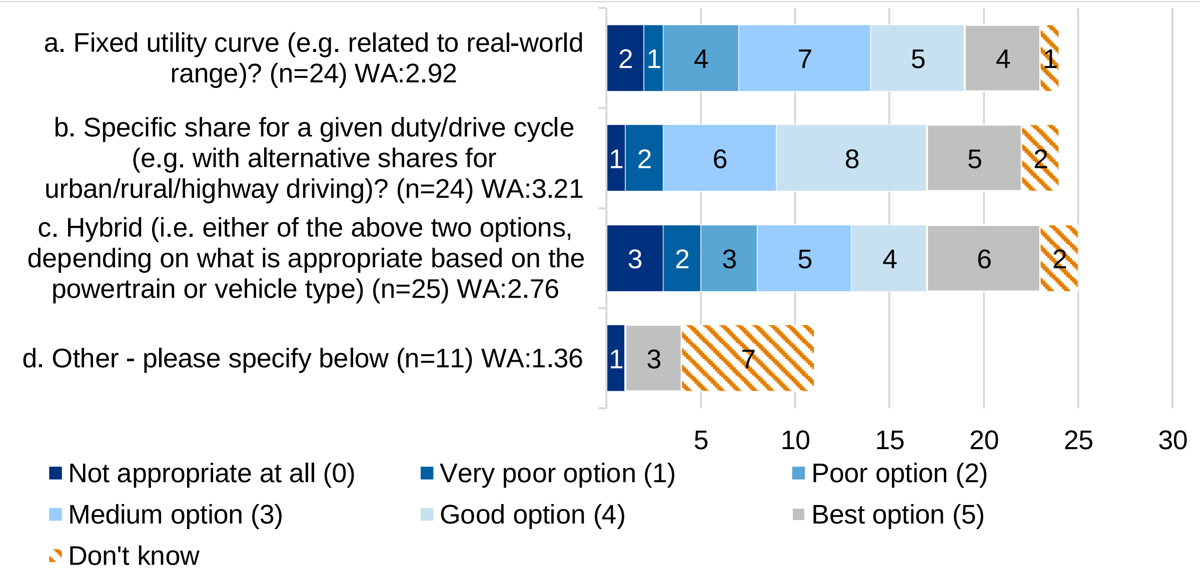
Among those that suggested other alternatives, one stakeholder explained that WLTP driving profile / test procedure should be applied, which will also determine the share of electric driven mileage (utility factor), with sensitivities to cover the extremes also (e.g. 100% on either fuel). Two other experts suggested calculating the results for each of the fuel/energy carrier types as if the vehicle was powered solely by one type and, based on these results, also present different fuel/energy carrier scenarios.

In the comments provided, one expert that supported both option A and B equally noted that the first option might be enough, given the scope of the study, as long as it is based on real world experience. For another respondent, the specific share approach will give more accurate results, but it could be difficult to assess and agree on the data.

For respondents that preferred option C, one highlighted that it was important that specific drive cycles can be used to enable benchmark between similar vehicles, another noted that ideally the analysis would consider both behavioural aspects and individual trip distances but data might not be available; for a third respondent, the optimisation strategies for hybrid vehicles require a methodology that works for all the vehicles (performances for the full electric mode, the whole ICE mode and a utility factor). They added that the calculation of the parameters that are used to determine the utility factor(s) must be as detailed as necessary to make the accurate description of the system under consideration.

One other respondent that was not satisfied with any of the options indicated that dual-fuel vehicles / plug-in hybrids are often not optimally used and are operated largely via emitting fuels. They suggested improving option B might be done by utilising collected data from fuel consumption meters (for urban/rural/highway driving).

Figure 3-21: Approaches for defining the share of operation on different fuels



Q16 Response by the project team to results and comments:

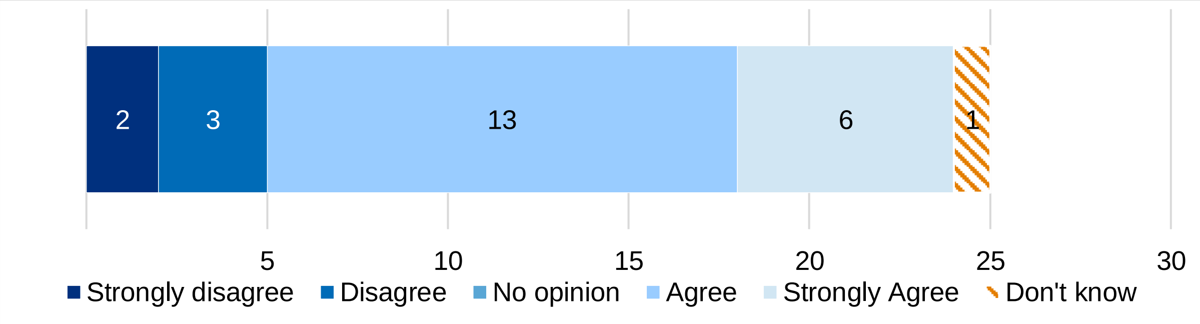
It is concluded there was good support from most experts for all three of the options proposed, with the strongest support for approaches where the share was based on the operation/duty cycle and consideration of how the distribution of different operational modes changed between different road types. The proposals will therefore be taken forward reflecting this emphasis.

Sensitivities will also be considered to reflect concerns over extreme cases (e.g. owners not regularly plugging in PHEVs, or in contrast making more significant efforts to operate in electric mode).

"Question 17. Do you agree with the proposed (inventory methods) approach for characterising/estimating tailpipe emissions of air pollutants, such as those regulated by Euro standards?"

Figure 3-22 shows that the majority of stakeholders agreed with the proposed approach to use inventory methods to characterise vehicle emissions[1], highlighting the importance of accounting for real world emissions. Two stakeholders that disagreed noted that the legal thresholds for NO_x and PM should be used whilst SO_x is not considered to be relevant. Other stakeholders suggested RDE tests and fuel consumption meters might serve as additional indicators of performance in the real-world.

Figure 3-22: Proposed approach to characterise vehicle emissions (n=25)



Q17 Response by the project team to results and comments:

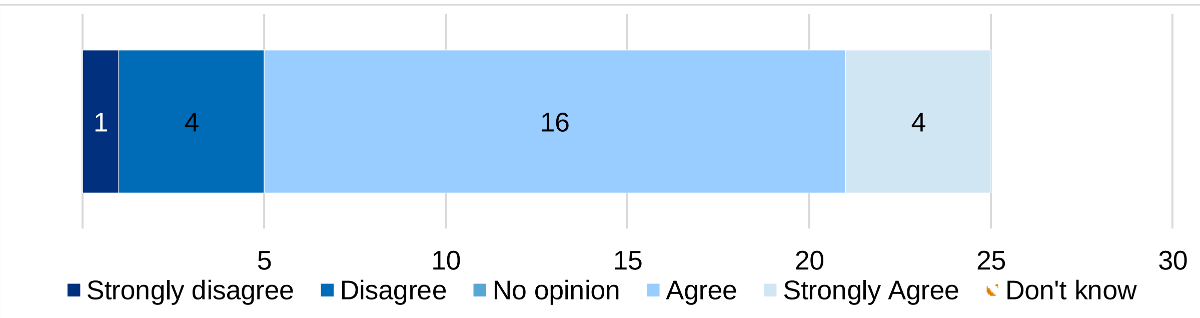
Most respondents agreed or strongly agreed with the proposed approach; it will be taken forward unchanged. The historical evidence is clear that the lab-based legal thresholds for emissions (i.e. the Euro standards) do not reflect reality (and also cannot account for different shares of driving on different roads). The proposed inventory methods account for both of these aspects (including anticipated greater convergence of regulatory and real-world performance as a consequence of in-service testing, RDE), as well as tyre and brake wear.

There is some uncertainty on how air pollutant emissions might change in the future beyond Euro 6 / VI, and additional consultation will be performed with stakeholder experts on whether/how such changes might be accounted for.

"Question 18. Is the proposal for characterising electrical energy storage (and sizing this) appropriate?"

Overall, the greater part of stakeholders supported the proposal for characterising electrical energy storage (Figure 3-23), highlighting the importance of (future) differences in battery chemistries and material use.

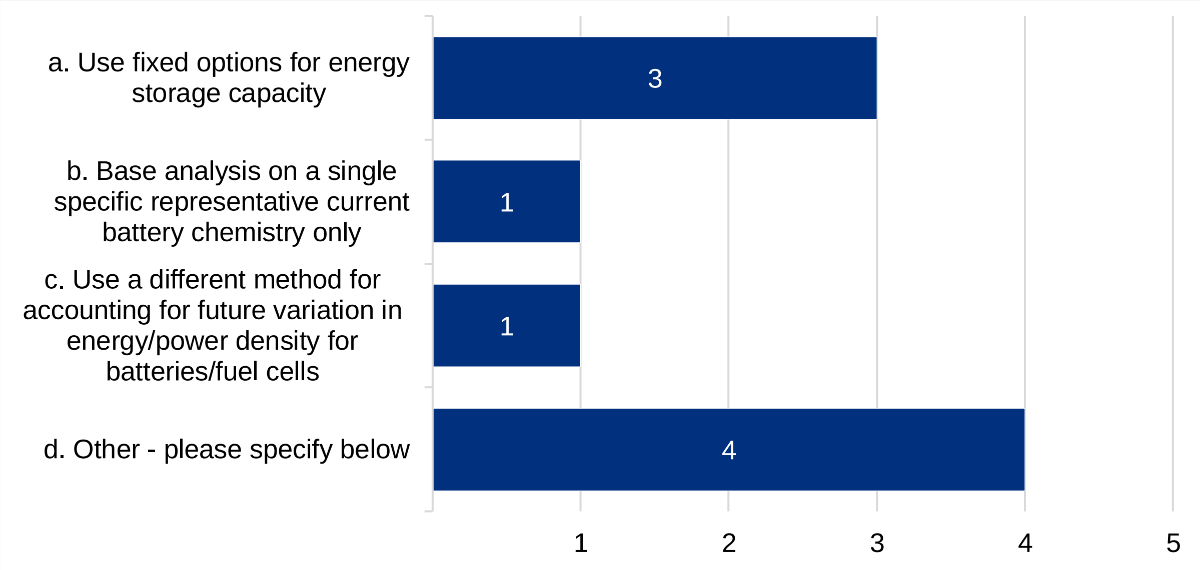
Figure 3-23: Proposed approach to electrical energy storage (n=25)



[1] Tailpipe emissions (i.e. air quality pollutants such as NOx (NO, NO_2), PM (PM10, PM2.5), etc. as well as certain GHG emissions – i.e. CH_4 and N_2O) can be calculated using existing inventory methods (e.g. COPERT or HBEFA) for most recent Euro standards for conventional vehicles average. Such inventory-based methods to account for real-world effects and variations by road type. A number of non-tailpipe emissions (i.e. tyre & brake wear, resuspension, and VOC emissions from fuel tanks) can also be estimated using these inventory-based methodologies.

Among those that disagreed (Figure 3-24), four suggested using a different approach: 1) depends on the goal of the study; 2) model reality; 3) & 4) use the NMC battery chemistry as a basis and estimate improvements. Three also recommended using fixed options for energy storage capacity.

Figure 3-24: Alternative approaches to define electrical energy storage



Stakeholders suggested other components that should be analysed in more detail, namely fuel cells (supported by 17 stakeholders). Other suggestions include: power electronics, hydrogen/LPG, H2 storage, electric motor.

Q18 Response by the project team to results and comments:

It is concluded that most experts have agreed with the approach for characterising energy storage with a more detailed approach for batteries <u>and</u> fuel cells, taking into account potential future technical development (e.g. in Wh/kg or W/kg), vehicle electric range / energy consumption, with appropriate sensitivities. The proposals will therefore be taken forward unchanged. However, also to reflect the uncertainty in this area, and discussions at the Stakeholder Workshop, a limited data validation exercise for key assumptions with relevant stakeholders will also be considered.

"Question 19. How should the number of battery replacements required be calculated for fully electric vehicles?"

On the modelling of battery replacements, stakeholders were asked to provide their views on the most adequate approach from a list of options (Figure 3-25). Neither of the three suggested options have gathered strong support, their average scoring by stakeholders (WA) ranging from 2.28 to 3.28. Among the three, the option to estimate battery replacement based on [X] (to be defined) full charge/discharge cycles scored higher.

Concerning option A, one stakeholder explained that this option accurately reflects the loss of battery capacity which has a certain number of certified charge/discharge cycles (also usually reflected in their warranty). They also suggested taking into account battery chemistry. Another stakeholder also recommended considering fast charging implications. Similarly, another respondent suggested an improvement to this option by considering the share of quick charging, and noted that battery aging depends partially on damage by heat build-up in the battery.

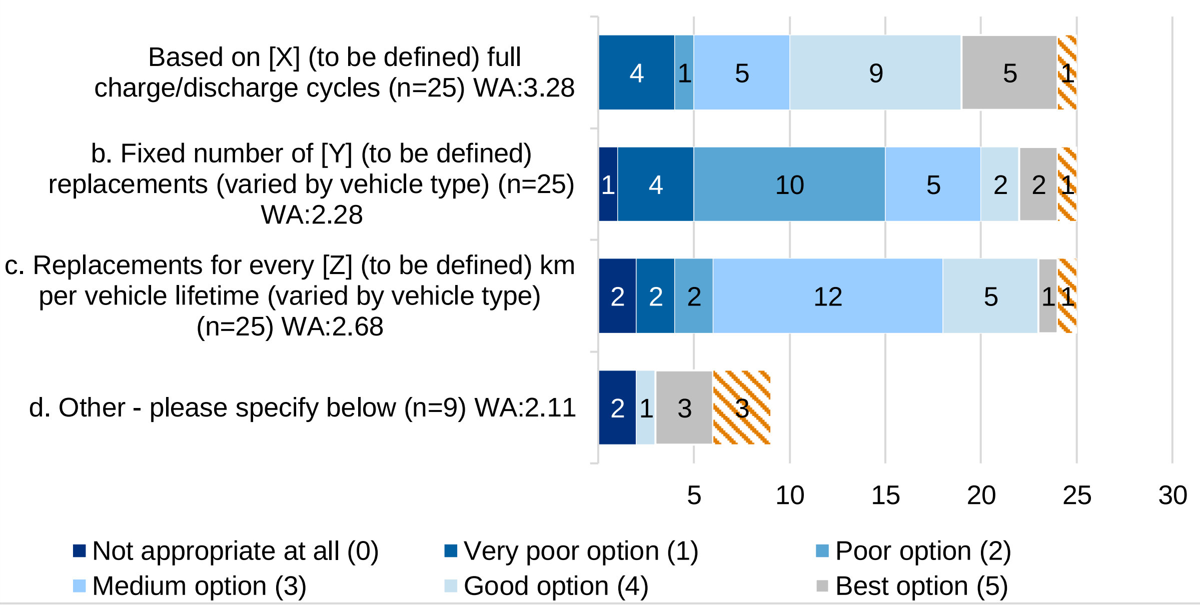
In the case of option B, two stakeholders suggested that the battery lifetime should be equivalent to the lifetime of the vehicle.

Regarding option C, one respondent advised that the service of the battery (functional unit in Wh, defined for each vehicle type usage profile) should be used to define how many km of the vehicle type it can power, before a replacement. For another respondent, determining the battery replacement interval is quite complex (due to various factors e.g. temperature, charging method, battery chemistry) and therefore a simpler approach would be sufficient; however for an extended lifetime mileage scenario, battery size should be accounted for.

Another stakeholder is of the view that all options are subject to significant errors and therefore recommended to take into account main battery durability parameters as a function of battery chemistry: calendar time, temperature (usage, storage), charging power (C-rate), SoC usage range.

Furthermore, respondents were also asked whether other powertrain components should also be included for potential replacement for certain vehicle types. Three stakeholders identified fuel cells (one specifically in the case of HDVs) as important to consider also – i.e. reflecting uncertainties in their durability / lifetime. One stakeholder also suggested CNG or hydrogen tanks might need replacing within the vehicle lifetime.

Figure 3-25: Potential approaches to modelling battery replacements



Q19 Response by the project team to results and comments:

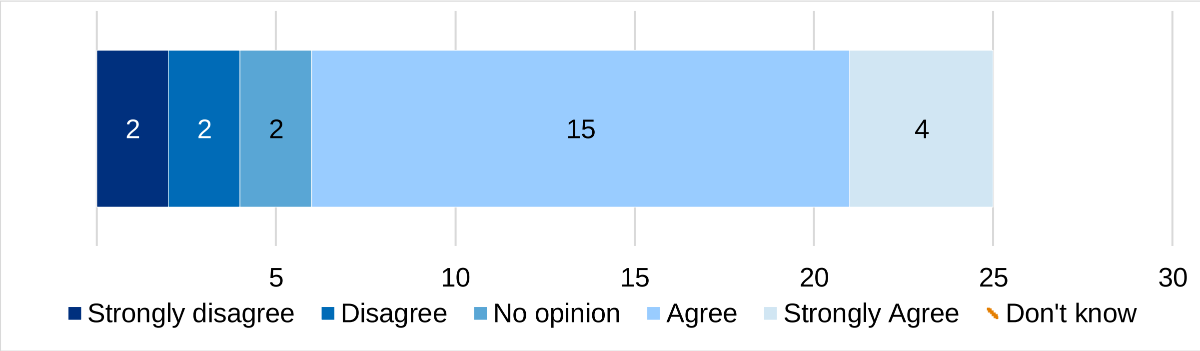
It is concluded that the majority of experts have agreed with the approach for accounting for the frequency of energy storage replacement based on [X] (to be defined) full charge/discharge cycles. This will enable a dynamic link to the assumptions on battery sizing/electric range and lifetime mileage (and potential sensitivities on these elements). The technical performance of batteries with regards to cycle life are likely evolve (improve) over time; assumptions in this regard should also be tested/validated with relevant stakeholders.

As a refinement, it is proposed to investigate whether fuel cell replacement should also be included on a similar basis.

"Question 20. Do you agree with the proposed approach to account for variations in vehicle activity and lifetime (i.e. age dependant annual mileage, and accounting for EU-average shares of activity by road type, with sensitivities)?"

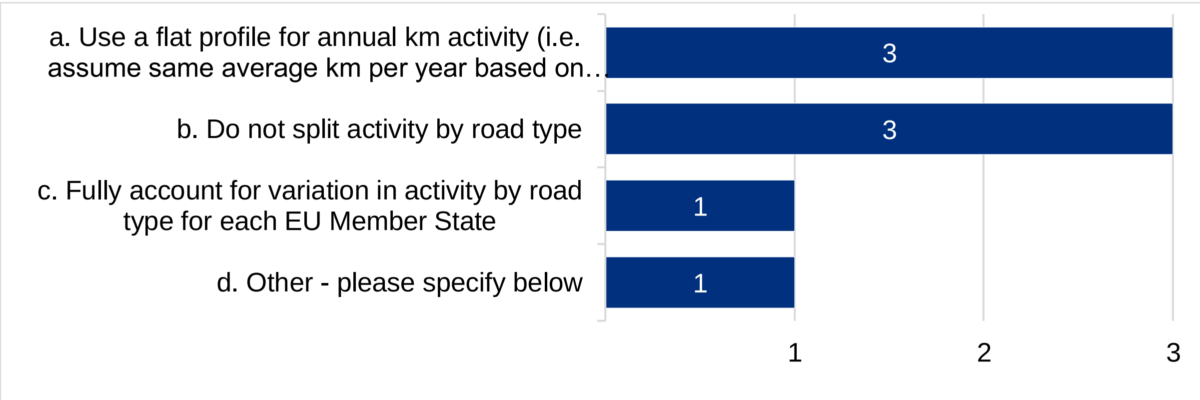
Concerning the vehicle activity and lifetime, most stakeholders have shown their agreement with the proposed approach (Figure 3-26). Two stakeholders added that new developments (e.g. V2V and V2I, sharing vs private vehicles) can affect usage patterns and thereby should be reflected in the modelling of vehicle activity and lifetime.

Figure 3-26: Proposed approach to define vehicle activity and lifetime (n=25)



Among the few that disagreed (Figure 3-27), three suggested to use a flat profile for annual km activity (i.e. assume same average km per year based on total lifetime in years and lifetime km with no variation by vehicle age), whereas three recommended not to split activity by road type.

Figure 3-27: Alternative approaches to define vehicle activity and lifetime



Q20 Response by the project team to results and comments:

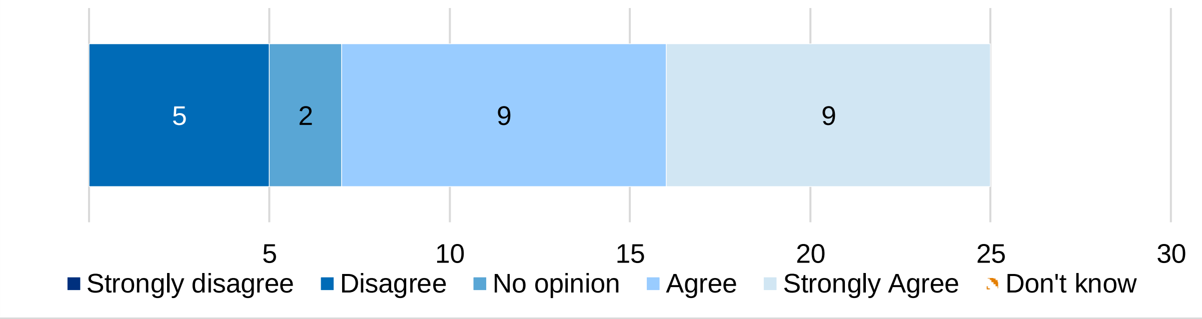
There is strong agreement for the proposed methodology, so this will be taken forwards unchanged. A flat annual km profile will not accurately account for impacts due to changing fuel/electricity mix over the life of the vehicle. In addition, without the split by road type, emissions from real-world operation will be less accurately characterised and the importance/significance of urban emissions will not be able to be assessed.

"Question 21. Does the proposed methodology adequately account for the main sources of variability from a temporal (time) perspective, that can reasonably be accounted for?"

Stakeholders were also generally supportive of the proposed consideration of temporal aspects (Figure 3-28). Reasons for disagreement include the following:

- There might be a need to include additional considerations depending on the goal of the study (one respondent)
- The sources of variability "Should be based on facts only" (one respondent)
- Not relevant since no major changes and impacts are expected (two respondents)
- The study should have a limited timeline since the analysis of future trends can suggest that the model is valid for longer periods of assessment without errors (one respondent)

Figure 3-28: Proposed consideration of temporal aspects (n=25)



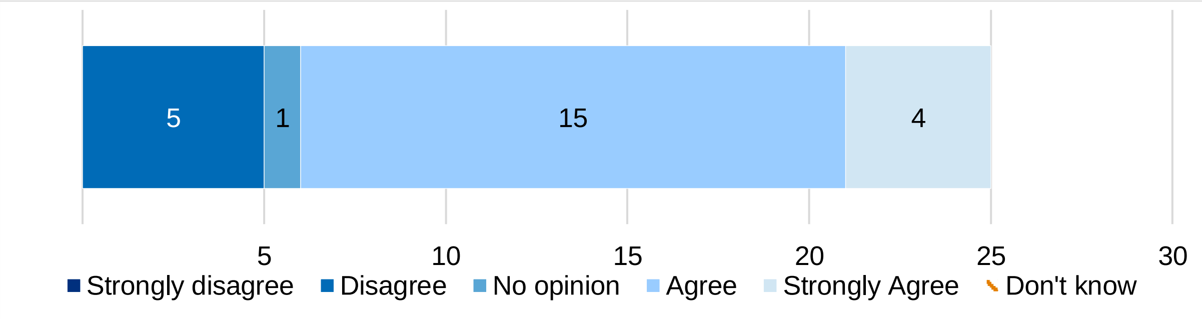
Q21 Response by the project team to results and comments:

The majority of respondents agreed the methodology captured the most important aspects of potential temporal variability. The analysis of future impacts is inherently uncertain, and key parameters will be explored through suitable sensitivities to acknowledge this and better understand these.

"Question 22. Does the proposed methodology adequately account for the main sources of variability from a spatial perspective?"

Similarly, respondents were also generally supportive of the proposed consideration of spatial aspects (Figure 3-29). The main reasons for disagreeing included a suggestion to keep the analysis simple as there are too many variations, and also a suggestion to simplify (four respondents) to use WLTP data and not real-world estimates, accounting also for different shares of urban / rural / motorway driving. In contrast, two other stakeholders suggested also increasing complexity to take into account also other variations, such as weather/climate, driving, road types and topography (i.e. 'hilliness').

Figure 3-29: Proposed consideration of spatial aspects (n=25)



Q22 Response by the project team to results and comments:

It is concluded that the majority of experts have agreed with the approaches proposed, so these will be taken forward. The main area that has been raised (also in earlier questions 14 and 15) relates to potential accounting for impacts of particularly hot/cold climates (i.e. air conditioning/heating) on BEV (vs ICE powertrains). We will investigate whether a sensitivity to account for this variation might be feasible. Accounting for other elements (e.g. topography, other local conditions) is not feasible.

3.2.1 Section 2: Vehicle specifications and operation conclusions

A summary of the conclusions, clarifications and refinements resulting from the analysis of the round 1 (R1) survey results, and the proposal for round 2 (R2), is presented in the table below.

Table 3.1: Summary of the round 1 (R1) survey conclusions, proposed refinements and whether/how the individual questions will be taken to round 2 (R2) of the survey

Q	Topic	R1 Conclusion, clarifications and refinements	R2 Status
12	Overall approach for baseline vehicles	There was good agreement on the approach; *Refinements:* based on feedback the passenger car segment at least will be further broken down into at least 2 categories (potentially up to 4). *[*TBC - a limited validation exercise may be held on key assumptions with relevant stakeholders, e.g. for heavy duty vehicles where fewer real examples are available to benchmark assumptions against.]*	**Refining question** and comments only.
13	Component-based approach for defining alternative powertrains	There was strong support for the proposed approach, so this will be taken forwards. *Refinements:* Benchmark/cross-check results from the approach with real-world models where feasible / appropriate, and revise assumptions where necessary. *[TBC - a limited validation exercise may be held on key assumptions with stakeholders, e.g. electric range, improvements in battery energy density, cycle life, etc.]*	Closed, comments only.
14	Approaches for defining vehicle energy consumption	There was some disagreement by stakeholders on certain elements of the proposed approach, which appears to be due in some cases due to a lack of clarity on the methodological proposals. Additional information has been provided, and further improvements in the level of consensus will be sought based upon this. *Refinements:* To also consider a sensitivity on energy consumption due to hot / cold climates due to larger impact on energy consumption for BEVs vs ICEVs.	**Open**, additional information and feedback
15	Dynamic adjustment of energy consumption based on battery mass or vehicle loading	Most stakeholders indicated both of the two identified options should be taken forwards, so these will be implemented. The issue of impacts of air conditioning/heating (particularly with reference to BEVs) will be addressed under the response to Q14 above. *Refinements:* None.	Closed, comments only.
16	Operational share for PHEVs or dual-/bi-fuel vehicles	All three options identified were viewed positively by respondents, with the strongest preference for consideration of different duty cycles and on the distribution of the energy consumption share between different road types. *Refinements:* Sensitivities to explore extreme behaviour cases (e.g. for PHEVs) will also be considered.	Closed, comments only.
17	Approach for tailpipe emissions of air pollutants	Most respondents agreed or strongly agreed with the proposed approach; it will be taken forward unchanged. *Refinements:* None.	Closed, comments only.

Q	Topic	R1 Conclusion, clarifications and refinements	R2 Status
18	Characterising electrical energy storage/sizing.	There was strong overall support for the proposals for characterising energy storage/sizing. They will therefore be taken forward. *Refinements:* Most respondents also recommended fuel cell /hydrogen storage should also in more detail, so this will also be taken forwards. *[TBC - to address concern/uncertainty in this area, a limited validation exercise may be held on key assumptions with stakeholders, e.g. electric range, improvements in battery energy density, etc.]*	Closed, comments only.
19	Calculation of battery replacements	There was strongest support for defining replacements according to battery full charge/discharge cycles. This option will also facilitate dynamic changes depending on other assumptions (vehicle size, mileage, etc) so this options is proposed to be taken forwards. *Refinements:* It is proposed to investigate whether fuel cell replacement should also be included on a similar basis.	**Open**, feedback on favoured / proposed approach and extension to fuel cells.
20	Vehicle activity and lifetime	There was strong agreement with the proposed methodology, therefore it will be taken forwards unchanged. *Refinements:* None.	Closed, comments only.
21	Accounting for the main sources of temporal variability	There was a majority agreement of stakeholder experts, and the methodology will be taken forwards unchanged. *Refinements:* None.	Closed, comments only.
22	Accounting for the main sources of spatial variability	There was a majority of agreement of stakeholder experts, with the main area identified for potential improvement relating to impacts of hot/cold climates on energy consumption of BEVs. This is covered in Question 14. *Refinements:* As above.	Closed, comments only.

Notes: TBC = to be confirmed.

3.3 Section 3: Methodological considerations for vehicle production, maintenance and disposal

Overall, responses received to the first round of the survey also convey a general level of support for the proposed methodology for vehicle production and end-of-life. Nevertheless, assumptions on location of production, glider standardisation and recycling quotas raised more concerns amongst stakeholders.

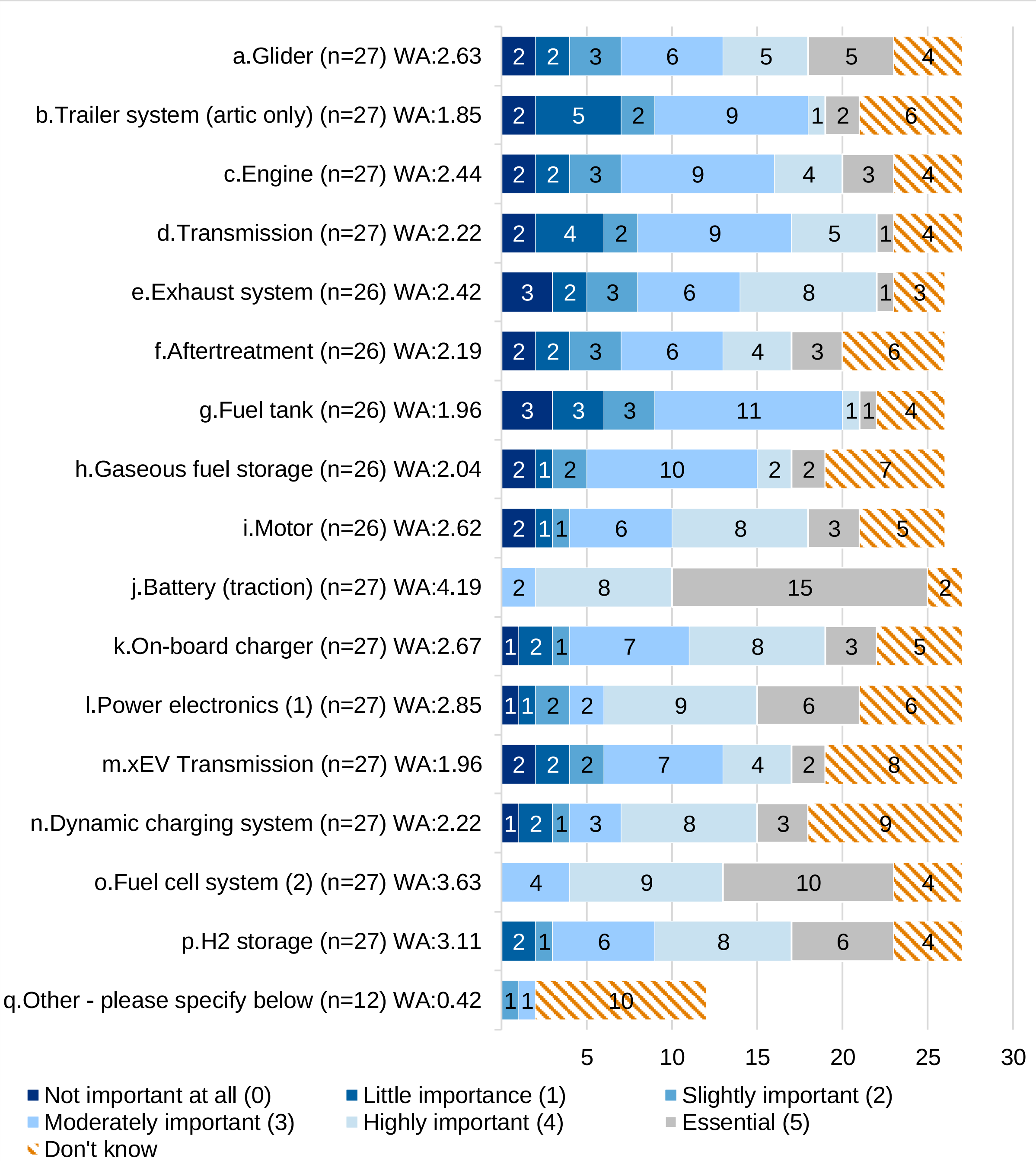
"Question 24. For which components is a differentiated inventory necessary to provide an adequately detailed assessment for the average/overall vehicle market?"

Respondents were asked to score, for a list of components, the importance of using a detailed, differentiated material inventory to characterise that component so that it adequately allows for a detailed assessment of the vehicle market. Figure 3-30 shows that respondents considered the traction battery (WA: 4.19), the fuel cell system (WA: 3.63) and the H2 storage (WA: 3.11) to be particularly important components which require a more sophisticated/detailed approach. On the other hand, components that scored the lowest include the trailer system (artic only, WA; 1.85), the fuel tank (WA:

1.96) and the xEV transmission (WA: 1.96). Stakeholders that suggested other components referred to fuel cell stacks, tires and interiors and thermal management (especially for EVs).

In the comments provided, two stakeholders highlighted the importance of taking into account the rapid technology developments associated to batteries and fuel cells. Another two stakeholders indicated that the production location is also an important factor that should be reflected in the analysis.

Figure 3-30: Proposed components for which a detailed assessment is required



Q24 Response by the project team to results and comments:

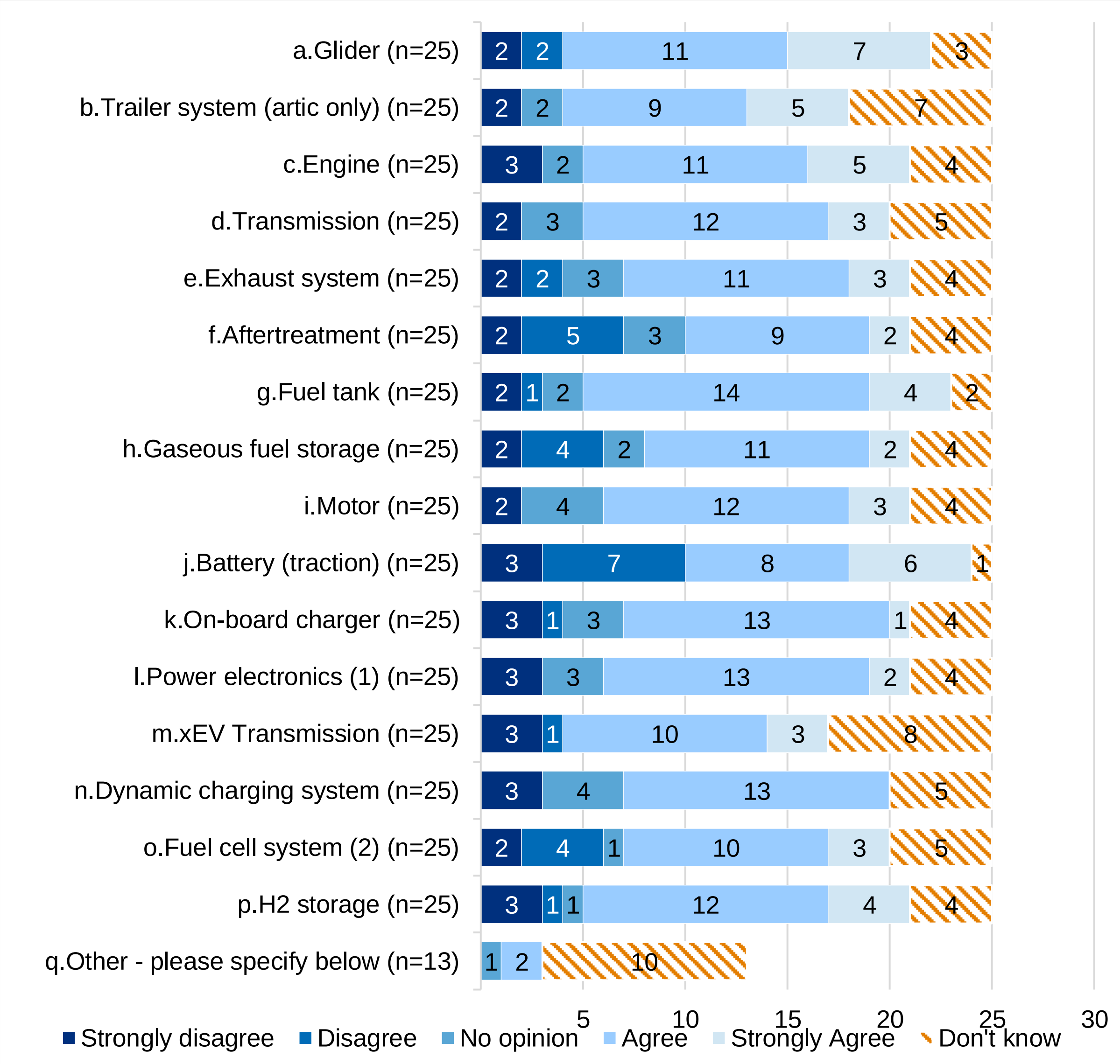
It is concluded that the proposed components are regarded as mostly important and almost sufficient for a detailed assessment of the average/overall vehicle market.

"Question 25. Do you agree that the indicated components may be calculated similarly between different vehicle types using appropriate scaling factors?"

Figure 3-31 shows that most of the respondents (strongly) agreed with the proposal to use scaling factors to define these components for each vehicle type relatively to the baseline vehicle. Components that generated more polarised views were the traction battery, the aftertreatment system and the fuel cell system.

Four stakeholders provided comments on the scaling of batteries between vehicle types, highlighting that: 1) packing/cooling of the battery does not scale with capacity; 2) the charging system does not scale with battery size; 3) battery scaling should take into account battery chemistry limitations which affect material and energy balances; 4) differences in batteries between vehicle types require a more detailed analysis. In addition, one of these stakeholders also noted that the aftertreatment system may substantially differ between vehicle types depending on emission limits.

Figure 3-31: Components for which scaling factors can be applied to scale between different vehicle types



Q25 Response by the project team to results and comments:

It is concluded that scaling factors are appropriate for most components and will therefore be used in the study accordingly. Further aspects beyond simple scaling will be considered for the traction battery, the aftertreatment system and the fuel cell.

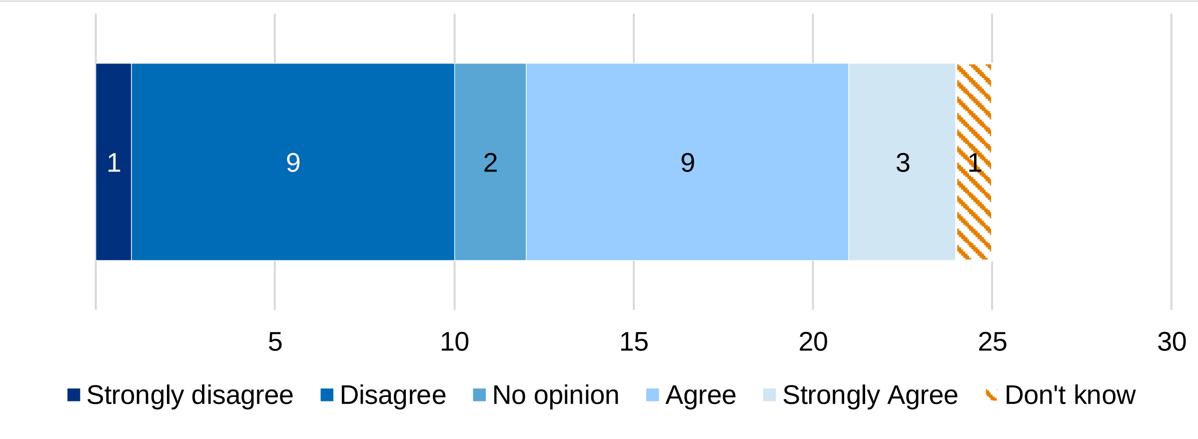
"Question 26. Based on the component-level approach proposed, do you agree that material composition of the glider (i.e. excluding powertrain, energy storage, components, etc.) can be approximately standardised for each of the six generic body types (i.e. car, van, rigid lorry, articulated lorry, bus, coach)?"

On the glider, respondents had mixed views on the proposal to define a standardised material composition of this component for each of the six generic body types: of 25 responding, 12 (strongly) agreed compared to 10 that (strongly) disagreed (Figure 3-32).

Among those that agreed, only one respondent provided further comments, suggesting that secondary weight increases should be considered so that the weight of the glider is adjusted due to the use of larger battery packs; material composition should however remain constant.

Those that disagreed explained that standardisation is difficult given that different OEMs use different materials. For example, two respondents indicated that there are substantial differences between aluminium and steel intensive architectures, they recommend differentiating material composition by segment too. Another stakeholder highlighted the possibility of category creep between powertrain types. For another respondent, only some OEMs use lightweight materials.

Figure 3-32: Assumptions regarding the glider



Q26 Response by the project team to results and comments:

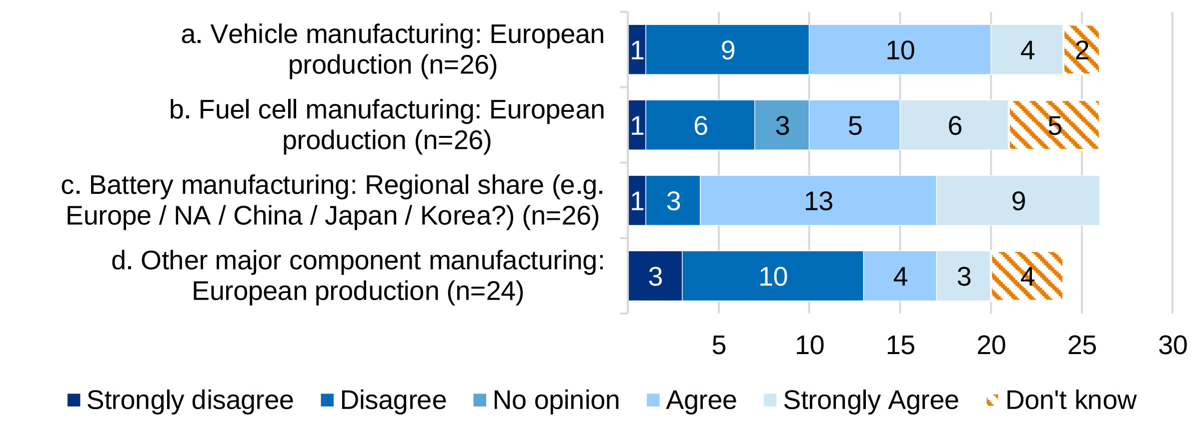
Using a standardised material composition by vehicle type enjoys slightly more agreement than disagreement among the stakeholders. Nevertheless it is acknowledged that the diverse vehicle market in reality may lead to considerable differences in material composition for specific vehicle types. Since the study explores generic vehicle types and transport service rather than specific vehicles, the approach of using standardised material composition will nevertheless be pursued. Reasonable care will be taken to reflect the average market mix for vehicle bodies. Material with relevant differences in usage can be explored in sensitivities.

"Question 27. Is the assumption of a European average vehicle production with typical countries of origin for important components reasonable for the goal and scope of the study?"

More respondents agreed than disagreed with the proposal to assume a European average production but with typical countries of origin for important components as shown in Figure 3-33.

In their comments, six respondents highlighted that certain components or vehicles used in Europe are also imported from other regions and thus a regional share to characterise vehicle production would be more adequate. In addition, three other respondents noted that there are also substantial differences in impacts from production between European countries and therefore suggested that more differentiation would be appropriate. Two stakeholders also indicated that the country of origin of the materials used in the components matters even if the component is produced in the EU and therefore suggested to use regional shares to account for material production in components or vehicles. Finally, six stakeholders also pointed to the importance of considering differences in electricity mixes and energy sources.

Figure 3-33:Assumptions on place of production



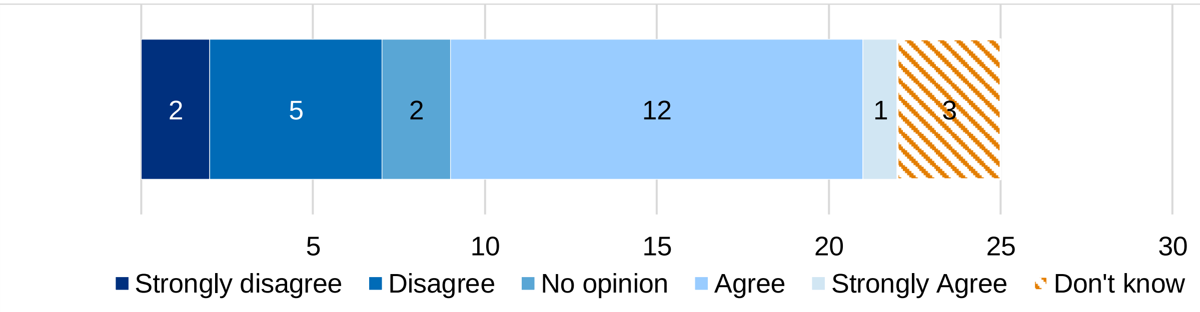
Q27 Response by the project team to results and comments:

More respondents agreed than disagreed with the proposal of considering average European conditions (e.g. in respect to electricity) for vehicle assembly. Nevertheless, reasonable concern has been voiced at the Expert Workshop which argued towards differentiation of European vehicle producing countries as well as consideration of vehicles from outside the EU. It is therefore suggested to consider an electricity split reflecting the market mix of EU new registrations by country (e.g. based on OICA vehicle production statistics and Eurostat data on imports). Likewise, the countries of origin will be considered for important components as suggested.

“Question 28. Do you agree that European Recycling quotas for end-of-life vehicles can be assumed?”

Most respondents (strongly) agreed with the use of the European Recycling quotas for end-of-life vehicles (Figure 3-34). Further comments provided, however, refer to the general EoL approach and therefore have been considered for question 10. Even though many respondents (strongly) agreed with the use of European recycling quotas in the survey, concerns have been voiced at the Stakeholder Workshop that also export of vehicles should be taken into account. Furthermore, uncertainties in the further development have been pointed out. Here EU policies and targets can be considered. One expert commented that when an attributional cut-off approach is used, European recycling quotas would not have any impact in the vehicle LCA and can therefore be disregarded.

Figure 3-34: Views on the use of European recycling quotas for end-of-life vehicles



Q28 Response by the project team to results and comments:

If a cut-off approach is used as a default end-of-life methodology for a large number of materials, recycling quotas/rates are of limited importance. Nevertheless recycling quotas/rates will remain relevant for a complementing end-of-life-approach (e.g. avoided burden or hybrid approach). It is concluded that considering European recycling quotas/rates for the current situation is appropriate for vehicles remaining in the EU for the full vehicle life cycle. The relevance of vehicles with an EoL outside the EU needs to be further evaluated, also in light of a potential default cut-off approach.

"Question 29. What do you believe is the most appropriate/pragmatic way to account for the potential second life application of batteries?"

The majority of respondents supported the proposal to account for the potential second life application of batteries (Figure 3-35). When questioned about the most appropriate approach to do this, respondents were divided between two main options (Figure 3-36):

- Option a: Credit applied based on comparison of LCIA of second use battery versus an alternative reference case (WA:3.1).
- Option b: Credit applied based on the avoided use of an equivalent new energy storage battery (WA:3.14).

Figure 3-35: Views on second life application of batteries (n=25)

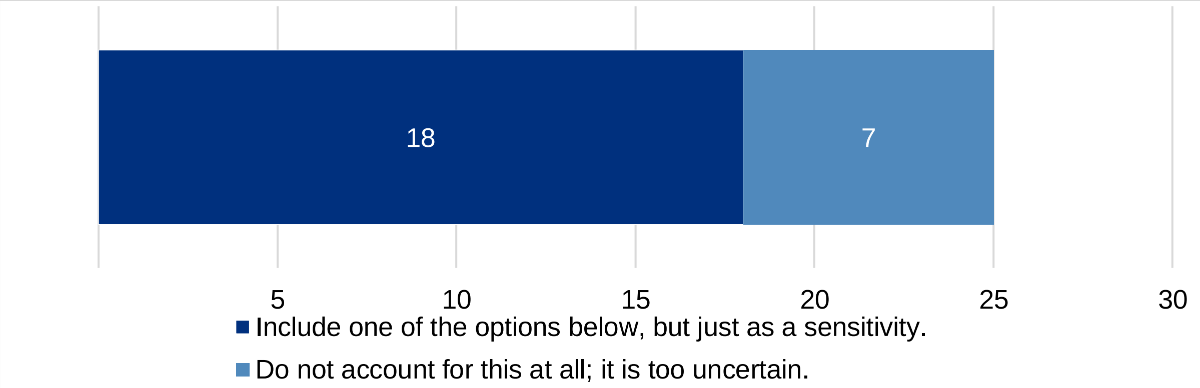
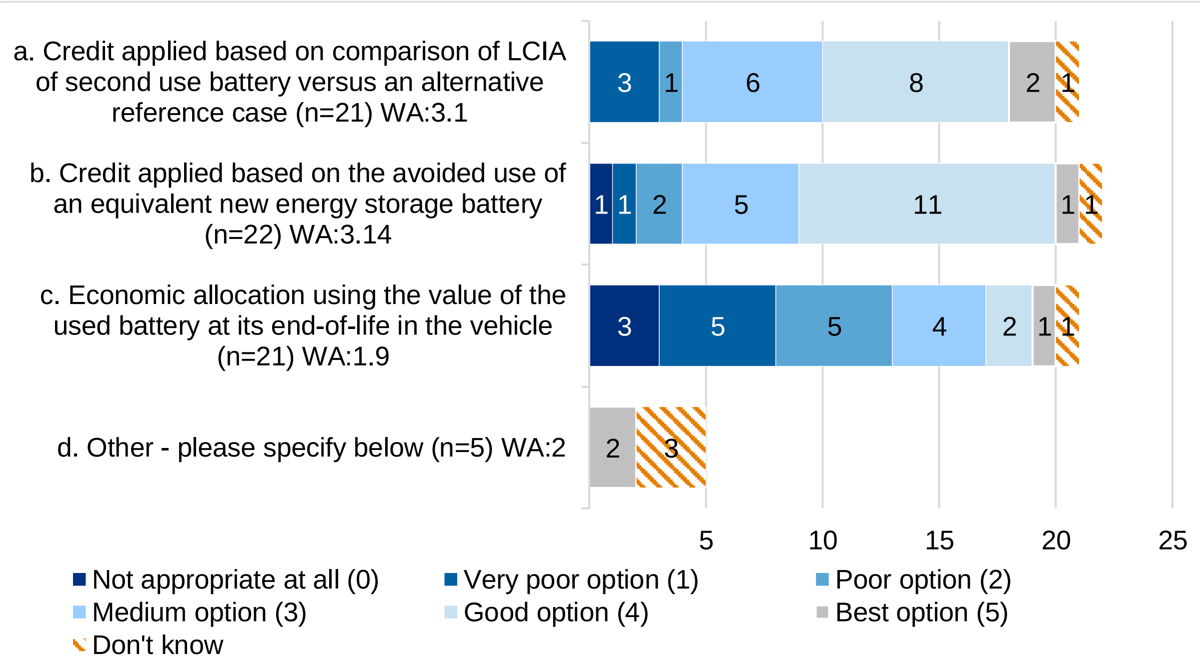


Figure 3-36: Options for accounting for the potential second life application of batteries



Overall respondents saw huge uncertainties associated with possible second life applications of vehicle batteries.

One respondent preferred option b since the economic allocation for second life approach is still not mature whilst batteries for second life need partial re-manufacturing, and therefore an LCIA based method is not practical. One stakeholder which also preferred option b noted that the amount of avoided use of energy storage is quite uncertain as it depends on the condition at the EOL of the battery.

One expert suggested applying option c since option a could be quite burdensome and option b is not appropriate, since it is unclear whether stationary applications for batteries would exist at all without a supply of (cheap) used batteries.

One expert advised a system expansion approach, whilst two other noted that there is still a high level of uncertainty regarding use cases of second life applications. For another respondent, second life applications should be included, eventually with a growing adoption curve. One respondent commented that second life of batteries is only feasible, if the first user intends the battery to be reusable after the end of its first life. One expert thought that an economic allocation is not possible, since no market values for used batteries (apart from their scrap value) exist today. However, two experts found that even if no market for used car batteries exists today, this will change in the next few years and should be considered in a sensitivity. One stakeholder also noted that the burdens at the EoL of a battery can be considerably and should be allocated to the vehicle (whether or not a second use is done). One expert suggested to just give a credit for the materials recycled at the end of the battery life.

Q29 Response by the project team to results and comments:

Even though the importance of this topic was recognised, concerns have been voiced due to the high uncertainty. It is therefore concluded that second life of batteries will only be considered as sensitivity in this study and not as a default in the vehicle life cycle. Applying a credit based on avoided use of an equivalent new storage appears to be the most feasible option and was also supported by the majority of the stakeholders. This option will therefore be further explored as a sensitivity in the study.

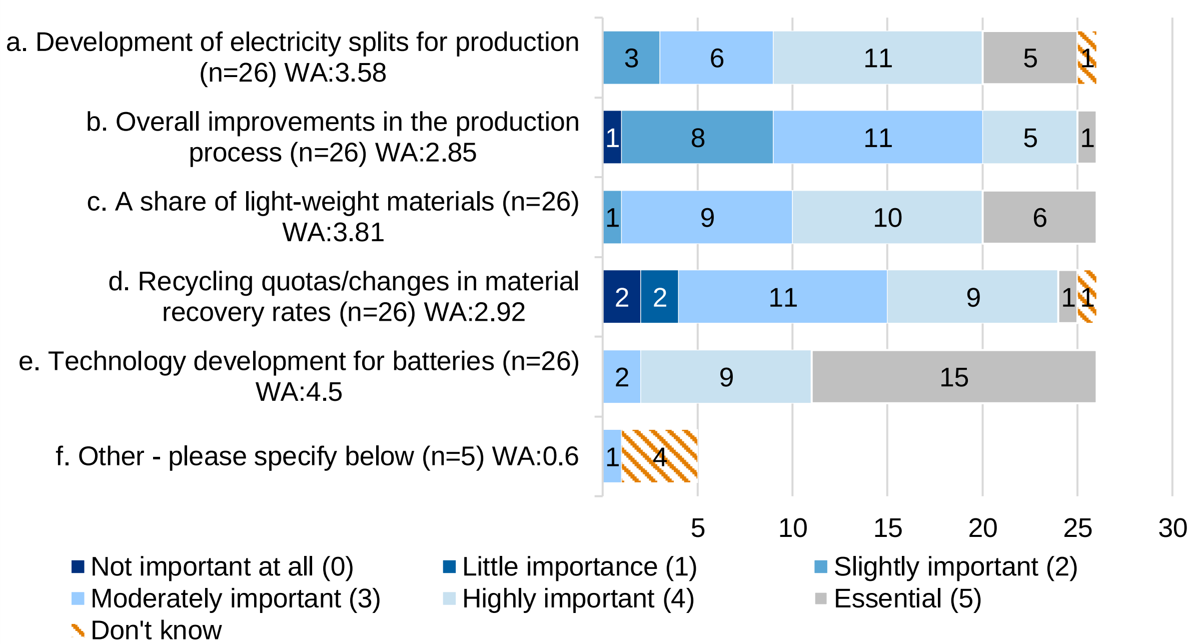
“Question 30. Which of the following temporal variations for vehicle/component production need to be taken into account?”

To a large extent, respondents were supportive of the proposed consideration of temporal aspects, especially in regard to the technology development for batteries (WA: 4.5), the share of light-weight materials (WA: 3.81), and the development of electricity splits for production (WA: 3.58).

In the comments provided, two stakeholders referred to the importance of considering changes over time associated to batteries. Two other respondents highlighted the relevance of accounting for future material changes, whilst two other respondents indicated that the decarbonisation of material carbonisation is too uncertain to be able to accurately predict and thus one of them does not recommend their estimation on the basis of electricity carbon intensity. Another stakeholder advised that the methodology should be consistent and consider future changes not just for xEVs but also ICEVs, whilst another suggested that prioritisation is required given the number of factors that could be analysed from a temporal perspective.

Further comments have been provided at the Expert Workshop. Here consideration of an overall increasing vehicle weight vs. potential light-weighting was suggested as well as shifts in material composition between metals and plastics. It was also pointed out the flow of so called “critical” materials would be important additional information.

Figure 3-37: Proposed considerations of temporal aspects



Q30 Response by the project team to results and comments:

The proposed temporal aspects have been largely supported by the stakeholders. It is therefore proposed that a temporal variation should be considered for the electricity splits for vehicle and component production as well as overall improvements in the production process (especially for battery production), shifts in the material composition of the vehicle body (vehicle weight, light-weight materials), policies on use of secondary material/ recycling quotas and new battery chemistries.

3.3.1 Section 3: Vehicle production, maintenance and end-of-life conclusions

Q	Topic	R1 Conclusion, clarifications and refinements	R2 Status
24	Relevant components	There was good level of support for the proposed components for which a detailed assessment is required. *Refinements:* None.	Closed, comments only.
25	Scaling factors	There was good level of support for the proposed components for which scaling factors can be applied to scale between different vehicle types. *Refinements:* Further aspects beyond simple scaling will be considered for the traction battery, the aftertreatment system and the fuel cell.	Closed, comments only.
26	Material composition	There are mixed views on the proposal to define a standardised material composition of the glider. *Refinements:* Reasonable care will be taken to reflect the average market mix for vehicle bodies. Material with relevant differences in usage can be explored in sensitivities.	Closed, comments only.
27	Spatial differentiation of vehicle production	It has been suggested to consider a further differentiation of European vehicle producing countries as well as of vehicles from outside the EU. *Refinements:* Depending on data availability consider differentiation of European vehicle producing countries as well as consideration of vehicles from outside the EU by	**Open**, refining question

		using an electricity split reflecting the market mix of EU new registrations by country of origin.	
28	Recycling quotas	It is concluded that considering European recycling quotas for the current situation is appropriate for vehicles remaining in the EU for the full vehicle life cycle. *Refinements:* The relevance of vehicles with an EoL outside the EU needs to be further evaluated, also in light of a potential default cut-off approach.	**Open,** refining question
29	Second life of batteries	It is concluded that second life of batteries will only be considered as sensitivity in this study and not as a default in the vehicle life cycle. Applying a credit based on avoided use of an equivalent new storage appears to be the most feasible option and was also supported by the majority of the stakeholders. *Refinements:* The proposed option will be further explored as a sensitivity in the study.	Closed, comments only.
30	Temporal considerations	There was good level of support for proposed temporal considerations (electricity splits for vehicle and component production as well as overall improvements in the production process (especially for battery production), shifts in the material composition of the vehicle body (vehicle weight, light-weight materials), policies on use of secondary material/ recycling quotas and new battery chemistries). *Refinements:* None.	Closed, comments only.

3.4 Section 4: Methodological considerations for liquid and gaseous fuel lifecycles

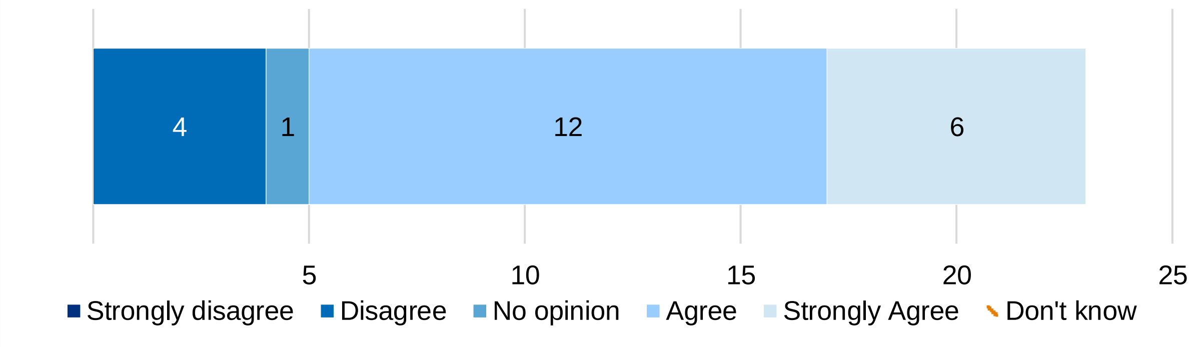
The views provided by stakeholders responding to the first round of the survey reveal both areas of agreement (e.g. functional unit, impact categories) and disagreement (e.g. deal with multi-functionality in refining and natural gas processing using economic allocation) with our methodological proposals for liquid and gaseous fuel life cycles but also some uncertainty regarding specific areas (e.g. definition of a biogenic residue, inclusion of ongoing soil organic carbon losses, accounting for account marginal crop emissions from primary biogenic feedstocks).

“Question 32. It is proposed the functional unit of the fuel production stage of the vehicle LCA should be 1 MJ of fuel delivered into the tank of the vehicle; do you agree?”

The majority of respondents supported the proposal to use 1 MJ of fuel delivered into the vehicle tank as the functional unit for the fuel production stage (Figure 3-38). In their comments, one respondent indicated that per km functional unit is not useful for this stage, whereas another also noted that the proposed functional unit allows for the necessary functionality and flexibility. In addition, two stakeholders that agreed also suggested to refer to Lower Heating Value (LHV), that is, 1 MJ (LHV). Another respondent advised to consider passive discharge, battery venting or CNG / LNG venting.

On the other hand, among those that disagreed, three stakeholders argued that only one functional unit should apply according to ISO 14040 and there is no need to differentiate the functional unit between stages. Another respondent suggested that the functional unit should be expressed as a Diesel Equivalent (i.e. the energy content of diesel fuel, approximately 37 MJ/l). One other expert that responded ‘no opinion’ suggested that if this unit is selected, then a link to the vehicle functional unit (ton-km) must be used to compare vehicles with different powertrains.

Figure 3-38: Choice of functional unit for the fuel production stage (n=23)



Q32 Response by the project team to results and comments:

It is concluded that 83% of respondents agree with this choice of functional unit for this sub-section of the vehicle life cycle and this will therefore be taken forwards. Practically, this functional unit will enable the practitioners to calculate impacts generated by fuel production, which can then be added to and transformed into impacts in the 'vehicle in use stage'. Those will be expressed in the functional unit of the overall vehicle life cycle (vehicle km), which represent 'well to wheel' impacts.

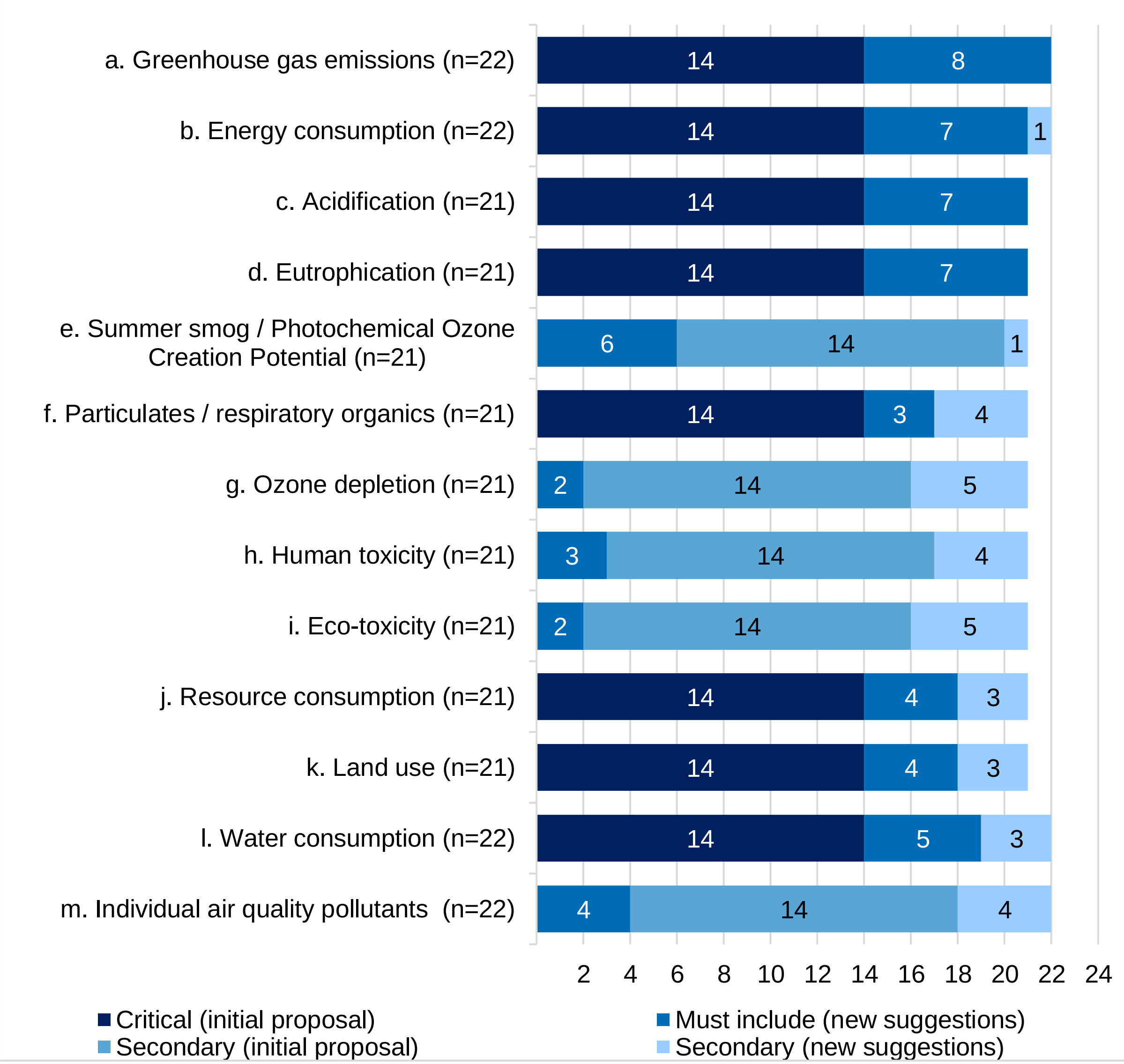
"Question 33. Do you agree with the proposed environmental impacts/mid-points for fuels?"

Similar to question 9 in section 1 of the survey (section 0 in this document), respondents were asked about the study's proposals to cover a range of impact categories (divided into two main lists, *critical impact categories*, and *secondary impact categories*), aiming to determine the most important categories for the fuel production stage. Figure 3-39 summarises the views of stakeholders on which impact categories are critical and which are secondary, aggregating all the responses received, i.e. both those that agreed and disagreed:

- If they agreed with the proposal, the critical and secondary impact categories in the proposal were considered – their responses are marked as *Critical (initial proposal)* and *Secondary (initial proposal)* in the figure;
- If they disagreed with the proposal, they were given the list of all impact categories and were asked to re-classify each category as 'must include' or 'secondary importance' – their responses are marked as *Must include (new suggestions)* and *Secondary (new suggestions).*

More respondents agreed that the proposed coverage of impacts in the study is adequate (14 of 23 (strongly) agreed compared to 9 that (strongly) disagreed).

Figure 3-39: Proposed coverage of impact categories for the fuel production stage



In line with our proposal, most respondents agreed that the following impact categories are critical/secondary:

- Critical: Greenhouse gas emissions, energy consumption, acidification, eutrophication, particulates/respiratory organics, resource consumption, land use, water consumption.
- Secondary: ozone depletion, human toxicity, eco-toxicity, individual air pollutants.

There are however more divided views over the relevance of summer smog or POCP. In our proposal, this indicator was considered to be secondary but the majority of those that disagreed (six of seven respondents) suggested that it should be included. As for question 9, one respondent noted that POCP is an important indicator given that smog is an important impact in cities. Indeed, five stakeholders referred to their comments provided in question 9 and five other respondents argued that the list of impact categories should be the same across all stages. Similarly, one expert advised that methodological weaknesses should be considered explicitly when conducting and evaluating the LCA (e.g. toxicity categories or insufficiently aggregated data sets). Furthermore, one other respondent suggested including exhaust air quality pollutants in the analysis.

Q33 Response by the project team to results and comments:

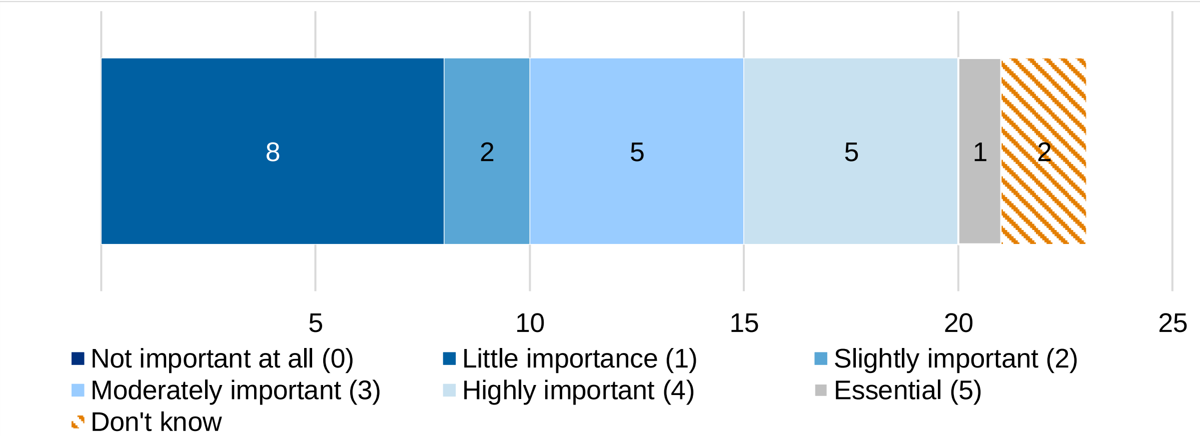
The issue of impact categories is addressed for the whole LCA methodology under "General Methodology" (Section 1).

"Question 34. How important is it to include the emissions from infrastructure/capital goods in the LCA of fuel production?"

Figure 3-40 shows that respondents only consider the inclusion of infrastructure/capital goods in the fuel production stage as slightly important (WA: 2.26). Reasons provided to justify its exclusion are: small impacts expected from including it in the LCA (four respondents), and low quality of data (3 respondents). Nevertheless, one of these respondents indicated that major changes in vehicle production could have an important effect in infrastructure. For another stakeholder, its inclusion would create confusion without significant added value since the comparative analysis would focus on existing infrastructure against a new purpose-built infrastructure –the respondent advised that this LCA study should not be retrospective, but instead should be used to inform future policy.

Among those that supported its inclusion, one expert argued that this was an essential aspect given the high share of renewable energy whilst another two suggested that all fuel infrastructure should be considered, including oil extraction and refinery. For one of them, this would make the analysis consistent with options that are radical departures from existing transport systems and it would establish whether their contributions are significant or not. Similarly, another respondent noted that infrastructure could be significant for some novel or low volume fuels, whereas another suggested to first understand whether impacts would be relevant and only then consider including infrastructure.

Figure 3-40: Importance of including capital goods in the fuel production stage (n=23)



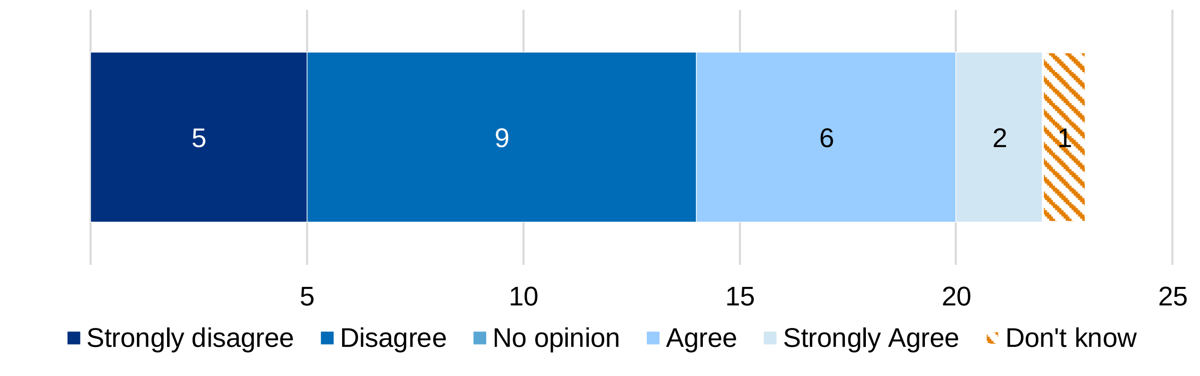
Q34 Response by the project team to results and comments:

It is concluded that respondents gave a moderately higher importance to the inclusion of capital goods in the LCA. Impacts associated with capital goods may be significant for low volume alternative fuels, electrolysis and renewable electricity production. Necessary data is likely to be available. We therefore propose to include emissions associated with capital goods in the fuel production chain.

"Question 35. It is proposed that multi-functionality in refining and natural gas processing should be dealt with using economic allocation; do you agree?"

Most of the respondents disagreed with the proposal to deal with multi-functionality in refining and natural gas processing using economic allocation, as shown in **Error! Not a valid bookmark self-reference.**. Assessing comments reveals that stakeholders overwhelmingly advocate for either avoiding allocation through system subdivision or else finding physical relationships of the various products and co-products of the refinery for allocation along the lines of ISO 14040.

Figure 3-41: Multi-functionality in refining and natural gas processing (n=23)



Q35 Response by the project team to results and comments:

In light of the disagreement of round 1 survey respondents with the proposal of allocating burdens according to the economic value of all products of crude oil refining, we suggest consideration of an alternative modelling approach by Horst Fehrenbach and Axel Liebich (ifeu).

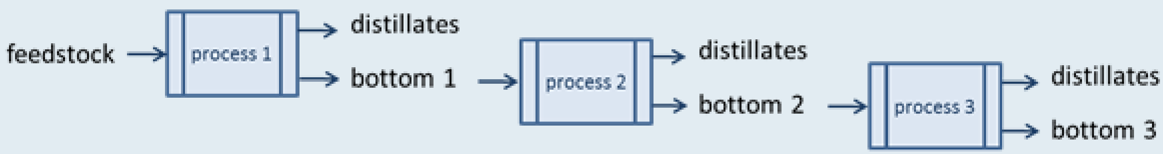
This natural science based approach has the additional benefit of avoiding the need to project future prices of refinery products as the LCA is projected out towards 2050.

The approach suggested for discussion here follows a series of allocation rules according to flows in the refinery as follows:

1. In general, allocation is weighted according to the products' energy content, i.e. their lower heating values
    - Rationale: the majority of refinery products are used for energy purposes.
2. The burdens for the first step of separation (atmospheric distillation) are allocated to all co-products, including the atmospheric residue (bottom product)
    - Rationale: all co-products from atmospheric distillation will end up in marketable final products.
3. The burdens for any subsequent process step that is intended to reduce the quantity of non-intended (see definition of 'residues' and 'non-intended' below) products (i.e. vacuum distillation and cracking) are allocated to all co-products except for exactly the non-intended bottom products (see definitions below).
    - Rationale: all these downstream processes within the refinery are intended to reduce non-intended products in favour of increasing the yield of the majorly intended co-products; hence, the burdens are allocated only to the intended products.
4. Retention of feedstock: The 3rd rule refers to the allocation of the respective process burdens; it does not include the allocation of feedstocks. The input material (feedstock) into a refinery process step is always allocated according to the 1st rule: e.g. visbreaker residue takes 40 % of the totalized co-product output of a visbreaker cracker, thus 40 % of the visbreaker input (vacuum distillate) and its upstream burden is allocated to the visbreaker residue
    - Rationale: Although the downstream processing steps (cracking) are not intended to produce bottom products only to reduce them, the remaining bottom products derived from these processes (e.g. heavy fuel oil, petroleum coke) are defined as refinery products and not as wastes; if the 3rd rule would also apply for the allocation of feedstock, all final products from bottom products would finally achieve LCIs with zero burdens and emission; de facto they would be treated the same way as waste.

Definitions:

Residues: residues are always treated as co-products, never as waste – despite having certain “waste attributes”. The suggested combined allocation procedure adopts ISO’s consideration of “partly co-products and partly waste” according to the following scheme:



- Bottom 1 is one of the co-products from process 1 and therefore treated like all co-products (distillates and bottom) from process 1.
- Bottoms 2 and 3 are non-intended outputs from processes 2 and 3, respectively, because these processes are intended to reduce the occurrence of residuals. Consequently, they don’t carry any burdens from process 2 and process 3, respectively. The “co-product part” is connected with the attribution of feedstock and expenditures/emissions from process 1, while the “waste part” is reflected by neglecting expenditures/emissions from process 2 and 3.

Non-intentional co-products: Given the complexity of the configuration of refineries and the multitude of co-products, defining the primary aims of running a refinery is challenging. Consequently the model under discussion adopts the following step-wise approach to distinguish between intended and non-intended co-products:

- Step 1: final products with market prices higher than crude oil are considered to be intended.
- Step 2: final products with market prices lower than crude oil but which supply basic products for markets which cannot be served easily by alternative products (e.g. bitumen, for a comprehensive list, see Appendix B) are considered to be intended.
- Step 3: intermediate outputs, which are not traded as standard refinery products (e.g. vacuum residue) are always straightforward according to the allocation rules as defined: bottom products (output) made from bottom products (input) are always non-intended.

As a result, only heavy fuel oil (HFO), refinery Sulphur, vacuum residue and cracker residues are considered non-intentional.

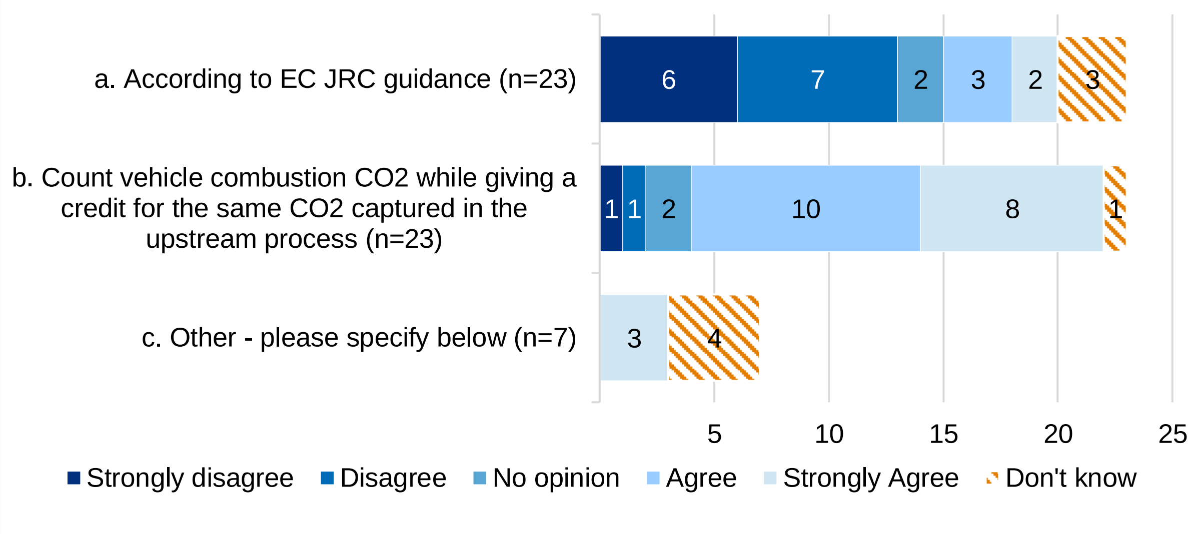
“Question 36. For fuels produced from secondary carbon feedstocks, what do you think is the most appropriate way to account for the carbon contained in them?"

Overall, respondents preferred the second option, that is, to count vehicle combustion CO_2 while giving a credit for the same CO_2 captured in the upstream process (Figure 3-42). Two respondents pointed to the need to account for all emissions from the life cycle irrespective of whether they are included in the ETS market; whereas two other noted that the JRC guidance is not sufficiently transparent. For another stakeholder, option B is more appropriate also since it rewards the right kind of investment decision and creates a distinction between CO_2 that is being sequestered (CCU material) and CO_2 that is being re-released (CCU Fuels). One other expert also argued that the producer of the CCU fuels should also be rewarded for the effort to make a CCU fuel rather than just the user of the CCU getting all the credit.

One stakeholder that agreed indicated that the approach should be consistent with biofuel LCAs.

Furthermore, three stakeholders suggested alternative approaches: two suggested that the counterfactual fate of the captured carbon dioxide should be specified and taken into account accordingly, whereas another suggested using a system expansion approach for CCU, arguing that the origin of carbon has to be taken into account and credit to its production process has to be ensured if carbon is used for synthetic vehicle fuels.

Figure 3-42: Accounting for carbon in secondary feedstocks



Q36 Response by the project team to results and comments:

Results show preference for taking account of the credit for the CO_2 capture.

Discussions at the workshop revealed that it is preferable to consider fossil and biogenic secondary feedstocks separately.

In line with this, we suggest that for secondary fossil feedstocks (i.e. fossil feedstocks produced as a waste/residue of another primary process, including waste fossil CO_2), carbon must be explicitly tracked in the LCA so that e.g. avoided emissions in upstream/primary processes are given a credit and emissions from fuel combustion are accounted for (system expansion). For example, when CO is used as a feedstock it would be given a credit for avoided emissions (not only CO_2, but also other substances) from the primary process, and then counted as a CO_2 emission only when the fuel is combusted. This credit would be taken into account in the overall LCA.

We suggest that for secondary biogenic feedstocks (i.e., biogenic feedstocks produced as a waste/residue of another primary process, including waste biogenic CO_2), the carbon must be explicitly tracked in the LCA so that e.g. avoided emissions in upstream/primary processes are given a credit and emissions from fuel combustion are accounted for. For example, when biogenic waste is used in liquid fuel production a credit is given for avoided methane and biogenic CO_2 emissions from waste decomposition, and then counted as an emission of biogenic CO_2 when the fuel is combusted.

This question has been reformulated and split into two questions (on biogenic and fossil feedstocks, separately) in round 2 of the survey to facilitate responses to the various points of suggestion.

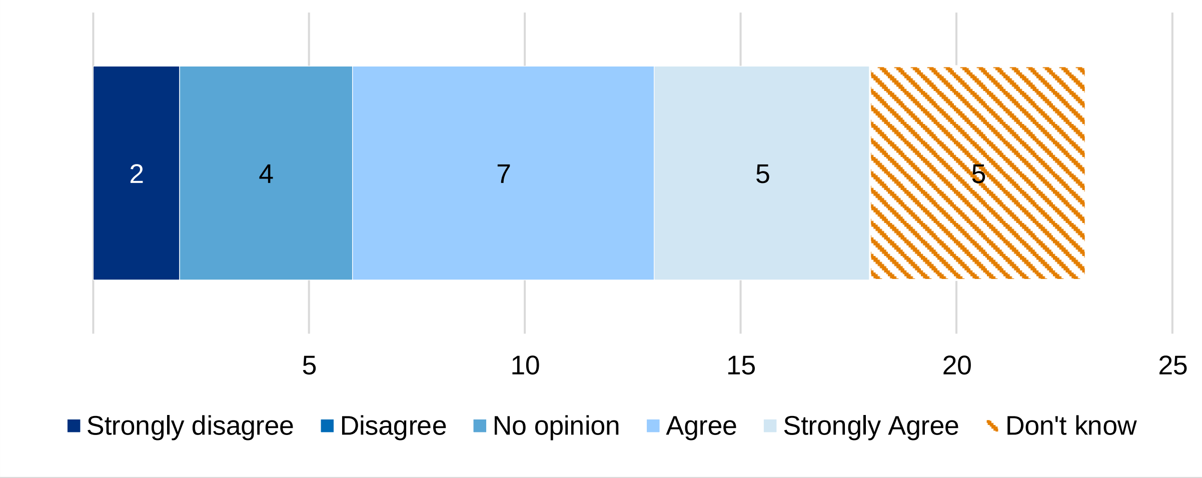
"Question 37. Do you agree that the effects of counterfactual uses of secondary (fossil and biogenic) feedstocks have to be considered in the fuel LCA?"

Most respondents were in agreement with the proposal to include the effects of counterfactual uses of secondary (fossil and biogenic) feedstocks (Figure 3-43). In the comments, stakeholders raised a number of questions and made some recommendations.

One stakeholder recommended presenting the counterfactual impacts separately from the process-related impacts, whereas another respondent also suggested the presentation of ranges of impacts. For one respondent, this adds complexity to the analysis but it could be done to maintain the consequential approach throughout the study. Conversely, for one respondent that strongly disagreed the degree of uncertainty is too high to be included.

In addition, one stakeholder suggested that this should be done only with assumption that large-scale secondary feedstock is commercially available.

Figure 3-43: Counterfactual uses of secondary feedstocks (n=23)



Q37 Response by the project team to results and comments:

Respondents were in favour of including the effects of counterfactual uses of secondary (fossil and biogenic) feedstocks but discussions at the workshop revealed that fossil and biogenic feedstocks should be considered separately.

We suggest that in cases where the secondary fossil feedstock was diverted from an existing productive use (e.g. waste plastic combusted to generate heat or power), the indirect emissions associated with replacing this useful product should be assigned to the secondary fossil feedstock. This represents a 'system expansion' approach to include the previous use of the secondary fossil feedstock.

We suggest that in cases where the secondary biogenic feedstock was diverted from an existing productive use (e.g. straw combusted to generate heat or power), the indirect emissions associated with replacing this useful product should be assigned to the secondary biogenic feedstock. This represents a 'system expansion' approach to include the previous use of the secondary biogenic feedstock.

This question has been reformulated and split into two questions (on biogenic and fossil feedstocks, separately) in round 2 of the survey to facilitate responses to the various points of suggestion.

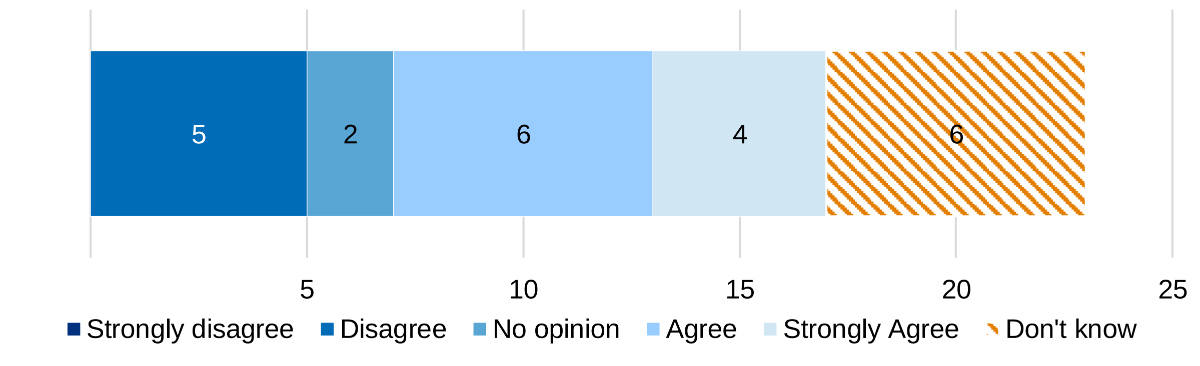
"Question 38. Do you agree that, even though the methodologically most robust option to consider the impacts of counterfactual use of secondary feedstocks is to assess the 'marginal' environmental impact, it is more appropriate in an LCA study to use the average environmental impact instead?

On the approach to estimate counterfactual uses of secondary carbon feedstocks, more respondents (strongly) agreed (i.e. ten of 23 responding) but six didn't know and five disagreed with our proposal to use the average environmental impact. In their comments, respondents revealed some confusion and raised a number of questions.

One respondent that agreed with the use of the average environmental impact noted that this is more appropriate for comparison purposes. Another respondent was of the opinion that this method is less complicated and could be appropriate, but it was recommended that the average impact is calculated as the "new average without/minus the diverted streams" and not the "old average before the stream was diverted". Another respondent recommended using the JEC methodology.

One stakeholder that disagreed indicated that the use of the average value should be justified with the reporting of marginal data.

Figure 3-44: Approach to counterfactual uses of secondary carbon feedstocks (n=23)



Q38 Response by the project team to results and comments:

The question in round 1 of the survey was not formulated clearly enough. To clarify, we suggest considering average environmental impacts (as opposed to marginal impacts) owing to practicable feasibility throughout the LCA of fuel production chains.

The questions in round 2 of the survey has been reformulated to enable detailed responses.

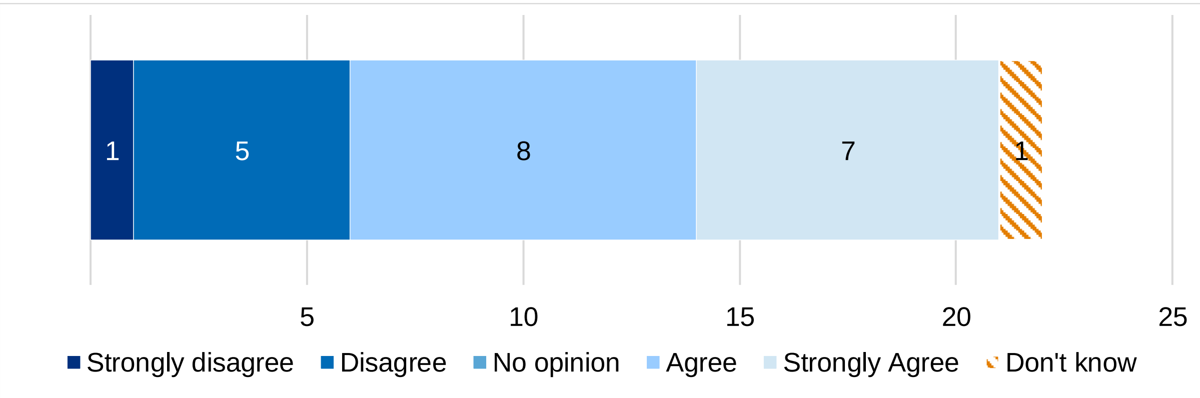
"Question 39. Do you agree that indirect land use change has to be included in the fuel LCA?"

Of the 22 respondents, 15 (strongly) agreed with the proposal to include indirect land use change (Figure 3-45), explaining that it is usually included in biofuel LCAs (three respondents), should be included in the discussion on counterfactuals (one respondent), and its importance is well reported in the literature (one respondent). One respondent suggested that indirect land use change should only be considered if supported by a robust calculation and well-defined methodology (it may change during the lifetime of the vehicle), and another acknowledged the difficulty of estimation but recommended its inclusion through sensitivity analysis (if resources allow) based on a suitable model.

Other respondents that also agreed recommended that it should also apply to secondary fuels (e.g. forest residues due to changes in soil organic carbon content) (one respondent), for all fuels not only biofuels (e.g. PV on arable land) (two respondents), and rare metals / earths mining (one respondent). One other expert also advised not to limit the analysis of indirect effects to indirect land use change only.

Among those five stakeholders that disagreed and provided comments, the methodology is not robust and mature enough and is controversial in the scientific community.

Figure 3-45: Inclusion of indirect land use change (n=22)



Q39 Response by the project team to results and comments:

Overall, most respondents agreed with the proposal for inclusion of indirect land use change. Only some respondents "disagreed" and the expert workshop held on February 25 revealed that this disagreement is rather related to the terminology of "direct" vs "indirect" land-use change. Some stakeholders disagree with the concept of "direct" land-use change and suggested evaluating any land-use change (direct or indirect) through "land-use scenarios" by using global economic models such as GLOBIOM or GTAP. However other stakeholders expressed a preference to evaluate direct LUC through an attributional LCA whereas iLUC would be addressed through a consequential approach.

In light of the above, the following observations can be drawn:

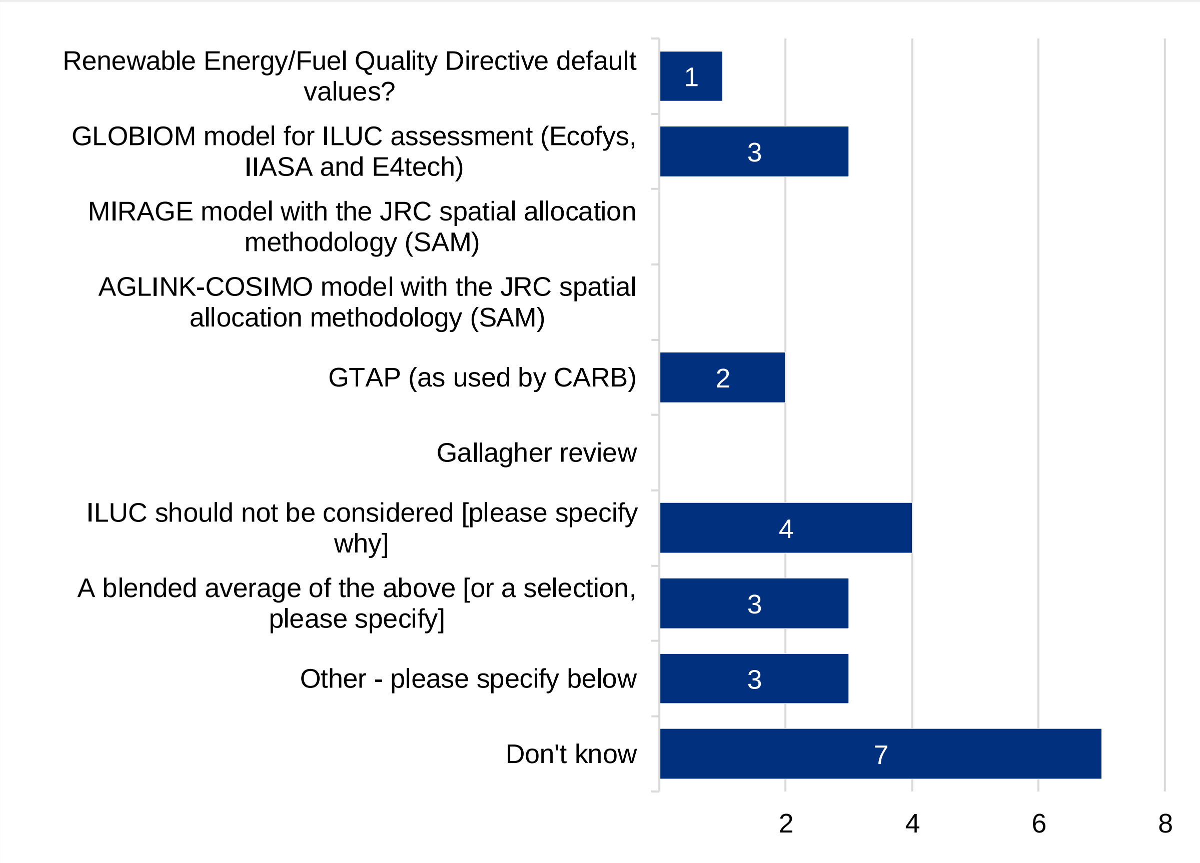
- Almost all stakeholders agree that impacts from all types of land-use change are important and should be evaluated.
- Some stakeholders disagree with the distinction between direct and indirect land-use changes and with the use of two distinct modelling approaches to measure them.

Therefore, there appears to be a solid consensus over taking both types of LUC (direct and indirect) into account but more discussion and research will be needed to find a consensual terminology and a consistent approach to evaluate them.

"Question 40. What do you believe is the best way to characterise indirect land use change?"

When asked about the most appropriate methodology to characterise indirect land use change, seven respondents didn't know (out of 23 responding), and four suggested that ILUC should not be considered (Figure 3-46). The options that gathered most support were GLOBIOM model for ILUC assessment (Ecofys, IIASA and E4tech), and a blended average of the options listed (three respondents each). Overall, stakeholders noted in their comments that the proposed options have their advantages and disadvantages (one respondent even recommending a sensitivity analysis of the different approaches) but for two experts the GLOBIOM model appears to be the most appropriate as it is widely recognised and recent.

Figure 3-46: Characterising indirect land use change (n=23)



Q40 Response by the project team to results and comments:

As mentioned above, disagreements exist over the best approach to address different types of land-use change. The responses reveal that the use of GLOBIOM comes out ahead of other models, which were picked by fewer respondents or not picked at all. It was confirmed at the expert workshop that GLOBIOM would likely be more adapted to the EU context.

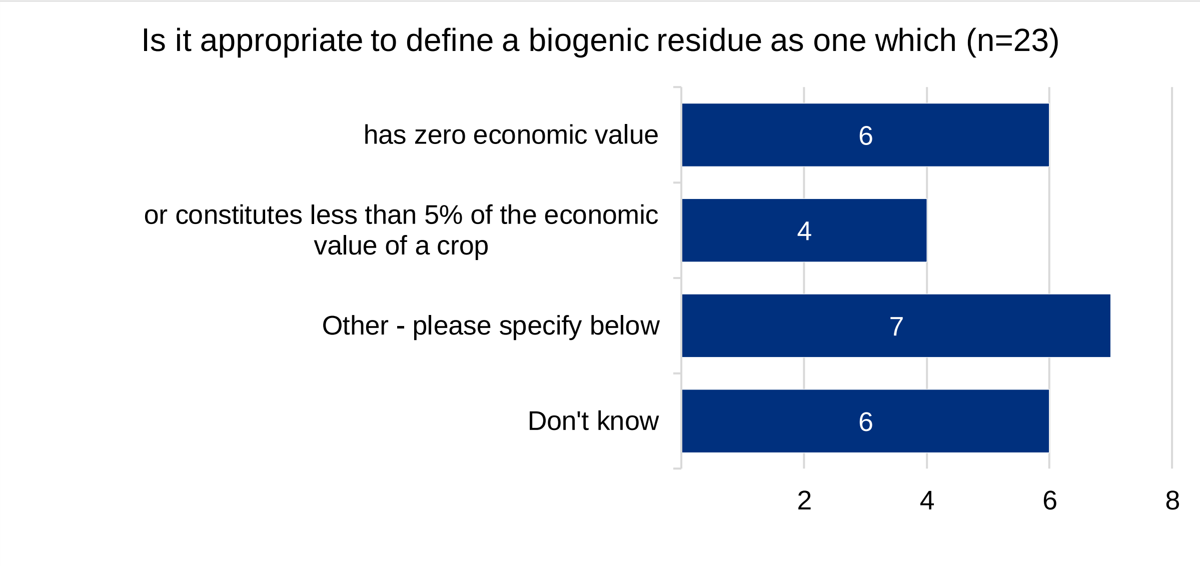
“Question 41. Is it appropriate to define a biogenic residue as one which [choose option]?”

Respondents were also unclear about how to best define a biogenic residue: of the 23 responding, seven specified other options (one suggesting using data from ICCT biofrontiers research on 2nd generational biofuels and sustainable gas), six didn’t know, and six agreed with defining them as having zero economic value.

For the stakeholders that selected ‘other’, one explained that it is not relevant to define waste, whilst another argued that economic figures should only be used as a last option. Another expert indicated the difference between waste and residue (i.e. residue always has economic value and therefore impact on environment from previous process).

Two other stakeholders alluded to the relevance of considering changes over time: biogenic residue may currently have zero economic value but become an important product with market value in the future. One explained that this would be an issue if allocation by economic value is being proposed. For another respondent, the definition depends on many factors such as crops, regions, and farming practices.

Figure 3-47: Defining biogenic residue (n=23)



Q41 Response by the project team to results and comments:

Results show heterogeneous replies, a majority of which are either “don’t know” or “other” (but with only one actual suggestion). This indicates that the question was not properly formulated. The initial question relates to the proposal to treat residues and waste differently from dedicated crops or forestry products. It is proposed to not use the waste vs residue distinction and consider both as residues, and treat them differently than conventional feedstocks in the LCA methodology. This is because, in practice, a very limited number of feedstocks actually qualifies as true waste and from an LCA point of view (consequential approach – see below), a distinction between waste and residue would not bring significant added value.

We now propose to define residues, following the EU RED II definition, i.e. “‘residue’ means a substance that is not the end product(s) that a production process directly seeks to produce; it is not a primary aim of the production process and the process has not been deliberately modified to produce it”.

Finally, we suggest using a consequential approach to model impacts from residues, as it would allow capturing systemic impacts from diverting residues from other uses.

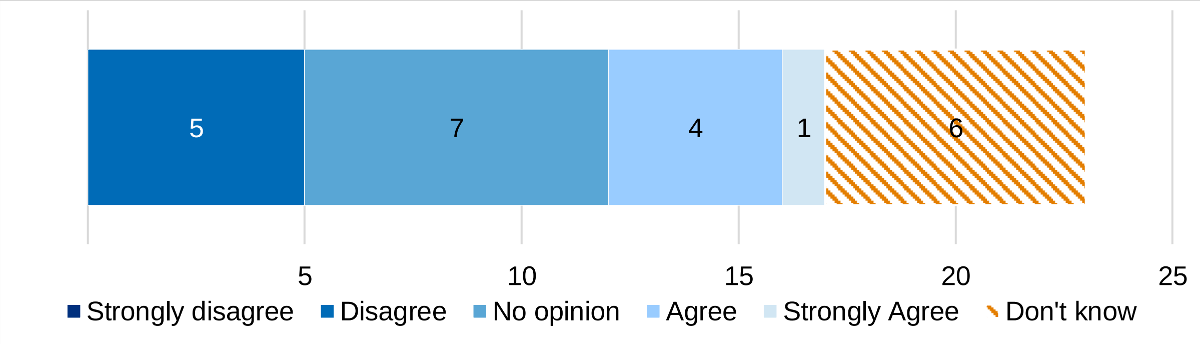
“Question 42. Is it feasible to include ongoing losses in soil organic carbon in the fuel LCA?”

A great part of the respondents had no opinion or didn’t know whether it is feasible to include ongoing losses in soil organic carbon (SOC) (Figure 3-48).

One respondent that agreed explained that it might be possible, but it should be determined if it is relevant for the goal of the study, whereas another suggested to include gains also, highlighting that there is an issue associated to the regional carbon stock data and release rates. For another respondent, these can be included as long as the existing land use flows from the PEF flow list 3.0 can be characterised.

Two respondents that disagreed argued that the methodology is too complex, non-transparent and a source of uncertainties. For another expert, soil organic carbon loss will depend on "use rate". On the other hand, one respondent agreed with the inclusion but only if reliable data are available. Another respondent indicated that a method for estimating losses in soil organic carbon due to direct land use change has already been proposed by the JRC in relation to the EC RED, but, if there is a specific issue with "ongoing" losses, it needs to be explained so that solutions can be devised.

Figure 3-48: Inclusion of ongoing losses in soil organic carbon (n=23)



Q42 Response by the project team to results and comments:

The limited response on this topic observed during round 1 of the survey was confirmed during the Expert Workshop. Few stakeholders expressed any strong views on the topic; those who commented on the topic consider that changes in SOC would not significantly impact final results in most cases and that potential options would not adequately address changes in SOC. For cases where SOC may significantly impact results, one suggestion was made to use GBEP indicators, but those require primarily in situ measurements of soil carbon, which appears impractical in the context of conducting an LCA. This will be further investigated in the second round consultation.

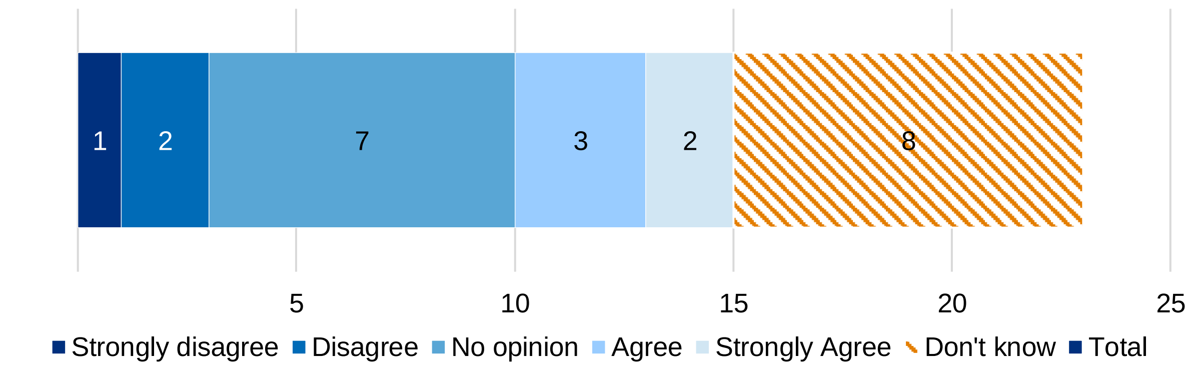
“Question 43. Do you agree that the LCA for fuels from primary biogenic feedstocks should take into account marginal crop emissions?”

Most respondents also had no opinion or didn’t know whether marginal crop emissions associated to fuels from primary biogenic feedstocks should be taken into account (Figure 3-49).

For one stakeholder that disagreed, attributional modelling would be more appropriate, and another respondent indicated that the proposal is too complex. One respondent was not sure if it was relevant for the European context, whereas another explained that it should be included and that it is not appropriate to consider that the GHG emissions for crops converted to fuels in Europe correspond to the inputs for make up crops in other countries. Another stakeholder suggested that this proposal needs to be considered case by case.

One expert that agreed recommended to identify the marginal production pathway and generate LCI accordingly, and another stakeholder identified relevant literature regarding system extension / capturing crops in functional unit.

Figure 3-49: Inclusion of marginal emissions per tonne of crop from fuels from primary biogenic feedstocks (n=23)



Q43 Response by the project team to results and comments:

With 65% of the respondents not knowing or without an opinion, this question was not properly understood. It may have been understood as referring to multi-cropping systems, either through rotation or intercropping, in which several crops are cultivated on the same land. Multi-cropping systems pose the question of allocating agricultural inputs and associated impacts over the different crops.

On the other hand, the initial question actually related to the use of average vs marginal data for the inputs required for crop cultivation. While the latter would capture the granularity of local situations (e.g. additional fertilisers required to compensate for less productive land), the practicality of such approach in an LCA context (e.g. availability of data) remains uncertain. Therefore, the use of average data remains the preferred option to date, with a preference for average values based on a specific type of soil for the cultivated crop(s).

3.4.1 Section 4: Liquid and gaseous fuel cycle conclusions

Q	Topic	R1 Conclusion, clarifications and refinements	R2 Status
32	Reference flows	Good level of agreement with the proposed choice of functional unit for this sub-section of the vehicle life cycle. *Refinements:* None.	Closed, comments only.
33	Environmental impacts/mid-points	The coverage of impact categories will be the same as for the whole LCA methodology under “General Methodology” (Section 1). *Refinements:* None.	Closed, comments only.
34	Emissions from capital goods	Good level of support for inclusion of capital goods in the fuel production chain. *Refinements:* None.	Closed, comments only.
35	Addressing multi-functionality at the refinery	Some disagreement with the proposal of allocating burdens according to the economic value of all products of crude oil refining. *New proposal:* we propose to use a modelling approach by Horst Fehrenbach and Axel Liebich (ifeu) which consists of a series of allocation rules according to flows in the refinery.	**Open**, new proposal and feedback.
36	Accounting for secondary feedstocks	Results show preference for counting vehicle combustion CO_2 while giving a credit for the same CO_2 captured in the upstream process – this proposal will be taken forwards, however discussions at the workshop revealed that it is	**Open**, additional information

Q	Topic	R1 Conclusion, clarifications and refinements	R2 Status
		preferable to consider fossil and biogenic secondary feedstocks separately. *Refinements:* This question has been reformulated and split into two questions (on biogenic and fossil feedstocks, separately) in round 2 of the survey to facilitate responses to the various points of suggestion.	and refining question.
37	Counterfactual uses of secondary feedstocks	Good level of agreement with the proposal to include the effects of counterfactual uses of secondary (fossil and biogenic) feedstocks but discussions at the workshop revealed that fossil and biogenic feedstocks should be considered separately. *Refinements:* This question has been reformulated and split into two questions (one on biogenic and fossil feedstocks respectively) in round 2 of the survey to facilitate responses to several points of suggestion.	**Open**, additional information and refining question.
38	Approach to counterfactual uses of secondary feedstocks	Results indicate need for clarification and suggest that the question was not formulated clearly enough. *Refinements:* To clarify, we suggest considering average environmental impacts (as opposed to marginal impacts) owing to practicable feasibility throughout the LCA of fuel production chains.	**Open**, additional information and refining question.
39	Inclusion of indirect land use change	Good level of support for inclusion of indirect land use change. Disagreement is linked to terminology of “direct” vs “indirect” land-use change. *Refinements:* We take this opportunity to investigate if the fuel LCA methodology should aim to evaluate <u>any</u> land-use change caused by fuel production (both fossil and biogenic).	**Open**, refining question.
40	Characterising indirect land use change	No agreement over the best approach to address different types of land-use change. GLOBIOM was the option that gathered more support in both the survey and workshop. *Refinements:* Further views on the appropriateness of this model will be sought in round 2 of the survey.	**Open**, refining question.
41	Biogenic residue	A mix of responses revealed that the question could be formulated more clearly. *Refinements:* It is proposed to not use the waste vs residue distinction, but to consider both as residues (under the term ‘secondary biogenic feedstocks’) and treat them differently than ‘primary’ feedstocks in the LCA methodology. This will be further evaluated in round 2 of the survey.	**Open**, additional information and refining question.
42	Soil organic carbon	Limited responses received during the survey and workshop. It will be further investigated in the second round consultation. *Refinements:* None.	**Open**, additional information and refining question.
43	Marginal emissions per tonne of crop	A mix of responses revealed that the question could be formulated more clearly.	**Open**, additional information

Q	Topic	R1 Conclusion, clarifications and refinements	R2 Status
		Refinements: Clarification provided with rephrasing of the initial question, along with more background + additional questions referring to multi-cropping systems, either through rotation or intercropping, in which several crops are cultivated on the same land. Need to investigate the allocation of agricultural inputs and associated impacts over the different crops.	and refining question.

3.5 Section 5: Methodological considerations for the electricity lifecycle

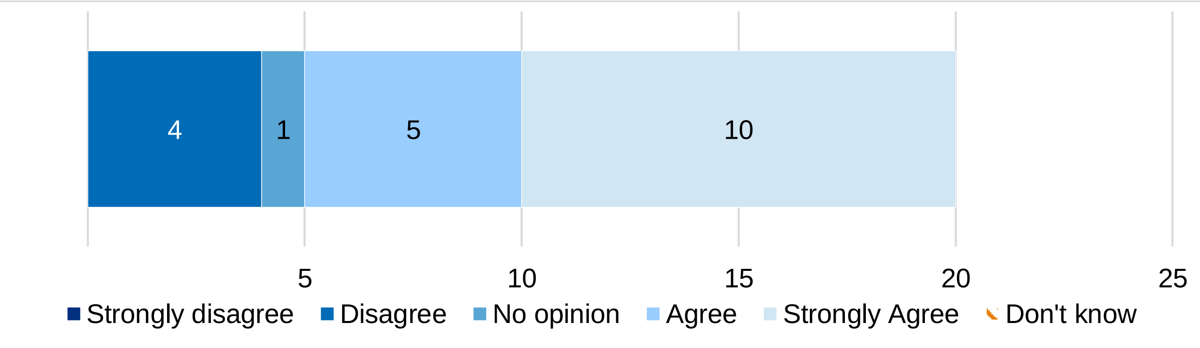
Experts responding to the first round of the survey also generally supported the methodological proposals for the electricity life cycle. However, there were still mixed views on certain proposals such as the cut-off criteria and data sources.

"Question 45. Do you agree that the proposed differentiation between the different countries with respect to level of detail of electricity generation is justified?

The majority of experts (strongly) agreed with the proposal for differentiating between countries with respect to level of detail of electricity generation (Figure 3-50). Two stakeholders highlighted the importance of taking into account future changes in electricity generation mix. Another respondent advised to also consider the source of electricity, and one other expert recommended to use data for current electricity supply from the ecoinvent database (attributional and consequential) and adjust market shares.

Among those that disagreed, two stakeholders suggested to use a European average grid mix for baseline modelling, and perform a sensitivity analysis based on electricity source. For another stakeholder, using generic electricity generation scenario could be the best approach if the goal is to compare across conventional and alternative powertrain technologies. One expert also added that consumer differences are relevant (e.g. charging times, electricity provider, etc) and thus should be considered.

Figure 3-50: Differentiation of electricity generation (n=20)



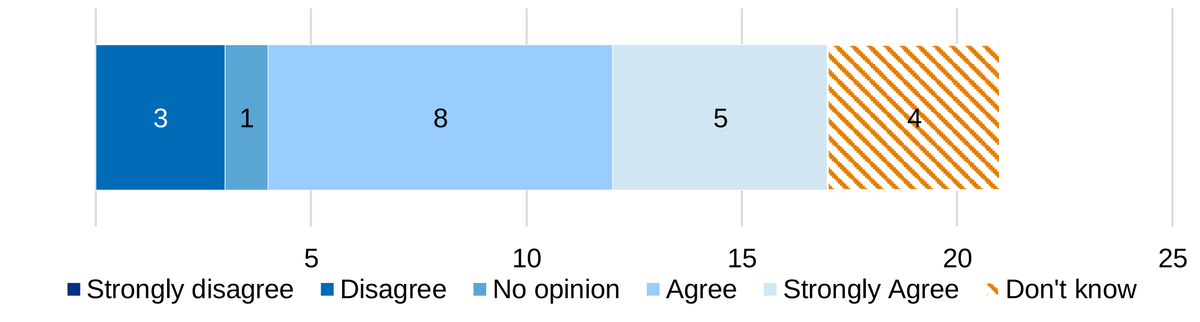
Q45 Response by the project team to results and comments:

A differentiation in terms of level of detail between countries inside and outside of the scope of this study is validated by the majority of stakeholders. For countries under scope, electricity generation will be modelled while for countries outside of scope, datasets or emission factors from established data providers such as ecoinvent or other sources, e.g. IEA will be utilized. As a default, the yearly average (consumption) mix will be assessed. In order to account for the significant differences in power generation, bespoke mixes or results from individual electricity chains, e.g. wind power or lignite, could be explored as sensitivities using our methodological approach. A more detailed assessment of potentially influencing factors such as consumer (charging) behaviour not only is difficult to predict but also goes beyond the scope of the project.

"Question 46. Do you agree that the proposed modelling of generic generation types with additional country/technology-specific variables is sufficient?

Most respondents agreed with the proposal to model generic generation types (Figure 3-51). One expert explained that a more detail analysis would not add significant value, and another suggested to take into account changes in technology over time. For two other respondents, it depends on the goal of the study.

Figure 3-51: Modelling of generic generation types (n=21)



Q46 Response by the project team to results and comments:

Although results indicated strong support for the proposed approach, written answers showed some lack of clarity in the phrasing of the question and its intent. Therefore, some further context and slight re-phrasing is provided for round 2 of the survey. The proposed approach comprises three main steps:

(1) Modelling individual electricity chains by power generation type (kWh_{el} generated by coal, hydro, gas, etc.) on a defined average baseline technology level.

(2) (Potential) adjustment of baseline technology level to reflect regional/country-specific characteristics (e.g. efficiencies, fuel quality, level of emission control).

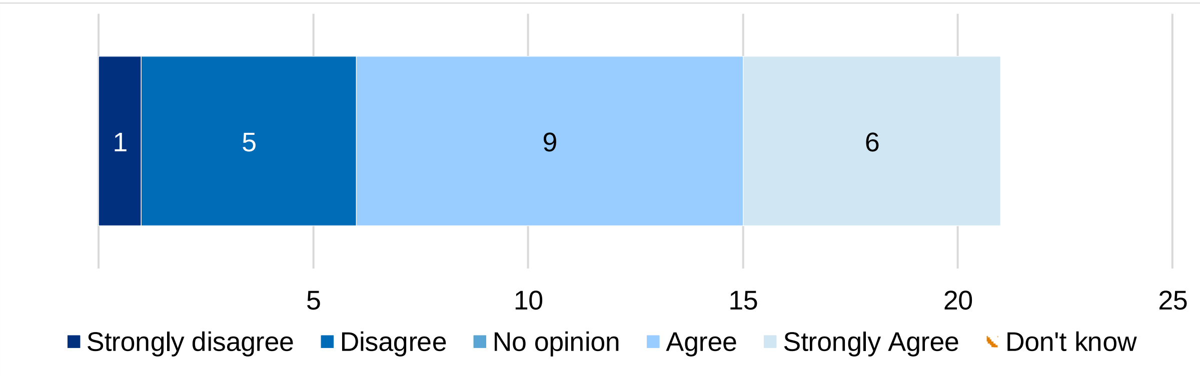
(3) Weighting of different power generation types by regional/national share on power generation (i.e. electricity split).

"Question 47. Are the suggested fuel / generation technologies listed sufficient?"

More than two-thirds of the respondents supported the proposed coverage of fuel/generation technologies as shown in Figure 3-52. They have also suggested including other technologies such as geothermal and CSP (concentrating solar power). Moreover, allocation of co-generation of heat and power for natural gas, primarily, was suggested.

One expert noted that CCS is probably not a realistic large-scale solution by 2050, but nuclear energy will still be important in some countries, even in 2050. Another stakeholder suggested that DAC (Direct Air Capture) could become a solution to abate emissions, where CCS installation isn't justified due to too low utilization rates.

Figure 3-52: Coverage of fuel / generation technologies (n=21)



Q47 Response by the project team to results and comments:

The majority of stakeholders confirmed the list of suggested fuels and power generation technologies. However, some stakeholders suggested including further technologies, e.g. geothermal and CSP due to their potential future role. This, as well as the market shares of the other listed technologies, will be subject to change over time. The finite selection of technologies will be determined by the cut-off criteria depending on their underlying market shares. For technologies that produce both power and heat, allocation of emissions and impacts based on energy will be carried out.

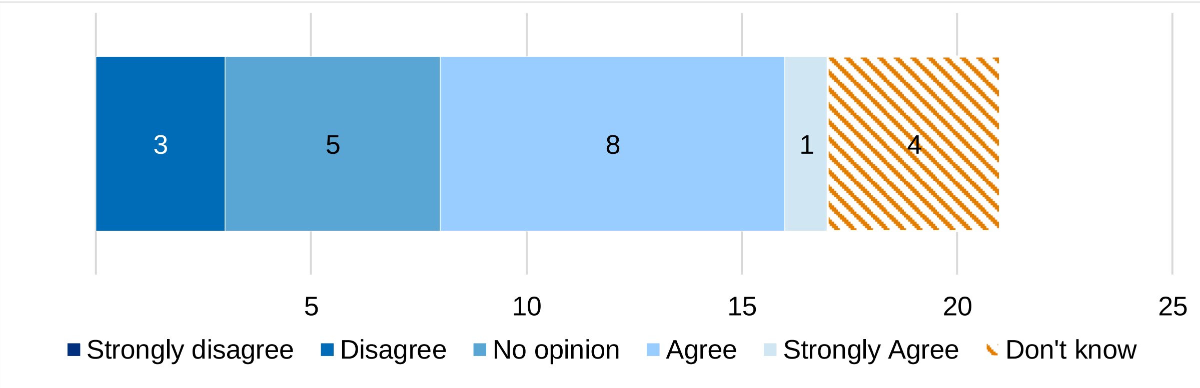
"Question 48. Do you agree that the proposed cut-off criteria are justified?"

Figure 3-53 shows that the majority of experts that provided an opinion on the matter (strongly) agree with the proposed cut-off criteria.

Three stakeholders indicated that the proposed cut-off threshold was not sufficiently justified, and one stakeholder that disagreed explained that, although using the cut-off criteria may be the only pragmatic approach, it should not be defined as a premise.

Among those respondents that agreed, one suggested to undertake an analysis of the impacts that would be excluded by the cut-off criteria since these tend to be highly variable, uncertain and small. Another respondent noted that it depends on how the share of all technologies < 5% is dealt with – it was advised that the share of renewables should be preserved in the extrapolation. One respondent recommended including the electricity consumed from imports/exports.

Figure 3-53: Appropriateness of cut-off criteria (n=21)



Q48 Response by the project team to results and comments:

The majority of stakeholders (with an opinion) confirmed the proposed cut-off criteria. However, multiple stakeholder stated the lack of a sound justification as to why 5% as cut-off is chosen. Against the background of the project and the variety of different technologies and countries, the proposed cut-off criteria allow to focus on all significant technologies while limiting the overall complexity. Moreover, data availability especially with respect to potential future technologies with low market shares is very limited with a high level of uncertainties. Therefore and, in addition, considering the overall scope of the study, a 5% cut-off is reasonable.

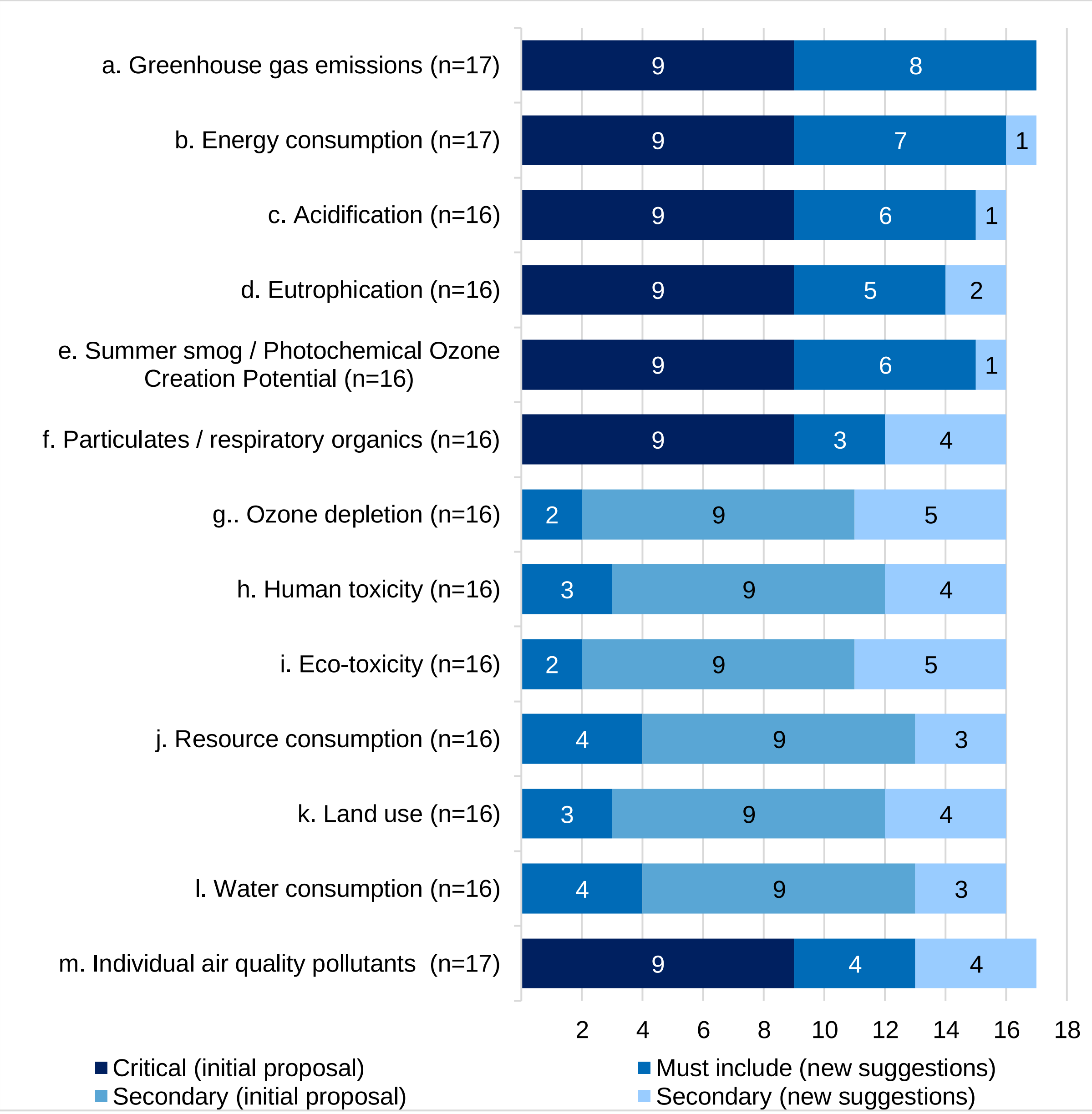
"Question 49. Are the suggested impact categories appropriate for the purpose of this study?"

Similar to question 9 in section 1 of the survey (section 0 in this document) and question 33 in section 4 (section 3.4 of this document), the proposals on the coverage of impact categories were presented (divided into two main lists, *critical impact categories*, and *secondary impact categories*) and respondents were asked to give their views on the most important categories for the electricity generation stage. Figure 3-54 illustrates the views of stakeholders on which impact categories are critical and which are secondary, aggregating all the responses received, i.e. both those that agreed and disagreed:

- If they agreed with the proposal, the critical and secondary impact categories in the proposal were considered – their responses are marked as *Critical (initial proposal)* and *Secondary (initial proposal)* in the figure;
- If they disagreed with the proposal, they were given the list of all impact categories and were asked to re-classify each category as 'must include' or 'secondary importance' – their responses are marked as *Must include (new suggestions)* and *Secondary (new suggestions).*

Responds had polarised views on the proposed coverage of impacts in the study with nine of 20 (strongly) agreeing compared to nine that (strongly) disagreed.

Figure 3-54: Proposed coverage of impact categories for the electricity generation stage



Overall, experts supported the study's proposed critical and secondary impact categories when looking at the combined answers. In the comments provided, seven respondents argued that the list of impact categories should be the same across all stages, and three other referred to their comments provided in question 9 and 33.

One stakeholder that disagreed noted that air pollution emissions (POCP, EP, HT, particulates) from power stations are only critical outside Europe. Another stakeholder argued that the impact categories of acidification and eutrophication are very site specific and would lead to misleading results. The study would need to consider drainage, rain fall, water quality regulation and other factor to accurately model acidification and eutrophication.

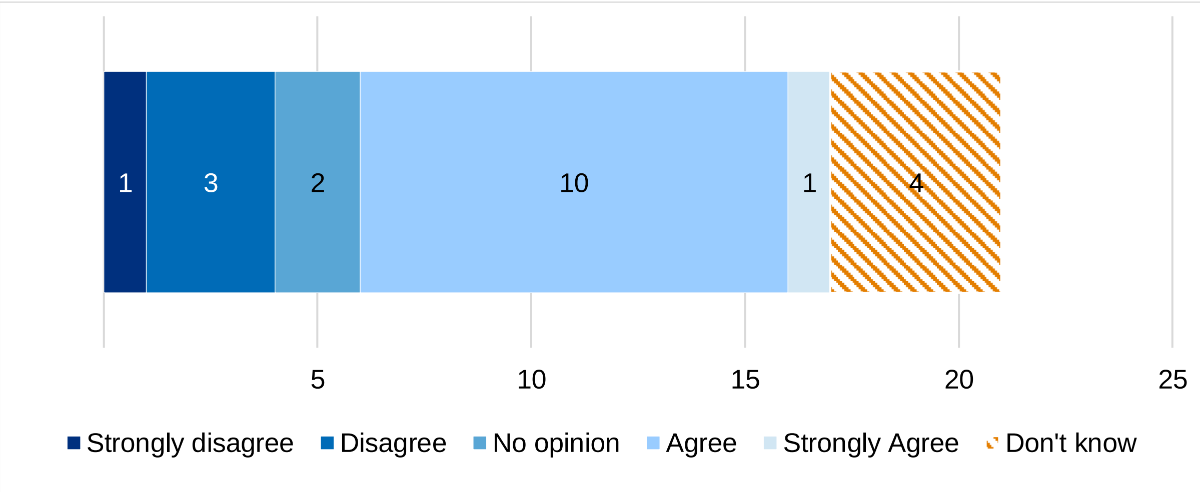
Q49 Response by the project team to results and comments:

While the majority of stakeholders generally agreed with the suggested impact categories, consistent categories across all stages is of key importance. Therefore, the appropriate choice of impact categories was addressed for the project as a whole under section 3.1, question 9.

"Question 50. Do you agree that the proposed primary data sources (which are mainly publicly obtainable data, except for certain data projections on electricity mix) are sufficiently robust, harmonised and transparent for the analysis?"

About half of the respondents were in agreement with the adequacy of the proposed primary data sources but four of 21 disagreed and another four did not know (Figure 3-55). Some respondents indicated that they needed more information in order to make a judgement on the appropriateness of the proposed data sources. For one expert, the examples provided are not sufficient to account for future emissions. Two other stakeholders recommended to rely on data from up-to-date commercial LCA databases. One respondent also warned about differences in national reporting and those communicated to the EU. For another expert, inconsistent datasets, based on different methodologies, and system boundaries may lead to wrong conclusions, and thus limit the direct use of literature data which may not be/are not based on consistent frameworks. Instead, it was recommended to use datasets with a certain standardized documentation and up-to-date industry datasets (preferably reviewed) such as databases of the European Commission (e.g. PEF initiative) and "GaBi LCI databases".

Figure 3-55: Appropriateness of data sources (n=21)



Q50 Response by the project team to results and comments:

A large share of stakeholders confirmed the appropriateness of the suggested data sources. We will prioritise sources based on consistency and comparability to other sources, e.g. in terms of system boundaries and general methodology. In addition to the already mentioned data sources, data from governmental agencies (national and international), research institutions, industry publications and guidelines as well as commercial LCA data bases will be utilized. For aspects of future developments and scenarios, data from the EC will be incorporated.

"Question 51. Should potential energy storage options be included in the analysis, e.g. in the case that power generation significantly changes; might they significantly impact the outcome?"

Figure 3-56 shows that 14 of the 21 respondents agreed that energy storage options should be included in the analysis. These experts were subsequently asked how the storage should be accounted for based on a list of proposed options (stationary batteries vs. potential utilisation of BEVs as intermediate storage, see Figure 3-57). Overall, respondents considered both proposed options to be medium options (WA: 2.92 – 3.62), slightly preferring the option to include in the analysis a stationary battery energy storage (/impacts of second life batteries) (WA:3.62).

Among those experts that agreed, two suggested that other storage mediums could be considered, such as e-fuels (P-t-X, H_2), and two other experts advised to include these options as a sensitivity analysis. For another two stakeholders, the use of stationary batteries to store energy is more relevant than V2G, questioning the potential negative impacts on battery lifetime, consumer acceptance and mobility. Another expert suggested assessing carefully the advantages and disadvantages of V2G.

Two stakeholders that responded 'don't know' explained that, from a methodological and practical point of view, it appears to be too complex, as it depends on local conditions. Similarly, one expert that disagreed argued that there is no need to introduce energy storage as long as the battery life duration is based on the vehicle usage only. If an energy storage usage is considered, it was suggested to develop an allocation approach but this would increase the complexity of the analysis. For another expert that disagreed, this is beyond the scope of this analysis.

Figure 3-56: Inclusion of energy storage options (n=21)

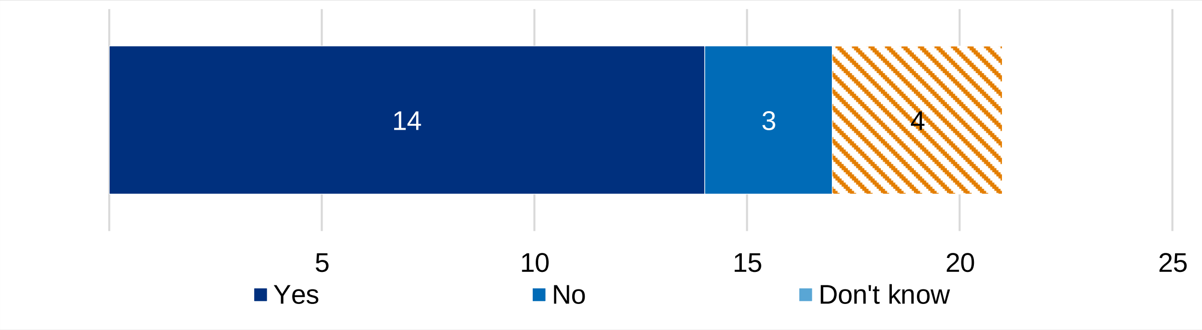
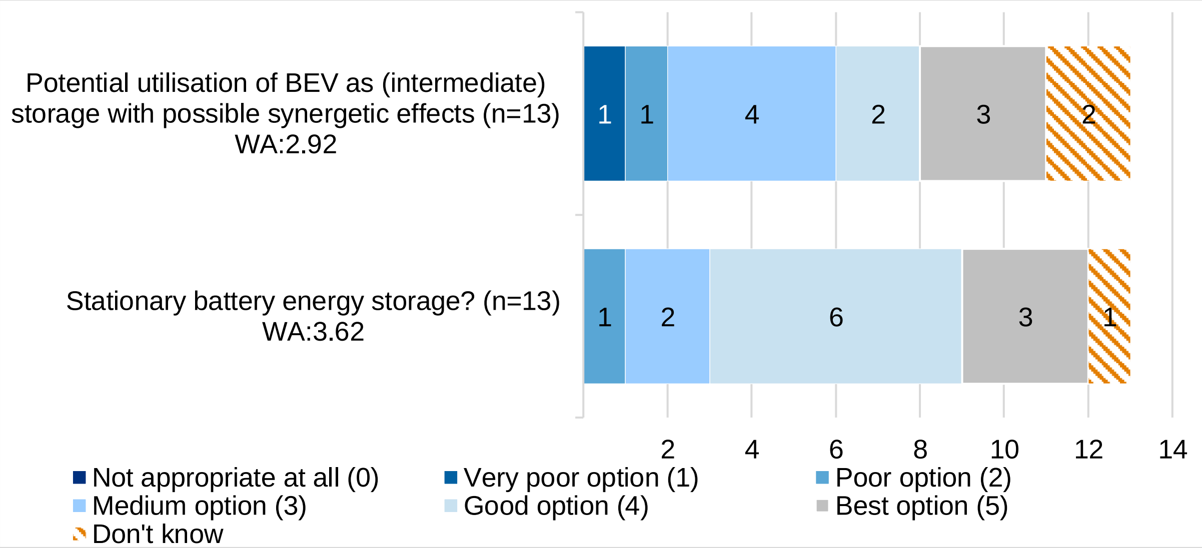


Figure 3-57: Accounting for energy storage



Q51 Response by the project team to results and comments:

The importance of storage options was validated by the stakeholders. As V2G concepts are highly uncertain both in terms of technical feasibility and consumer acceptance, stationary storage options will be assessed by sensitivity analysis.

"Question 52. What are the perspectives for electricity generation in the time frame from 2020 to 2050? If power generation significantly changes, are additional storage capacities needed? If yes, (how) could BEV be utilised as (intermediate) storage with possible synergetic effects?"

Three respondents suggested the adoption of specific scenarios to consider multiple policy trends (including the European Commission's long-term decarbonisation scenario, and Eurelectric's scenarios for the future of electricity generation post-2020).

Three respondents alluded to the importance of V2G as a suitable option to manage electricity demand and supply; however, multiple stakeholders noted that it is not clear to what extent V2G will be implemented (considering wear, return payment, etc). Moreover, stakeholders found that while V2G poses a potential opportunity, its application to this day is highly uncertain and difficult to address given the context of the study.

Another stakeholder recommended considering other energy storage options such as hydrogen and e-fuels. On the other hand, another expert argued that the vehicle's purpose is not to stabilise the grid. For another, this question goes beyond the scope of the study, explaining that it requires substantial energy system modelling, plus, vehicle to grid concepts perceived not to be very realistic and methodologically challenging from the LCA perspective.

3.5.1 Section 5: Electricity lifecycle conclusions

Q	Topic	R1 Conclusion, clarifications and refinements	R2 Status
45	Differentiation of electricity generation	Approach to differentiation of electricity generation in terms of level of detail between countries inside and outside of the scope of this study largely validated by stakeholders. *Refinements:* As a default, the yearly average (consumption) mix will be assessed for countries under scope. Bespoke mixes or results from individual electricity chains could be explored as sensitivities. For countries outside of scope, datasets or emission factors from established data providers to be used.	**Open**, refining question.
46	Modelling of generic generation types	Good level of support for proposed approach but additional clarity sought by stakeholders. *Refinements:* General approach is to use power generation types (coal, hydro, gas, etc.) and derive regional/national factors by further adjustments (e.g. efficiencies, fuel quality, level of emission control) and weighted by electricity split	**Open**, additional information and refining question.
47	Coverage of fuel / generation technologies	Good level of support for suggested fuels and power generation technologies. *Refinements:* None.	Closed, comments only.
48	Cut-off criteria	Good level of support for proposed cut-off criteria but additional justification was requested by stakeholders. *Refinements:* None.	Closed, comments only.
49	Impact categories	The coverage of impact categories will be the same as for the whole LCA methodology under "General Methodology" (Section 1). *Refinements:* None.	Closed, comments only.
50	Data sources	Good level of support for proposed data sources. *Refinements:* Further data sources (e.g. from governmental agencies, research institutions, industry publications, commercial LCAs) to be used. Data from EC will be used for aspects of future developments and scenarios.	Closed, comments only.

Q	Topic	R1 Conclusion, clarifications and refinements	R2 Status
51	Inclusion of energy storage options	Good level of support for inclusion of energy storage options. *Refinements:* stationary storage options will be assessed in more detail. V2G concepts will not be covered due to high uncertainty.	Closed, comments only.

List of Abbreviations

Abbreviation	
BEV	Battery Electric Vehicle (fully electric)
CNG	Compressed Natural Gas
CCS	Carbon Capture and Storage
CCU	Carbon Capture and Utilisation
CSP	Concentrating Solar Power
CO	Carbon Monoxide
CO_2	Carbon Dioxide
CO_2e	Carbon Dioxide equivalent
DAC	Direct Air Capture
EC	European Commission
eLCAr	E-Mobility Life Cycle Assessment Recommendations
EoL	End-of-Life
EP	Eutrophication Potential
ETS	Emission Trading System
EV	Electric Vehicle
FCEV	Fuel Cell Electric Vehicle (running on hydrogen)
GBEP	Global Bioenergy Partnership
GHG	Greenhouse Gases
GLOBIOM	(IIASA's) Global Biosphere Management Model
GTAP	Global Trade Analysis Project
H_2	Hydrogen
HTP	Human Toxicity Potential
ICE	Internal Combustion Engine
ICEV	Internal Combustion Engine Vehicle
IEA	International Energy Agency
ILCD	International Reference Life Cycle Data System
ILUC	Indirect Land Use Change
ISO	International Organisation for Standardisation
kWh	kilo-Watt-Hour
LCA	Life Cycle Assessment
LCI	Life Cycle Inventory
LHV	Low Heating Value
Li-ion	Lithium Ion
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas
LUC	Land Use Change
MJ	Mega-Joule
MS	Member State

Abbreviation	
Mt	Mega ton (million tonnes)
NEDC	New European Drive Cycle
NGO	Non-Government Organisation
NMC battery	Lithium Nickel Manganese Cobalt Oxide (LiNiMnCo) battery
NOx	Nitrogen Oxides (includes nitrogen monoxide and nitrogen dioxide)
OICA	International Organisation of Motor Vehicle Manufacturers
PEF	Product Environmental Footprints
PM	Particulate Matter
POCP	Photochemical Ozone Creation Potential
PtX	Power-to-X (where X can be a variety of hydrocarbon liquid fuels or gases)
PV	Photovoltaic
RED	Renewable Energy Directive
RDE	Real Driving Emissions
SOC	Soil Organic Carbon
VECTO	Vehicle Energy Consumption calculation Tool
V2G	Vehicle-to-Grid
WA	Weighted Average
WLTP	World harmonised Light duty vehicle Test Procedure
xEV	Electric vehicles (includes BEVs, PHEVs, REEVs and FCEVs)